May 1960

Bell Laboratories RECORD

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Bell Laboratories **RECORD**

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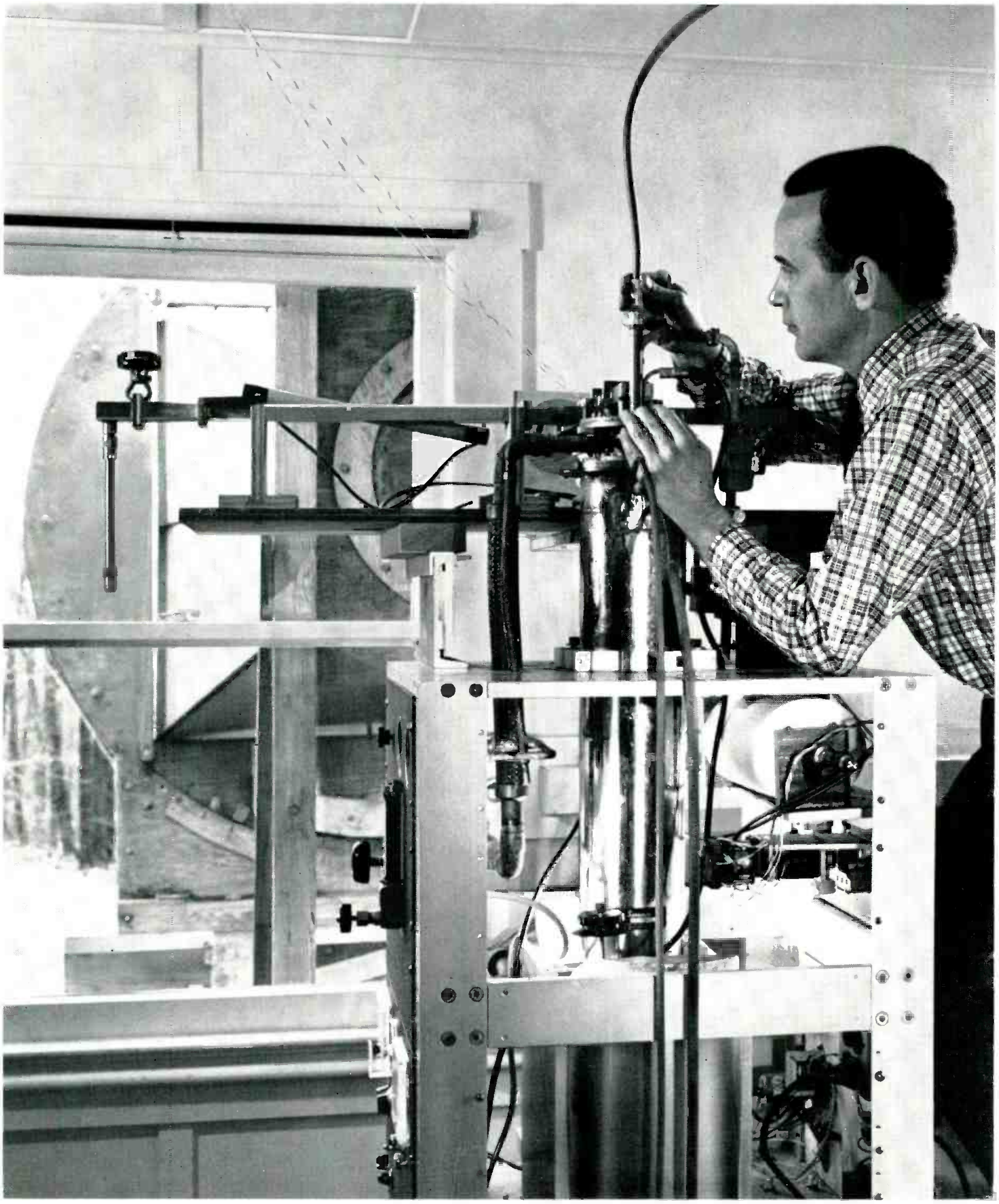
Contents

Cover

W. S. Apgar ties open-wire line to insulators preparatory to electrical testing at Chester, New Jersey. Automated controls determine ac and dc leakage at insulators, particularly in inclement weather (see page 177).



D. C. Hogg prepares maser amplifier for measurements of tropospheric "noise"—minute radio signals generated by the thermal energy of gases in the air. Signals are received by the rotatable horn-reflector antenna seen through the window.

One of the unavoidable by-products of electronic amplification—the basis of all long distance communication—is unwanted electrical "noise." In future long-range systems, including schemes like TV signals bounced from orbiting satellites, engineers may combat noise by . . .

M. Brotherton

AMPLIFYING WITH ATOMS

Every so often, communications science achieves a spectacular advance against a major obstacle. One such obstacle is the "noise" inherent in amplifiers. Against this noise, the Bell Laboratories solid-state maser scores an immense advance by making it possible to receive clearly microwave signals about a hundred times weaker than those previously detectable. The maser—an acronym for Microwave Amplification by Stimulated Emission of Radiation—can receive these weak signals over a frequency band of about 25 mc. When combined with this useful bandwidth, high sensitivity opens the way to transmission goals that were formerly beyond reach—for example, the transmission of television programs and hundreds of telephone conversations via signals reflected from satellites.

The maser is also notable from a scientific point of view because it embodies a radically new approach to the amplification of radio waves. This article explains this new approach to amplification—maser action—for those who do not have the background or inclination to grapple with a rigorous technical presentation.

Origins of the Maser Principle

Where does the maser come from? The original idea seems to have occurred to several physicists at about the same time, both here and abroad. It first took practical form when Professor C. H. Townes and his students at Columbia University conceived and built a maser using ammonia gas. Subsequently, Professor N. Bloembergen at Harvard University worked out, in theory, a maser amplifier that used a paramagnetic crystal. Picking up the idea, Laboratories' scientists H. E. D. Scovil, G. Feher and H. Seidel went on to construct the first solid-state maser (RECORD, *July*, 1958). Picturesquely, the latest model, which is to be used in Project Echo, the satellite-reflection test, employs a synthetic ruby that is cooled to temperatures approaching absolute zero.

But how can a ruby amplify? In one way, a ruby amplifies like an electron tube; for like the elements in an electron tube the ruby takes energy from electrons and passes it along to the electrical signal to be amplified. However, in a most important way, the ruby amplifier is radically different. Electron tubes work with electrons that are *free*—that is, they are boiled out of a hot cathode, spilled into a vacuum, and then whipped into motion by an electric field. By contrast, the ruby works with electrons that remain locked up in their atoms.

A ruby is composed of aluminum, oxygen, and chromium. Of these, chromium alone provides the ruby with its amplifying properties. In the ruby maser, atoms of chromium are used as storage points for energy that microwaves can release. The energy that these chromium atoms store is of a particular kind.

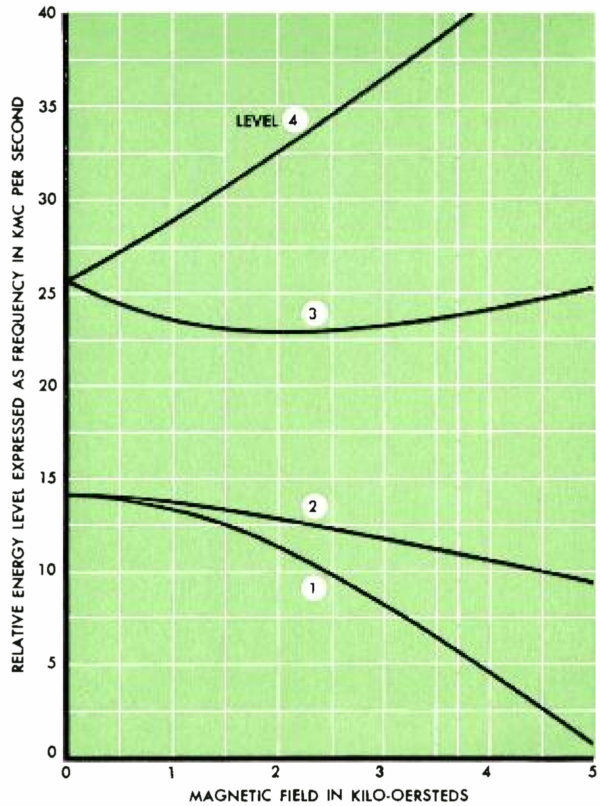
In an atom, we can picture planetlike electrons existing in orbits around a sunlike nucleus. This gives an atom several kinds of energy. The energy that gets into the headlines is centered in an atom's nucleus. However, this nuclear energy does not concern us; neither nuclear fission nor fusion are involved in maser activity.

The chromium atom also possesses energy in the form of the orbital energy of its electrons. By skipping from one orbit to another, these orbiting electrons can change their energy levels. And depending on whether the electrons skip toward the nucleus or away from it, they emit or absorb energy in the form of light ranging from infrared to ultraviolet. The net result is the delightful and mysterious fiery red color for which the ruby is renowned.

What makes rubies red, however, also has no part in maser action. For this, still another kind of energy is called into play. Every electron in an atom is a spinning magnet, possessing energy due to its magnetic moment. It is this magnetic energy that the solid-state maser utilizes, an energy which physicists have long studied but only recently learned to apply in amplification.

Magnetic Energy Put to Work

With its spinning electron magnets, an atom is, so to speak, full of magnetism. In some atoms, each electron-magnet has a compensating mate which spins in the opposite direction and is oppositely magnetized. The net effect of these balanced pairs of electron-magnets is zero. As a result, such atoms are magnetically neutral, and we cannot affect them by applying a magnetic field. This is the situation with most atoms as they exist in chemical compounds.



Relative energy levels in ruby crystal versus *applied magnetic field. Crystal is tuned to about 5 kmc by adjusting applied field. Broken line at right shows typical operating point of ruby masers.*

Not so with the chromium atoms in a ruby. As a result of the way that each chromium atom is bonded to its partners, aluminum and oxygen, it has in one of its orbits three maverick electrons—electrons which do not have compensating mates of opposite magnetization. These we *can* affect by applying a magnetic field.

How are these three electrons—each a spinning globe of electrical charge magnetized along its spin axis—arranged in their atomic orbit? And how do they move around as they spin? It would be nice if one could draw a simple picture. But physicists working with the esoteric concepts of modern atomic theory say that we cannot draw simplified diagrams that are also true.

Though one cannot say exactly what the three maverick electrons look like, we have a very good idea of how they behave. They are locked together by atomic forces, so that their magnetic axes are always parallel and have the same north-south direction. Thus, they behave like a single bar magnet. We know, too, that a bar magnet in an applied magnetic field possesses an amount of energy that depends on the angle it makes with the direction of the applied field.

In a maser, the ruby is subjected to a magnetic field. In each chromium atom, the "magnet" that corresponds to the three locked-together electrons turns, orienting itself with the direction of the surrounding field. If we could look at each such magnet, we would see it pointing not just in any direction, but always in one of four directions. Each direction corresponds to a specific energy level, so that each chromium atom (because it contains a "magnet") is at one of four levels.

Making Atoms Jump

Maser action depends on the fact that we can make these magnets jump from one orientation to another, thus making an atom gain or lose energy. How do you make an atom jump? Answer: shoot it with a photon—a packet of radiant energy. When a photon strikes a chromium atom, the orientation instantly changes and the energy level of the atom rises or falls.

Where does one get such photons? In this instance, we get them from the microwave signal to be amplified. Here, the nonphysicist must twist his imagery to accept one of nature's paradoxes.

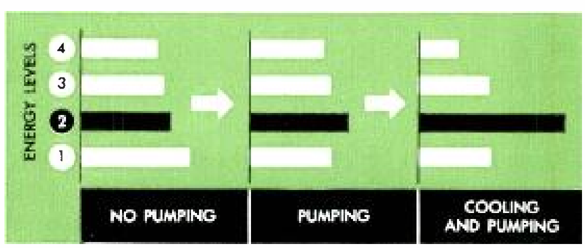
Quantum theory tells us that radio waves have two faces which seem to bear little resemblance to one another. In most radio phenomena, these waves behave as we ordinarily picture them—as vibratory motions cutting sinuous curves through space. But in the submicroscopic world of a crystal, radio waves appear quite differently, and herein lies the paradox. To the atoms of a ruby, an incoming microwave signal appears as a stream of photons, armed with the ability to make atoms jump up or down in energy level.

To unlock a door, the key must fit. Likewise, to make atoms jump, photons too must fit, in their own way. To change the energy of an atom from one level to another, the energy of the photon must be very close to the energy difference between the two levels involved. The necessary equality is obtained by making use of two facts. First, the energy of a photon is equal to the product of a constant and the frequency of the microwaves; second, the difference between energy levels depends on the strength of the applied magnetic field. Hence, the energy of the photons may be exactly "tuned" to the difference between two specific energy levels. A plot of the relationship of these two factors for the four energy levels involved is shown on the opposite page.

In a ruby maser, the signal to be amplified is tuned to the energy difference (measured in frequency) between levels 1 and 2. Let's follow this tuned signal into the crystal. As photons plow into atoms, electron magnets snap into new positions, and energies abruptly change. If the atom is in level 2, it jumps down to level 1, losing energy. The lost energy appears as a new photon, which is added to the microwave signal. The signal is thus amplified. If the atom is in level 1, however, it absorbs the impinging photon and jumps to level 2. In this case, the signal loses a photon and is attenuated. Thus loss is opposed to gain. Which will win?

The answer depends on the relative number of atoms in levels 1 and 2. And this in turn depends on the law that governs the energy distribution in the crystal as a whole. The effect of this law on the population of atoms at the various energy levels is shown on the left in the bar chart on this page. As the lengths of the bars indicate, there are more atoms at the lower levels than at the higher levels; hence, an incoming signal meets more atoms in level 1 than in level 2. The signal therefore loses energy and is attenuated. To get amplification, we must upset the crystal's natural equilibrium so as to maneuver a surplus of atoms into level 2.

As noted earlier, a signal must be closely tuned to the energy difference between two levels to cause action between the atoms that lie at these levels. Also, the energy-*versus*-field plot shows that the energy differences are decidedly unequal. Consequently, the action that results from the incoming signal tuned between levels 1 and 2 does



Microwave signal gains photons from level 2, loses them to level 1. "Pump" signal raises atoms from level 1 to level 3. As atoms pour into level 3, they drop rapidly to level 2, and thereafter comparatively slowly to level 1. Result is a small surplus of atoms in level 2 (center), and some amplification of the signal. Cooled crystal provides more atoms in level 1 for the pump to raise to level 3. This leads to more atoms in level 2 (right), hence stronger amplification.

not have any effect on atoms between levels 2 and 3 or between any other pair of levels. Because of this happy situation, a signal tuned to another pair of levels can be simultaneously sent into the crystal without interfering with the action going on between levels 1 and 2. This independence of activity at different levels permits us to unbalance the natural energy distribution in the crystal. Conversely, it is important to point out, this all-important unbalancing operation, and hence maser action, could not occur if the energy differences between levels were equal.

How Atoms Amplify

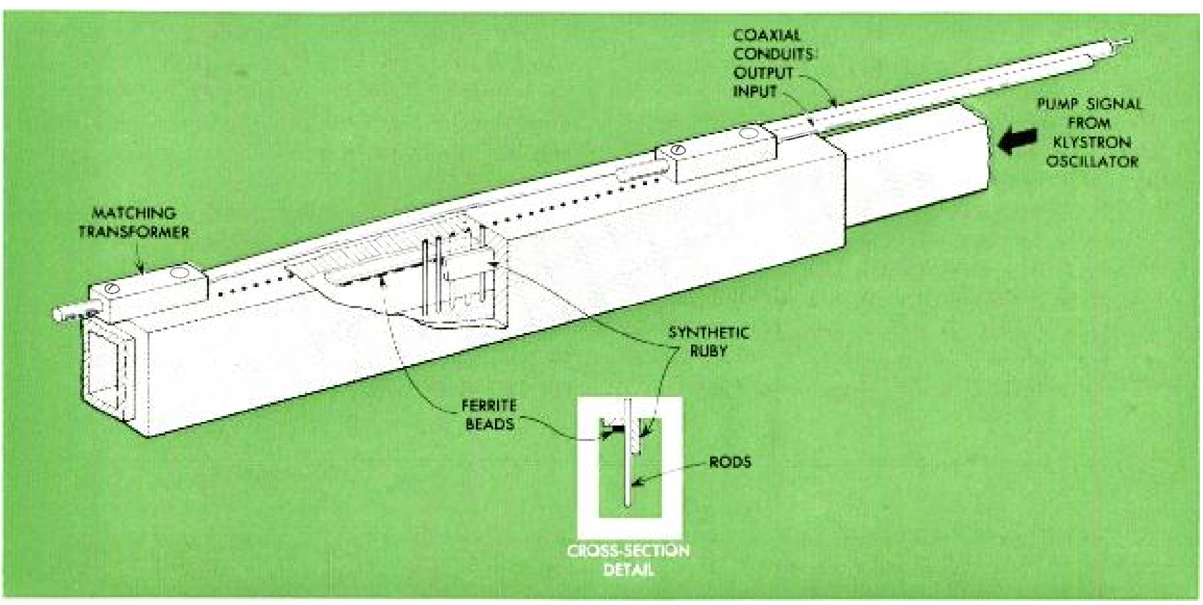
To harness the natural situation, we apply a second signal, from a klystron oscillator, to the crystal. This signal is tuned to the energy difference between levels 1 and 3. The general physical arrangements for introducing this second signal, known as a "pump" are shown in the diagram below. This illustration also shows most of the other important physical aspects of maser operation.

The effect of this pump signal is illustrated by the middle group of bars on the bar chart. A klystron pumps energy into atoms at level 1, hoisting them to level 3. To restore its natural equilibrium, the crystal promptly evicts the surplus atoms by dropping them to level 2. Thus, we artificially supply a surplus of atoms at level 2.

This is what we want, but there is one more condition needed to achieve amplification. If atoms drop away from level 2 as fast as newcomers arrive, we cannot establish a significant surplus. Thus, it is necessary to delay the departure of atoms from level 2. The crystal itself provides the necessary delay, dropping atoms more slowly than newcomers arrive. As a result, a surplus of atoms piles up in level 2 and amplifies the input signal.

The gain obtained with the pump alone is small. To achieve practical amounts of gain, the crystal's natural equilibrium must be upset still further. This is done by cooling the crystal. Cooling alters the natural equilibrium of the crystal in a way that favors even larger populations of atoms at the lower levels. Thus, many more atoms tend to populate level 1. There they are pumped, which lifts them to level 3. The end result, as shown in the right-hand set of bars on the chart, is a larger surplus of atoms in level 2 and significantly strong amplification. For maximum gain, the crystal is cooled to the lowest practically obtainable temperature—that of liquid helium.

Atoms in number beyond our imagining become involved in the maser amplification of a microwave signal. In a typical five-inch maser ruby, there are 6×10^{22} atoms. About 1 in 5000, or 12×10^{18}, are energy-storing chromium. The energy in each incoming microwave photon is



Arrangement of the solid-state maser. The magnet and cooling chamber, which surround this structure are not shown. Rods slow the signal to prolong interaction with ruby. Ferrite beads provide isolator action, prevent harmful signal reflections within cavity. "Pump" energy from a klystron oscillator, at approximately three times the frequency of the signal to be amplified, is absorbed by the crystal. Transformers match impedance of coaxial leads to that of the cavity.

R. W. DeGrasse, one of the designers of the solid-state maser, holds a synthetic ruby and comblike "slow-wave" structure. Microwave signals are coupled to the ruby by the comb. The magnetic atoms in the synthetic ruby amplify the signals.

only 4 x 10^{-24} watt seconds, but its impact on energy-laden level 2 is spectacular. Colliding with an atom, it knocks off a new photon. Joining forces, the two photons knock out two more. Ultimately, for every photon entering the ruby, a thousand more are released. Thus, the signal is amplified a thousand to one in power, or 30 decibels.

Furthermore, this high order of amplification is obtained over a range of frequencies because of another important factor at work in the crystal. Within its compact atomic structure, each spinning electron is acted on not only by the magnetic force we apply but also by magnetic forces exerted by neighboring atoms. The latter magnetic force varies slightly from atom to atom. Hence, the net magnetic force on an electron varies slightly from atom to atom and, in turn, so does the energy level. This means that different atoms react to different incoming frequencies. As a whole, the crystal reacts to, and can thus amplify, frequencies varying over a range of 25 mc.

In this respect, the solid-state maser stands in sharp contrast with the original ammonia-gas maser, which is essentially a narrow-band device. The gas maser is mechanically simpler, for it does not require an applied magnetic field or a pump oscillator. Also, it is not cooled.

The ammonia molecule is seen as existing at one of two energy levels. A molecule at the higher level possesses extra energy—energy that can be released by a microwave photon tuned to a frequency close to 24 kmc. When struck by a 24-kmc photon, an ammonia molecule at the higher energy level sinks to the lower level, releasing a new 24-kmc photon. Thus, ammonia gas with an excess of upper-state molecules can be used to amplify a microwave signal at 24 kmc.

Ordinarily, ammonia gas contains both high- and low-energy molecules. To obtain an excess of higher-energy molecules, the gas is passed through a nonuniform electric field normal to the direction of flow. The lower-energy molecules are acted on by the field and drawn aside. The higher-energy molecules pass through to a cavity resonant at 24 kmc. As microwaves are fed into the cavity, they release energy from the high-energy gas molecules, and are thus amplified. Practically, an amplification of about 20 db is obtainable.

Operating frequency is preset by nature in the ammonia molecule, and it varies very little. This invariability precludes the diverse frequency response which characterizes the solid-state maser. On the other hand, it enables the gas maser to produce the steadiest oscillation ever realized. For this reason, the gas maser may be the clock (actually a frequency standard) used in satellites for the ultraprecise measurement of time.

Future Communication Via Maser

Both gas and solid-state masers share a characteristic of enormous promise in the shaping of future long-distance communications. Both are almost entirely devoid of the "noise" generated in conventional electron-tube amplifiers. There are no heated cathodes boiling out electrons, no electrons sent hurtling through a vacuum to collide noisily with an anode, control grids and other metal surfaces. Further, noise originating in the thermal motion of the maser crystal's atoms become negligible in an operating temperature that is close to absolute zero.

The ultra-sensitivity of the solid-state maser has already proved its usefulness in experiments at the Holmdel, New Jersey, location of Bell Laboratories. For the first time, accurate measurements were made of minute noises generated by the air itself. The results have a vital bearing on transmission by signals reflected from satellites. For these tests, a version of the Laboratories' solid-state maser supplied the low noise, broadband amplification required.

The crucial test of a missile is an actual firing. But even this is not enough to test the full effectiveness of new weapons and at the same time lay the groundwork for future missile systems. Firings must take place as part of a carefully planned program of field tests designed to yield information concerning the missile's flight and the performance of its components.

R. W. Benfer

White Sands Branch Laboratory: Test Center for Nike Missiles

In September 1946, a few people from Bell Laboratories and the Douglas Aircraft Company launched the first Nike missile. The event took place in New Mexico, at a site now known as the White Sands Missile Range. At stake was a new concept of weaponry that some considered visionary and all considered ambitious. The concept was that a rocket-powered missile could be electronically guided by commands from the ground to destroy a fast-flying aircraft taking violent evasive action.

A few seconds after lift-off, the dummy airframe of this first Nike separated cleanly from its booster and coasted in supersonic ballistic flight. It did so with the aid of considerable "body english" and enthusiastic cheering and chest-beating from the observers on the ground. This historic missile was the progenitor of the Nike family. In the next few days, two more successful flights were conducted, and two weeks later, the first Nike airframe with a sustaining propulsion system was launched. Even the more conservative were convinced that the confidence placed in this pioneering effort was fully justified.

Along with the success of these first flights, however, came the sobering realization that testing missiles was to be a very difficult and challenging business, full of surprises. The next few flights included some failures that were even more spectacular than the successes. Some missiles died sudden and violent deaths, leaving little evidence of their maladies, while others lingered just long enough to produce at least some information for analysis.

Techniques for field-testing rocket-powered missiles, therefore, developed into very careful and orderly procedures. Of primary importance, of course, was the safety of the residents of the area and of the personnel on the range. Also of great importance were time and money. Economically, it is necessary to get the maximum possible test data from every missile expended, and the program was often under the extreme pressure of schedules characteristic of defense work.

The safety factor became more and more important as the missiles increased in speed, range and versatility. With supersonic velocity and a ballistic range which could exceed the limits of the testing area, the missile presented new problems to the engineers responsible for flight-test planning. All agencies concerned with the project promptly began developing the needed safety devices and instrumentation. Douglas Aircraft personnel pioneered the design of a "fail-safe" system to break up the missile on command or on loss of communication contact. The Army Ordnance Corps enlisted assistance in improving optical and radar devices for tracking missiles, as well as computing and plotting devices to predict the point of impact on the ground at the conclusion of a flight. Such devices, in addition to yielding flight data, were needed to determine when a missile was departing enough from its planned performance so that it had to be destroyed. This equipment and the practices developed for testing, plus the many refinements and improvements made over the years, have resulted in a commendable record of flight safety at the White Sands Missile Range.

During the early flights, performance data were obtained chiefly with two cameras mounted in the missile. One photographed an instrument panel, and the other — rigged as a heliograph — had four wide-angle lenses to produce a photographic record of the sun and the horizon, a record which described all attitudes of the missile during flight. The film from these two cameras therefore gave a continuous account of many of the details of the missile's orientation and speed, and of the performance of its components.

For those who like to camp out on wastelands, this is an acceptable method of gathering data. Search teams had to bivouac up-range, find the points of impact and recover the films from the debris. Many technical experts were educated in the care of handling of a shovel. Without doubt, dwindling enthusiasm for this chore was a strong impetus to technical advances in radio telemetry.

The Guidance Concept

Analyzing the photographic records was a slow process, but it yielded sufficient information to reconstruct the flight history and to identify sources of trouble. By mid-1948, the knowledge accumulated on about 20 rounds had resulted in the development of a single JATO booster unit to replace the original cluster of four which had complicated the problems of launching and of separating the missile and booster. Liquid-fuel propulsion systems were more fully understood, and many other refinements were introduced into

This is the 1946 model of the Nike missile, progenitor of the Nike family. With its solid-propellant booster and liquid-propellant sustainer, this historic missile is the great-great-grandfather of the Nike family. It represents the beginning of a new concept in aerial defense tactics.

the hardware designs. It was now time to embark on the more sophisticated programs which were to test the Nike concept of command guidance.

For a guided missile to respond properly to up-down and right-left steering commands, its attitude in space must be known at all times. Thus, the Nike missile was designed to assume and maintain a selected orientation with respect to rotation about its long dimension. In other words, it stabilizes itself in roll before it executes a steering command in a specified direction.

The first attempts to stabilize the missile in its roll position revealed some unexpected behavior characteristics. It was apparent that aerodynamic damping in high-altitude, supersonic flight did not correspond to predictions based on the preliminary data. Fortunately, however, an efficient telemetry system was now available. With its 28 channels of information, this system sent back from the next three rounds enough data to complete the design of a roll-stabilization system. The missile now had a "sense of direction."

Testing of Steering Ability

The next series of tests was therefore designed to determine Nike's ability to accept and execute steering orders. The air-borne programmer, first developed to "exercise" or try out the roll system, was revised to issue a few simple but exacting orders to accomplish climb and dive maneuvers. This "single-step" approach to steering in any direction was carefully planned to reduce the uncertainties that can delay and confuse analysis if too much is attempted in critical phases of a test program.

Subsequently, composite steering orders for both climb and turn maneuvers were transmitted to the missile by the first engineering models of the Nike missile-tracking radar, which could also send a "burst" order to test the detonating system for the warheads.

During the next four months, test firings demonstrated the missile's ability to perform controlled maneuvers on command. Its structure, power plant, control system, and air-borne guidance components evolved into a workable, tactical configuration. In addition, equipment and techniques for preparing, handling and launching missiles were refined and qualified by test. Nike was now demonstrated to be a true guided missile, remotely controlled from a ground-based installation. It could out-run and out-maneuver any bomber aircraft then in existence or foreseeable for some time.

Concurrently with this missile-firing program other Bell Laboratories and Douglas Aircraft groups were designing and improving the many ground-based units of the system. And it was about this time that all work entered a crash schedule of designing for production. This changed the complexion of the firing program at White Sands considerably. Most firings were conducted to solve specific hardware problems in support of production.

Despite all the confidence in a test program of this type, there is no proof like an actual demonstration. Nothing is more convincing to the critical observer than to have missiles engage a number of real drone aircraft, then have a survey party count the number of shattered aircraft wings on the Range, and divide by two! But one must also consider the expense of such demonstrations. This was anticipated in the advance planning, and a Bell Laboratories parallel program of computer simulation had been under way for some time. By simulating hundreds of flights of missiles and aircraft in the laboratory, this program actually set the pace for development. It remained for the field tests to validate the results and to explore marginal conditions.

These full-scale tests were carefully planned to yield all possible information on Nike's field of fire and on how effectively it could intercept targets. Once again, the agencies involved in the tests produced ingenious instrumentation in support of the program. For example, since the only type of drone available at the time was the modified B-17, it was instrumented to perform a trick 2g spiral maneuver at the most critical time when the missile would have most difficulty in intercepting it. As additional examples, Douglas Aircraft Co. personnel designed a unique wide-angle camera for the drone, and the Army's Ballistic Research Laboratories developed a special ground-based photographic theodolite system to record events in the crucial intercept zone. Missiles that did not carry warheads were equipped with a token "spotting" charge, producing a brilliant flash, to indicate visually the result of sending a command to detonate at intercept.

In the meantime, the Missile Range people improved their instrumentation used to record all events from launch to impact, and Bell Laboratories installed the first engineering model of the complete ground-guidance system. The tracking radars were equipped with bore-sight cameras to photograph their performance as the missile and target were tracked.

These and many other careful preparations were well justified. On November 27, 1951, a Nike missile, under control of its command-guidance equipment, became the first such weapon to engage an aircraft target successfully. In all, during this section of the testing program, the missile scored two direct hits with unarmed missiles and two kills with warheads. The final result of these tests was the tactical weapon system known as Nike Ajax.

Much of the subsequent story of White Sands testing naturally concerns the present- and future-generation weapons—Nike Hercules and Nike Zeus. Rather than present the Hercules and Zeus programs chronologically, however, it will be sufficient merely to outline some of the main trends in testing techniques and to describe a few of the more significant developments.

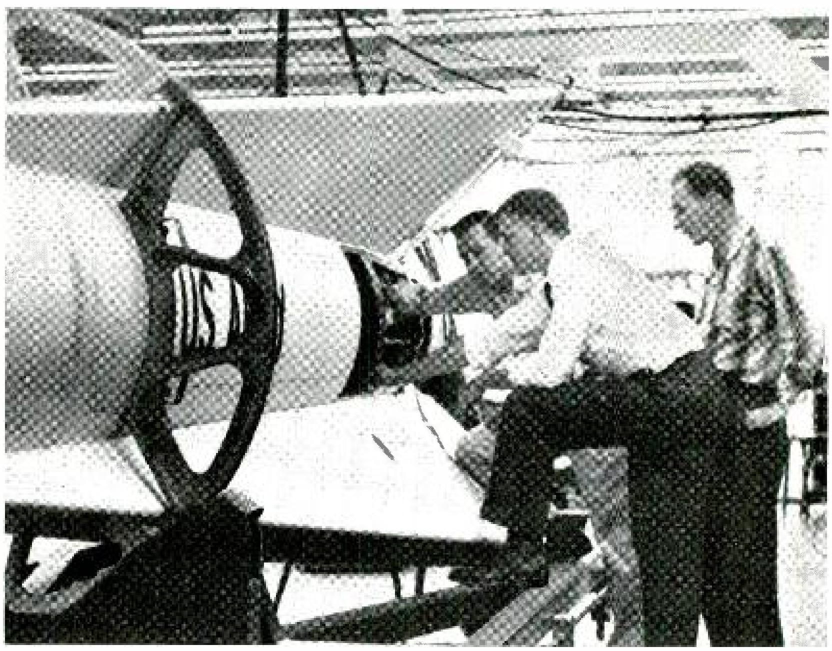
Recent missile testing at White Sands has further emphasized the role of simulation. The Hercules ground-guidance system at the Range is equipped with a target and missile simulator that feeds flight-path information into the servos of the tracking radars. Realistic tracking noise is superimposed. With this equipment, test conditions are generated to excercise the system prior to expending real missiles or targets. It is also possible to duplicate the conditions of an actual flight as an aid in analyzing the results.

As an additional refinement, other devices integrated with the simulator permit engaging a simulated target with a real missile. The missile carries both a token spotting charge for the cameras and a burst of metallic chaff for radar detection. By programming the simulator to represent targets that fly at very high speeds and with great maneuverability, it is possible to get data that would be practically or economically impossible to obtain with real targets.

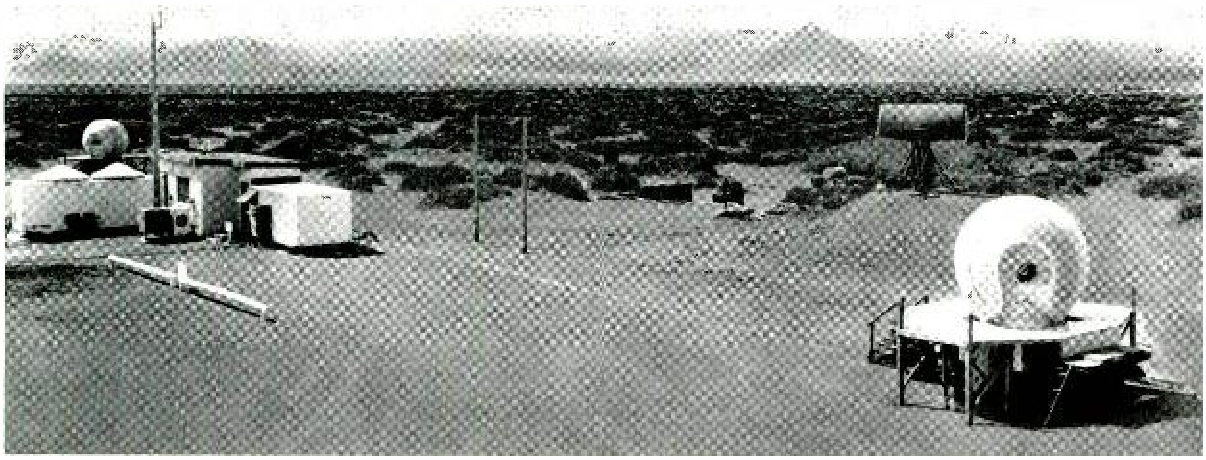
Another interesting development is an ingenious trick that, in effect, allows one missile to accomplish several test objectives. The missile carries multiple spotting charges, each detonated by successive burst orders. A number of trajectories are computed to embrace various realistic intercept or "end-game" conditions. First, the missile intercepts either a real or simulated target. Then it coasts under programmed orders until the computer can recycle to the next target (simulated) and pick up the new end-game orders. By this method, a single flight has completed as many as four intercepts, much to the amazement, and to the credit, of those who conceived the idea.

Contributions by many agencies have advanced the art of missile testing. Drone squadron personnel have perfected formation flights and low-altitude "hedge-hopping" missions. Electronic indicators are supplementing photographic devices for recording flight data. A cooling chamber has been designed to cover the complete missile and launcher. This chamber, which is quickly removable before launching, permits operational tests at extreme sub-zero temperatures.

Evidence of the importance of these improved testing facilities is apparent in the rapid progress of the Nike-Hercules program. The first Hercules was fired in January, 1955, and with the benefits of past experience, efficient procedures and improved facilities, field-test people could now take



Jim Morgan, left, Dick Tegmeyer, center, of Bell Laboratories, and Lyle Smith of Douglas Aircraft Co., inspect the guidance system of a missile at White Sands.



Nike Hercules ground guidance system at White Sands Missile Range. Consisting of one tracking and two acquisition radars operating in conjunction with an analog computer, this production system typifies the many subsequent installations at sites throughout the United States.

the failures and surprises in stride. In less than 3½ years from the first experimental firing, Hercules was combat ready.

Development testing is continuing at White Sands to assess the full performance capabilities of the Nike family of weapons, and to evaluate improvements in meeting new threats from small, high-speed targets in the presence of countermeasures. Nike-Hercules has destroyed drones flying at about Mach 2.5 at altitudes over 70,000 feet. With the help of special high-altitude targets, the region above 100,000 feet is being explored. The desert floor at the Range is scarred with impacts at surface targets, demonstrating Hercules' versatility in the weapons field.

Zeus: The Newest Nike System

The Nike Zeus, the only anti-ICBM missile system presently under development, has been successfully test-fired at White Sands (RECORD, *March*, 1960). A three-stage missile, Nike Zeus is launched with a solid propellant booster developing 450,000 pounds of thrust. This is the most powerful single-unit rocket ever fired in the United States.

An intercontinental ballistic missile warhead, traveling at speeds of more than 15,000 miles per hour, can arch across 5,000 miles in less than 30 minutes. Consequently, the success of a counter missile depends on early detection of the enemy ICBM. To accomplish this, the Zeus system uses highly sophisticated detection, tracking and coordination elements. Like the Ajax and Hercules, the Nike Zeus employs a ground-based guidance system with a radio-radar link between control equipment in the missile and the guidance computer.

Preliminary flight tests conducted at White Sands are designed to evaluate the aerodynamic characteristics of this new weapon which promises to be the most deadly defensive missile ever developed.

Laboratories-developed acquisition and surveillance radar and guidance permit Zeus to "lock on" to a hostile missile the moment it comes within detection range. The battery computer follows the action through its radar systems, and the Zeus missile is triggered at the critical instant, destroying the enemy intercontinental ballistic missile a safe distance from the potential target zone.

These few aspects of missile testing at White Sands, as interesting as they are to the participants, may still not convey the magnitude of the project. It is difficult to appreciate the true complexity of the test programs and to realize how all problems were increased in difficulty by the newness of the field and the pressure of time. But Nike's operational successes, during the short period since World War II, demonstrate how effectively an Industry-Military team has met a critical challenge to our national defense.

Modern electronic switching circuits using solid-state devices pose very special challenges to mechanical and equipment design. This calls for a new kind of switching equipment consisting of plug-in circuit packages in air-conditioned cabinets.

D. C. Koehler

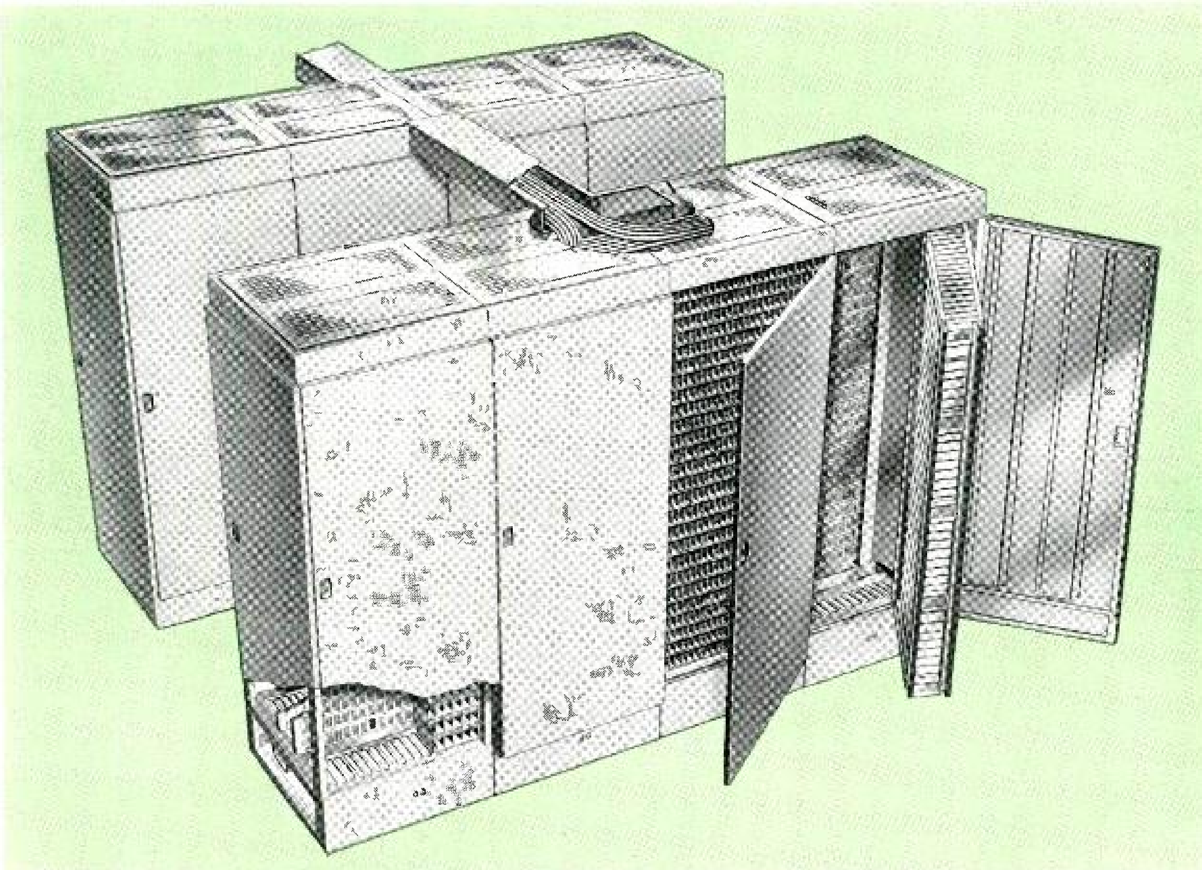
Mechanical and Equipment Design For an Electronic Central Office

The advent of electronic switching systems poses new kinds of problems for mechanical and equipment designers. Modern solid-state devices are much more compact and temperature sensitive than electromechanical apparatus. Further, it is no longer sufficient merely to interconnect components according to predetermined circuit schematics for proper circuit performance. The length and orientation of leads, together with associated distributed capacitance and coupling, have such a dominant effect on circuit performance that designers must frequently readjust the values of components and sometimes even change the circuits themselves. Thus, the circuit and mechanical designs must be developed simultaneously and neither can be completed independently of the other. This requires the highest degree of cooperation between the various design groups, with free interchange of information through all stages.

The mechanical and equipment designs described in this article have been used in an experimental electronic switching system developed for use in the Laboratories to study new electronic techniques and equipment arrangements. We expect that the design for future systems will be modified according to knowledge gained with this equipment and also to meet new requirements.

To fulfill the need for the first electronic switching system, however, mechanical and equipment designers have developed new types of circuit packages and cabinet-mounting arrangements which are strikingly different from anything found in our present telephone switching offices.

The electronic switching cabinets, shown on the next page, consist of steel frameworks covered with aluminum panels which have an attractive blue and gray vinyl finish. The doors on the front and rear have magnetic latches and flush handles and open by finger pressure. Each cabinet is 7 feet high, 2 feet deep and 28 inches wide, permitting use of Bell System standard 23-inch mounting plates. Equipment is mounted from both front and rear to reduce floor space and lengths of leads among large numbers of packages. Local cabinet wiring occupies the center, and is made accessible by swinging open the hinged gates on which equipment in the front of the cabinets is mounted. The 115-volt ac power for convenience outlets is carried by ducts in the cabinet bases, whereas the 230-volt operating power and various dc and pulse leads are carried through the cabinet tops. Attractive overhead ducts have been designed to carry the wiring across aisles.



Equipment cabinets have swinging gates on front side for easy access to wiring. Louvers in base (note cut out section view) control upward flow of the conditioned air needed for switching units.

For the benefit of temperature-sensitive diodes and transistors, conditioned air is blown upward from pressurized ducts in the base of the cabinets, past the circuit packages in the front and rear, and out into the room through grills in the cabinet tops. Separate adjustable louvers near the base in both the front and rear of each cabinet permit apportioning the air from a common supply according to the amount of heat to be dissipated in each area. Most of the cabinets dissipate less than 1 kw, but some of those containing electron-tube circuits will dissipate more than three times this amount. Hopefully, improved characteristics of newer solid-state devices may obviate the need for air conditioning in future systems.

Components of most circuits are mounted on plug-in printed wiring boards of three varieties, as shown in the lower photograph on page 175. Narrow 1.6- by 7-inch phenol fiber boards with etched wiring and edge-clinched components are used where the components are tiny, and where circuits permit use of sufficiently small numbers of components with longer wiring interconnections through the sockets to other packages. About 70 per cent of the boards are of this type. The edge-clinched component leads are on uniform ¼-inch centers that allow rapid assembly with tools which trim the leads and form them around the edges of the board on a "gang," or group, basis. The formed leads are gang soldered to the printed conductor patterns on the two sides by dipping the edges of the board in a solder bath. This not only connects the component leads to the circuit patterns, but also forms interconnections between the patterns themselves.

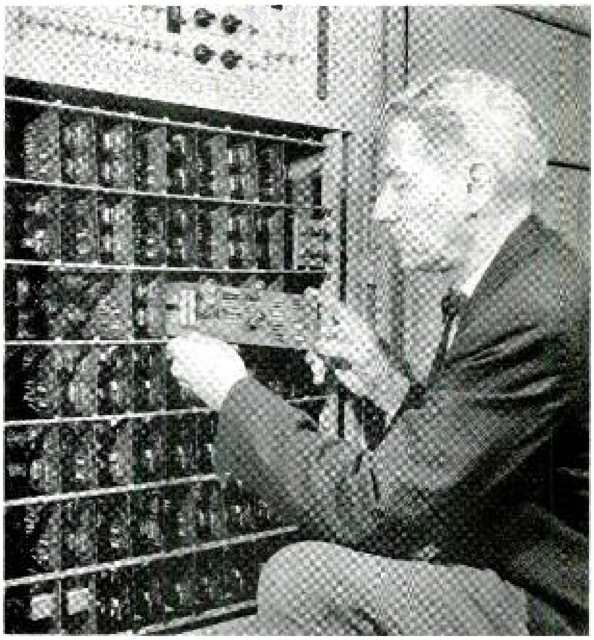
Such an assembly technique has several advantages when compared with solder dipping the flat face of the board. With flat dipping, care must be taken (1) to avoid damage to the board material because of heat from the solder bath, and (2) to avoid ragged "whiskers" of solder which sometimes project perpendicularly from the surface.

The narrow boards are designed to accommodate one or two transistors mounted in holes near the outer end. Leads from these transistors are attached to printed conductors which run directly to the end of the board and connect with the remainder of the circuit pattern through a special plug; the latter interconnects conductors on the two sides of the board. Removal of this plug isolates the transistors, so that electrical checks can be made without taking them from the printed-wiring board.

Somewhat larger 3.6- by 9-inch boards are used in electron-tube circuits, where as many as 66 components are interconnected by leads for which the shunt capacitance must be kept small — too small to permit using connectors. Components are attached by threading their leads through holes, clinching against printed conductors on the reverse side, and soldering.

Although not as simple as edge-clinching and edge-soldering, these operations have also been mechanized with a variety of machines built for this purpose. For example, machines have been used at the Laboratories for assembling and soldering components to limited numbers of boards. The assembly machine is loaded with components of a given code, and these are assembled in the appropriate position on each board of the lot. This is repeated for other components until all are assembled. During the assembly process, the machine trims the component leads, bends them at right angles, inserts them through the holes, and clinches them on the reverse side. For soldering, the boards with assembled components are

Photograph shows three different varieties of printed-wire boards used in electronic switching. These are illustrated by the inverter amplifier, left, electron tube flip-flop, center, and junctor circuit.



E. Ley inserts a printed-wire board into special test equipment for system's temporary memory.

clamped to a steel plate with clearance holes at the location of each clinched lead. The board and plate assembly are then depressed into the surface of a hot solder bath; this forces the solder to enter the holes and wet the clinched leads and adjacent areas of the circuit paths. Thus, the board is protected by exposing only limited areas to the hot solder.

Still another variety of printed-wire board (varying in size up to 3.3 inches by 10 inches) is used in certain circuits of the switching network. These circuits also require relatively large numbers of closely associated components of sizes too large to permit using the smaller boards. In addition, many of the terminals are connected in parallel with other similar boards. This led to the adoption of the same "pinch" terminal design used in the P carrier system (RECORD, *July*, 1959). These terminals engage 0.040-inch diameter wires supported in molded phenolic details. Connections are multipled simply by extending these wires between the various board positions. The wires are gold plated and the terminals are palladium coated to assure low-resistance and noise-free contacts.

With the exception of the P carrier terminals mentioned above, the printed-wire boards plug into connectors of a special design developed for the electronic central office (ECO). All of them have twelve terminals, and are used singly for the narrow printed-wire boards or in carefully-aligned pairs for the wider boards. Each connector consists of two molded phenolic body halves and a simple insulating spacer that supports two groups of six contact springs. Assembly is facilitated by a metallic strip which holds each contact group together; this is sheared off after the connector has been assembled. The springs are designed for a contact force of about 200 grams each, with a high compliance to minimize variation in force with board thickness. The spring contacts and mating conductors on the printed-wire boards are gold plated to assure low contact resistance. The connectors are held together by spring clips, which also anchor the connectors to the mounting plates without screws. To minimize errors, the connectors contain code teeth which make it possible to insert only those printed-wire boards that have slots in the corresponding positions.

An important advantage of this connector and package design, is the ability to locate readily a particular package or connector via its coordinate location. Package 14G, for example, is quickly found in the 14th row from the bottom (starting with row zero) and the G or 7th position from the left. Similarly, the associated connector may be quickly located. This, together with an efficient arrangement of terminals on ¼-inch modular centers, substantially reduces the wiring time. The combination of modular terminal centers, wrapped connections, and small polyvinylchloride-insulated wire results in an orderly wiring arrangement—even with terminal densities as high as 1152 per square foot. Such wiring may consist of single conductors in various gauge sizes, and also of small-diameter coaxials, twisted pairs, and special close-twisted pairs with ½-inch twist length. In some applications, these special pairs are almost as suitable for pulse transmission as the small-diameter coaxials.

Some major components of the electronic office, such as the flying-spot store semipermanent memory (RECORD, *October*, 1959), have special problems in mechanical and equipment design. These require the use of plug-in chassis as well as printed-wire boards for the electronic circuity, and other mechanical components such as lenses, photographic plates and motor devices. Future electronic systems will no doubt require still other equipment arrangements to satisfy new needs as they arise. This brief accounting of some of the hardware considerations involved in the present electronic system has sought to show the progress made on the physical problems associated with some experimental units.

Intensity of Sound Affects Listener's Ability to Locate Direction of its Source

Recent research at Bell Laboratories has looked into the ways people locate the direction of sound. The results may be the improvement of stereophonic radio and TV programs, which are transmitted nationwide over telephone facilities.

In the experiments, two microphones in the ears of a dummy were substituted for human ears. The dummy's head reproduced the "shadowing" of sound by a human head. Persons participating in the tests wore the extra "head" so that motions of their heads would not be reproduced, because even very small movements influence hearing. The experiments were conducted in a "dead" room—one with sound absorbent walls—so that reflections would not affect the results.

The natural sounds received in each microphone were altered electronically and delivered to the earphones. Listeners were asked to point to the apparent direction of the altered sound. Normally, the ear that is closer to a sound hears it earlier and louder than the other ear. Here, however, artificial differences in time delay and intensity were introduced, and acoustics scientists found that the factor of intensity is more important than previously believed. If sound reaches one ear first but reaches the other ear somewhat louder, the hearer becomes confused.

R. L. Hanson, right, sends electronically altered sounds to Mary Lou Hartig's "extra" head. She then indicates the apparent direction of sounds.

By developing a comprehensive and automatic system for measuring the transmission leakage at the insulators on open-wire lines, outside plant engineers have reached a more complete understanding of an important factor in the design of telephone equipment—inclement weather.

J. H. Shuhart

Automated Environmental Testing At the Chester Laboratory

The pioneer electrical communication circuits were what we now call "open-wire" lines. These basic transmission paths consist of bare wires supported on glass, ceramic, or plastic insulators mounted on the crossarm of a telephone pole.

While very considerable quantities of such lines are still built each year, competing facilities, such as multiple-line wire and cable, have gradually supplanted open wire except for situations where relatively few circuits are required and conditions are otherwise favorable. Accordingly, development work on such lines has largely stopped.

This article tells the story of how insulators have been evaluated under actual outdoor exposure conditions. The leakage data presented as a function of aging, frequency and weather conditions are still very useful for the operation and maintenance of the large amount of open wire remaining in the telephone plant. Actually, as will be brought out later, the evaluation of insulators has been reduced to such an automatic basis that very little manpower is required to carry it on. The equipment is therefore still in use for the evaluation of a few types of insulators of major current interest.

Although it was the original method of transmission, and in many ways is one of the simplest, open-wire lines nevertheless require very subtle and precise engineering for optimum electrical performance. In addition to the many and variable electrical considerations, there are also many physical factors which in turn affect the electrical properties. Important among these are the size, type, and spacing of the conductors, pole spacing, environmental conditions, and the type of insulators used to support the conductors.

Numerous types of electrical losses which affect transmission can occur on open-wire lines. The most variable of these is the shunt loss, or "leakage," at the insulator supports. Essentially, leakage is transmission power that finds a "natural" electrical path—through dampness or moist air—from one conductor to another or from a conductor to some ground path. Leakage therefore varies considerably between dry and wet weather. Like the weather, leakage is an ever-present problem, and Bell Laboratories has been interested in its characteristics for many years. As an outgrowth of this interest, outside plant development engineers have vigorously pursued the improvement of, and testing techniques for, insulators for open-wire transmission.

Testing Insulators

At the Chester, New Jersey, location of Bell Laboratories, more than thirty types of insulators have been characterized. These include standard commercial types, experimental varieties, and insulators for special applications like "dead-end" and mid-span use. The insulators are made of glass, porcelain, rubber and various plastics, including those with the trade names Selectron, Marlex and Hyfax. Some of the glass types have been treated with silicone in an effort to improve their surface-leakage characteristics.

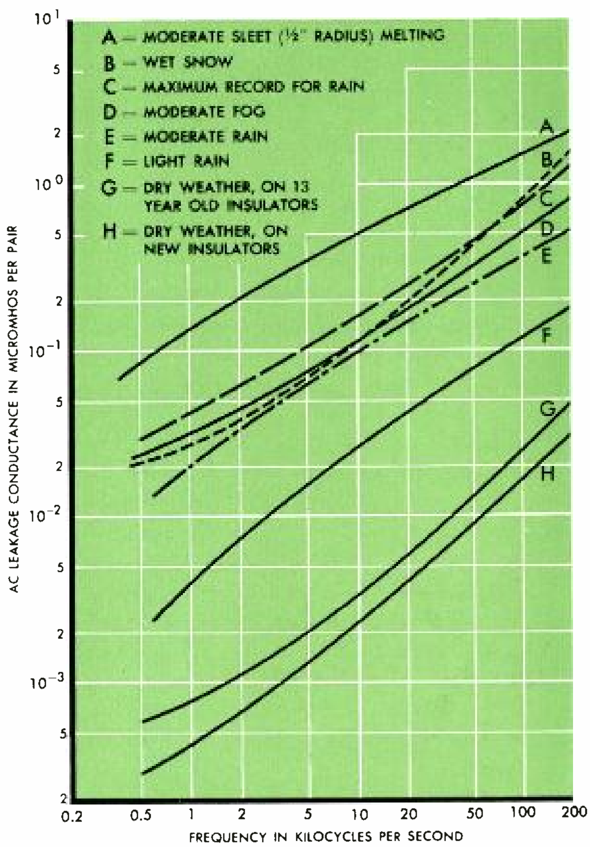
These insulator specimens were studied under natural weathering conditions, and some have been exposed at this outdoor laboratory for more than 25 years. Many insulators have also been brought in from areas where various sources of contamination are present to determine the degradation caused by such environments. Corrosive deposits from chemical plants, soot, and salt spray are typical contaminants.

The data obtained in these insulator tests are analyzed for two specific purposes. First, they provide important information for the engineering of open-wire lines. For example, the data indicate the relative leakage performance, as well as the average and maximum values observed, for the types of insulators currently manufactured. Second, the data are invaluable in the study of new designs, materials, and surface treatments for improving insulators and for designing insulators for new applications.

The test facility at Chester obviously could not be manned at all times, whereas "we're going to have weather, whether or not." It was therefore the custom for a dedicated engineer to dash out to Chester at any time, day or night, when interesting weather conditions of the more unpleasant kinds—rain, fog, or sleet—occurred. Eventually, tiring of this uncomfortable procedure, the engineers concerned with these insulator studies developed a comprehensive and automatic system for testing the leakage characteristics of open-wire insulators. Basically, this insulator-testing facility measures the open-circuit impedance of a line that is short enough to make propagation effects negligible. The values of capacitance and conductance on this line, obtained during all types of weather conditions, may then be substituted in a well-known propagation equation to determine the attenuation characteristics directly attributable to leakage.

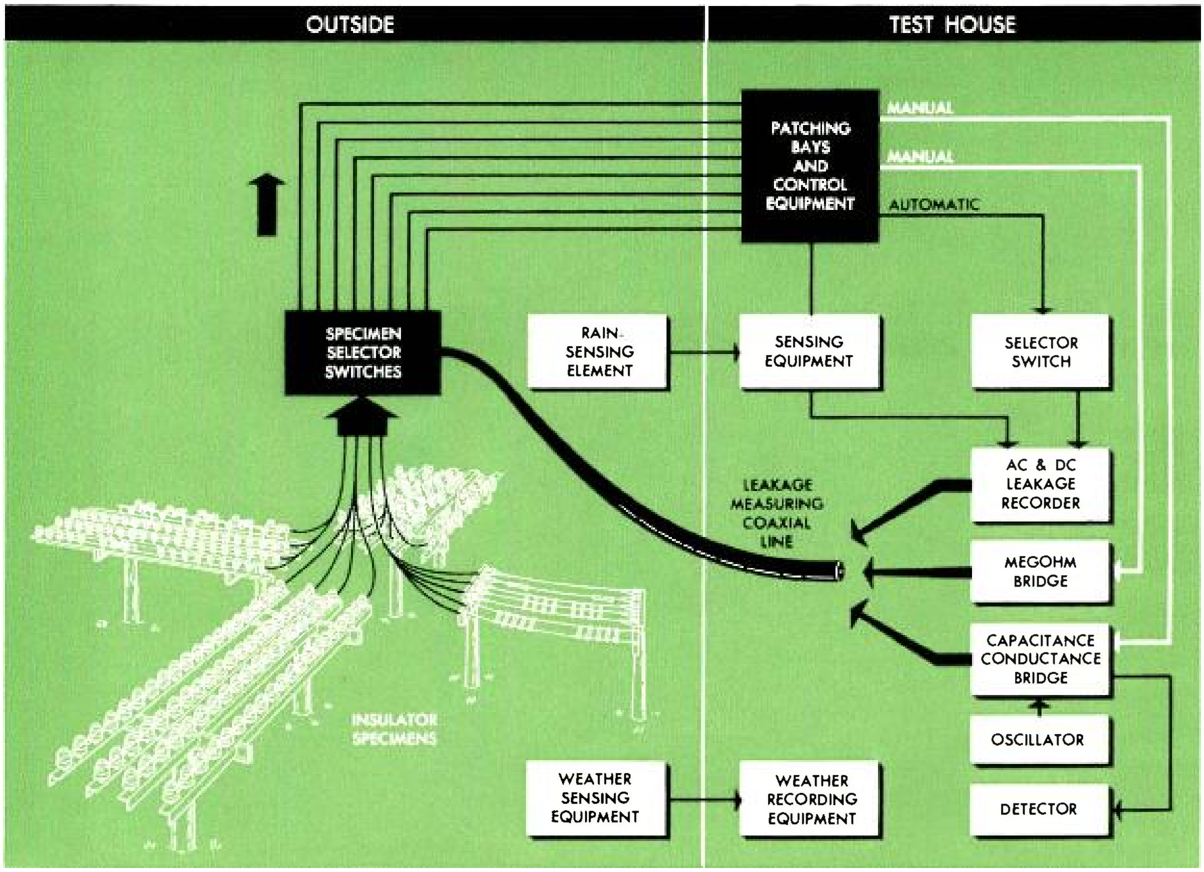
For testing, the insulators are placed on racks, as shown in the diagram on page 180. This arrangement permits "weathering" the specimens in natural environments, so that the test conditions closely simulate actual field installations. Since only a small quantity (usually 20) of each type of insulator is tested at one time, errors must be minimized by precautions in setting up the specimens and in establishing the measuring techniques.

The insulator specimens can be connected, one group at a time, to a single coaxial cable leading to the measuring equipment. A special switching arrangement, called the "specimen selector," automatically selects and connects the groups



Typical ac leakage data for a group of DP insulators taken during various types of storms.

The author adjusts the sensitivity of the equipment that automatically records wet-weather losses of insulators used primarily for open-wire lines. Recorder, shown at the upper left, is plotting a record of losses on 12 types of insulators.



Block diagram of insulator testing arrangements. Insulator specimens are placed on racks specially designed to facilitate uniform weathering and to minimize extraneous losses. Test and control equipment is contained in a master test bay inside the test house. Tests measure ac and dc leakage.

to be tested. This switching scheme is of some interest because it uses sealed-in-glass reed switches, developed at the Laboratories (RECORD, *September,* 1955). These switches are ideal for this application because of their very low capacitance and surface leakage.

The general arrangement of the test setup is shown in the diagram above. Insulator specimens, in sets, are permanently wired to the specimen-selector unit, which selects specimens both automatically and manually. The patching bays, indicator pilot lamps and sequence-switching units control the actuating coils associated with the glass-sealed switches of the selector.

The test arrangement has been designed to measure leakage on both kinds of power that a telephone line must carry—ac for voice and carrier and dc for signaling. To measure these leakages, there is a capacitance-conductance bridge with an associated oscillator and detector for testing open-circuit impedance in the frequency range between 0.1 and 200 kc (from which ac leakage is derived); a megohm bridge for measuring dc leakage; and a recorder which provides continuous data on both dc and ac leakages. Sensing equipment and control equipment are used in conjunction with the automatic recording equipment. These units turn the recorder and its auxiliary equipment on at the first indication of inclement weather, and the leakage recorder remains in operation until the storm subsides.

Weather-recording equipment provides continuous information on temperature, relative humidity, rate of rainfall and wind velocity. This information is correlated with the leakage studies and has also proven very helpful in many other test programs at the Chester Laboratory. Leakage studies are confined principally to periods of inclement weather, although dry weather tests are made periodically for correlation purposes. The opportune time for testing is chosen by observing the trends of the recorded leakage data and the desired storm characteristics portrayed on the weather recorder.

In a routine test, one makes an "initial" bridge balance at the desired frequency, with none of the actuating coils of the selector energized. This gives the capacitance and conductance of the test lead. Then, after a particular coil corresponding to the specimens to be measured is energized, "final" capacitance and conductance readings are made. The difference between the initial and the final readings is the total capacitance and conductance of the group of insulators. These values are then used to calculate the capacitance and conductance per pair of insulators—the form in which the information is most useful.

Measuring Leakage

Measurements of ac leakage are repeated for the selected group of specimens at a number of frequency intervals to provide a smooth curve. To cover the 0.1- to 200-kc band usually requires measurements at a minimum of seven frequencies. It is also usually desirable to compare at least twelve types of insulators during a particular storm. Since this involves at least 84 bridge balances and data notations, it is imperative that every possible time-saving trick be employed to complete the test before there is any change in the weather. The minimum running time for such a test is around 20 minutes, or four to five bridge balances and recordings per minute. This means that whoever is monitoring the equipment must make a fairly accurate guess as to the probable duration of uniform storm characteristics at the start of a test.

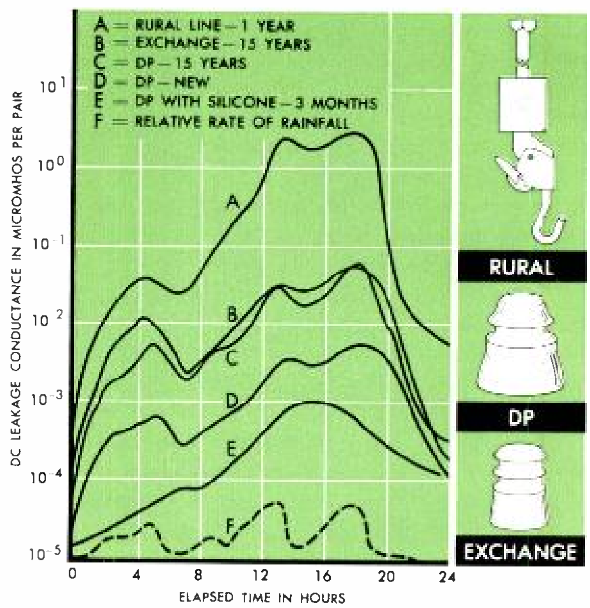
The ac bridge readings are supplemented by continuous measurements of dc leakage, and these data are plotted on the recorder for the entire storm period. Usually, this recorder compares the dc-leakage characteristics of twelve types of specimens. It is capable of measuring conductance values ranging from 0.0001 to 100 micromhos per pair of insulators. In terms of resistance, this represents a spread of from 10,000 ohms to 10,000 megohms.

A recent addition in further automation of the test arrangement is a unit for continuously recording capacitance and conductance at selected frequencies. This unit, plus the dc-leakage recorder mentioned above, provides a complete record of capacitance and conductance variations during a storm. These two units also show the relationship between dc and ac leakages for various weather conditions.

To this point, we have been concerned principally with leakage measurement, not with the significance of such measurements. An examination of some of these leakage data, gathered over the years, will help to point up some of the "whys" of the measuring techniques. As stated earlier, the leakage characteristics of an insulator depend largely on three factors: (1) the nature and intensity of a storm, (2) the effects of aging on the insulator surface, and (3) the design and the material of the insulator. The relationship of these three factors to dc leakage, for a typical rain-storm, is shown in the first of the accompanying graphs. As the curves indicate, there is an enormous range in leakage—in this case, it varied by about five orders of magnitude.

These curves also illustrate well the pronounced effect that the design of insulators has on leakage. For example, an experimental insulator (curve A and top inset), which has no effective "dry path" for the conductor, has roughly one-hundred times more leakage than the DP type (curve C or D and middle inset). Aging characteristics also show up well here. Leakage on DP insulators, for instance, increased five- to ten-fold after 15 years of exposure (comparing curves C and D).

Another interesting example of aging shows up in connection with DP insulators that were given a silicone surface treatment. Curve E shows the leakage on the treated insulators after they were aged about three months, and indi



Typical dc leakage data taken during a rain storm. Curves show how leakage varies with design, age, and storm intensity. Insets at right show appearance of insulators depicted in curves.

cates that their performance is roughly five times better than new, untreated insulators (curve D).

Other comparison tests on silicone-treated specimens showed even better results. When initially installed, their leakage was only one per cent of that of new, untreated insulators. However, after a single year's aging, the silicone treatment showed only a very slight improvement over untreated insulators of the same age.

On the first of the accompanying graphs (*page 178*), some observations are plotted to show variations in ac leakage during various types and degrees of inclement weather. The comparisons are made for DP insulators only, and indicate that the losses increase with the amount of rainfall. They also indicate that fog, especially when acting on this skirted insulator, can produce losses that are even greater than those observed during a moderate rain. Snow on the insulators and crossarms produces very wide variations, depending on texture and quantity.

Icing Causes Other Problems

Icing creates the greatest leakage. When the line conductors become iced, however, the abnormally high attenuation caused by the energy losses in the ice makes leakage across the insulators relatively unimportant because so much energy is lost to the coating of ice in the span. Sometimes the attenuation due to icing of the wires increases to the point where repeaters in the line cannot overcome it. A build-up of ice is also very serious because it may result in mechanical breakdown of the line.

To obtain truly comprehensive data, insulator studies must cover not only the normal inclement conditions such as rain, fog, snow and sleet in various degrees and combinations, but also the effects of contamination of the insulator surface by airborne deposits of dirt, salt spray, chemical and corrosive fumes, sand blasting, aging, and, last but not least, the effects of insects living and dying under the skirted portion of the insulators.

Coverage of such a multitude of conditions may appear to have been an ambitious program, especially when one must rely upon nature to supply all the variables. Or it may also seem that a program of this type could have been accelerated by testing under artificially produced weather conditions that could be laboratory controlled. Although such procedures have been investigated at various times, the results have never correlated satisfactorily with data obtained under natural conditions.

Recent improvements in the methods of automatically switching teletypewriter messages are a result of a new switching system developed at Bell Laboratories. This system, the 82B1, is designed for easy and rapid installation, and it permits messages to be sent to an unlimited number of addresses.

Automation i

Automation in handling teletypewriter messages within the United States became an accomplished fact for the U. S. Navy early in 1959. This resulted from the development by Bell Laboratories of a new automatic teletypewriter switching system — the 82B1. The system was designed to meet standard military requirements for communications procedures and became a part of the Navy's worldwide written-communication network supporting its fleet activity. While the 82B1 contains certain operational features specific to Navy requirements, it is also completely compatible with the automatic teletypewriter systems of the other military services. Thus, messages can be switched automatically from one service to another.

Teletypewriter-message switching differs significantly in principle from the more familiar telephone switching. What similarity there is, does not go beyond the concept of networks of lines radiating from a switching center to each station it serves. In the 82B1 system the originators of messages do not "converse" with the recipients. Instead, operators at the stations of origin prepare the messages on sending teletype-

E. R. Robinson

Teletypewriter Switching

writers. (Preparation includes delivery-address information at the beginning of each message and an end-of-message code at the end.) The messages then are sent automatically into the teletypewriter switching center where they are temporarily stored. Subsequently, automatic switching operations relay them to outgoing lines serving the stations of destination. At the destination stations, the messages are typed automatically on receiving teletypewriters. Thus, the entire operation is automatic except, of course, for the preparation of the message at the point of origin and the removal of the typed copy from the receiving teletypewriter at the delivery point.

Before development of the 82B1 began, planning engineers at Bell Laboratories set forth two fundamental design objectives. The first was to eliminate any possibility of a complete failure in the event of damage to, or failure of, any component. The second was the requirement that equipment be arranged to permit installation of a complete new switching center, or the expansion or contraction in size of an established center, within a short interval of time. This would be necessary during periods of military emergency.

To achieve these objectives, Laboratories engineers designed the system on the "building-block" principle; that is, each switching component is housed in a package which can be easily replaced in case of failure. Only two kinds of packages are required to build up a teletypewriter switching center — incoming cabinets and outgoing cabinets. These contain all the flexibility of features needed to adapt them to any application.

The 82B1 system can handle as many as 100 incoming lines and as many as 220 outlet destinations. Each cabinet is fully equipped to serve in systems of any size up to the maximum. Also, each cabinet contains its own rectifiers for dc power requirements, so that an office does not need a common power plant.

The incoming cabinet terminates switching center inputs. These may be either incoming lines from stations where the messages originate, or they may be incoming trunks from another switching center. An incoming line may be shared, on a party-line basis, by from two to five stations; or it may be used exclusively by only one station. The former case is known as a multi-station line; the latter, as a single-station line. An incoming cabinet can handle either one multi-station line and one single-station line or trunk, or two single-station lines or trunks.

Each incoming cabinet has two typing reperforator-transmitters — one for each input. These are machines that record and store the incoming messages in perforated and printed-tape form and subsequently transmit them "cross-office" to similar machines in the outgoing cabinets. The incoming cabinet also has a director circuit, with an associated non-typing reperforator-transmitter, that performs the switching operations for both inputs. These reperforator-transmitters operate at a cross-office speed of 200 words a minute. Therefore, the average message is relayed from the incoming line cabinets to the outgoing line cabinets in a matter of seconds.

The other type of switching center package — the outgoing cabinet — was designed for a high degree of adaptability. This side of the switching office must serve a variety of outlets: single-station or multi-station outgoing lines, with the former involving from one to ten channels; single- or multi-channel trunk groups, with up to ten channels in the latter case; and intentional or miscellaneous "intercepts." Each cabinet can serve two outlets. One may be any of the various kinds of outlets mentioned; the other also may be any of the kinds except a multi-station line.

A typical arrangement of the new 82B1 teletypewriter switching system. The two major pieces of equipment in this office—the incoming cabinet and the outgoing cabinet—permit rapid physical changes to be made with a minimum amount of effort and time on the part of the installers.

The outgoing cabinet contains two "bid" receivers which accept switching bids for the two outlets served. Since one of these outlets may be a multi-station line, the cabinet also contains a transmitter-start circuit. This is a device which "polls" each station on the line for traffic and starts its transmitter automatically when the station has a message to send.

Outgoing cabinets have four non-typing reperforator-transmitters. Here again, complete flexibility of assignment is possible. Generally, at least two of these machines are assigned to one outlet to minimize delays in switching messages across the office. Successive messages for a particular outlet are switched to the two machines alternately, and their transmitters alternate in sending messages to the outgoing line.

When deemed necessary, however, a third machine can be assigned for an outlet. "Urgent" messages can be switched to this third machine. A message in this "priority" machine will cause its transmitter to take control of the line as soon as any message in progress has been transmitted. Furthermore, the transmitter will retain control of the line until it has processed all urgent messages awaiting transmission. Only then will control revert to the two "regular" machines.

Traffic volumes to be delivered to a given destination may often exceed the capacity of one outgoing-line channel. For this reason the design makes it possible to have as many as ten machines and ten line channels serving a single destination. To minimize potential delay in getting a message from the incoming to the outgoing line, it is usually desirable to have more machines than line channels for an outlet — up to the point where more than four channels are required. Under such conditions, as the line channels become idle, they are switched automatically to the transmitters of the machines that have messages awaiting transmission. This ensures that any message waiting in an outgoing machine will be transmitted to its destination over the first idle line channel that becomes available.

The incoming and outgoing cabinets are interconnected by cords and plugs. Moreover, keys and "patching" facilities within the cabinets make them readily adaptable to numerous applications. These features permit complete factory testing and they greatly reduce installation and testing times when a system is installed or expanded. Furthermore, they provide the utmost security against a complete failure of the system when only a single component fails.

Safeguards for messages that pass through the 82B1 system include two kinds of intercept features incorporated in the switching center. With one of these — intentional intercept — an attendant can operate a key to direct a message to an alternate machine at the switching center. He would do this for a station that was closed for the day or temporarily out of service. The diverted message can then be released later when the station is able to receive it. The other feature — miscellaneous intercept — automatically intercepts any message that is incorrectly addressed or whose address has been garbled by line or equipment trouble. This action is accompanied by alarm indications to warn the attendant that he must take manual corrective action.

A Unique Feature

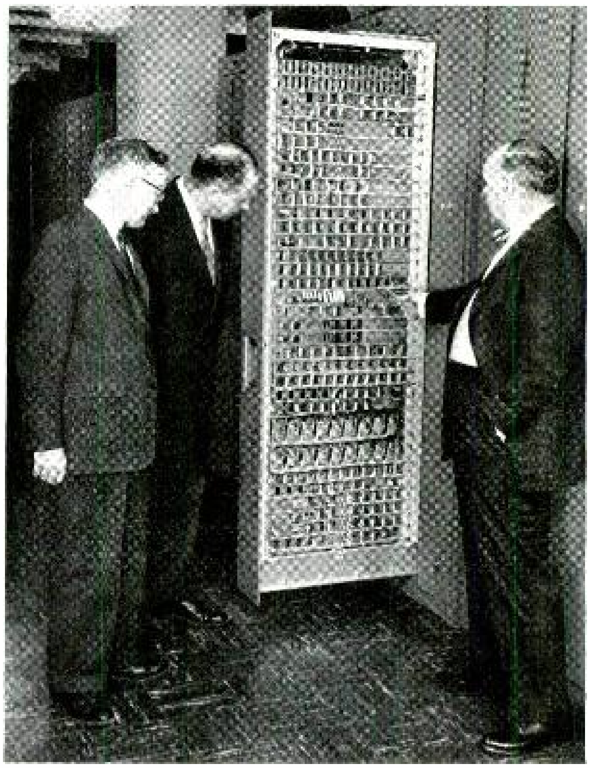
Another important feature of the switching center design is the method of handling multiple-address messages. Any message may be addressed to as many destinations as desired. Such multiple-address messages are switched directly from incoming to outgoing cabinets; the system does not have to resort to special multiple-address handling equipment. This feature, unique to the 82B1 system, removes any limitation on the amount of traffic that may be multiple address in character by eliminating the need for a common multiple-address handling position with its attendant capacity limitations. It also eliminates the vulnerability the system would otherwise have to failure of such a common unit.

Occasions sometimes arise when it is necessary to re-run a message from a switching center because of some difficulty that occurred during the original transmission. Accordingly, a monitoring typing reperforator is attached to each outgoing line channel from the switching center. These machines prepare a duplicate copy of each outgoing message in the form of perforated and printed tape, ready for re-transmission if the need arises. The outgoing cabinet "feeds" these monitors independently of the line. Thus their copy of the messages will be unaffected should line trouble have been responsible for the original transmission difficulty.

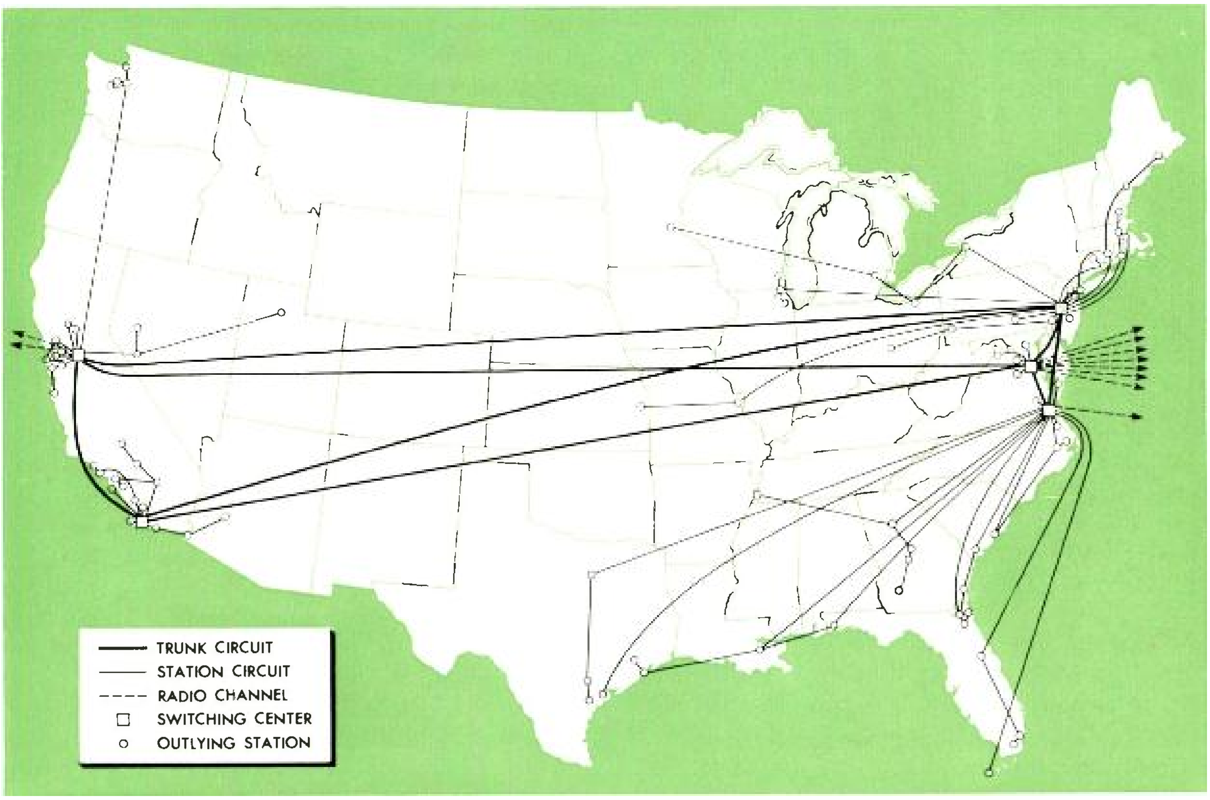
For machine and circuit maintenance, each switching center includes complete testing arrangements. These comprise specially designed test benches, equipped for checking all features of machine performance, as well as circuits for testing the performance of the switching equipment. The latter are cabled to wall cabinets situated at strategic locations throughout the switching center. There they appear on flexible, connector-equipped cords that can be attached to corresponding connectors in the particular equipment cabinet whose circuits are to be tested.

A new line of teletypewriter machines is used throughout the 82B1 system. This permits a choice of line operating speeds of 60, 75 or 100 words a minute, depending upon the volume of traffic a line must handle. Automatic teletypewriter switching systems were heretofore limited to 60 or 75 words a minute.

Each station normally has two teletypewriters. One is a sending machine that prepares messages in the form of perforated tape and transmits them automatically to the switching center. The other is a "receiving-only" teletypewriter for recording in page form the messages delivered from the switching center to the station. The sending machine has a pivoted-head transmitter that can "climb up" the tape and transmit the last character perforated. With this feature, operators need not tear off the prepared tape at



R. R. MacLaughlin, left, and F. B. Crowson, center, observe as G. A. Locke discusses how packaging is arranged in vertical drawer of a cabinet.



Network of routes within continental United States serviced by the 82B1 teletypewriter switching system for the United States Navy. With 82B1, messages are handled faster than ever before.

the end of a message for insertion in the transmitter — as was necessary with the older types of machines. An optional feature is an auxiliary transmitter that handles messages prepared on auxiliary perforating equipment or from feeder circuits of light-load stations not directly connected to the 82B1 system.

Each station also has a control unit. Where a station has exclusive use of the line, this unit functions only to prevent the transmitter from sending a message until the operator has completed perforating it. The control unit also transmits automatically a "start-of-message" code.

For stations sharing a line, the control unit works with both the sending and the receiving machines. In addition to the operations previously described, it starts the station transmitter when the station is polled and has a message to send. It also automatically requests polling when a message becomes available to the station during a period when the line is idle. Furthermore, it controls the connection and disconnection of the receiving-only teletypewriter for the delivery of a message to the station. All lines are operated on a full duplex basis; that is, any station on the line can transmit a message to the switching center at the same time that it or other stations on the same line receive a message.

One of the operating chores in an automatic teletypewriter switching center of the 82B1 type is that of keeping the reperforator-transmitters supplied with fresh tape. In the 82B1 system, the machines are supplied with a 3000-foot roll of tape, rather than the customary 1000-foot roll. This means that the tape supply requires replenishing only one-third as often, perhaps not oftener than once in every 24 to 30 hours of operation. The chore is further lightened by a "tape splicer." This device permits the leading edge of a new roll of tape to be butt-spliced to the end of an exhausted roll with a thermoplastic bonding material. Therefore, it is unnecessary to stop the machine to replenish the tape.

The 82B1 system being furnished the Navy comprises five switching centers and over 200 stations. Navy experience with it shows their written communications are now being handled faster and more efficiently than ever before. Furthermore, the service requires fewer operating personnel.

Laboratories researchers have built the most sensitive radio receiver ever demonstrated. This receiver, which can detect thermal noise from the sky, uses the fantastic new solid-state maser.

EXTREMELY SENSITIVE RECEIVER BUILT WITH MASER AND LOW-NOISE ANTENNA

News of Radio Research

Recent experiments have been conducted at the Holmdel location of the Laboratories with a low-noise antenna and receiver combination. The work was carried out by D. C. Hogg and E. A. Ohm, of the Electronics and Radio Research Department, and R. W. DeGrasse and H. E. D. Scovil, of the Solid-State Device Development Department. It represents another step along the way to trans-oceanic communication by reflections of signals from passive earth satellites.

The antenna-receiver combination has a lower noise-temperature than any complete receiving system ever before demonstrated. It measures noise generated in the atmosphere with a new high in precision. With such a low-noise system, engineers could extend the range or increase the bandwidth of telemetering equipment used for rocket probes into space.

The receiving system comprises a horn-reflector antenna which uses a narrow beam that is highly directional, and which picks up very little noise from the surrounding terrain. This antenna is coupled to a low-noise traveling-wave maser that amplifies in one direction only *(see page 162)*. With the horn-reflector antenna pointed vertically skyward, engineers have obesrved the overall input temperatures to be as low as 17.6 degrees K. for signals at 5.65 kilomegacycles. This figure is the total amount of noise contributed by the sky, antenna, and maser.

Measurements with the antenna pointed directly upward so that it intercepts a minimum of the earth's atmospheric envelope showed the zenith sky temperature to be about 2.5 degrees K. at 6 kilomegacycles. Theoretical calculations confirm these measurements.

Improvements now under way indicate that it is possible to have systems with an over-all noise temperature of 7.5 degrees K. at 6 kilomegacycles, or of 5 degrees K. at 2 kilomegacycles, for signals coming from near the sky's zenith.

The ultimate sensitivity of an earth-based communication system is limited by the thermal noise generated in the earth's atmosphere. In the past, practical limits were imposed by the high noise-temperatures inherent in available microwave receivers and by noise picked up by antennas from the "hot" earth. This limit in sensitivity may one day be lowered, however, with low-noise amplifiers and antennas that do not pick up signals originating behind them and at their sides.

Such devices could also extend the use of radio telescopes to ten times their present range in detecting radiation from hydrogen gas emitted from far distant galaxies. They could be useful in investigating interplanetary radio signals of all kinds, regardless of origin.

With the antenna pointed at the horizon, the noise input is observed to rise to a value near 200 degrees K. Accordingly, the advantages of the low-noise receiver can't be fully used in point-to-point earth communication. On the other hand, in space or satellite communication—where the antenna is pointed 10 degrees or more above the horizon—the system is thirty times more effective than a conventional microwave receiver.

Three Visual Concepts Announced At the American Optical Society Meeting

Three new concepts in the field of visual research were reported by Bell Laboratories scientists at the Spring Meeting of the American Optical Society, held April 8 and 9 in Washington, D. C. All the Laboratories participants are members of the Visual and Acoustics Research Department.

The first of these reports described experiments that indicate the role of pattern recognition in depth perception. Bela Julesz told how computer-generated stereo pictures give rise to peculiar and sometimes unexpected depth effects in binocular vision. In stereoscopic viewing, separate picture fields are presented to the right and left eyes. Relative positions of objects in these two fields are slightly displaced horizontally. This condition is known as "binocular parallax." Perception of depth involves the determination of the binocular parallax for corresponding points in the pictures.

News of Visual Research

How the brain determines equivalent patterns, which usually differ in brightness and shape, in the right and left fields is important both theoretically and practically. But it has been extremely difficult to determine experimentally. Observation of standard, photographic stereo material involving familiar objects is so customary for observers, that the depth perception takes place in thousandths of a second—too fast for easy experimentation.

In the Julesz technique, an electronic computer generates and prints artificial stereo picture patterns which a person then views through a stereo viewer. The attempt to see depth in unfamiliar material slows down the mental processes enough to permit observation. Adaptation may take up to a minute, after which a predetermined pattern in depth appears. Once it appears, however, the pattern is very stable. One of the fields can be distorted considerably without degrading the observed pattern to a comparable degree. It can be defocused, have random noise inserted, or be changed in relative size, without losing the depth impression.

The two main possibilities on how depth is perceived differ as to the order in which an image is perceived and fused in the two visual channels. One hypothesis holds that each optical "channel" in a human being searches for a pattern individually, and when it finds the pattern, compares it with that perceived by the other. The second hypothesis holds that the entire visual fields of both eyes are fused first, and then the brain searches for patterns in the fused field.

During the experiments, Mr. Julesz carefully controlled the computer patterns for each field to ensure that each pattern appeared to be completely random, and that there were no familiar patterns visible when the subject viewed them monocularly. When subjects viewed them stereoscopically, however, they saw certain correlated patterns in depth. This and other experiments using similar techniques eliminate the possibility of depth perception by the first hypothesis—the independence of the channels. The second possibility, then, seems more likely. By using this method light is shed on certain pattern recognition problems involved in depth perception.

Work on this aspect of vision began during an investigation of the possibility of programming a computer to recognize differences in depth automatically—in other words, to "see" in stereo. Topographic map-making could be greatly simplified, for instance, if differences in depth could be measured automatically by a computer instead of by the tedious manual-visual comparative methods now used.

Experiments in vision in which an observer can see only a negative after-image of an object were reported by George Sperling. His paper described the apparatus and procedure for producing a negative after-image without a prior positive image. These images appear as if they are photographic negatives. For example, in one experiment a hand holding a dollar bill appeared as a green hand with a pink bill.

In the procedure, an intense image (pattern or object) is flashed for a very short time, and then followed by a plain white field which lasts for one-fifteenth of a second. When the intensity of the test image is carefully adjusted, and it occurs about one-hundreth of a second before the white field, then the image will look like its photographic negative. Objects that are lighter than the surrounding area will appear darker, and colors will appear as their complements.

Mr. Sperling reported data which show the conditions under which a small white test spot against a black background will appear differently. For instance, it can be made to appear as a dark spot against a light background, a spot which quickly jumps from light to dark, or a white spot followed by a lingering dark image. Under certain conditions, it will not appear at all. If the relative intensities are carefully adjusted beforehand, then all of the above conditions can be observed simply by varying the time lapse between the test spot and the plain white marking flash.

Although complementary after-images without positive prior images were first reported by an Englishman, Shelford Bidwell, in 1897, Bell Laboratories experiments have quantitatively shown the close ties between the phenomenon of after-images and ordinary images in the visual system.

Scientists hope that studies of the basic properties of vision such as after-images will aid man in understanding the very complicated workings of the eye and the nervous system.

The third paper told of experimental results that have shown the eye can "remember" a great deal of information for a short time; much more than would be inferred from asking a person to "read back" information he has seen in a brief flash. Also, information stored in this "temporary memory" can be allowed to fade gradually or can be erased selectively by succeeding stimuli. Erasure takes place before the viewer is actually aware of what he has seen.

Emanual Averbach describes display of letters and the marker system which has been used in tests of short term memory capacity in humans.

These experiments were conducted at Bell Laboratories by Emanuel Averbach and Abner S. Coriell. The investigators flashed an array of letters on a screen. They were followed, a short time later, by a "marker" which pointed to one of the positions previously occupied by a letter. Initially, two horizontal rows of eight letters each were flashed for one-twentieth of a second. The screen then remained blank for a variable period, up to one-half second, after which a solid vertical bar appeared for another one-twentieth of a second above or beneath one of the letter positions. When the bar followed the letters immediately, the viewer was able to identify the letter correctly in 60 to 70 per cent of the trials. This ability decreased gradually with increasing time lag to about 20 to 25 per cent when the marker was presented one quarter of a second later.

In the second set of experiments, sixteen letters were exposed to the viewing subject for one-twentieth of a second. After this exposure and a variable-length blank interlude, a circular marker was flashed at one of the letter locations. This circle was large enough so that if it were exposed simultaneously with the letter, the letter would be completely inside it. In contrast to the experiments where bar markers were used, the ability of a subject to identify the marked letter dropped abruptly in one-tenth of a second to about 10 to 20 per cent. The circle apparently "erased" the letter from the viewer's visual memory. Interestingly enough, this erasure occurred even when the letters were exposed to one eye and the subsequent circle to the other.

Messrs. Averbach and Coriell feel that these experiments indicate the presence of a short term visual memory which is capable of very fast "read in," but which "reads out" information to the more permanent memory relatively slowly. This storage apparently includes a mechanism by which new information tends to erase the old. The temporary storage time is approximately a quarter-second, and the minimum storage capacity determined experimentally ranged between 37 and 54 bits, depending on the subject tested. The maximum capacity has not yet been determined.

While the results reported represent very early experimental work, Bell Laboratories visual research scientists hope that additional investigations along these lines will shed light on how the nervous system stores and scans information, as well as on the manner in which such information is transferred to and processed in the brain.

Tiros Weather Satellite Placed in Orbit by BTL Command Guidance System

The Tiros I meteorological satellite, the nation's newest space vehicle, was directed into its circular orbit with the Command Guidance System developed at Bell Laboratories. Tracking data indicates that the National Aeronautics and Space Administration's weather satellite has achieved the most nearly circular orbit of any space vehicle yet launched by either the United States or Russia.

News of Space Activities

Recent data on the satellite, launched April 1, shows that the apogee, or high point of the orbit, is 465.9 statute miles and the perigee, or low point, is 428.7 statute miles—a spread of only 37 miles. The mean altitude of 447.3 miles is within one mile of the desired mean.

This accuracy of orbit was achieved by the same radio-inertial guidance system developed by the Laboratories and the Western Electric Company for use in the first squadrons of the Titan intercontinental ballistic missile. It was also used last year to guide the successful tests of the Thor Able re-entry vehicles. Included in these tests were the first nose-cone recoveries from missile flights of approximately 5,000 miles. Capable of achieving what Laboratories engineers describe as "pinpoint accuracy," the guidance system is well suited for space experiments, such as Tiros, where very precise control is required to obtain the desired orbit.

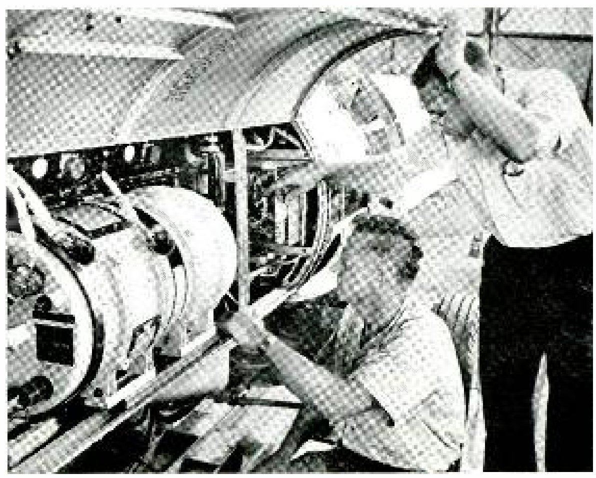
In this command guidance system, a ground-based radar continuously determines the position of the missile during the powered portion of its flight. A Remington-Rand Univac digital computer developed for the guidance system accepts this position data. From previously stored trajectory information for the particular mission, the computer figures the appropriate orders to steer the missile on its proper flight path. These corrective orders are transmitted by radio to the missile and are applied to its autopilot and control system.

Ground-based elements, such as the radar and computer, can be used over and over again to fire many ICBM's or launch many space vehicles. The units placed in the missile itself are kept to a minimum to promote reliability in an environment that is far more severe than that on the ground. This points up an advantage of the command guidance system—the reduction in cost and weight of air-borne equipment. Each pound of equipment in the second stage and in the "payload," or satellite, requires hundreds of pounds of fuel for launching. Therefore, a reduction in weight of the guidance system means that additional instruments can be placed inside the satellite.

A further advantage of this ground-controlled system is that it gives an ICBM squadron commander a quite accurate prediction of where the warhead will land, based on the computer's calculations at the end of the missile's powered flight.

Tiros—the name stands for Television and Infra-Red Observation Satellite—is designed to use television cameras for gathering weather data which is relayed back to earth. Two cameras in the satellite feed pictures into separate magnetic tape recorders for playback when the satellite is interrogated by ground stations at Kaena Point, Hawaii, and Ft. Monmouth, N. J.

Placing the Tiros satellite in its very accurate circular orbit is the first use of the Bell Laboratories Command Guidance System in a NASA project. A three-stage Delta space vehicle, now under development for NASA will also use the Bell Laboratories guidance system. This launch vehicle and the command guidance system will be used for a second Tiros satellite, a forthcoming echo-type, passive-communications satellite, and other satellites and space probes of the Delta program.



T. J. Greiser and D. R. Hagner examine second stage of the Air Force Thor-Able missile used to launch the NASA Tiros I weather satellite.

LATEST INORGANIC GLASSES LIQUID AT ROOM TEMPERATURE

A new series of inorganic glass compositions, some of which are liquid at room temperature, have been recently developed by A. D. Pearson and W. R. Northover of the Metallurgical Research Department. These glasses are composed of varying proportions of the elements arsenic, sulfur, and bromine. Their preparation and properties were described at a meeting of the American Ceramic Society in Philadelphia, Pennsylvania, on April 25.

News of Chemical Research

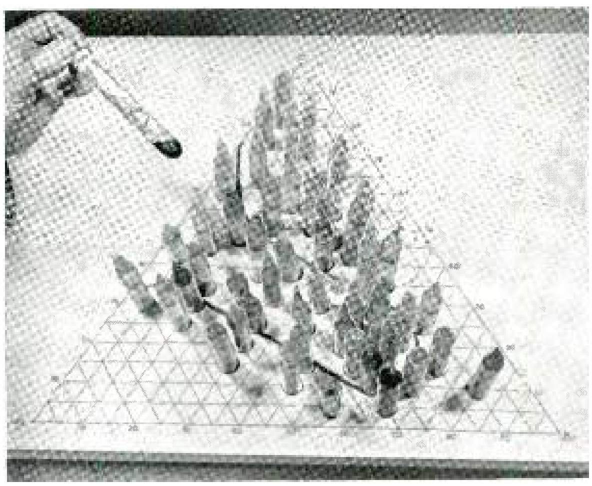
Previous work at Bell Laboratories on compositions of arsenic, sulfur (or selenium), and thallium produced glasses which soften somewhat above room temperature, and become fluid enough to use for dip-coating at temperatures between 125 and 350 degrees C. This is 300 to 400 degrees lower than any previously known low-melting-point glass. The substitution of iodine for thallium in the sulfur compositions later produced glasses with somewhat lower softening points, with several softening below room temperature. A few of these are highly fluid at temperatures below the boiling point of water.

The replacement of the iodine by bromine to form the new three-element compositions permits even lower softening temperatures and high-fluidity temperatures. Chemists can achieve wide ranges of softening points by varying the chemical compositions. Several are as fluid as glycerin at room temperature. For example, substantial amounts of bromine (up to 20 per cent) can be added without dropping the softening temperature below room temperature. However, the addition of greater amounts permits softening and high-fluidity temperatures to decrease to room temperature and below.

Within a large area of variation in composition, the glasses do not devitrify over extended periods of time. In other words, they do not crystallize or precipitate one of the elements.

Although studies of chemical resistance have not been completed, the new compositions appear to show the same characteristics as the previously reported low-melting glasses (RECORD, *July*, 1959). They are relatively stable toward acids, but are attacked by alkalies. They tend to hydrolize in water, a tendency that increases in compounds with lower softening points. The solids are good dielectrics, with resistivity values as high as 10^{15} ohms-cm. The resistivities of the liquid compositions are not as high, however, being only of the order of 10^{8} ohms-cm. Measurements of all electrical properties have not been completed.

Another interesting aspect of the new glasses is their optical transmission properties. They are all transparent, ranging in color from ruby red to light amber. The indexes of refraction measured so far are between 1.9 and 2.0, which is comparatively high for glasses.



Samples of the new low-melting glasses in their quartz ampules after having been heated to approximately 400 degrees C and agitated moderately. Tube of sample depicts its liquid properties.

The glasses are relatively simple to prepare. The measured amounts of each of the constituents are weighed into a quartz tube with a "pulled-down" neck. The contents are then frozen in liquid nitrogen and the tube is evacuated and sealed off. These sealed tubes or "ampules" are then encased in a simple pipe-bomb, and heated in an oven at about 400 degrees C for three to four hours. A simple agitation brings about the formation of the glass. The rate at which the mixture cools to room temperature does not appear to be critical.

Oxygen May Be Key to Magnetic Annealing

News of Materials Research

One of the unsolved mysteries of metallurgy—magnetic annealing—is coming closer to solution through basic physical research being conducted at the Laboratories. For many years, metallurgists have known that if soft magnetic alloys of nickel-iron (such as Permalloy) and nickel-cobalt-iron (such as Perminvar) are heat-treated in a strong magnetic field, their magnetic moments will tend to align to produce a magnetically oriented material. In other words, they will become permanent magnets. This tendency arises from a phenomenon called "uniaxial magnetic anisotropy" introduced by the heat treatment. Heretofore, scientists have not satisfactorily understood the origin of this uniaxial anisotropy, which is essentially the property of "taking" magnetization in one direction only.

Besides merely wanting to understand anisotropy in magnetic metals, Laboratories scientists are interested in the phenomenon because the Bell System uses large quantities of alloys, such as Permalloy, for inductor cores. Fine Permalloy tapes are also used for "Twistor" wire, which appears in various electronic memory devices (RECORD, *November*, 1959). In addition, it is possible that thin films of these magnetic alloys could be used in memory devices for digital computer circuits, since they can be switched from one direction of polarization to the opposite direction with an overriding magnetic field. Switching times for such films could be as short as 10^{-9} second (one billionth of a second). Also, they could be used in non-destructive-readout memory devices by having a magnetic field, which does not override the built-in field, sense the polarization.

The theory of magnetic-field annealing has been debated for some time. Generally accepted is the theory of short-range "ordering" of the metal atoms in the alloy. Recent work at the Laboratories indicates, however, that magnetic polarization does *not* result when these alloys are heat-treated in a field unless about 14 parts per million (ppm) of oxygen are present in the alloy. Less than this amount of oxygen precludes the development of uniaxial anisotropy in the annealed alloys.

At oxygen contents between 14 and 20 ppm, there seems to be little variation in the strength of the anisotropy. Although there appears to be little appreciable change in the magnetic response for reasonable increases above this level, substantially greater amounts of oxygen may result in the formation of oxides of the constituent metals.

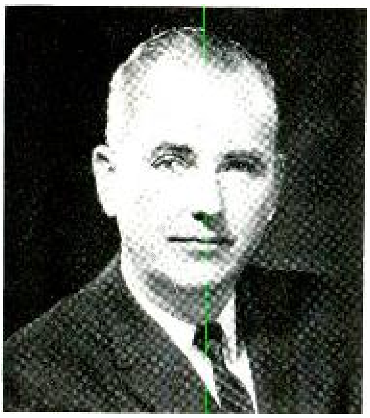
Although the mechanism by which oxygen causes this effect is not yet fully understood, R. D. Heidenreich and R. D. Burbank, of the Chemical Research Department, and E. A. Nesbitt of the Physical Research Department theorize that: The oxygen atoms settle on a plane of atoms of the crystal at certain elevated temperatures, resulting in a displacement or dislocation of the next parallel plane of atoms. When enough of these oxygen atoms are present, the alloy can be magnetically oriented by heat treatment in a magnetic field.

It is difficult to confirm this effect of oxygen because it is almost impossible to point out the location of the oxygen atoms in the alloys by x-ray or neutron-diffraction techniques. Even when the alloy itself has segregated, there is no way to distinguish between the atoms of cobalt, nickel and iron. Also, of course, the minute quantities of oxygen involved make analysis difficult.

Practically, it seems that more uniform magnetic materials can be produced by paying proper attention to the control of the amount of oxygen present in the alloy. However, a great deal more study will be required before the theoretical basis for the phenomenon of magnetic annealing is understood in complete detail.

news in brief

W. K. MacAdam Elected Vice President Of A.T.&T. Co.



W. K. MacAdam

Walter K. MacAdam has been elected vice president of the American Telephone and Telegraph Company. He will be Coordinator of Defense Activities for the Bell System.

Mr. MacAdam has been Assistant Chief Engineer of A.T.&T. since last October. He began his telephone career in 1937, as a student engineer in the Long Lines Department of the company. He has been division plant superintendent for Long Lines in Denver, engineering superintendent for Western Electric on the DEW (Distant Early Warning) Line project, and area chief engineer for Long Lines at White Plains. In 1956 he was named transmission engineer for A.T.&T. and last July, building and equipment engineer.

D. A. McLean Wins Miniaturization Award

David A. McLean of the Component Development Department was named winner of the 1959 Miniaturization Award by an industrial miniaturization awards committee. The Award, a bronze sculpture representing an abstract form, the concept of miniaturization, was presented on March 20 in New York City.

The winning entry is a new method of forming printed-circuit patterns containing passive circuit components (RECORD, *September*, 1959). It increases greatly the reliability of the circuit while at the same time allows considerable reduction in size. The technique of "sputtering" bombards a cathode with ionized gas molecules, dislodging atoms of metal which then redeposit themselves on nearby surfaces. This permits a single metal, tantalum, in fine and intricate patterns, as well as capacitors, resistors and most of the interconnecting circuitry to be formed directly onto a rigid base.

The new thin-film technique makes it possible to produce lines as narrow as one-thousandth (0.001) of an inch in width and spaced only one-thousandth of an inch apart.

U. S. Way Ahead In Telephone Census

"The World's Telephones," recently published by the A.T.&T. Company, shows that telephones in the United States still outnumber those in all the rest of the world. The report shows the United States, with 66,645,000 telephones at the beginning of 1959, accounted for more than 50 per cent of the world's total of 125 million.

The United Kingdom with 7,525,000 sets, ran second to the United States in total telephones. Canada was third with 5,123,000, followed closely by the German Federal Republic with 5,090,000. Russia has an estimated 3,700,000 telephones.

Laboratories Men Honored by IRE

Two Laboratories men, Harry Nyquist, a retired member of the Laboratories, and James Gewartowski, of the Electron Tube Development Department, were honored at the 1960 convention of the Institute of Radio Engineers in New York.

Mr. Nyquist received the *1960 Medal of Honor* "for fundamental contributions to a quantitative understanding of thermal noise, data transmission and negative feedback." Mr. Gewartowski was awarded the *1960 Browder J. Thompson Memorial Prize Award*, which goes to the best technical contribution and presentation written by an author under thirty. His paper was entitled, "Velocity and Current Distributions in the Spent Beam of the Backward-Wave Oscillator."

Round-the-World Phone Service Marks Twenty-Fifth Year

Last month marked the twenty-fifth anniversary of the first round-the-world telephone call. On April 25, 1935, Walter S. Gifford, A.T.&T. President, talked to T. G. Miller, Vice President in charge of the Long Lines Department, in another room of the same building in New York City. But these men's voices traveled over a 23,000-mile circuit of wire and radio channels encircling the globe.

AMA Patent is Largest Ever Granted

Last month the United States Patent Office granted to the Laboratories the largest patent in history. Issued to A. E. Joel. Jr. of the Switching Systems Development Department, the patent covers the fundamentals of the assembler-computer — equipment forming part of the Automatic Message Accounting (AMA) system. The document consists of 354 sheets of drawings and 266 pages of printed text. It weighs nearly eleven pounds.

The assembler-computer is a highly complex, but relatively compact equipment. Its eleven relay cabinets and eight tape-machinery cabinets take up only about 300 square feet of floor space.

Designed to be more efficient than the separate assembler and separate computer it replaces, the new equipment also eliminates many errors inherent in the pair of devices. The assembler-computer reads from tape calling and called telephone numbers, as well as the starting and finishing times of calls. It sorts out from these tape entries the information belonging to each call, computes the charges, and transmits the information to other accounting center equipment, which prints the bills.

Optical Maser Patented

A new improvement on the maser principle *(see page 163)*, the optical maser, has been patented by A. L. Schawlow, of the Physical Research Department, presently on leave as visiting professor at Columbia University, and C. H. Townes, professor of physics at Columbia and consultant to the Laboratories. The patent was assigned to the Laboratories.

The optical maser coordinates the molecules of ordinary light so that they will emit their radiation in phase. The result is light at a single frequency.

Essentially a narrow length of tube, the device contains a quantity of gas or solid that provides the molecules to be excited. The light rays reflect from each end of the tube repeatedly, building a stable standing wave in the resonator. This results in a very narrow and well-defined beam of light.

Laboratories Announces Graduate Fellowships

Bell Laboratories has named fifteen winners of the 1960-61 Bell Telephone Laboratories Graduate Fellowships. These fellowships have been granted yearly to outstanding students working toward the Doctor of Philosophy degree in sciences relating to communications. Each fellowship carries a minimum grant of $2,000 to the winner and an additional $2,000 to cover tuition, fees and other costs at the university he has selected for his doctoral work.

The fellowship program was established by Bell Laboratories in 1955 to encourage study and research in engineering and science related to communications technology. This year's winners make a total of 65 graduate students who have been aided by the program. Seventy-nine fellowships in all have been granted, some students winning the fellowship twice. Three of this year's winners have previously won.

Awards are based on the candidates' demonstrated ability, the relevance of their graduate program to the broad field of communications technology, and the likelihood of their professional growth. The awards are made on recommendation of a committee of scientists and engineers from the technical staff of the Laboratories, in collaboration with the faculties of the applicants' schools. One hundred and one students applied for the 15 awards made.

Among this year's winners, four will study electrical engineering, five physics, two chemistry, one mathematics, two statistics and one metallurgy.

The 15 fellowship winners, their home towns, and their schools are: Richard T. Aiken, Baltimore, Md., Carnegie Institute of Technology; Saul Blumenthal, Ithaca, N. Y. Cornell University; David R. Brillinger, Ontario, Canada, Princeton University; Joseph C. Burgiel, Ware, Mass., Massachusetts Institute of Technology; Benoy K. Chakraverty, West Bengal, India, Carnegie Institute of Technology; Francis A. Collins, Austin, Texas, Harvard University; John G. Fikioris, Boston, Mass., Harvard University; Bruce B. Lusignan, Palo Alto, Calif., Stanford University; Hiroshi Minato, Yamaguchi, Japan, Harvard University; Jamshid N. Naghizadeh, Teheran, Iran, University of Chicago; Wu-Chung Hsiang, Princeton, N. J., Princeton University; Lawrence C. Kravitz, Chicago, Ill., Harvard University; Cecil A. Nanney, Black Mountain, N. C., University of Chicago; Craig K. Rushforth, Stanford, Calif., Stanford University; William Streifer, Providence, R. I., Brown University.

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Miller, C. E., see Geller, S.

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Pierce, J. R., *Spacious Fantasies*, Trans. I.R.E. Prof. Gp. on Military Electronics, 4, pp. 3-5, Jan., 1960.

Pierce, J. R., see Cutler, C. C.

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Sauer, H. A., and Turner, D. R., *Ohmic Contacts to Semiconductors*, J. Electrochem. Soc., 107, pp. 250-251, Mar., 1960.

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Slepian, D., *On the Detection of Gaussian Signals in Gaussian Noise*, Nuovo Cimento Supplemento, No. 2, pp. 583-587, 1959.

Soder, R. R., and Van Uitert, L. G., *Single Crystal Tungstates for Resonance and Emission Study*, J. Appl. Phys., 31, pp. 328-330, Feb., 1960.

Spencer, E. G., and LeCraw, R. C., *Spin-Lattice Relaxation in Yttrium Iron Garnet*, Phys. Rev. Letters, 4, pp. 130-131, Feb. 1, 1960.

Tartaglia, A. A., see Porbansky, E. M.

Treuting, R. G., see Geller, S.

Trumbore, F. A., see Porbansky, E. M.

Turner, D. R., see Sauer, H. A.

Van Uitert, L. G., see Soder R. R.

PATENTS

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

Anderson, J. R. — *Ferroelectric Storage Circuits*—2,928,075.

Andrews, F. T., Jr. — *Magnetic Core Circuit*—2,930,903.

Berger, U. S. and Cocchiaro, M.—*Integer Analyzer and Sequence Detector*—2,929,048.

Blakely, B., Jr.—*Line Switching Systems*—2,297,968.

Blefary, V. F. and Ignatowitz, M. —*Visual Display Apparatus*—2,931,027.

Bogert, B. P.—*Transmission and Reconstruction of Artificial Speech*—2,928,901.

Brown, L. C. — *Illuminable Controller*—2,931,021.

Busala, A., Schenker, L. and West, F.—*Subscriber Call Transmitting System*—2,927,971.

Cocchiaro, M., see Berger, U. S.

Cutler, C. C.—*Electron Discharge Device for Signal Translation*—2,927,243.

Cutler, C. C.—*Transmission Systems Employing Quantization*—2,927,962.

Doherty, W. H.—*Electrical Conductor Having Transposed Conducting Members*—2,930,833.

Doherty, W. H.—*Magnetic Transmission Systems*—2,929,034.

Edson, J. O.—*Negative Impedance Repeater*—2,927,967.

Englemen, H.—*Q-Meter Circuit*—2,929,988.

Grubbs, W. J., Jr.—*Nonreciprocal Transmission Assembly*—2,927,-283.

Hines, M. E. and Kirkpatrick,

PATENTS (CONTINUED)

W. E.—*Narrow Band Image Transmission*—2,929,869.

Iglesias, D. E.—*Contact Member for Semiconductor Translating Device*—2,928,031.

Ignatowitz, M., see Blefary, V. F.

Jacoby, G. E. and Ketchledge, R. W.—*Gas Discharge Device*—2,929,962.

Ketchledge, R. W., see Jacoby, G. E.

Kirkpatrick, W. E. and Sears, R. W.—*Dual Picture Direct View Storage Tube*—2,929,957.

Kirkpatrick, W. E., see Hines, M. E.

Korb, G. E.—*Directional Couplers*—2,930,995.

Ligenza, J. R.—*Method of Treating Silicon*—2,930,722.

Lundstrom, A. A.—*Radar Systems Employing Random Pulsing*—2,927,317.

Middaugh, J. K. and Young, W. R., Jr.—*Automatic Data Reader*—2,927,730.

Miller, R. L.—*Determination of Pitch Frequency of Complex Wave*—2,927,969.

Miller, S. E.—*Frequency-Selective Wave Coupling System*—2,929,-032.

Miller, S. E.—*Multi-Mode Automatic Tracking Antenna System*—2,931,033.

Miller, V. F.—*Portable Welding Tool*—2,929,913.

Pferd, W.—*Mechanical Coin Totalizer*—2,929,869.

Quate, C. F.—*Low Noise Velocity Modulation Tube*—Re 24,794.

Ruthroff, C. L.—*Frequency Discrimator*—2,928,940.

Schawlow, A. L. and Townes, C. H.—*Masers and Maser Communications System*—2,929,922.

Schenker, L., see Busale, A.

Sears, R. W., see Kirkpatrick, W. E.

Shebanow, M. S.—*Switching Device*—2,929,895.

Townes, C. H., see Schawlow, A. L.

Weller, D. C.—*Carrier Telephone Systems with Carrier-Shift Signaling*—2,027,966.

West, F., see Busala, A.

Wier, J. M.—*Transistor Multivibrator Frequency Control*—2,929,030.

Wohlhieter, M.—*Method of Fabricating Coils*—2,929,132.

Wolfe, R. M.—*Ferroelectric Counting Circuit*—2,930,906.

Young, W. R., Jr., see Middaugh, J. K.

TALKS

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

A.I.E.E. DESIGN AUTOMATION SURVEY COMMITTEE MEETING, Phoenix, Ariz.

Halline, E. G., *SIMPROCOL—A Simulation Program for Combinational and Sequential Logic Circuitry.*

Martellotto, N. A., *A Computer Program to Determine Test Conditions for Combinational Logic Circuits.*

Sellers, G. A., Jr., *Automatic Preparation of Auto-Facturing Information.*

Rosenthal, C. W., *A Computer Program for Preparing Wiring Diagrams.*

OTHER TALKS

Allen, F. G., *P-Layers on Vacuum Heated Silicon*, Electrochemical Soc. Conf., Columbus, Ohio.

Andersen, W. W., and Hines, M. E., *Circuit Principles for Application of Esaki Diodes at Microwave Frequencies*, I.R.E. International Solid-State Circuits Conf., Philadelphia, Pa.

Anderson, E. W., Douglass, D. C., and McCall, D. W., *Self Diffusion of Polyisobutylene in* CCl_4, A.C.S. Meeting, Cleveland, Ohio.

Anderson, P. W., *New Developments in Superconductivity*, Stanford University, Palo Alto, Calif.

Barney, H. L., *An Experimental Transistorized Artificial Larynx*, New York Soc. of Laryngology and Otology Meeting, N. Y. C.

Baruch, P., *Mobility of Radiation Induced Defects in Germanium*, Carnegie Institute of Technology, Pittsburgh, Pa., 3/15; University of Illinois, Urbana, Ill., 3/24; Purdue University, Lafayette, Ind., 3/25; Oak Ridge National Laboratory, Oak Ridge, Tenn., 3/30; University of Virginia, Charlottesville, Va., 4/1/60.

Becker, G. E., *Adsorption of Gases on Mercury at 77°K*, Sixth National Vacuum Symposium of American Vacuum Soc., Philadelphia, Pa.

Bell, D. T., *Computer Programs in Transmission Networks Design*, I.R.E.-A.I.E.E.-S.I.A.M., University of Pennsylvania, Philadelphia, Pa.

Benes, V. E., *Extensions of Wiener's Tauberian Theorem for Positive Measures*, A.M.S., N. Y. C.

Benes, V. E., *Probabilistic and Tauberian Methods for Analyzing the Stability of Certain Integro-Differential Equations*, A.M.S., Chicago, Ill.

Benes, V. E., *A Stability Theorem for Nonlinear Equations*, A.M.S., N. Y. C.

Berkowitz, D. A., *Dark DC Conductivity Measurements on Zinc Sulfide Crystals*, Massachusetts Institute of Technology, Physical Electrons Conf., Cambridge, Mass.

Bittmann, C. A., Davis, R. E., Kirkpatrick, R. J., and Saari, V. R., *Circuit Applications of a Coaxially Encapsulated Microwave Transistor*, I.R.E. International Solid - State Circuits Conf., Philadelphia, Pa.

Black, H. S., *The Present Status of Waveguide Communications*, I.R.E., Western Soc. of Engineers' Bldg., Chicago, Ill.

Bozorth, R. M., *Kinds of Magnetism and Their Origins*, University of North Dakota, Grand Forks, N. D., 2/16; Marquette University, Milwaukee, Wisc., 2/18/60.

Bozorth, R. M., *Some Properties of Magnetic Superconductors*, University of North Dakota, Grand Forks, N. D., Feb. 17, Marquette University, Milwaukee, Wisc., Feb. 18.

Bozorth, R. M., *Review of Magnetic Materials*, Conf. on Electrical Engineering in Space Technology, Dallas, Tex.

Brattain, W. H., *Introduction to the Physics and Chemistry of Surfaces*, Fall Meeting of Electrochemical Soc. Semiconductor Symposium, Columbus, Ohio.

Brown, W. L., Donovan, P. F., Mackintosh, I. M., and Miller, G. L., *Silicon p-n Junction Radiation Detectors*, Symposium Scintillation Counter Conf., Washington, D. C.

Caffrey, R. E., *High Purity Nickel Alloys*, A.I.E.E., N. Y. C.

Calbick, C. J., *Replication by Platinum-Carbon and by Germanium*, New York Microscopical Soc. & New York Soc. of Electron Microscopists, N. Y. C.

Chynoweth, A. G., *Experimental Confirmation of the Tunneling Laws at Narrow p-n Junctions*, A.P.S. Meeting, N. Y. C.

Cohen, B. G., *What Are These Things Called Compound Semiconductors?* University of Rhode Island, Kensington, R. I.

Coke, E. U., and Rothkopf, E. Z., *The Prediction of Free Recall from Word Association Measures*, Eastern Psychological Association, N. Y. C.

Crowell, M. H., *A Penn State Alumnus at BTL*, Pennsylvania State University, University Park, Pa.

Cutler, C. C., *Television Relaying by Passive Satellites*, I.R.E. Prof. Gps. on Broadcasting & Communications Systems, Pepco Auditorium, Washington, D. C.

Dacey, G. C., *Esaki and Other Special Diodes*, I.R.E. Electronics Seminar, Dallas, Tex.

Dacey, G. C., *Properties of Esaki (Tunnel) Diodes*, I.R.E. Solid-State Circuits Conf., Philadelphia, Pa.

D'Asaro, L. A., *Esaki Diodes*, Ohio State University Department of Electrical Engineering Seminar, Columbus, Ohio.

David, E. E., Jr., *Digital Simulation of Communication Systems*, A.I.E.E.-I.R.E.-S.I.A.M. Symposium on Computer Application, Philadelphia, Pa.

Davis, R. E., see Bittmann, C. A.

Deeg, E. W., and Lo, W., *Bending Characteristics of Low-Melting Glasses in the System As-S*, Mechanical Properties of Engineering Ceramics Conf., North Carolina State College, Raleigh, N. C.

Donovan, P. F., see Brown, W. L.

Dougherty, H. J., *Switching Logic and Control Systems*, A.I.E.E.-I.R.E. Meeting, Rutgers University, New Brunswick, N. J.

Douglass, D. C., see Anderson, E. W.

Drenick, R. F., *Adaptive Systems*, A.I.E.E.-I.R.E., N. Y. C.

Drenick, R. F., *Theory of Nonlinear Transducers*, Columbia University, N. Y. C.

Dworkin, S., *Research for Film Production at Bell Laboratories*, Division of Audio-Visual Instruction of National Education Association Conv., Cincinnati, Ohio.

Early, J. M., *Transistors—Present and Future*, Electrical Engineering Department Colloquium, Rensselaer Polytechnic Institute, Troy, N. Y.

Engelbrecht, R. S., and Mumford, W. W., *Parametric Amplifiers: Historical Background and Recent Results with UHF Traveling Wave Amplifiers*, Binghamton Section I.R.E., Endicott, N. Y.

Feldman, D., *Exotic Power Sources for Electronic Systems*, Pratt Institute, Brooklyn, N. Y.

Ferrell, E. B., *Simple Methods of Data Analysis*, Statistical Association of City College of New York, N. Y. C.

Fitch, A. H., *A Comparison of Several Dispersive Ultrasonic Delay Lines Using Longitudinal and Shear Waves in Strips and Cylinders*, I.R.E., National Conv., N. Y. C.

Frisch, H. L., *Adsorption of Polymers and Properties at Surfaces*, National Bureau of Standards, Washington, D. C.

Garrett, C. G. B., *A Review of Surface Properties of Molecular Solids as Judged by Analogy with Germanium and Silicon*, Princeton University Conf. on Semiconduction in Molecular Solids, Princeton, N. J.

Garn, P. D., and Kessler, J. E., *Thermogravimetry in Self-Generated Atmospheres*, A.C.S. National Meeting, Cleveland, Ohio.

Gertz, R. H., *Some In-Service Reliability Determinations Through A Quality Assurance Program*, A.S.Q.C. Metropolitan Conf., N. Y. C.

Harmon, L. D., *Artificial Neurons*, Los Alamos Scientific Laboratory, Los Alamos, N. M., Feb. 2; Sandia Corp., Albuquerque, N. M., Feb. 3; U. S. Naval Electronics Labs, San Diego, Calif., Feb. 4; Caltech Conf. on Cerebral Systems, Pasadena, Calif., Feb. 9; Detroit Chapter I.R.E., Detroit, Mich., Feb. 19, 1960.

Haugk, G., *Municipal Government*, Rocksbury Women's Club, Succasunna, N. J.

Higgins, W. H. C., *Command Guidance for Ballistic Missiles and Space Vehicles*, Syracuse Chapter of the Armed Forces Communications Electronics Association, Syracuse, N. Y.

Hines, M. E., see Andersen, W. W.

Horton, A. W., Jr., *Careers in Industry*, Panel Discussion Princeton University, Princeton, N. J.

Iwerson, J. E., *The New Fast Transistors*, I.R.E., University of Connecticut, Storrs, Conn.

Kabak, I. W., *Simulation as an Initial Systems Planning Tool*, Polytechnic Institute of Brooklyn Graduate Mechanical Engineering Seminar, Brooklyn Polytechnic Institute, Brooklyn, N. Y.

Kirkpatrick, R. J., see Bittmann, C. A.

Kisliuk, P., *Binding Energy and Mobility of Nitrogen Atoms on Tungsten Crystal Surfaces*, A.P.S. Meeting, N. Y. C.

Kopp, W. J., *Transistors and Their Use*, North Nassau Zone of the N. Y. State Teachers' Association, Glen Cove, N. Y.

Kostkos, H. J., *New Horizons in Communications*, Electrical Society of Montreal, Montreal, Canada.

Lax, M., *Cascade Capture of Electrons in Solids*, Brookhaven National Laboratory, Upton, N. Y.

Lax, M., *Fluctuations from the Non-Equilibrium Steady State*, University of Oregon, Eugene, Ore.

Lax, M., *Long-Range Forces and Lattice Vibrations in Diamond-Type Crystals*, University of Pennsylvania, Philadelphia, Pa., Mar. 1; University of Oregon, Eugene, Ore., Mar. 7, 1960.

Lo, W., see Deeg, E. W.

Lundberg, J. L., *Polymer Polydispersity*, Villanova University Chemistry Department Seminar, Villanova, Pa.

Mackintosh, I. M., see Brown, W. L.

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

Miller, G. L., see Brown, W. L.

Moore, E. F., *Machine Models of Self - Reproduction*, Princeton University Electrical Engineering Department Colloquium, Princeton, N. J., Feb. 24, Bell Telephone Laboratories, Holmdel, N. J., Mar. 11.

Morgan, S. P., *Applications of Multimode Waveguide Theory*, Institute of Mathematical Sciences, New York University, N. Y. C.

Mumford, W. W., *Technical Aspects of Microwave Radiation Hazards*, Microwave Research Institute, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Murphy, R. B., *The Problem of Outliers—When We May Reject Outlying Observations*, A.S.Q.C. Annual Conf. of Metropolitan Section, N. Y. C.

Och, H. G., *The Nike Family*, Chatham Adult Education Program, Chatham High School, Chatham, N. J.

Pearson, G. L., *Conversion of Solar to Electrical Energy*, Sigma Xi Soc. of the Lehigh Valley, Lehigh University, Bethlehem, Pa.

Peck, D. S., *A Mesa Transistor Reliability Program*, Sixth Joint Military-Industry Guided Missile Reliability Symposium, Fort Bliss, Tex.

Pierce, J. R., *The Exploitation of Space*, Engineering & Scientific Societies of Richmond Area, Richmond, Va.

Pierce, J. R., *Satellite Communication*, Poor Richard Club, Philadelphia, Pa., Mar. 1; Colloquium of the Physics, Electrical Engineering & Mathematics Departments Syracuse University, Syracuse, N. Y., Mar. 24, 1960.

Quirk, W. B., *Electronic Switching Systems*, A.I.E.E., St. Louis, Mo., Feb. 17; A.I.E.E.-I.R.E., Wichita, Kans., Feb. 18, 1960.

Reiss, H., *Statistical Mechanics of Liquids*, Chemistry Department Princeton University, Princeton, N. J.

Saari, V. R., see Bittmann, C. A.

St. James, L. N., *Verification of Flight Reliability — Missile Guidance Unit*, Fort Bliss, El Paso, Tex.

Schawlow, A. L., *Fine Line Optical Spectra in Solids*, IBM Research Laboratory, Poughkeepsie, N. Y., Feb. 25; Columbia University, Feb. 26, 1960.

Schawlow, A. L., *Sharp Line Optical Spectra of Solids*, Research Seminar Technical Group, Syosset, L. I., N. Y.

Seidel, H., *Design Aspects of Parametric Amplifier Systems*, Bell Telephone Laboratories, Arnold Auditorium, Murray Hill, N. J.

Singleton, J. B., and Sloan, H. D., *A Thermal Compression Bonded Low Temperature — Coefficient Voltage Regulating Diode*, A.I.E.E. Winter General Meeting, N. Y. C.

Slepian, D., *The Problem of the Distribution of Zeros of Gaussian Noise*, P.G.I.T.-S.I.A.M., Massachusetts Institute of Technology, Cambridge, Mass.

Slichter, W. P., *New Understanding of the Nature of Solid Polymers*, A.C.S. Student Chapter, Brooklyn, N. Y.

Sloan, H. D., see Singleton, J. B.

Smith, K. D., *Science and Research in Space*, North Plainfield High School Parent Teachers Association, North Plainfield, N. J.

Spencer, E. G., *Ferromagnetic Resonance in Gallium Substituted Yttrium Iron Garnet*, A.P.S., N. Y. C.

Suhl, H., *The Random Phase Approximation*, University of Illinois, Urbana, Ill.

Thayer, P. H., Jr., *Nike and the Air Defense of Our Country*, University of Tennessee, Knoxville, Tenn.

Thomas, D. E., *Esaki Diode Characterization*, A.I.E.E. National Convention, N. Y. C.

Van Bergeijk, W. A., *Hydrostatic Balance in Amphibian Larvae*, Drew University Chapter of Beta-Beta-Beta, Madison, N. J.

Van Haste, W., *Engineering Challenges in the Submarine Telephone Cable Project*, Engineer's Week Program, Western Electric Co., Allentown, Pa.

Wilkinson, R. I., *Congestion Theory*, Operations Research Seminar Massachusetts Institute of Technology, Cambridge, Mass.

Wolfe, R., *Exotic Methods of Energy Conversion*, A.I.M.E. Philadelphia Section, Philadelphia, Pa.

THE AUTHORS

M. Brotherton

M. Brotherton, a former Britisher, was born in France. During World War I, he served in the British Army, both as a combat soldier and in the debatably less lethal function of army cook. Afterward, he studied physics at the University of London and obtained a Ph.D. in thermionics under the aegis of Nobel Prize winner, O. W. Richardson. He joined the Laboratories in 1927, and worked on the development of wave filters. He also developed capacitors, and wrote a book, "Capacitors: Their Use in Electronic Circuits." With the Publication Department since 1943, his chief interest has been the Laboratories technical advertising series, which appears on the back page of this magazine and 36 others. He is a member of the National Association of Science Writers. Mr. Brotherton is the author of "Amplifying with Atoms" in this issue.

R. W. Benfer, author of "White Sands Branch Laboratory: Test Center for Nike Missiles," graduated from the University of Illinois with a B.S.E.E. degree in 1929 and joined Electrical Research Products, Inc. (a subsidiary of the Western Electric Company). Here he designed and developed sound equipment for motion pictures. Following a special project on the design of the sound system for General Motors "Futurama" exhibit at the World's Fair in New York, Mr. Benfer transferred to the Hollywood office to design sound recording equipment for motion picture studios. During World War II, he transferred to Bell Laboratories and participated in designing military fire-control systems. After a special assignment with Task Force Frigid in Alaska, he joined the Nike project in system engineering and flight testing of guided missile systems. In 1953, Mr. Benfer was put in charge of the permanent Laboratory resident organization at White Sands Missile Range. He is now Director of the White Sands Laboratory. A native of Indiana, Mr. Benfer is a member of Eta Kappa Nu and the American Ordnance Association.

R. W. Benfer

D. C. Koehler graduated from the University of Illinois in his home town of Urbana, receiving the degree of B.S. in general engineering in 1941. Coming directly to the Switching Apparatus Development Department at the Laboratories, he participated in the mechanical design of the M9 gun data computer, various bombsight and anti-aircraft radar equipment, the M13 depth-charge mechanism, and the UB and wire-spring relays. He received his M.S. degree in E.E. from the Stevens Institute of Technology in 1950, and since 1954 he has supervised the mechanical design of the switching network, flying-spot and barrier-grid stores for the experimental electronic central office. His article in this issue deals with the mechanical and equipment techniques for the electronic central office. Mr. Koehler is a member of Tau Beta Pi, Phi Kappa Phi and the Society of Photographic Scientists and Engineers.

D. C. Koehler

J. H. Shuhart, a native of Pennsylvania, received the degree of E.E. from Lehigh University in 1926. That year he joined the Development and Research Department of the A.T.&T. Company where he conducted tests on the transmission quality of various new designs for use in open-wire lines. After transferring to the Laboratories with his department in 1934, he continued these studies until the outbreak of World War II and then worked on radar designs for submarines and surface

J. H. Shuhart

vessels. In 1948, Mr. Shuhart transferred to the Outside Plant Department where he is presently engaged in electrical characterization studies of open-wire and cable facilities. Mr. Shuhart holds several patents pertaining to devices for outside plant use. He is the author of the article "Automated Environmental Testing at Chester Laboratory," in this issue.

E. R. Robinson, a native of Sandusky, Ohio, received his B.E.E. degree in 1929 and his M.S. degree in 1930 both from Ohio State University. He then joined the Long Lines Department of the A.T.&T. Co. where until 1952 he was concerned principally with the supervision of the teletypewriter station installation and maintenance methods, costs, and performance results and the engineering of private line teletypewriter switching systems. In 1952 he transferred to the Department of Operation and Engineering of the A.T.&T. Co., and in 1954 he joined Bell Laboratories. Since coming to the Laboratories, he has been in charge of a group responsible for special systems engineering of automatic and manual private line teletypewriter switching systems. He is a member of Tau Beta Pi and Eta Kappa Nu and an associate member of Sigma Xi. Mr. Bobinson is the author of the article, "Automation in Teletypewriter Switching" in this issue.


E. R. Robinson