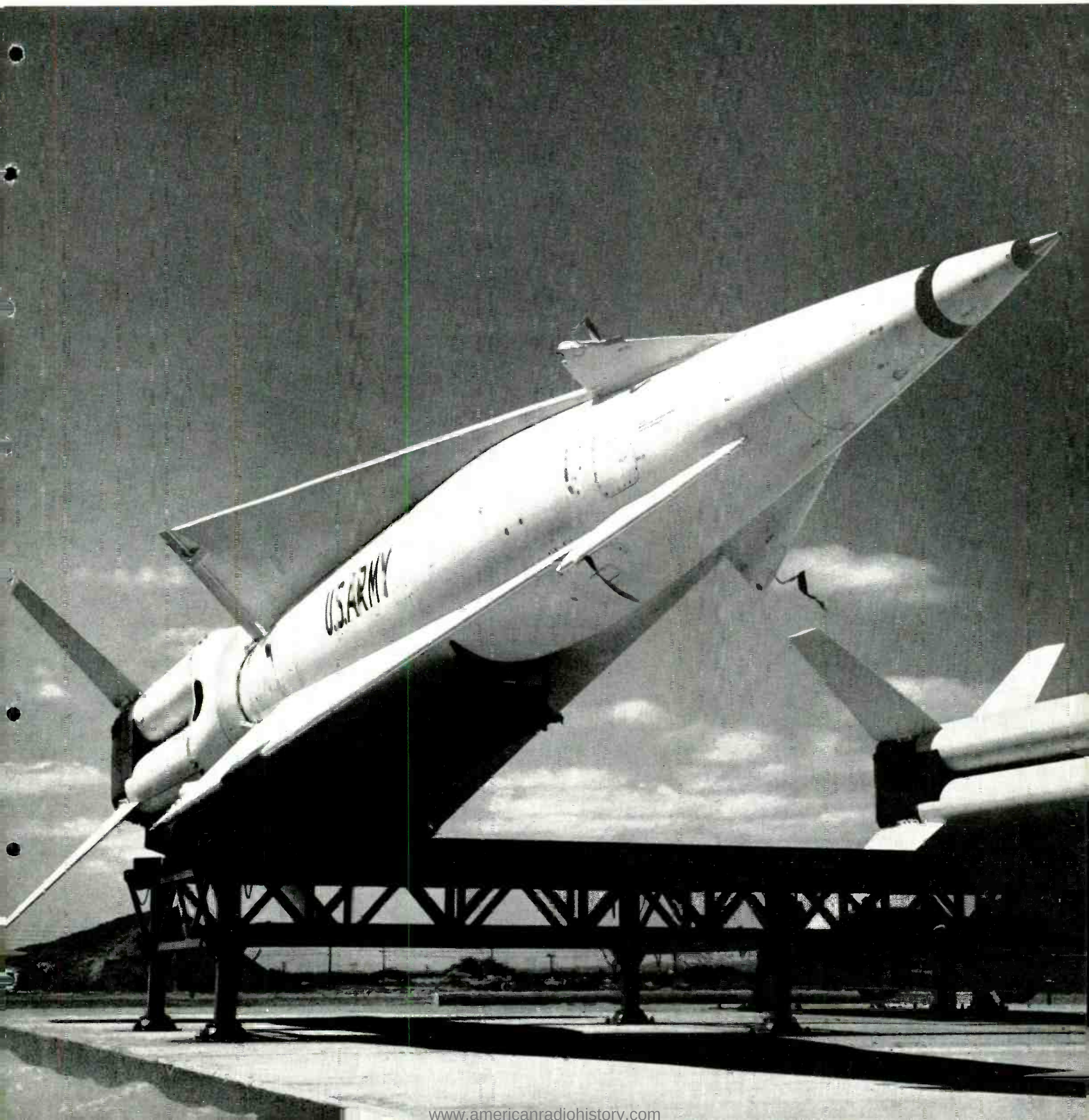
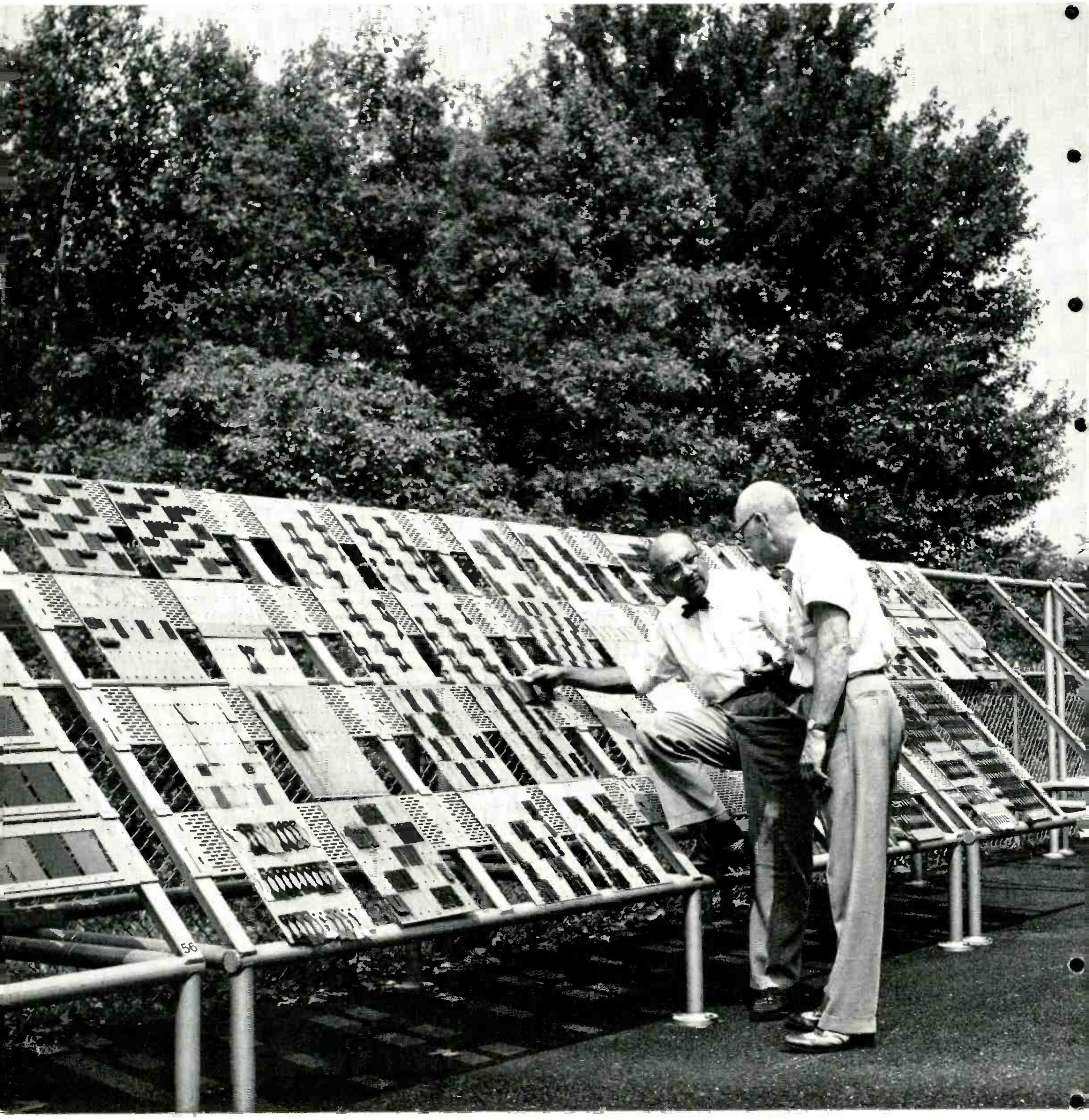
September 1958

Bell Laboratories
RECORD





W. L. Hawkins, left, and L. Dorrance compare laboratory samples of polyethylene with similar samples under test at the outdoor exposure plot at the Murray Hill location of the Laboratories.

The oxidation of polyethylene insulation is a phenomenon as omnipresent as the air and heat or light which cause it. Carbon black additives screen out light very well. But heat-energized oxidation presented a serious problem until chemists at Bell Laboratories developed a whole new family of sulfur-containing protectants for suppressing thermal oxidation.

F. H. Winslow

New Protectants for Polyethylene

One of the most versatile of the modern "plastics" was discovered about twenty-five years ago as a by-product of basic research. British chemists, studying the properties of ethylene gas at high pressures, unexpectedly produced a peculiar, waxy solid — the first polyethylene. Because of its superb dielectric properties, this new plastic was soon in great demand as an electrical insulator.

The debut of polyethylene in the Bell System came in 1941, as the insulation on an early coaxial cable, which connected Baltimore and Washington. During World War II, the short supply of polyethylene limited its use to radar equipment and other devices that operate at high frequencies. A little over a decade ago, however, polyethylene became available in commercial quantities, and the subsequent growth in its production and uses has been spectacular.

By 1957, total annual production throughout the world was approaching a billion pounds. And the Bell System was using nearly twice as much polyethylene as all other plastics and rubbers combined; primarily for sheathing and insulating thousands of miles of cable and billions of feet of cable conductor. Polyethylene is tough, light in weight, low in cost, low in moisture absorption, easy to apply to wire and cable, and has a low dielectric constant and loss. But it also has one serious weakness — it readily oxidizes. Through the process of oxidation, polyethylene slowly loses its mechanical and electrical strength when exposed to oxygen in the presence of heat or ultraviolet (generally solar) light.

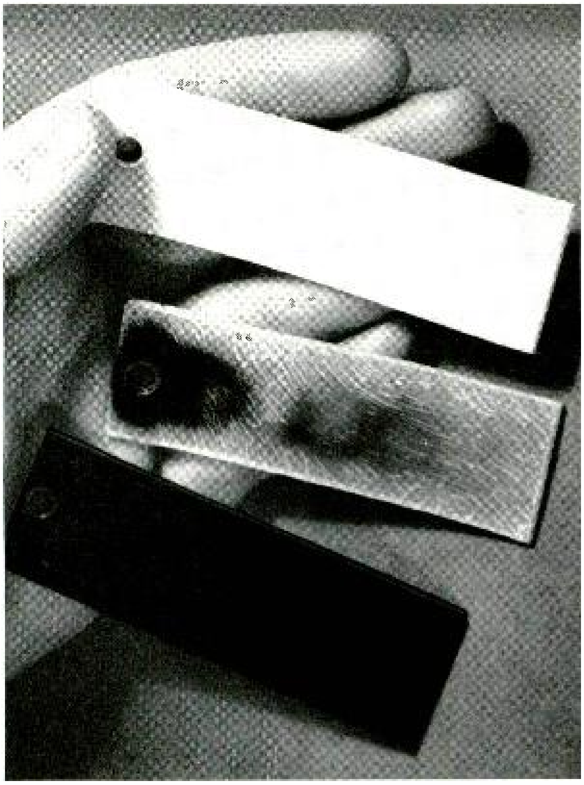
Research chemists at Bell Laboratories have been aware of the oxidation process for some years, and have studied the phenomenon in detail. This research has recently culminated in the development of a whole new series of antioxidant compounds which, when added to polyethylene, will counteract serious oxidation for more than twenty years. Indeed, some of these new protectants have proved so effective in accelerated tests that they seem to contradict current concepts concerning the mechanism of antioxidant activity.

Antioxidant action is so subtle that it defies an accurate explanation. Even the basic phenomenon — oxidation — is not entirely understood, but the action is closely related to structure.

Chemically, polyethylene belongs to the same family as paraffin wax. They look alike and feel alike, and they both have low moisture absorption and good dielectric strength. But unlike the wax, polyethylene is tough and strong. Its strength comes from the huge size of its molecules, which are composed of atomic units of carbon and hydrogen linked together like a chain. The molecular structure of polyethylene and the other organic compounds discussed in this article are shown in the accompanying table of structures. In the wax, the number of atoms per molecule is a few hundred; in the polymer, it is a few hundred thousand.

The polyethylene used for wire and cable insulation has occasional short branches appended to the long, "main" chain of the molecule. Because of their enormous size, and the bulk of the branch groups, the polymer molecules cannot pack together tightly like a bundle of wood dowels. Instead, the plastic is made up of a loose, intertwined mass of molecules, more like a bundle of twigs. Although the branches contribute a great deal to the flexibility of the plastic, "branch points" are the most reactive areas of the molecule and are very vulnerable to oxidation. Branching also makes the plastic mass so porous that much of its mass is constantly exposed to oxygen. Consequently, the degradation of polyethylene by atmospheric oxygen is not an outer surface effect as it is on metals, it takes place internally as well.

Oxygen from the surrounding air, then, can easily permeate the polymer structure. If at the same time the polyethylene molecules are activated by absorbing energy in the form of heat or ultraviolet light, oxidation follows. The reaction course is uncertain, but is thought to start when a polymer molecule is energized to the point where it will combine with atmospheric oxygen. This oxidized molecule then transfers its activity to a neighboring polymer molecule, which in turn reacts with more oxygen, and the process proceeds throughout the mass like a game of tag.



These small samples of polyethylene with various additives were exposed at Yuma, Arizona, for about 3½ years. Severe cracking is evident in the two samples, center and top, containing, respectively, 1 per cent of a blue organic dye and 2 per cent zinc oxide. The sample at the bottom, containing 2 per cent carbon black, shows no cracks and has retained its original flexibility.

Without interference, this cycle repeats itself thousands of times, leaving behind a trail of oxidized polymer molecules. To make matters worse, the oxidized molecules sometimes split into highly reactive fragments which spread or accelerate the process. As a result, the original properties of the polyethylene are affected in two ways: (1) some oxygen combines with the plastic to lower its dielectric strength, and (2) some of the oxygen either cuts the giant molecules into pieces or joins them into a rigid network, causing the plastic to become weak and brittle.

The conditions that produce oxidation — thermal or photo energy plus atmospheric oxygen — are present in almost every environment in which polyethylene-insulated or sheathed cable is used. In addition, the plastic is raised to high temperatures in the wire-coating process. To withstand these conditions, the plastic needs two types of protection: against oxidation caused by heat and against oxidation caused by light.

Photo oxidation, caused by sunlight, is the most damaging. Fortunately, however, solar light can be screened out of the polyethylene by dispersing through it exceedingly small particles of carbon, called carbon black (RECORD, *July*, 1957). Unless this is done, one year of outdoor exposure is enough to ruin unprotected polyethylene. Samples of polyethylene that do not contain carbon black are shown in the adjacent photograph. The deep cracks that are apparent in the unprotected samples would allow moisture to enter telephone cables and disrupt the circuits. The cracks are also visual evidence of the extreme brittleness caused by oxidation (RECORD, *January*, 1958).

Exactly the same symptoms of deterioration are apparent in *thermal oxidation*. Oxidation due to heat presents a different set of problems, however. For example, the dielectric properties of polyethylene can be degraded to the point of uselessness by exposure to air for less than one hour at the high temperatures required for milling and extrusion. Also, carbon black, so effective in screening out light, adds to the thermal oxidation problem by absorbing photo energy and converting it into heat. Some thermal oxidation is therefore unavoidable, since there exists no practicable means for excluding all heat from the polymer.

Protecting polyethylene then, is a matter of stopping the oxidation at an early stage, rather than preventing it entirely. For this purpose, special organic compounds, called antioxidants, are used. At present, chemists believe that these compounds diffuse among the relatively immobile polymer molecules to reach sites of oxidation. The antioxidants then halt the hit-and-run oxidation cycle by absorbing the energy from excited polymer molecules. This prevents the reactive molecules from passing on their excess energy to other polymer molecules in the vicinity.

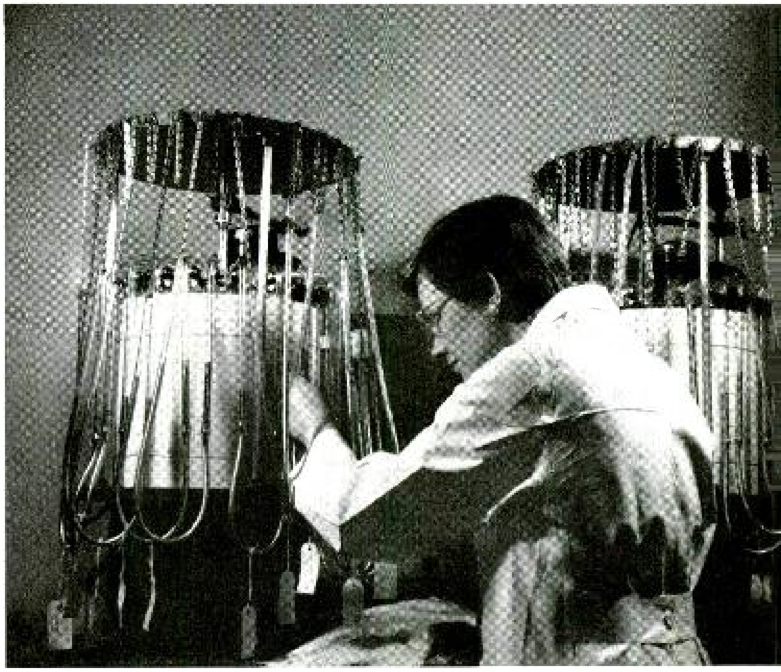
By this energy-absorbing action, a single molecule of antioxidant may save hundreds of polymer molecules from attack by oxygen, and may thereby extend the useful life of virgin polyethylene several hundred-fold. In the course of this protective process, the antioxidant is gradually consumed until eventually none is left to prevent the normal destructive oxidation.

Antioxidants are commonly used to protect all kinds of commercial products from oxidation. They are used in perishable foods to prevent spoilage, in gasoline to suppress the formation of gum-like oxidation products, and in most plastics and rubbers. Nearly all commercial antioxidant compounds belong to two chemical families: (1) *phenols*, which are derivatives of carbolic acid, and (2) *aromatic amines* — a class of ammonia derivatives. These two classes of common antioxidants are represented in the table by Compound B and Compound C, respectively. The letter R in the diagram represents groups of atoms that are often attached to the basic molecule to intensify its activity. This protective action is primarily due to the hydrogen atoms bonded directly to either the oxygen or nitrogen atoms.

Compound C, along with carbon black, was originally used to protect polyethylene. Carbon black acted as a shield against sunlight during service and the antioxidant protected against heat during both processing and service. Several years ago, however, W. L. Hawkins of the Laboratories showed that the combination of carbon black and Compound C was incompatible. Specifically, his experiments proved that conventional protectants lost most of their effectiveness in the presence of carbon black.

Ideally, the safest way to test the effectiveness of an antioxidant is to duplicate the actual service conditions. But this takes too much time, so supplementary methods, in which the plastic and antioxidant mixture are tested at elevated temperatures, are generally used for rapid evaluation. Perhaps the simplest test procedure involves measuring the amount of oxygen absorbed by a polymer sample enclosed in a glass apparatus. An apparatus for testing oxygen uptake is seen in the illustration at the right. The measured oxygen consumption is directly related to changes in the mechanical and electrical properties of the plastic.

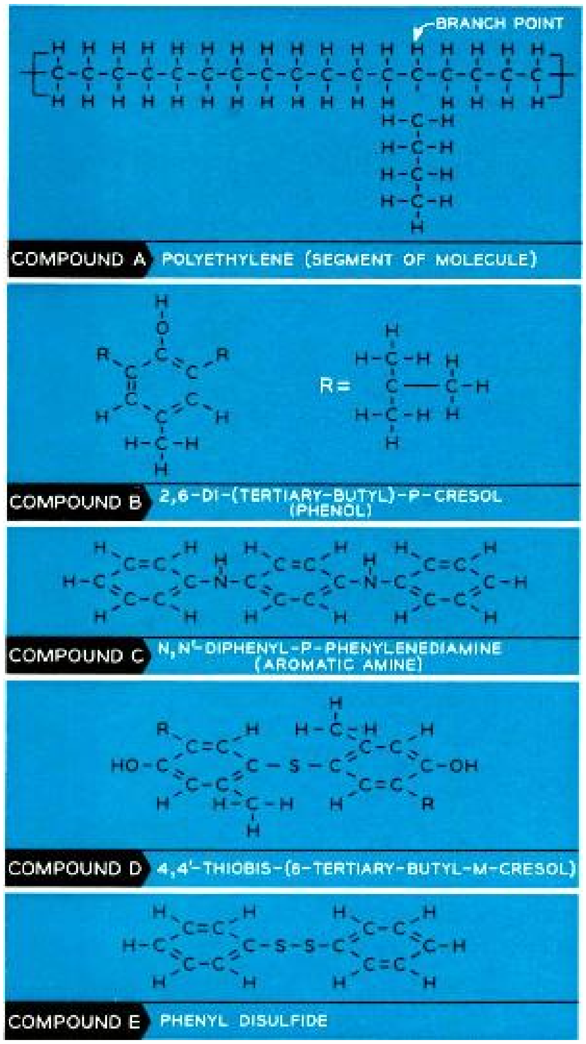
With this testing technique, many different types of known antioxidants were examined under varying conditions. In the course of these experiments, Hawkins and V. L. Lanza discovered that the behavior of a commercial antioxidant which contained sulfur was most peculiar. Instead of a reduction in its ability to stop oxidation in the presence of carbon black, the sulfur compound actually gained effectiveness as an antioxidant. Even more surprisingly, the total protection against oxidation exceeded the sum of the separate contributions of carbon black and the sulfur antioxidant. This intriguing sulfur compound (Compound D in the table) consisted of two phenolic units joined by a sulfur "bridge."



Mrs. B. B. Loeffler checks and records the oxygen uptake of a sample of polyethylene with a protectant added. By matching the level of the mercury in the tubes, she can determine how much of the oxygen in the tube has been absorbed by the sample, also enclosed in the tube. Bath behind the glass tubes contains heated silicone to keep the samples at a constant temperature.

The sulfur bridge apparently served two functions. It increased the activity of the phenolic units, and more important, it improved the antioxidant activity of the phenolic units in the presence of carbon black. When the OH groups in the compound were replaced by a hydrogen atom, the protectant completely lost its antioxidant activity. This showed that except for its added antioxidant activity in combination with carbon, the sulfur compound acted as a typical phenolic antioxidant.

A further modification of the sulfur antioxi-



COMPOUND A POLYETHYLENE (SEGMENT OF MOLECULE)

COMPOUND B 2,6-DI-(TERTIARY-BUTYL)-P-CRESOL (PHENOL)

COMPOUND C N,N'-DIPHENYL-P-PHENYLENEDIAMINE (AROMATIC AMINE)

COMPOUND D 4,4'-THIOBIS-(6-TERTIARY-BUTYL-M-CRESOL)

COMPOUND E PHENYL DISULFIDE

Structure of a portion of polyethylene molecule (A) *and protectant molecules* (B, C, D *and* E). *Individual atoms that make up the molecules are represented by letters:* C *for carbon,* H *for hydrogen,* O *for oxygen,* N *for nitrogen, and* S *for sulfur. The locations of the letters represent in two dimensions the approximate location of the atoms in the molecule. Atoms in a molecule are held together by valence bonds, represented in the diagrams by the dashes between the letters. A double dash in the "rings" shows a double valence bond.*

In a sense, these diagrams of molecular structure are similar to circuit schematics. Like the components in an electrical circuit, the arrangement and number of the components (atoms) of the molecule determine its properties or activity. By adding, subtracting or rearranging atoms, the chemist can produce molecules more nearly suited to his purpose. "Tailoring" has limits, however.

dant disclosed another new possibility. The basic antioxidant molecule with a double sulfur bridge (Compound E) is no longer a phenol since it does not contain the OH unit. It is therefore not an effective antioxidant when used alone. But in concert with carbon black, it acquires a remarkable degree of antioxidant activity. Many additional types of molecules containing sulfur or its "cousin" in the periodic table, selenium, behave like the compound (E) with the double sulfur bridge. Some of these molecules are polymeric substances — giant antioxidant molecules — which have the added advantage of remaining in the polyethylene longer than ordinary, small-molecule protectants.

A point concerning the characteristics of this new family of sulfur-containing protectants is still obscure. That is the interplay between the antioxidant molecules and carbon — an effect that produces a sum much greater than the total of its parts. When the facts are known, it is quite possible that these sulfur compounds will not be antioxidants at all. The real protective action may reside on the surface of the carbon black particles dispersed throughout the plastic, whose antioxidant activity may be only reinforced or renewed by reaction with the sulfur compounds. Support for this proposal was found at Bell Laboratories by B. S. Biggs and Hawkins, who showed that certain carbon additives themselves act as mild antioxidants (in accelerated tests).

An important part of the story of the development of these new antioxidants was the constant question, "are accelerated tests reliable enough in evaluating protectants?" Recent experiments at the Laboratories have attempted to verify the accuracy of accelerated tests by testing the protectants at temperatures intermediate between accelerated-test and actual-service conditions. Data from these experiments, over the past two years, tend to confirm the reliability of accelerated tests, with one notable exception. The latest data reveal that carbon black, alone, has been under-rated as a protectant. Actually, some carbons now appear to be effective antioxidants at temperatures approaching those encountered in service.

This observation opposes a basic tenet of antioxidant theory — that the protectant to be effective must be free to move to the site of incipient oxidation. This cornerstone of present antioxidant theory must be re-examined, however, if, as it now seems, carbon particles in fixed positions hundreds of angstroms apart are able to check oxidation in its early stages.

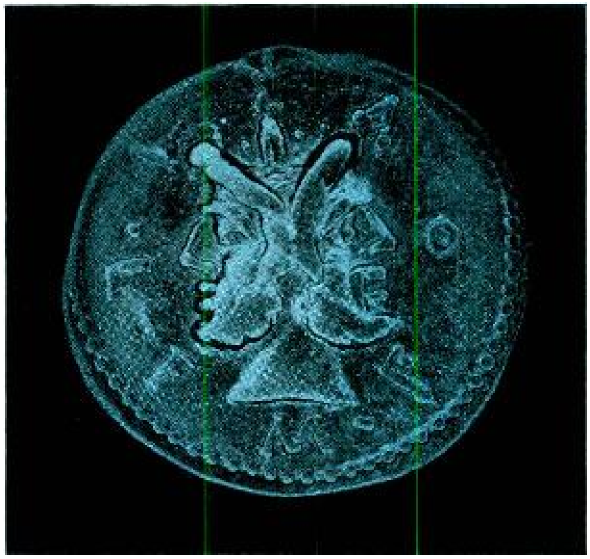
The consequences of a revised theory may have practical as well as fundamental importance. There are already indications that special carbon additives — combination light screens and antioxidants — may eventually prove to be the ideal outdoor protectants for polyethylene.

Today, telephone switching is at a unique juncture of its history. It is looking in two directions as it never did before; it is crossing a threshold that separates two profoundly different technologies. A thoughtful reflection on this situation is a rewarding experience, and it is instructive to weave such reflection around an ancient Roman symbol.

John Meszar

JANUS AND SWITCHING

Our title links an ancient Roman god and a twentieth century technology. In so doing it raises the immediate and spontaneous question: What's the association?



A Roman denarius, second century B.C., from the collection of H. Kelly. Photography by M. J. O'Brien. (Enlargement is about three diameters.)

Well, let us hasten to state promptly that there is, of course, no direct association. Switching, the art and science and technology of telephone interconnecting, certainly does not have its roots in ancient mythology — it has only a few decades of history behind it. The Romans indeed had nothing to do with it.

Still, how often does it happen — either during a lively conversation or during moments of quiet reflection — that if one is searching for a striking reference to illuminate the ramifications of one's thoughts, what comes to mind as most appropriate is a symbol out of our heritage of myth, legend or history. Thus, if the many facets of serene happiness are to be evoked, reference to the Garden of Eden will certainly do it; in contrast, the Tower of Babel will instantly convey a sense of utter confusion. Mention Ivan the Terrible and you elicit visions of savage brutality; but reference to the Sirens stimulates thoughts of irresistible lure. Solomon is the accepted symbol for unexcelled wisdom, while Biblical Job is the common example for patience amid trials and tragedies.

It is in this spirit of using a meaningful symbol out of the remote past to illustrate the unique present state of switching, that Janus was chosen. Sometime or other, all of us have read or heard about this ancient Roman god. He was the diety specifically of thresholds, gates, and entrances, which we cross to go from one area to another. In a broader sense, he was the god of the boundary that separates the "whence" from the "whither," the beginning from the end, the accomplishment from the anticipation. As a fitting representation, his statue in his temple had two faces. These were gazing in opposite directions — one toward the West, toward "past high noon", the other toward the East, toward "day's dawn." Even nowadays we refer to him often — by way of the first month of the year, which was dedicated to him as looking both into the past and the future. Thus, for the present juncture of switching, where this technology looks in opposite directions as it never did before — when it is crossing a boundary that separates great accomplishments in-being from fascinating visions just aborning — Janus is indeed a most appropriate symbol.

For the next few paragraphs let us develop this theme; let us join company with this Roman god of our title, stand next to his pedestal in the land of switching, and gaze away with him in opposite directions. First, let us look toward the West, in the direction of "past high noon," where lie the imposing switching structures built by decades of inventing, precision thinking, imagination and craftsmanship. Then we'll turn toward the East, in the direction of "day's dawn," where dazzles a beguiling mixture of switching hope and certainty, of semi-fantasy and near-reality.

The Accomplishments of Switching

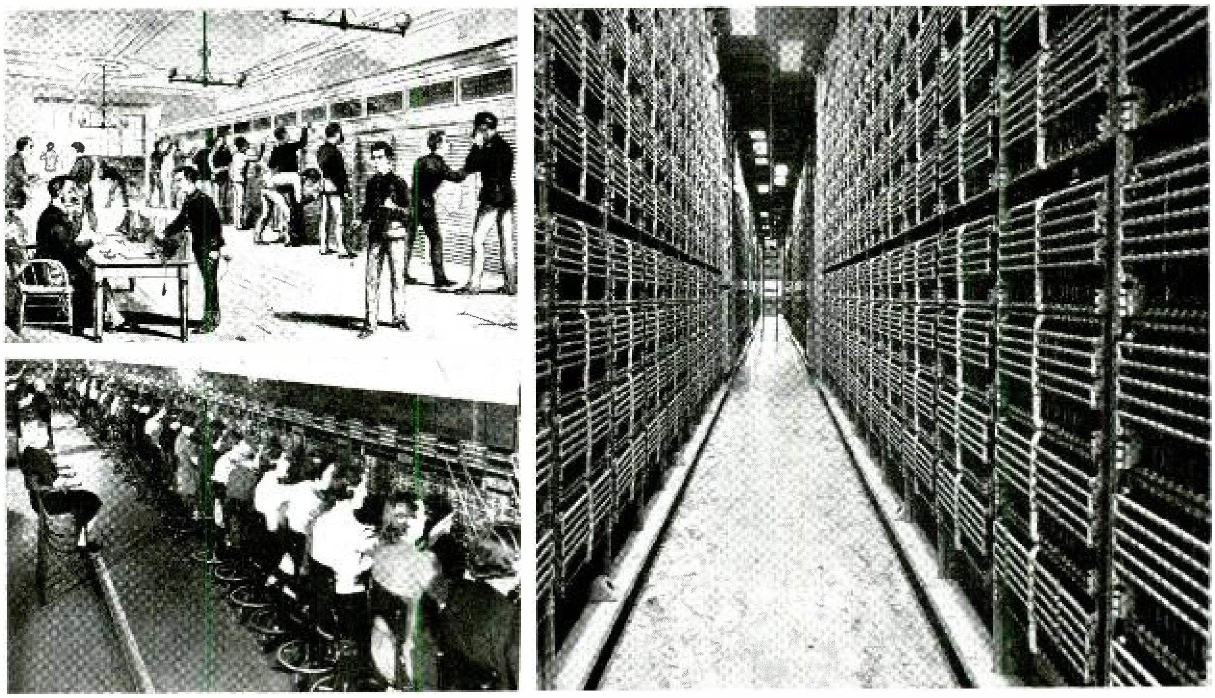
Starting with an early central office where a few rambunctious boys linked together a small number of telephone lines with crude interconnecting facilities, what switching technology has superbly accomplished up to now is to devise a nationwide society, an organized hierarchy of information-processing "machines" whose bold purpose is to link together swiftly, on a moment's notice, any two of over 60 million telephones in the country, so that people who desire to converse with each other can do so — irrespective of where they are on this continent or how far apart they happen to be. This single sentence states the stark essence of the mission of this switching machine-hierarchy, but it does not readily evoke a sense of the extraordinary complexity of the job. That complexity has its roots in the size and character of our country — a vast, vigorous, enterprising and dynamic nation requiring nowadays, on the average, the staggering total of approximately 180 million telephone connections daily.

To repeat: currently, switching machines set up daily 180 million individual, private, custom-made voice paths, most of them within seconds of request, some linking neighbors in a village, others stretching from coast to coast. That's what is needed by this nation to keep family members in contact, to carry on business, to expedite commerce and trade, to perform government functions — in short: to keep things humming. That this is a gigantic task can be readily sensed even from such a matter-of-fact statement of the over-all accomplishment. However, it is more fascinating — and more evocative of appreciation — to try to visualize the job in terms of the myriads of information bits that have to be daily memorized and manipulated, the unbelievably intricate patterns of intra-office and interoffice linkages whose "busy-idle" status has to be repeatedly ascertained, the uncountable series of elementary but rigorous decisions that control-circuits have to make — in short, the prodigious amount of mechanized intelligence that has to be brought into play in setting up 180 million near and far telephone connections.

The magnitude of this task is indeed such that even an inordinate number of the original switching systems — the human operators — would be totally inadequate to match it in standards of speed, accuracy, reliability and economy. To perform the task today, and to be ready for the sure growth of tomorrow, telephone switching engineers have devised a variety of automatic systems — robots whose working capabilities range from the limited to the enormous, and whose levels of specialized built-in intelligence bracket the near-moron and the startlingly capable. These robots are integrated into a nationwide machine-society, a machine-hierarchy, with different echelons of responsibility implied in such prosaic names as Regional Centers, Sectional Centers, Primary Centers, Toll Centers and Central (End) Offices. This is a perfectly disciplined, ideally cooperative hierarchy whose thousands of members — big or little, humble or exalted — are ceaselessly at work, alone or in intimate collaboration with each other, to carry out their joint mission of weaving every day of the year a new pattern of 180 million strands in a communication tapestry spread over an entire continent.

A Tribute to Achievement

One does not have to reflect long, or know much about the internal intricacies of this switching machine-hierarchy to conclude that it must be one of the highest triumphs of human inventiveness and imagination; that in its physical and conceptual dimensions, in the usefulness of its function, in its influence on our society's economic, social and cultural progress, it has not many equals among human achievements. It is indeed one of the true answers to the type of



To date, switching has progressed from the early manual boards to modern automatic crossbar offices. Electronic switching may in the future add a chapter to the history of telephone service.

challenge so well articulated by the famous architect, Daniel H. Burnham:

> *"Make no little plans; they have no magic to stir men's blood and probably themselves will not be realized.*
>
> *"Make big plans; aim high in hope and work remembering that a noble-logical diagram once recorded will never die, but long after we're gone will be a living thing, asserting itself with ever-growing insistency."**

Now, this begins to sound like a eulogy and we had better discontinue it or we'll have to go back and rephrase our title as: An Ode to Switching. Let us at this point simply recall that these remarks were the outcome of following one direction of the dual-gaze of our symbol, Janus, in the land of switching. This look was toward the West, in the direction of "past high noon," and looking in that direction we could not resist expressing high praise for the accomplishment we saw. Let all those who have contributed, or are now contributing to its creation — for it is still in the process of evolving and growing — bask proudly in its existence, be their contribution ever so modest or outstanding.

To further justify this pride in achievement, let our eyes linger for a moment more in the direction of "past high noon". And deliberately let this last look be not at the over-all shape of the switching accomplishment, but let it be a "look under the hood."

For one who is taking his first look under the hood in switching, the reaction may be one of sharp disappointment. It is almost like discovering a fraud. The uninitiated is certainly justified in anticipating that the robots of the switching hierarchy that perform prodigious feats of mechanized intelligence have been created out of some uncanny devices, capable of information-receiving and memorizing and decision-making functions. But behold! These robots consist of but frame upon frame full of drab hardware — electromechanical relays and switches in monotonous repetition.

Now, conceptually as well as in basic physical implementation, an electromechanical relay is simplicity itself. Current flows through a coil of copper wire, and the resultant magnetic field moves metallic contacts to touch or to separate. That is all there is to a relay — in principle. Granted that reliable, economical, long-life relays draw heavily on such scientific disciplines as mathematics, physics, chemistry, magnetics and metallurgy. Nevertheless, their fundamental principle is always the same simple one of moving contacts in response to current in their coils. There are, of course, surprising variations in the

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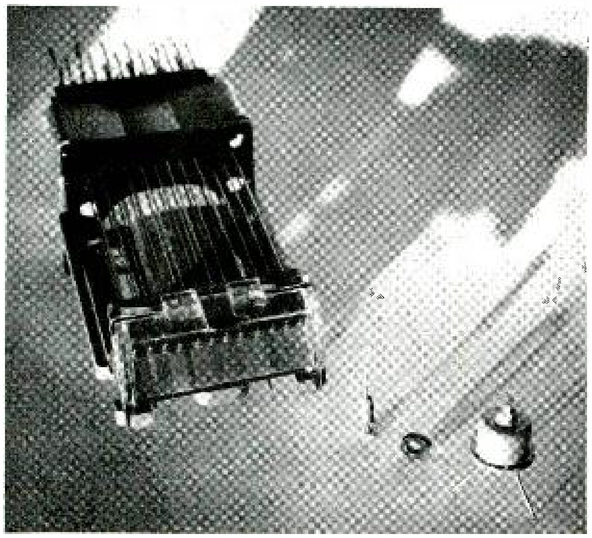
* From a speech delivered in London at the Town Planning Conference, 1910. Reprinted by permission of D. H. Burnham, Jr.

details of putting this simple principle to work. Thus, there are the unburdened relays that move but a single metallic contact; and there are the work-horse types that actuate up to dozens of contacts. There are those that close and open contacts in a random order; and there are those that do it in a precise sequence. Some respond to a whisper of current through their windings; others obey only a powerful surge. There are the fast ones — and the sluggards, the delicate ones — and the rugged, the modern — and the dated. But there is no variation in their underlying principle, or in their single function of "closing" and "opening" metallic contacts.

New Functional Units

Up to now, this little commoner, and its bigger brothers like the crossbar switch, were practically the sole elemental building blocks available to the switching system designer. But through imagination and ingenuity, and a most extensive application of rigorous logic, out of such artless devices and pieces of wire — and practically nothing else — the switching systems designer fashioned control circuits that could count, receive and memorize information, make selections, calculate, arrive at logical decisions, and perform other similar actions akin to routine functions of the human mind. Moreover, he synthesized these functional units into the nationwide hierarchy of complex robots which — given no more instruction than a dialed ten-digit number — will swiftly and unerringly search out the telephone it represents anywhere in the country, link it up to the caller over the spiderweb of telephone highways and by-ways, and repeat variations of this feat scores of millions of times a day.



Wire-spring relay is representative of the present state of telephone switching. Transistors, along with other electronic devices and new concepts of systems design, are a sign of the future.

We are now ready to gaze with Janus in the opposite direction — toward East — in the direction of "day's dawn."

To the sensitive, to the perceptive, dawn is a stirring time — a time when the earth is flooded with the golden-colored light of newborn optimism, of fresh hopes, of high expectations. Listen to the simple yet ever so expressive song:

"There's a bright golden haze on the meadow
There's a bright golden haze on the meadow
The corn is as high as an elephant's eye,
An' it looks like it's climbin' clear up to the sky.
Oh, what a beautiful mornin',
Oh, what a beautiful day,
I got a beautiful feelin'
Ev'rything's goin' my way."[*]

Figuratively, the sensitive and the perceptive in the land of switching are right now humming the same kind of song. There is in the air of this land the same exhilaration of newborn optimism, of fresh hopes, of high expectations, of a new dawn — the dawn of electronic sophistication.

Most of us have nowadays a general, even if not necessarily a precise, sense of what electronic sophistication means in switching. It means the use of an array of new and intriguing devices conjured up in the minds and workshops of our research associates; the transistors — hardly more than rugged grains of crystal, yet ever ready to efficiently generate, or reshape, or amplify, electrical signals; the solid diodes — sturdy morsels of material which can serve as electric gates, instantly opening or closing circuit paths; plastic cards — with geometric patterns of narrow silvery ribbons for mounting and interconnecting these elements and their tiny companions of resistors and capacitors into functional packages; ferromagnetic cores — minute rings that can store a current surge and toss it out at the moment requested; gas tubes — diminutive switches that flip silently between conducting and non-conducting states; cathode-ray tubes that can write and read and change information on their glass surfaces as precision patterns of electric charge; photomultipliers — little devices that release an avalanche of electrons when struck by a pinpoint of light.

Emphatically, the switching system designer is no longer limited to his trusted but mundane hardware, the electromechanical relay. He right

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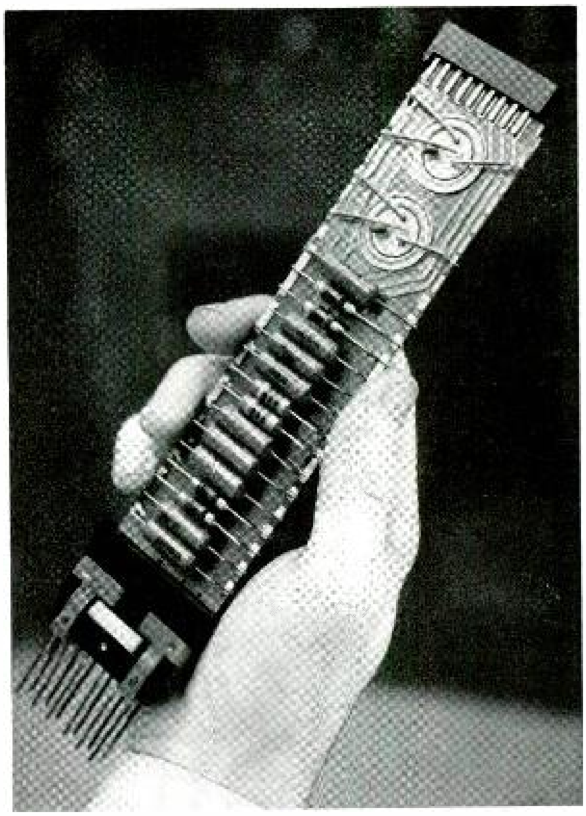
[*] Reprinted by permission. Copyright 1943 by Williamson Music Inc., N. Y. Words by Oscar Hammerstein, II. Music by Richard Rodgers.

now has in hand these elegant and even glamorous instrumentalities — and still others will be coming his way at an ever accelerating pace from the research workshops. These new devices in turn make it possible, even mandatory, to exploit fundamentally different switching system concepts which take full advantage of the extraordinary capabilities of these new devices. Thus, we are already well launched on the massive creative effort to bring into existence an electronic switching system which will indeed represent a profound departure in the evolution of switching.

The Shape of Things to Come

In this system, internal working steps will take but a millionth of a second — or even a fraction of a millionth. That is an astonishingly small time element. This system, in a wink of the eye, will be able to inspect its thousands of customer's lines, one by one, to determine which one needs attention and what kind. With equal speed, it will look over all the communication channels leading to and from other switching centers, to ascertain which ones call for what action in the progress of interoffice calls. Within this system — for the first time in the history of switching — there will be no physical motion involved in joining links together to establish a private voice path for the customer. The familiar movements of "switching in action," like the arm-sweeps of the switchboard operator from her keyshelf to jack field, the nimble hustle of the step-by-step selector from terminal to terminal, the smooth glide of the panel brush over its bank, and the sharp snap of the crossbar switch in closing a path — none of these will have its counterpart in electronic switching. Instead, voice-link continuity will be provided or denied by electronic gates that silently open or close as ordered by the system's "brain." Because of its phenomenal speed, one such brain, one centralized seat of built-in intelligence may suffice even in the largest switching centers to analyze and interpret the information pouring into the center from everywhere, to make logical decisions, and to command appropriate actions by the subordinate control units.

In such an electronic system, the innumerable detailed happenings will be coordinated by razor-thin signal pulses that will dart through the wires at lightning speed. And what compact yet abundant facilities this system may have for storing the immense amount of information it deals with! These information-storage or memory facilities make full use of the provoking but well-known fact that a simple code, consisting of elemental dots present or absent in combinations, can adequately represent nearly any type of information — be it poems or telephone numbers, psalms or stock quotations.



The new look in switching: miniature printed circuit board with its small electronic components.

Information memorized and manipulated by a switching system is of course not this diverse. To do its job, a switching system needs to memorize temporarily such information as: who has just initiated a call, who has just answered a ring, who has just hung up, who is dialing and what, and so on. Then there is the more permanent information that a switching system has to store: The physical point at which each customer's line enters the system, the service types of these lines, the location of access terminals for interoffice channels, the preferred and alternate routes toward a destination, and many others. In an electronic switching system such information — transient or semi-permanent — may be recorded as extremely compact patterns of invisible dots of electrons, or microscopic specks of darkness and transparencies. Recording, reading and erasing may be accomplished by cathode ray beams that flit about with an unparalleled precision.

These are but some hints, some advance cues of the shape of things to come in switching —

like preview flashes of an epic movie. And for extra inducement, let's just add one more flash.

In doing its assigned task, a switching system has to work out the rigorous consequences of numberless sets of internal and external conditions. There must be embodied within it, therefore, a complete and minutely detailed program of logical actions for all situations it is confronted with. Of course, these same situations, and the actions appropriate to them, have to be visualized and thought through by the designers of the system. So — says the inventive — why not tabulate and code all these human thought-processes, these statements of conditions and the corresponding logical answers, and store them in the compact but very abundant memory of the electronic switching system? For every situation, then, the system's brain need not go through the routine of working out the answer in a sequence of logical steps; it can simply look up and read the answer in its "little black book."

Total Break with the Familiar

These are the promises of the coming era in switching. This is what we see looking with Janus in the direction of "day's dawn." And a glimpse of these intriguing possibilities at least partly justifies our choice of this opposite-faced Roman god as an appropriate symbol of switching at the present time. For it is evident that with electronic switching, the break with the familiar will be complete. In the central office of this type, one will no longer hear the excited staccato of busy relays working out problems in rigorous and extensive logic; instead, there will be utter silence even as electron beams sweep over orderly arrays of infinitesimal dots. The lively rhythm of crossbar switches snapping segments of voice-tracks into place will not be heard; instead conversation paths may be indicated by the twinkling of small neon bulbs, crowded into enclosures like fireflies entrapped in a glass jar. Gone will be the practice of maintenance craftsmen tracing action in control circuits by inspecting the pattern of moving relays; instead, they will be catching glimpses of signal pulses scurrying like furtive ghosts across the face of an oscilloscope. These are but examples of truly profound contrasts. To try to visualize all of them puts a strain on the imagination.

A few paragraphs earlier, a modest tribute was paid to what we saw in the land of switching, looking in the direction of "past high noon." We should do no less when we look in the opposite direction — toward "day's dawn." What we see in that direction is certainly enough to lift the spirit of a man of switching; it is enough to prove to him that his clan is busy at the forefront of technology, pioneering, exploring, inventing, building — in general, matching performance with other contemporaries who rocket metal stars to whirl in the silent vastness of space. How did architect D. H. Burnham express it? Here is the direct continuation of the earlier quotation:

> *"Remember that our sons and grandsons are going to do things that would stagger us."*

And now, perhaps we are ready to part company with Janus, this Roman god of gates, and thresholds, and boundaries that separate. He served us well as a theme with his two faces gazing in opposite directions. But just before we leave him, let's look at him once more. He is an even better symbol for switching today than is suggested by what has been said already. Yes, he has two faces, and they do gaze in opposite directions. But he has only one head, one mind to coordinate all his observations from both directions, and to formulate all his decisions. Thus, he well symbolizes unity and "oneness," as well as the boundary that separates.

In so doing, he represents switching perfectly; for — if there is a single dominating feature of telephone switching technology, it is that of interlocking. In switching, devices are woven by wires into single-function units, which in turn are tied together into multifunctional circuits, which in turn are organized into systems, which in turn are interconnected into the nation-wide machine-hierarchy. In this hierarchy the old and the new are completely integrated; functionally, age and vintage are blurred beyond recognition. Every member of this hierarchy, sometime, somewhere, becomes a partner of any other member — with all that good partnership connotes. Thus, a brand new No. 5 crossbar system just put into service this morning has to accommodate itself to the set ways of the No. 1 type crossbar system dated mid-1930; the 4A long distance switching system, the first of which was installed only 5 years ago, has to be capable of intimate cooperation with the panel system designed four decades ago. Similarly, the electronic system, when it joins the ranks of the switching machine-hierarchy as its newest and finest member, will unquestionably have to team up over and over again with even the oldest type of member, the step-by-step system, to satisfy many of its customers' requests. In fact, the first call ever to go through the exploratory electronic switching sytem in Bell Laboratories, did terminate in a step-by-step satellite.

We began this little essay with the theme of profound differences now shaping up in telephone switching. Let us close it on this note of complete unity and indivisibility which is an inescapable characteristic of this technology.

NEW POLE-TYPE BUILDING

Simplicity in both appearance and construction is the keynote of a new building at the Laboratories' Outside Plant Field Laboratory at Chester, New Jersey. This unheated 40- by 60- by 11-ft. structure is used for the storage of vehicles and outside plant hardware and equipment.

After considering other types of construction, its designers selected a pole-type structure because of its low first cost and maintenance, as well as for its good appearance. The completed building has verified the wisdom of this choice in every respect, and for this reason the methods may have application to many Bell System construction problems where low cost of fabrication and maintenance is essential, and where speed is important.

This structure uses utility-type poles set in the ground as a basic support for corrugated aluminum roofing and siding. The rough framing is completed by carpenters using the simple techniques employed in the construction of telephone pole lines. Use of climbers and ladders makes it possible to erect the entire building without scaffolding. All heavy parts are handled with machinery. Completed in three weeks by a local contractor, the building was erected with a minimum of disturbance and with much less than the usual untidiness that goes with a construction job.

The site was first graded with a bulldozer to provide a base for a 6-in. gravel fill and a 4-in. reinforced concrete floor at the desired level. An hydraulic power digger was used to dig holes 5½ ft. deep for the 25 poles placed around the periphery of the building. A power derrick quickly set the penta-treated poles. Then the rafter supports were nailed to the poles and the nine roof trusses hoisted into position. The trusses, having a 40-ft. clear span, were fabricated on the ground using 2- by 10-in. and 2- by 6-in. timbers held together by 4-in. split-ring connectors and ¾-in. galvanized bolts. Addition of purlins and girts completed the framing of the structure. This framing was selected from standardized designs for pole-type structures. Designs are available for many variations of size and shape that tests and experience have proven can safely withstand wind and snow loading.

For a distance of three feet above the floor line, 2- by 10-in. tongue-and-groove, penta-treated planking was used for the walls. This provides extra strength near the floor where mechanical damage from the storage of heavy material is most likely. The remainder of the walls was sheathed with 0.019-in. embossed aluminum siding with 2½-in. corrugations. Aluminum-alloy spiral nails were used to attach the siding to the girts. The roof was then covered in the same way, and panels were furnished in proper sizes so that the only cutting necessary was that required to match the angle of the roof. The only trim was an aluminum ridge cap and 2- by 6-in. facia boards at the top of the end walls. Gutters were placed at the front and rear, and the under-eave spaces were boxed in with ¾-in. lumber.

Pole stubs were placed in the two rear corners of the building for two 12- by 16-ft. loading platforms four feet high. Extra full-height poles were placed at the center of the span, near the corners of the platforms, to support a hoist for use above the platforms.

The 4-in. reinforced concrete floor and a 2-ft. wide apron were poured and finished. When the concrete had set, the platforms were covered with 2-in. rough oak. The final operation was to hang the five 12-ft. wide, 11-ft. high sliding doors. They were framed on the job with wood and faced with aluminum siding.

The completed building has a good appearance and blends with nearby white-painted wood structures. Practically no maintenance is expected. Very satisfactory weatherproof shelter is provided at a cost of less than $3.00 per square ft. including engineering, grading, construction, incidental painting, wiring and all materials.

S. M. SUTTON
Outside Plant
Development Department

When the TRADIC project was established digital computers tended to be heavy items —both in weight and power requirements. In Phase One of the TRADIC program, Laboratories' engineers proved that high-performance transistorized digital computers were feasible in a laboratory environment; this paved the way for airborne systems to exploit the transistor.

J. R. Harris

TRADIC: The First Phase

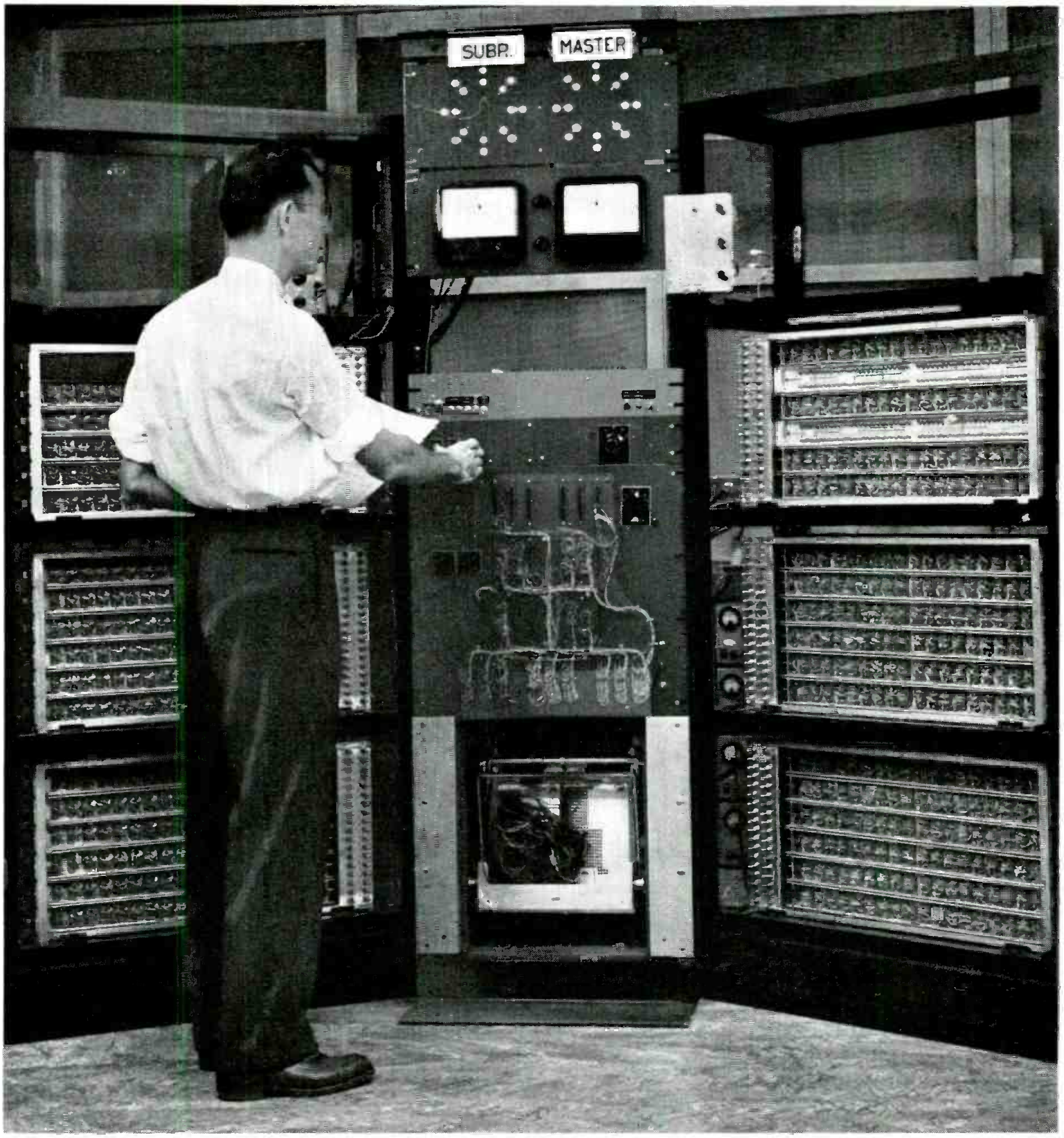
One day in 1951, J. H. Felker of the Laboratories was trying out a new point-contact transistor fabricated by the transistor development group. He first tried to make the new unit work in an amplifier circuit. That trial turned out to be rather discouraging, because the circuit seemed to want to oscillate in spite of all he did to stop it. What next? The persistent behavior suggested that it would be better to make use of the oscillation than to fight it; the new unit was tried in a simple blocking oscillator circuit — a monostable circuit in which triggering causes a single pulse to occur.

What he saw was a very fast pulse, rising and falling in a few hundredths of a microsecond, produced by a tiny circuit with a power-supply drain of only a few milliwatts. That event can be thought of as the conception of the TRADIC project; extensive work began months later when a group at Bell Laboratories set out, with Air Force sponsorship, to prove the feasibility of an airborne digital computer based on transistors.

Why was it that a tiny, fast, low-power, transistor blocking oscillator could hold such significance for computers? To answer this, we must examine what building blocks are needed. Digital computers are built from circuits that provide gain, logic and memory. For instance, the Bureau of Standards Eastern Automatic Computer (SEAC) uses electron-tube pulse amplifiers for gain and germanium diode gates for logic; the SEAC memory depends on delay lines wherein pulses circulate and can be sampled as needed. A high-speed transistor in a blocking oscillator circuit can be used as a pulse amplifier with the same pulse repetition rate as the SEAC computer — that is, one megacycle. The transistor circuit, however, goes far beyond the electron-tube pulse amplifier in its tiny size, low power consumption and prospects for long life. These characteristics are exactly what the military application requires. The low power consumption and low heat dissipation make it possible to put the amplifier — and the other building blocks as well — in a small space without generating excessive temperatures. The low voltages at which the transistor can operate make longer life possible in all components of the computing system.

The Solid-State Digital Computer

The first phase of the TRADIC project was intended to show successful operation, in the laboratory, of a high-speed, general-purpose, all-solid-state digital computer together with input-output equipment representative of use in an air-



Author at the control panel of the computer. This Phase One machine will finish the program of computation assigned to it before he can lift his finger from the start button.

borne control system. "General purpose" here means that the computer can add, subtract, multiply, and divide numbers, and move them amongst its internal units and its input and output gear, all under automatic control of any program which has been prepared and inserted into it. An airborne model of TRADIC has since been developed, and "Leprechaun" (RECORD, *July*, 1957) can also be considered an offspring of TRADIC.

The "Phase One" machine was completed in January, 1954. It was the first large transistor digital computer and it was probably the largest equipment unit in number of transistors (about 700) that had been built at that time. Once the machine was working properly, it was operated

24 hours a day in a reliability study that extended from May, 1954, to May, 1956. Meanwhile, other parts of the TRADIC program were in progress: a research program to bring the latest devices into our technology and a program to use and study the Phase One technology in the air. Our object in the present article is to consider the Phase One machine: what it is and how it has performed.

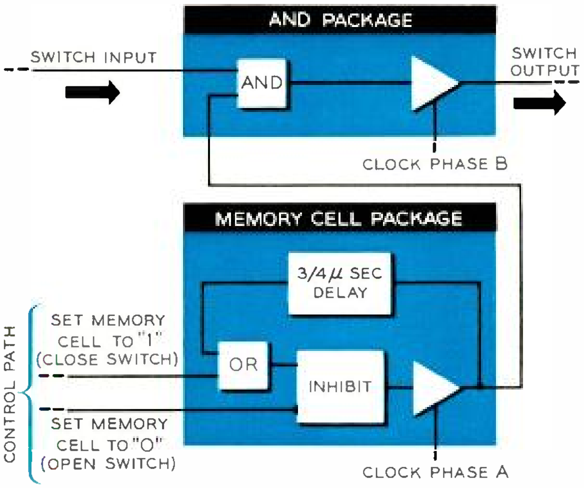
Like the SEAC family of computers, the basic circuits of the Phase One machine are pulse amplifiers, germanium diode gates and delay lines. Information is in the form of half-microsecond pulses with a pulse rate of one megacycle. Each pulse amplifier produces a delay of ¼ microsecond; amplifiers are synchronized with a central clock that supplies 4-phase, one-megacycle sine-wave signals. To illustrate how these basic circuits might be used in switching (and therefore in computing), the first of the three diagrams shows the electronic equivalent of a toggle switch made from amplifier, gate (logic) and delay circuits (RECORD, *June,* 1956).

The AND, OR and INHIBIT circuits do just what the names imply. To obtain an output from the two-terminal AND circuit, a signal must be applied to the upper input *and* the lower input. To obtain an output from the two-terminal OR circuit, a signal must be applied to the upper input *or* to the lower input or to both. The INHIBIT circuit transmits the pulse on its upper (unmarked) input unless a pulse is present on the input marked with a circle or bulge.

All of the functions needed in a computer — whether addition of a pair of digits, generation of a complicated pattern of pulses, counting, and so on — can be realized with AND, OR, INHIBIT and delay circuits. The building-block packages chosen for the Phase One machine are AND, OR, INHIBIT, delay, and the MEMORY CELL. The MEMORY CELL stores a single bit of information until asked for it at a later time. Each package contains a single-transistor pulse amplifier. For the most part, the Phase One machine is an assembly of packages plus interconnecting wiring.

The circuit of the AND package shown in the second diagram is typical of the Phase One circuitry; it can be thought of as a 4-input AND circuit followed by a pulse amplifier. This pulse amplifier, the heart of the computer, grew from the blocking oscillator mentioned at the beginning of the article. The transistor used is the Bell Laboratories type 1734, which evolved directly from the transistor of Felker's original test. This transistor has the original cylindrical Type A cartridge, whereas the present-day version of the transistor is hermetically sealed and is called the 2N67.

Operation of this kind of transistor pulse-amplifier circuit has been described in previous research, but a short description here seems in order. Information signals are positive pulses of about 3 volts amplitude with a base line at –2 volts. The clock wave is a sine wave of 10 volts peak amplitude. With this in mind, we can examine the operation of the AND circuit. Unless there are signal pulses simultaneously on all four inputs, capacitor C2 holds a relatively negative charge, and the emitter of the transistor is never positive enough to conduct. When pulses are applied to all inputs, C2 acquires a positive charge from R4. At this time, the clock wave goes negative and allows the base of the transistor to go negative. Current from C2 and R4 then flows in the emitter, and transistor action causes a flow of base and collector current. Base current flows upward in R1, causing the base and emitter voltages to go more negative. Diode CR3 then starts to conduct and switches the current from R3 into the emitter. The resulting collector current produces a positive output signal of about 3 volts amplitude that can be used to drive as many as seven similar packages. To bring the output pulse to a "clean" termination, the clock signal goes positive just one-half microsecond after the start of the output pulse and it then switches off the transistor.



The electronic equivalent of a toggle switch made from amplifier, gate (logic) and delay circuits. Building block packages for Phase One are AND, OR, INHIBIT, delay, and MEMORY CELL.

The system block diagram is shown as the final drawing. Note that there are six blocks, including the input coder and output decoder. Included is a shaft angle encoder using an optical code wheel (RECORD, *April,* 1954) that is separately mounted. This is a device for converting analog data expressed by the angular position of a shaft to digital data in the binary system.

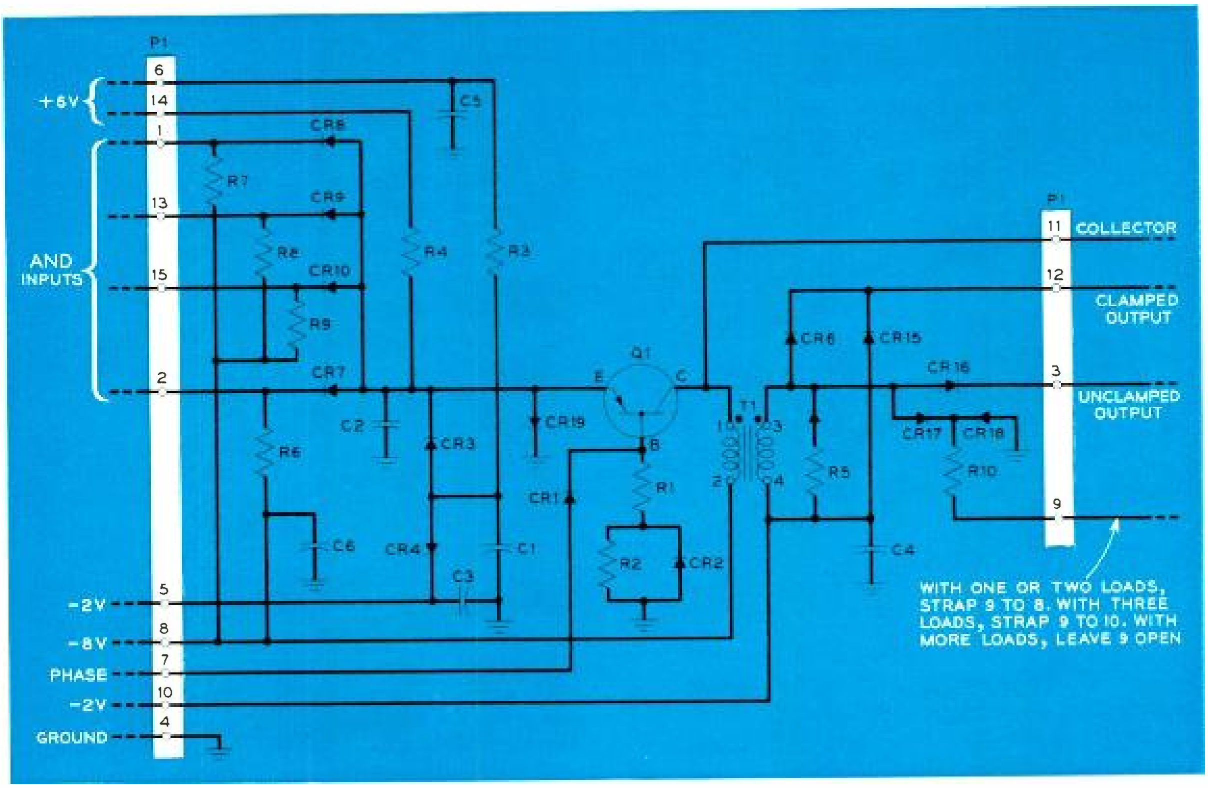
Operation of the computer is akin in many ways to that of the general-purpose machines now in widespread use. The programer writes out a set of mathematical operations that he wants to have carried out, noting the locations in the storage unit where data are to be put and from which data are to be taken, and calling for consultation of the input encoder and production of outputs at appropriate times. In the Phase One machine, the program is converted to machine language with a removable plugboard. Each mathematical operation, or step, requires two jumpers in the plugboard, one to specify the command and one to specify the address. The plugboard provides up to 64 regular steps of computation and one "subroutine" (also of the 64 steps) that can be called up repeatedly during the regular program.

To prepare for computing, the operator puts the plugboard into the machine, and he sets up any necessary constants in binary form on toggle switches in the storage unit. Now all that is left is to set the "mode switch" and press the start button. If the mode switch is set for a single pass through the program, the machine will finish the program (sometimes more than a thousand steps of computation) before the operator has finished pushing on the button!

The mode switch can also be set to repeat the program continuously. This is useful even when there is no changing input to the machine. An example is the computation of an antenna pattern in which the machine adds a slight increment to the angle being examined each time it passes through the program.

The control unit remembers which step of the program is in progress by means of a pair of 64-step counters, one for the master series of program steps and one for the subroutine. For example, when step 34 of the master program is to be performed, step 34 of the master counter is energized and the two holes labeled "34" (master) on the plugboard are energized. Suppose these holes have jumpers connecting them to one of a set of holes marked "add" and to one of a set of holes marked "storage register H." The storage unit, acting under this instruction, makes available the number in storage register H. The order generator, also acting under the instruction, generates a pattern of signals and feeds it to the arithmetic unit, causing it to add the number from H to the number already in the arithmetic unit. Associated with the plugboard is a large matrix of diodes and pulse transformers, the only substantial part of the machine not made from packages.

High speed is one of the attributes of the



WITH ONE OR TWO LOADS, STRAP 9 TO 8. WITH THREE LOADS, STRAP 9 TO 10. WITH MORE LOADS, LEAVE 9 OPEN

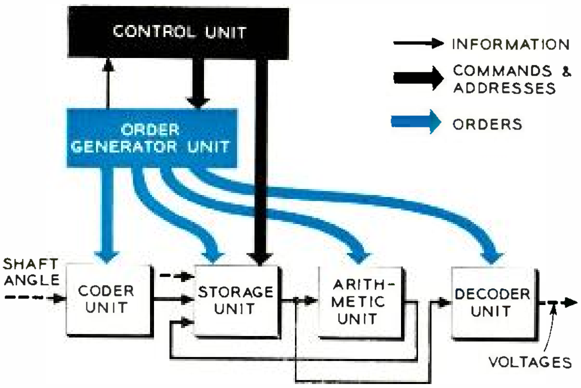
Circuit diagram of an AND package: essentially a 4-input AND circuit followed by a pulse amplifier. This amplifier is the "heart" of the computer and stems from the blocking oscillator itself.

Phase One machine. Even though its arithmetic unit operates on the digits of a number in serial fashion, it multiplies or divides 16-bit binary numbers in less than 300 microseconds and adds or subtracts in 16 microseconds. The storage unit for the results of arithmetic operations of the Phase One machine, though small in size, matches the arithmetic unit in speed. Each number is stored in a separate electrical delay line 16 microseconds in length, making access practically instantaneous to any location in the store.

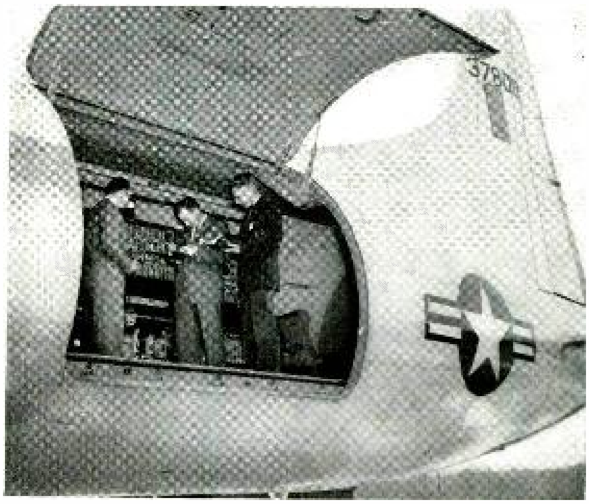
The output decoder has two channels for converting binary numbers to voltages. For something like an antenna pattern display, one channel is used to feed the X axis of an oscilloscope and the other feeds the Y axis. A voltage is generated by summing currents that have values 1, 2, 4, 8, 16, 32, and so on. The component currents are switched into a common load resistor by means of alloy junction transistors that have extremely low and constant voltage drop when conducting and thus permit a high degree of precision for the current values.

The Phase One machine uses only about 60 watts of dc power, which it gets from precisely regulated all-solid-state power supplies. Clock power comes from electron-tube equipment; it was, and is, difficult to get 30 watts of one megacycle power from transistor circuits. The only adjustable elements in the machine are those in the power and clock supplies, and these are used to adjust dc voltage and clock phase to standard values.

During the controlled life test, regular marginal checks were made to determine the condition of the machine. In this kind of test, a supply voltage is varied from its nominal value while the machine is operating, and the value at which the machine starts to make errors is noted. If the machine operates properly with a wide range of supply voltages, it is said to have good margins. If the margins are lower than normal, then some component has deteriorated.



System block diagram of TRADIC Phase One computer; there are six blocks, including the input coder and output decoder. It is at this site that analog data is converted to digital data.



Through big cargo door of plane, TRADIC Phase Two inspected by (l. to r.) O. P. Clark, M. M. Fuller and J. W. DeWitt, Jr. This computer was developed subsequent to the Phase One unit.

With marginal tests of this type, several transistors and several diodes were found to be deteriorating and were removed before they could cause trouble. One transistor and one diode failed without warning, and one transistor and two diodes were accidentally destroyed during maintenance. Even counting any removal as a failure, only 8 out of 684 transistors and 9 out of 10,358 diodes failed during the two-year test. These are failure rates of only 0.069 per cent and 0.0051 per cent per thousand hours, respectively. No resistors or capacitors failed.

The transistor and diode failure rates are both remarkably low compared with those of most electronic components. Observing the high failure rate of transistors with respect to diodes, one is led to wonder whether this is due to the comparative immaturity of transistor technology in 1953, when the units were built, or whether diodes are inherently more reliable. The answer lies in the future. The zero failure rate of resistors and capacitors is particularly remarkable and indicates what can be achieved by the use of very low power levels.

For the SAGE system, the telephone industry must provide many links between Direction Centers and radio sites for air-to-ground communication between Intercept Directors on the ground and intercept aircraft in the air. Laboratories' engineers have developed new signaling and switching arrangements for efficiently managing these links.

H. J. Michael

Selective Signaling and Switching for the SAGE System

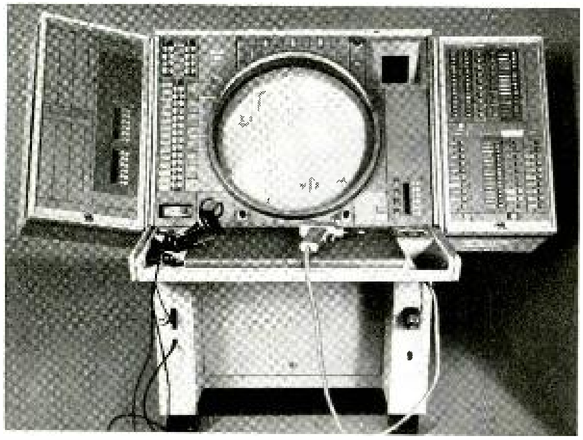
Communications, linking together all elements of the continental air defense system, play a vital role in national defense. A vast complex of radar networks, data-transmission networks, and ground-to-air communication systems guards against surprise air attack and will be used in directing aerial defense should this become necessary. Today all these communication systems are operated and coordinated manually. When one considers the increasingly large number of daily flights — both civil and military — and the ever-increasing speed of aircraft, this becomes a formidable problem. SAGE provides automation as the answer to this problem.

The name, SAGE, is coined from the words "semiautomatic ground environment." *Semiautomatic* indicates that humans are still used to perform certain functions. "Ground environment," as used by the Air Force, describes the many forms of electronic equipment strategically placed at ground locations to perform various operational services.

SAGE is not a new defense system but an enlargement and improvement of the existing manual defense setup. It will take the considerable volume of information from the radar networks and other sources and feed it into computers which, to a large extent, will take over the coordination now done manually. Whether the system is manual or automatic, however, voice communication between the ground and the airplane will continue to be a prime factor in the direction of defense operations as long as personnel are required to man the aircraft.

For defense purposes, the country is divided into air divisions, each of which in turn is divided into sectors. For adequate air coverage, radio sites are strategically placed within the sectors. In the SAGE system, the Direction Center (DC) becomes the focal point of control of radio communication within a sector. Operators, called Intercept Directors (IND), may selectively communicate with planes through any of the radio sites in the sector.

The many units of radio equipment — each on a different frequency — at each radio site, and the numerous IND's at the DC who require access to these radios, must be connected over outside-plant telephone facilities. Since these are vital communication links, the Air Force has specified that there be two independent trunk routes between the DC and each radio site.

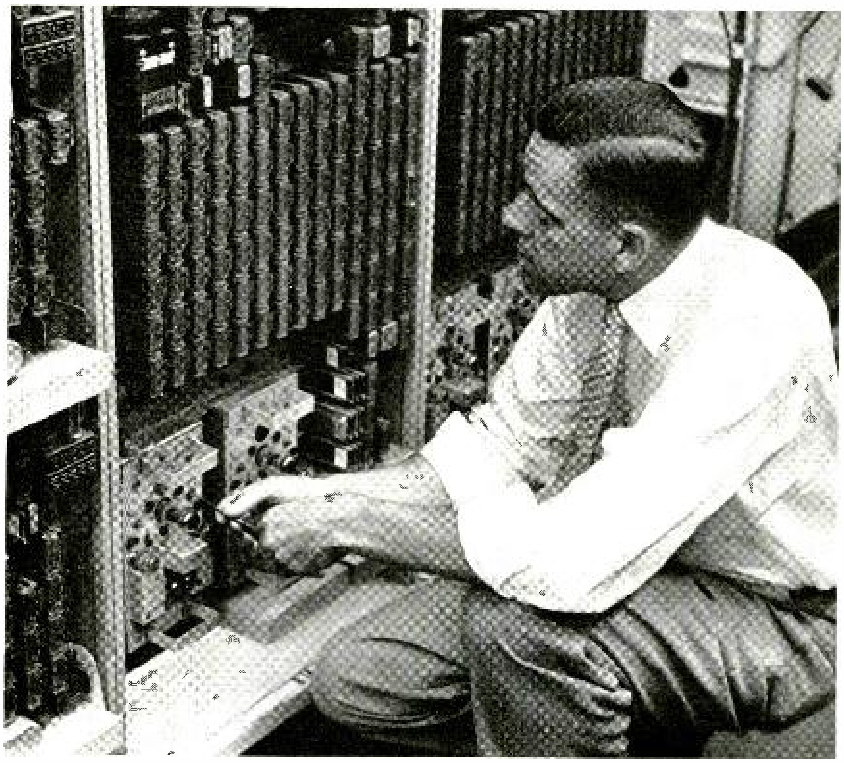


A full view of the Situation Scanning console used by the Intercept Director at Direction Center. A "transmitter-on-the-air" acknowledgment signal will light the ACK lamp on console.

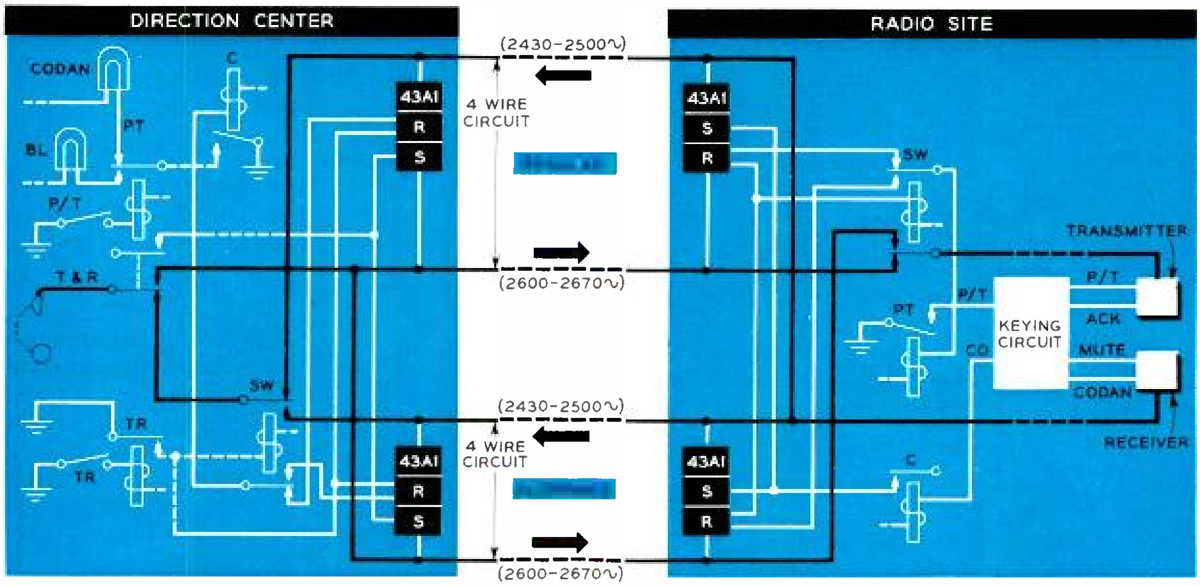
Two arrangements have been developed to furnish the necessary signaling and switching-control features for these circuits. In the first, referred to as Dual Facility (DF) operation, there are two 4-wire circuits — each following a different route — permanently terminated at each end in DF trunk equipment. There is one DF connection to each site for each radio channel. In the second arrangement, referred to as Common User Group (CUG) operation, common-control methods are employed, and the selection of trunks from a common pool greatly reduces the requirement for outside-plant facilities.

In both the Dual Facility and the Common User Group systems, the signals interchanged between the IND position and the radio site are the same; only the manner of establishing the connection is different. When an interceptor group of planes is ordered into the air, it operates on a previously assigned radio channel, and an IND at the Direction Center is assigned to control its operations. The console position is so arranged that it has access to that particular radio channel at all sites. The radio set to which it is connected employs the same frequency for receiving and for transmitting — one direction at a time. Thus, when the IND wishes to talk, he must transmit a push-to-talk (P/T) signal to key the remote radio — that is, to switch it into the transmitting condition from its normal receiving condition. For rapid trouble detection all trunks are continuously monitored, and a pilot tone is used to detect circuit failures. Should one of the lines associated with DF trunk equipment become open-circuited, or should the signaling on it fail, the circuit is switched automatically from the regular route to the alternate route.

To satisfy the requirements for trouble-signaling and regular signaling, the 43A1 carrier telegraph terminal was used as the best imme-



F. W. Monsees adjusts 43A1 carrier telegraph terminal used in SAGE air-to-ground communication system. The trunk connections proper are held under control of the site-selection signal key.



A functional outline of the signaling and switching features of DF operation. The IND, as he is seated at the console, has before him buttons which can select any radio site within the sector.

diate solution. This terminal is a 3-state system operating on a frequency-shift basis — one condition for each of two signal frequencies and a third condition for the off or no-tone condition. The two signal frequencies are referred to as "mark" and "space" frequencies from telegraph practice — where "mark" originally meant that current was flowing in the sounder magnet and "space" meant that no current was flowing. Since tone is normally always present on the line, the absence of tone can be used as an alarm switchover. The continuous presence of tone on the line, however, makes it necessary to set aside a small portion of the normal speech band for signaling purposes — an arrangement known as "slot" signaling. This is the first application of this technique in a standard Bell System circuit. About 300 cycles of the high end of the normal speech band are set aside for this purpose.

Theory indicates that taking a band of frequencies out of the upper end of the voice channel impairs articulation less than would taking a frequency band of the same width from the middle or lower parts of the channel. As indicated in the last diagram, blocking filters are provided to eliminate speech from the signaling channel and to prevent the signaling frequencies from interfering with speech. In this particular case, the effect on the over-all speech transmission capability of the voice channel is estimated to be no more than would be caused by a 2-db loss.

The schematic gives a functional outline of the signaling and switching features of DF operation. The IND, as he is seated at the console, has before him buttons with which he can select any of the radio sites within the sector. He also has "codan" lamps associated with each of the buttons to indicate when calls are being received from the planes. When an IND has operated a site button, he is connected to that site and his equipment is in the listening condition. In the idle condition, the frequency indicating the mark condition is transmitted from the DC and received at the radio site, and vice versa.

Calls received from a plane at any radio site will shift the signal frequency on the associated trunk to the space condition, which will light "codan" lamps at the DC corresponding to the sites receiving the signals. A speech path will be cut through from a site only when the IND has previously selected the site, or when he has selected no particular site and is in monitoring condition. Should an IND wish to communicate with the plane, he must operate the proper site button, if it is not already operated, and operate his push-to-talk switch — thus changing the signal frequency from the mark to the space condition in the outgoing direction. This causes the radio set to be transferred from the receiving to the transmitting condition.

When the transmitter is connected through and is on the air, the incoming signaling frequency is shifted to the space condition. This is the same signal that previously gave a codan indication. Because the P/T switch is operated, however, the equipment recognizes this as a transmitter-on-the-air acknowledgment signal and lights the ACK lamp at the console. The IND then knows that the system is ready for conversation. Any time the transmitter is on the air, the receiver is muted. Normally, this entire operation takes about one half second.

If an IND desires to reject a particular connection because it is noisy or because the level is low, he operates a transfer key. This initiates a switchover from the regular to the alternative circuit. The removal of signaling tone from the circuit for a short interval is recognized at the site end as a signal to make the switchover. The signal goes also to an Air Force maintenance panel at the site as an alarm indication, since it is felt that on most occasions the reason for the transfer will be a noisy radio.

With a large number of assignable radio channels at each radio site, and with a correspondingly large number of IND's manning the consoles, the use of DF trunks requires a considerable number of rather long outside trunk facilities. When one considers that conversation can be going on between the IND and only one radio site at a time, and that the other radio site lines assigned to this IND are for the most part lying idle, an arrangement that makes more effective use of the trunks is indicated.

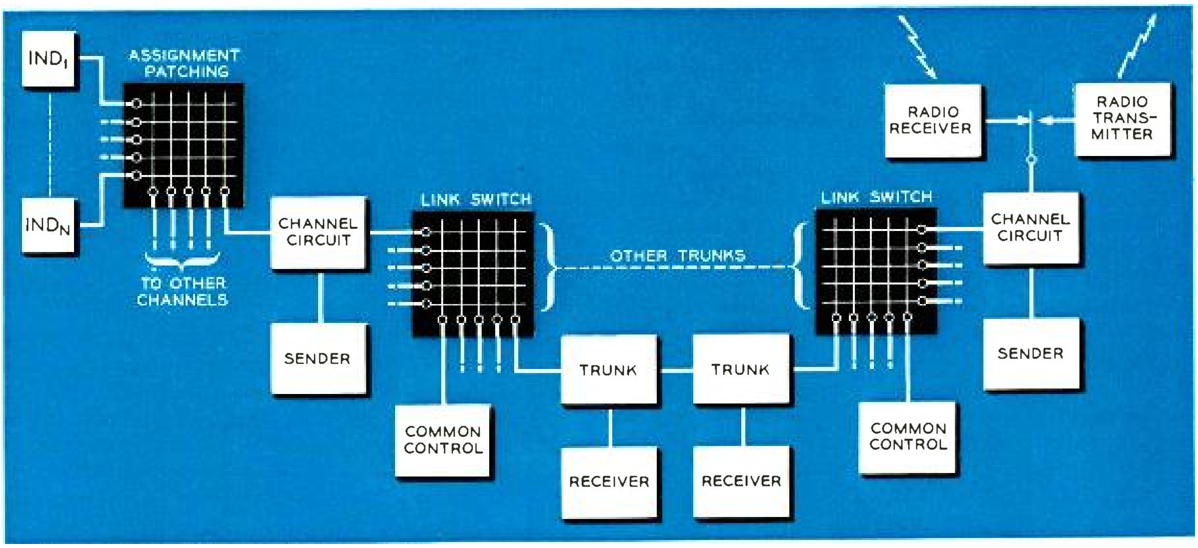
A form of concentration would reduce the number of outside trunks required and make the system more flexible without reducing traffic capacity. This concentrator system would be double-ended. The IND would then use trunks from a common pool routed over two separate geographical paths between the DC and the site to select a particular assigned radio channel. Similarly, incoming calls would be routed through the common trunk pool to the particular IND assigned. With this arrangement — known as the "Common User Group" system — trunks would be used more efficiently.

The number of trunks required to handle the traffic was determined from a traffic study. Conservative holding times, maximum traffic and computed circuit build-up time were used in the study. The results indicated that the size of the trunk groups could be reduced from 15 to 85 per cent for the different radio sites.

On the basis of this study, it was decided to employ Common User Group operation with all radio sites except possibly the one usually associated with the DC; for this, DF operation would be kept. In the Common User Group system the normal signals — P/T, acknowledgment and codan — between the remote radio site and the DC are still handled in the same manner as in the Dual Facility arrangement. Insofar as the IND or the pilot in the airplane is concerned, the method of operation is the same whether he is employing the regular DF trunk circuit or the CUG system.

The diagram below gives in outline form the over-all circuit arrangement in the CUG system. Senders, associated with each channel circuit, can send a single code corresponding to a particular radio channel or IND. Thus, to assign an IND to a particular radio channel he is connected to a channel circuit with a sender that will transmit the proper code. Each trunk has associated with it a receiver that can receive all codes. The signaling link used to communicate between the trunk circuits employs 43A1 terminals operating

An outline of the over-all circuit arrangement in the CUG system. Senders, associated with each channel circuit, can send a single code corresponding to a particular radio channel or an IND.



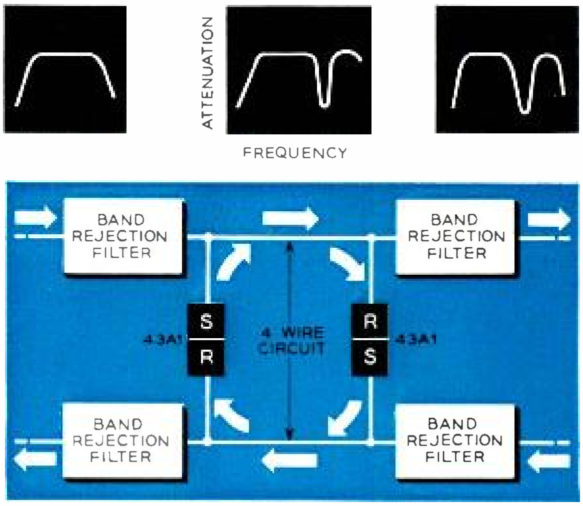
in the same manner as for the DF trunks.

The code used to select the radio channels contributes much to the reliability of the system. It is a time-division, pulse-length code consisting of a series of long and short pulses. Each code digit consists of two long and three short pulses (spaces) separated by short pulses (marks). Any other combination represents a false code and is rejected by the receiver. In addition, parity checking assures that the correct total number of pulses is received or no operation results. Considerable experience has been obtained with this code, and the probability of conversion to a wrong code is considered negligible.

In operating this CUG system under normal traffic conditions, the IND operates a site button to select a site, and the common control part of the system puts in a bid for an idle trunk to the site. When the trunk is connected, the code corresponding to the radio channel assigned to the IND is automatically transmitted. Reception of this code by the receiving circuit at the radio site results in connection of the incoming end of the trunk circuit at the radio site to the particular radio channel.

With the connection established, the IND may communicate with the plane by means of the normal control signals. The connection is normally held until the IND selects another site. Calls initiated from a plane through a site where the connection has not been previously established by an IND are set up just as calls originated from the Direction Center are. In this case the received carrier signal initiates the call, and the IND gets "codan" lamp indications. However, connections originated by the plane are held only as long as the carrier is being received from the plane. The connection is then automatically released.

It should be noted that it is still possible for each IND to reach his radio channel at the site even though there are considerably fewer trunks than there are IND's or radio channels. There may be cases where for one reason or another the number of outside trunks has been reduced to a level where all the traffic can no longer be handled. The Common User Group system has a feature to take care of this situation. As previously mentioned, the trunk connections are held under the control of the site-selection key. Although the trunk at this time is busy to the CUG control circuit, a conversation is not necessarily taking place. If when all trunks are busy, another IND operates his site-selection key, the system will automatically disconnect a few of the nontalkers. When a disconnected IND again wants to talk, operation of his P/T switch automatically re-establishes his connection. Once he does this, he is reconnected and remains so — unless disconnected again if not talking during another all-trunks-busy period.



Block diagram of "slot" signaling arrangement. Blocking filters are provided to eliminate speech from the signaling channel and to prevent signaling frequencies from interfering with speech.

As in the case of the DF trunk circuits, the CUG trunks are also continuously monitored. Should a trunk become open-circuited or a signal failure occur, the connection is automatically disconnected, a new one is established, and the trunk in trouble makes itself busy so that it may not be reseized. The IND can also reject a trunk by the use of his transfer key. The procedure here is the same as in the case of the monitoring failure, but the trunk is held busy only long enough so that it is not immediately reseized, and is then returned to the common pool.

Adequate alarms and status indications are provided to both the telephone company testboard and the Air Force. These maintain a current record of the status of all circuits at necessary locations to give a constant over-all view of CUG.

A trial of the Dual Facility Trunk Circuit has been made with satisfactory results. Units of this equipment have already been installed in some sectors. A trial of the Common User Group arrangement is now in progress and satisfactory operation is indicated.

The air/ground voice communication system — that is, the terminal equipment for switching and signaling and the outside plant facilities — was designed by Bell Laboratories and is being provided and maintained by the telephone companies on a service basis. This is another of the many ways in which the Bell System team is cooperating in their extensive efforts that help to solidify the defenses of the United States.

When television programs or hundreds of telephone calls are in danger of interruption by a transmission failure in the L3 Carrier system, automatic equipment rapidly switches a good line into service. Depending on the nature of the difficulty, the switch occurs either as a "fast" or as a "slow" operation.

E. C. Thompson

Automatic Line-Switching for L3 Carrier

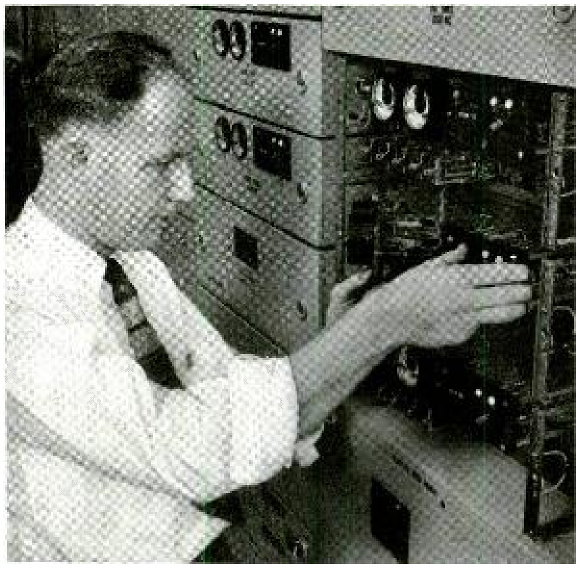
Reliability of service is a very important consideration in the Bell System, especially in a long-distance, heavy-volume transmission system like L3 Carrier (RECORD, *January*, 1954). Over a pair of coaxial tubes in a typical cable, 1,860 voice circuits or 600 voice circuits and one television program can be transmitted in each direction. Since circuits can be introduced and dropped anywhere along a 4,000-mile route, it is not difficult to imagine the confusion and service reaction that could result if the transmission path failed and a method were not available to insure the ready restoration of service.

A spare could be allocated for each coaxial line carrying service, but this is unnecessary for the same reason that an automobile does not need a spare for each of its four tires. Computations and limited experience with the earlier L1 Carrier System indicated that one stand-by line for up to three or four working lines in each direction of transmission should afford adequate protection if the spacing between switching points does not become excessive.

The problem then arises of how to switch the service to the stand-by line whenever transmission over the working line is degraded or interrupted. At best, manual switching is slow, for it requires coordinated effort by personnel at both the transmitting and receiving ends of an L3 coaxial section, many miles apart. When the lost time is multiplied by the many hundreds of telephone conversations being transmitted, the total service difficulty could be sizable.

In the event of a total failure, where a large number of circuits would be affected drastically, a very fast switching operation is desirable. Under other conditions, where fewer circuits are involved or where the line characteristic is deteriorating slowly, slower-speed switching is tolerable. The terms "fast" and "slow", of course, are relative and they include in each case the total time from the actual recognition of trouble until the completion of the switch. Both switching operations are sufficiently rapid that the user usually does not detect that a switch has occurred.

In a switching operation, use is made of six pilot frequencies spaced over the L3 spectrum. Whenever any one of these pilots deviates beyond prescribed limits, indicating that transmission has been degraded or lost, the change is recognized by a circuit termed a "switch initiator." This circuit translates the information de-



R. F. Morra working with Bell Laboratories models of L3 circuits. Pilot oscillator panels can be seen in the upper part of the photograph.

rived from the pilot frequencies into a switching operation.

Information concerning the condition of a line, received from pilot regulators, is either a dc voltage or current which is proportional to pilot power. The current is used to operate microammeter-type relays, one per pilot regulator, which close contacts on a prescribed deviation of the pilot from normal. These relays have a finite time of operation, and closure of their contacts triggers a switch. The dc voltage existing in the circuit associated with the main pilot is used to trigger electronic circuits to cause a fast switch, therefore eliminating for this one pilot the time of operation of its relay. Thus, since the main pilot with its associated equipment is the "watch dog" for the entire transmission band, it yields very short recovery time, and for this reason such vulnerable services as telephoto, television and telegraph are not adversely affected.

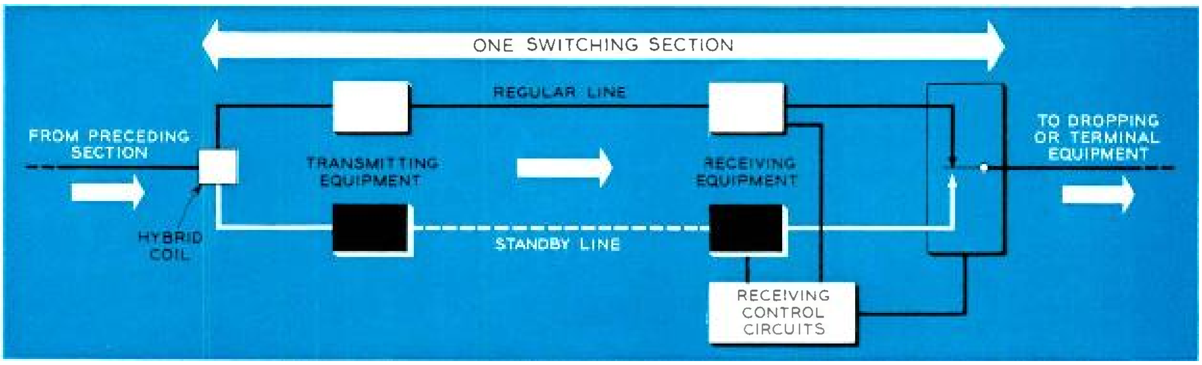
When one of the other pilots deviates and the main pilot is not affected, only a small portion of the entire transmission band is affected, and the slow switch yields a sufficiently short recovery time. A slow switch can be triggered by the main pilot, but only when this pilot drifts slowly enough to cause closure of a relay contact before it changes sufficiently to trigger the fast switch. In this case, the slow drift generally is no detriment to the services mentioned, and after the contact closes, the line is replaced in essentially the same time as that taken for the fast switch.

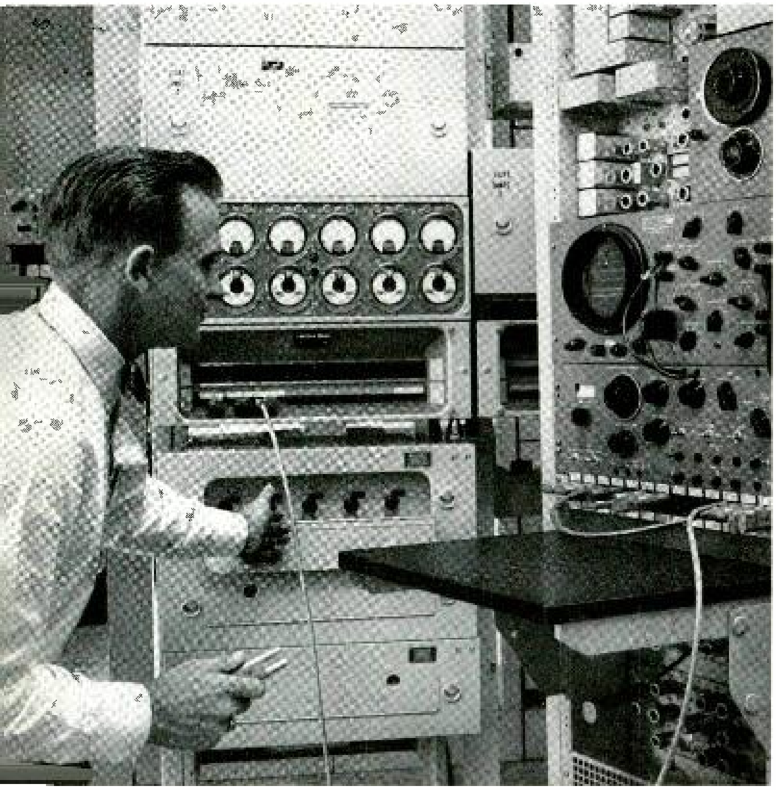
Dual or Multiline Operation

In some situations, as illustrated in the first block diagram, only two coaxials are used in a switching section — one for regular service and one for a stand-by. As indicated, the signal is double-fed (separated into two parts by the familiar hybrid coil arrangement) to both the regular and stand-by line. Thus, if trouble develops in the regular line, equipment at the receiving end merely interchanges the connection to maintain the continuity. The standard switching arrangements may be adapted to provide the simplified two-line switching shown in this illustration.

In a more typical case, however, the standby line must protect a number of service coaxials, as illustrated in the second diagram. This drawing shows that in multiline operation, switching must occur at both ends of the section, and that switching information must be sent from the receiving end to the transmitting end. All switching activities are directed from the receiving

The two-line L3 switching circuit arranged for one direction of broadband cable transmission: one coaxial line is used for regular service, while the other is used for standby protection.





C. G. Arnold testing experimental L3 equipment during development program at Bell Laboratories.

equipment end of the section by "switch initiators."

Switching information is conveyed by signals spaced 2 kc apart just below the L3 spectrum in the 280-296 kc region. These signals identify the line in trouble and control other functions important to the complete switching operation. To obtain a high signaling speed and dependability, these signals are sent over all of the coaxials in parallel for the reverse direction of transmission. Coupling filters are provided to separate the signaling paths from the transmission paths. Since each L3 section uses the same frequencies to control switching activity, other filters are provided between switching sections to prevent switching in following sections where no trouble exists.

An abnormal loss or gain in transmission of one of the coaxials of a multiline system initiates the following sequence of events. The initiator associated with the line in trouble sets up, or primes, its line switch — a mercury-contact coaxial relay (223A) inserted in the coaxial line. Simultaneously, a switching signal which identifies the failed line is sent to the transmitting end of the switching section over the coaxials for the reverse direction of transmission. Here it is picked off and directed by switching-signal filters to the proper transmitting-switch control circuit. This portion of the circuit operates a coaxial transmitting line switch to connect service to the stand-by line. At the same time, a "verification" signal is passed through this same transmission path to the receiving end of the station. This signal verifies the substitution of the line and then causes the receiving switch to operate.

The complete operation takes place in from 10 to 20 milliseconds after the main pilot exceeds the limits set for satisfactory system performance. Variations affecting only a portion of the L3 spectrum result in a slower switching response, in the order of 100 milliseconds. When transmission on the regular line returns to normal, a similar check of switch performance is also supplied upon release of the stand-by line.

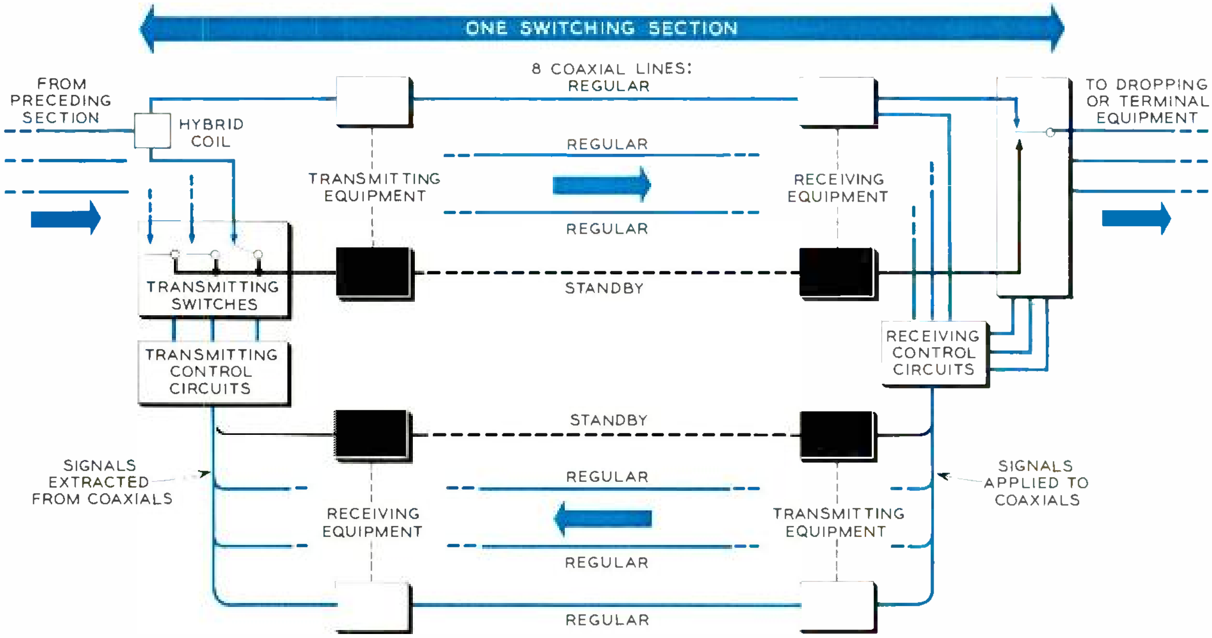
The Checking Process

Once operated, the initiator circuit locks up and begins a periodic checking process to determine the duration of the line fault. When this process determines that service can be restored over the regular high-frequency line, the initiator returns to normal, releasing the receiving line switch.

The transmitting line switch is released by transmission of a signal applied to the signaling path when the initiator releases. At the same instant that the release signal is transmitted, switch-initiator circuits associated with the other lines are locked out. Thus, no further switching activity can begin until the stand-by line has been released at both ends of the section. Satisfactory release of the transmitting line switch is acknowledged with a "release-check" signal, which enters the signaling path only when all transmitting switches have been restored to normal. When received, the release-check signal shuts off the release signal and removes the lockout from the remaining initiator circuits. Now a new switching operation could begin if this were required.

Switching sections are on the average about 125 miles long, and any change in pilot level is felt in all succeeding switching sections following a fault. If nothing were done to prevent it, all sections following the fault would switch, and in these sections the regular lines would needlessly be deprived of the stand-by protection. Such unwanted switching operations are prevented by permitting the system to switch only when it has been definitely established that the fault lies within the switching section.

With the two-line arrangement mentioned earlier, faults occurring in preceding sections appear on both the regular and stand-by lines. These are cancelled in the switch initiators, and switches are thereby avoided. In the multiline



The multiline arrangement for an L3 switching circuit; one direction of transmission is shown. Only one standby is necessary for protecting as many as three or four working coaxial lines.

circuit, such unwanted switches are prevented by making use of the transmission time of the switching signals. Each operated initiator inhibits the transmitting switch control for the following section. This inhibitor action is applied directly to transmitting control circuits located in the same office. Line-identification signals, although transmitted in a very short time, still require considerably greater transmission time than that required by the local inhibitor action, since they must travel from the receiving end of the section and pass through relatively narrow band-pass filters.

Only One Section Affected

In this way, switching is blocked in all sections except the one in which the fault has occurred. Should it prove impossible to restore service in the faulty section, perhaps because the standby is already being used, control circuits in the following section periodically and rapidly check to evaluate transmission conditions. During the period between checks, the stand-by line in these sections is made available to replace any other regular line if failure occurs.

Manual control is provided to facilitate taking high-frequency lines out of service for preventive maintenance routines. These switches are performed manually by initiating an automatic switching sequence in such a way that the duration of the resulting service interruption never exceeds about one millisecond.

Technical personnel concerned with maintenance of the L3 system must have knowledge of the circuit conditions set up by the automatic switching system. Information supplied by the switching-control circuits is therefore correlated in an alarm circuit to provide transmission alarms for the L3 system. Status of all lines is displayed in a lamp field, which is grouped with the manual switching controls to comprise a central operating point. The system provides for supervision and operation of an unattended switching point from an attended station over the B1 Alarm and Control System.

Carrier toll routes grow with increases in service demand. Initially, only a single coaxial line in each direction may be required. Ultimately, however, all eight coaxial lines may be used. On other routes, a single coaxial in each direction might suffice. To meet present and future service demands, the switch system is fully flexible to accommodate the two-line and multiline case.

Cape Canaveral Test Center:

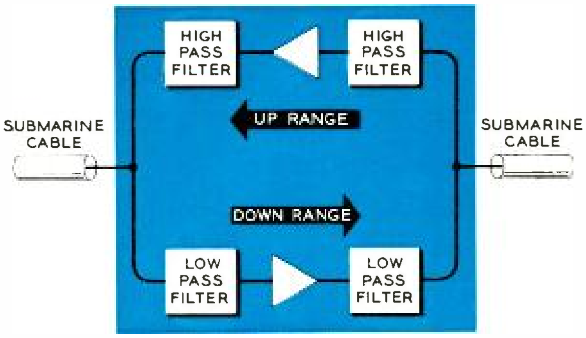
TRANSMISSION EQUIPMENT FOR SUBMARINE CABLE

As part of a long-range proving ground for guided missiles, a submarine cable system has been designed by Bell Laboratories. This Air Force system extends from Cape Canaveral, Florida, to Puerto Rico and provides communications services necessary to guided-missile work. As indicated in previous RECORD articles (*September*, 1956; *September*, 1957) the transmission plan for this system is basically similar to those used for carrier telephone transmission. The equipment is also similar to that used for telephone transmission of the carrier type. Many individual panel designs are, in fact, adaptations of standard equipment. Furthermore, where new panel designs were required, standard apparatus components and assembly methods were used insofar as possible. This made it possible to handle the project in much the same way as Bell System projects, and to make maximum use of the Western Electric Company engineering effort.

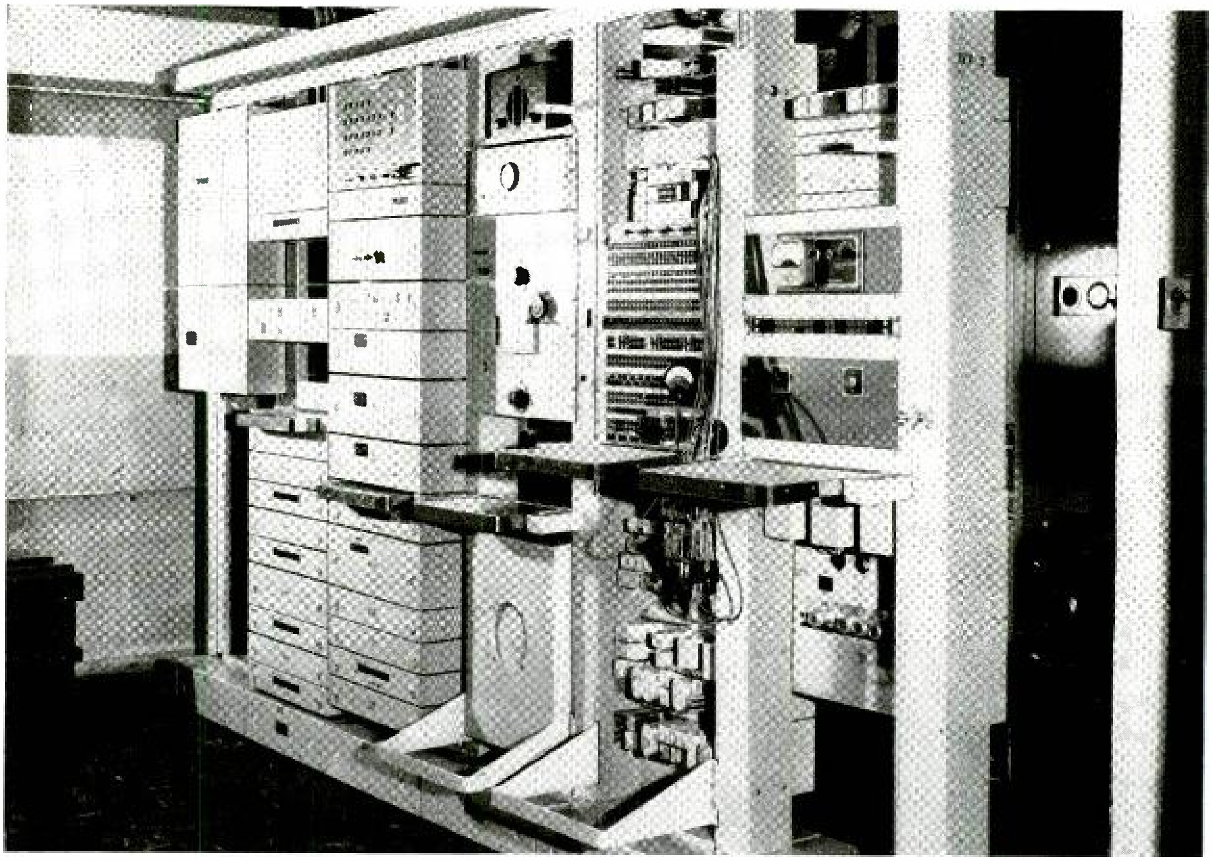
There were, however, some problems involved in the Air Force system that required special treatment. In general, these were associated with the unusual locations of the equipment, the use of submarine cable as a transmission medium, and the very high repeater amplifications that were often necessary. The detailed engineering effort carried out by the Laboratories was also somewhat more extensive than usual. This included such considerations as detailed floor plans, recommendations for building construction, and complete specifications for the wide variety of equipment needed at attended repeater stations.

Fortunately, it was possible to develop generally uniform arrangements for the equipment in the attended and unattended repeater stations. For both types, a basic arrangement evolved such that, at all except end terminal stations, three sets of equipment were required. Two of these were similar sets of filter equipment and the third either a repeater or terminal. (Since both directions of transmission are carried on the same cable in this system, high and low-pass filters are needed to separate the repeater equipment from both ends of the cable, as shown in the drawing.) At unattended stations, one set of filter equipment is usually located in the same hut as the repeater equipment. A second hut contains the other set of filter equipment. At attended stations, a similar arrangement is used with a third building — part of the observation station — which houses the terminal equipment.

In a typical repeater, the equipment panels are constructed in the same manner as those commonly seen in telephone toll offices. These panels, which include amplifiers, equalizers and power-distribution equipment are contained in cabinets fabricated of sheet steel and provided with gas-



In the transmission scheme for the Air Force proving-ground cable, high- and low-pass filters separate equipment from both ends of the cable.



Terminal equipment at the Cape Canaveral, Florida, station of the Air Force submarine cable system. Wherever possible, standard equipment and carrier methods were used for installation.

keted joints between case and cover. The repeater cabinets, as well as similar filter cabinets, are mounted in small huts constructed entirely of reinforced concrete.

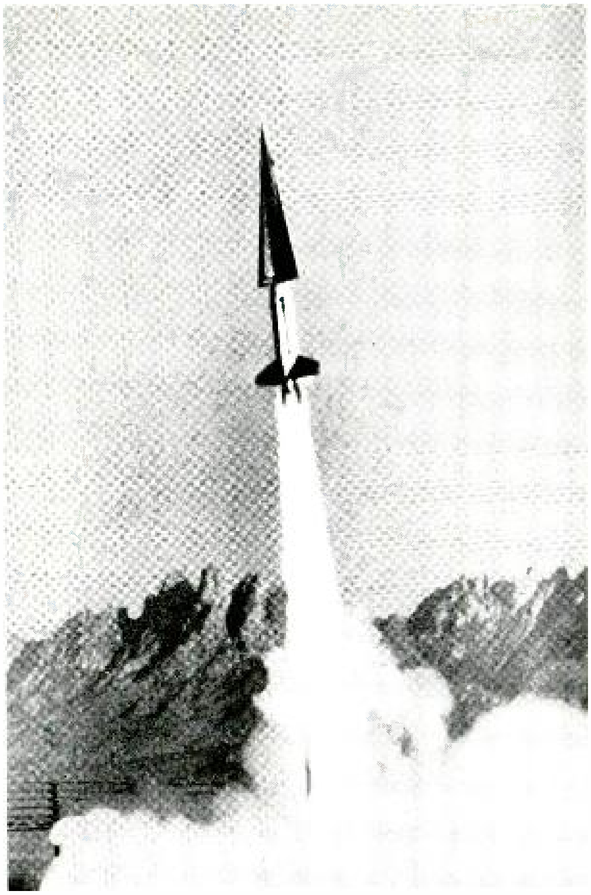
A special type of grounding system, remote from the cable landings, was required for the repeater cabinets. Since this ground conducts the power-supply current for the repeater, a low-resistance path was necessary to minimize the power-supply voltages. Also, since the nature of the system is such that flow of current at the ground is into the earth, a special type of construction was used. For each ground, six carbon rods, 5 feet long, were set vertically in holes about a foot in diameter. The holes were then filled with finely divided coke. The rods are interconnected by an insulated lead which extends to the repeater hut for connection to the repeater cabinet.

To insure a low-resistance path to earth, it was necessary to locate the ground rods in a place where they would be flooded by the tide. Although some ground rods were located in sand beaches, in most places the holes were bored into coral rock to a depth of seven feet or more. Such construction is relatively expensive, but grounds placed in coral rock are better protected from high seas than those placed in sand beaches. The latter may be subject to the effects of severe erosion.

Equipment was supplied for fourteen unattended repeater stations and nine intermediate and end terminal stations. This involved 50 filter and repeater cabinets and over 100 bays of transmission and signaling equipment, as well as the battery plants for the nine attended stations. Transportation of the equipment from Florida to the island stations was handled largely by a vessel chartered by the Western Electric Company, and installation was supervised by Western Electric Installation Department personnel. Installation effort, as well as job engineering, was minimized by issuing specification codes to cover shop assembly and wiring of complete bays and equipment cabinets insofar as possible. Despite unusual handling under often adverse conditions, all equipment was delivered and installed without major damage to any of the units.

P. T. Haury
Transmission Systems Development I

NIKE HERCULES IN PRODUCTION



A very much improved version of the Nike guided missile system has reached a substantial rate of production, according to the Western Electric Company, prime contractor on the project. This new version, designated the Nike Hercules, has many times the destructive power of the original Nike Ajax. It can carry a conventional or nuclear warhead, and it is considerably faster and has a much greater range than Nike Ajax, which has guarded key cities and strategic areas for the past four years.

Bell Laboratories work on computer-type controls for defense weapons goes back to the M-9 gun director of World War II. This antiaircraft weapon included an electronic computer for the rapid calculations necessary in detecting targets and in aiming and firing projectiles.

One of the crucial differences between conventional projectiles and the Nike missiles is that the latter are guided. And, until fairly recent years, it was doubtful whether a missile could in fact be steered through the complex and high-speed maneuvers necessary to intercept and destroy enemy aircraft despite evasive action.

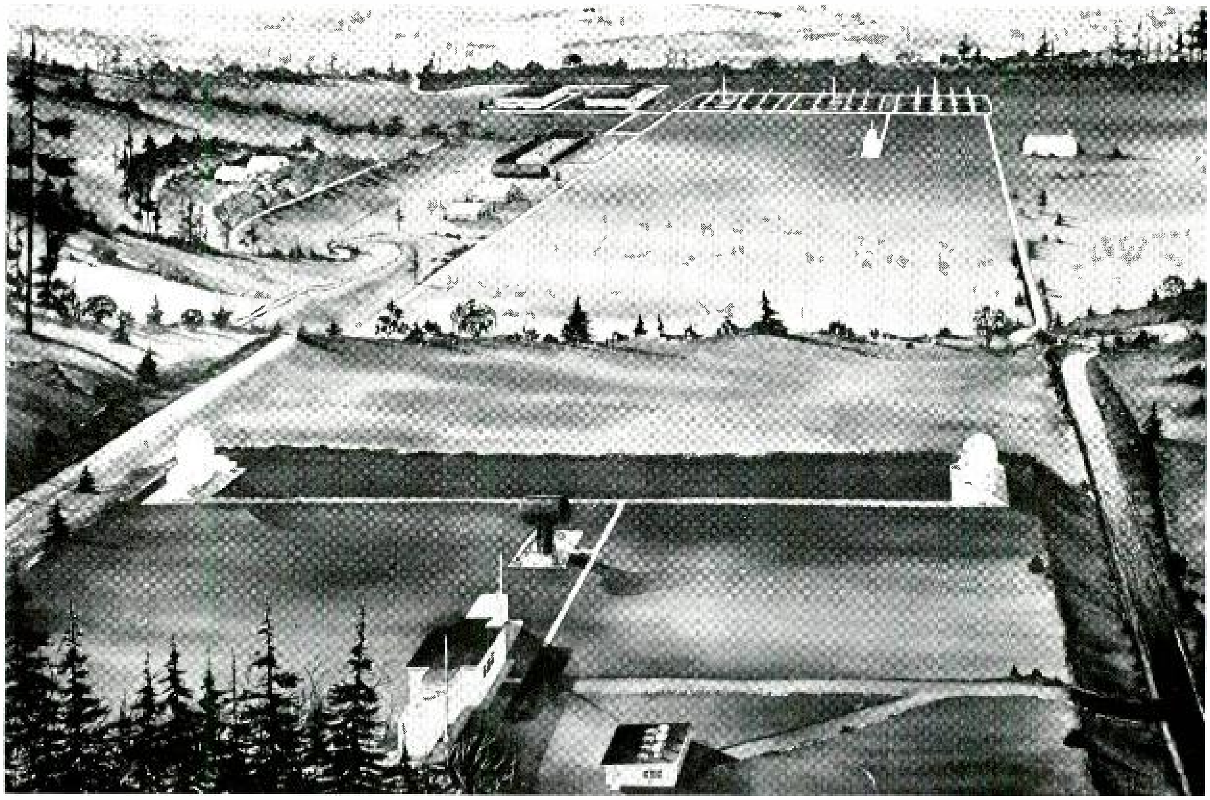
Then, basic studies of guidance at Bell Laboratories indicated that this problem was indeed solvable — a decision verified by the successful production and operation of the Nike Ajax.

Bell Laboratories has had the responsibility for the system design as well as the guidance and control for both the Ajax and the Hercules. In the course of this work, Laboratories engineers and scientists developed a radically new kind of communications and signal-processing system. To do so, they drew upon their extensive experience with complex Bell System communications systems and upon the many refined techniques for the transmission, reception and processing of electrical signals.

For the Nike missiles, complex mechanical, electromechanical and electronic components are put together to function as an integrated whole. Despite the complexity, however, the system operates with the very high degree of reliability required for military service. In addition, subassemblies are so designed and incorporated that they can be tested, and preliminary types of maintenance performed, by relatively untrained personnel.

The new system will be in the hands of operational Nike batteries around the country in the relatively near future, with first units to become operational in the Northeast and the Midwest. Hercules systems will eventually replace all Ajax systems, and they will make full use of present Nike Ajax sites and components. Replacement of the Ajax ground guidance equipment and modifications to launching equipment will make it possible to fire both Ajax and Hercules missiles. The new equipment for the Hercules system also adds to the effectiveness of the Ajax missile.

Nike Hercules has resulted from the same



Drawing of typical Nike Hercules installation. Three radar antennas are in foreground. The black antenna is used by the acquisition radar and the two white spherical type antennas are associated with the target and missile tracking radar. In background are launchers with missiles.

Army-industry effort that was responsible for the original Nike system. Under a U. S. Army Ordnance Corps contract, the Western Electric Company has been the prime contractor, with Bell Laboratories responsible for the system design. Douglas Aircraft Company, under Bell Laboratories technical direction, has responsibility for the research and development of the missile itself and for the associated launching and ground-handling equipment. Douglas is also the principal subcontractor and producer of these components of the system.

Although Nike Ajax is no longer manufactured, Hercules entered the production picture months before the last of the more than 10,000 Ajax missiles were delivered. An efficient transition from one missile to the other was reached because Western Electric and its more than 1,300 subcontractors on the Ajax were already functioning as a team. However, because the Hercules is more complex, the job became a bigger one, requiring extensive new tooling and test equipment as well as thousands of new parts. This new responsibility during transition was in addition to the 1,500,000 parts for the Ajax systems.

The greater range and speed of the Hercules calls for higher radar power and additional refinements which made it necessary to make extensive design changes in equipment, although the two systems are similar. The Hercules system also uses three radars, a computer, automatic plotting boards, power generators and miscellaneous equipment in the ground guidance system.

The new solid sustainer (second stage) motor used in the Hercules makes it possible to reduce substantially the number of personnel needed at a Nike installation, since many of the procedures for handling liquid propellants will no longer be required. The booster assembly also uses a solid type of fuel.

Although longer, heavier and more than double the diameter of Nike Ajax, the Hercules model has extreme maneuverability at altitudes far in excess of those capable of being reached by Ajax. The Hercules is also very effective at low altitudes. Its higher velocity permits swifter interception of all types of manned aircraft and known cruise-type missiles. Its increased lethality makes Nike Hercules the most effective weapon in America's air defense arsenal.

SIMULATION SPEEDS RESEARCH AT BELL LABORATORIES

Subject Highlights Laboratories Papers Presented at WESCON

One of the most interesting and promising new techniques for research — simulation — was discussed in several papers presented by Bell Laboratories scientists and engineers at the Western Electronic Show and Convention (WESCON) in Los Angeles last month. These papers illustrated two important ways that the simulation technique is currently being used at Bell Laboratories: the use of computers to simulate transmission systems, and a special simulation laboratory for studying the "human engineering" aspects of future communication systems, services and devices.

The simulation laboratory was described by H. D. Irvin of the Transmission Engineering Department (*SIBYL: A Laboratory for Simulation Studies of Man-Machine Systems*). Named "Sibyl" after the female oracles of ancient Greece who were supposed to be inspired by Apollo with the power to see into the future, the laboratory is arranged primarily for studying the human factors involved in the engineering of proposed communication equipment and services.

Simulation in this case may be defined as the technique of providing a test subject with specific machine experience by any means short of building the machine itself. In such human-factor tests it is generally desirable to collect information concerning the performance of the user without disturbing him or his environment in any way.

In normal usage, Sibyl is arranged to intercept telephone lines between the telephone equipment under test and the Bell Laboratories exchange. Privacy of the message is of course maintained at all times. It uses digital techniques and is composed mostly of electromechanical switching elements built up from small, modular units. These units are interconnected by extensive jack fields, which permit extreme flexibility of operation. Consoles for observation and manual control are also interconnected by this "patch-cord" method.

Tone-multiplex and dc signaling are used to link together the main machine and remote equipment. For example, in testing a user's reaction to a telephone equipped for push-button keying (dialing), equipment for converting push-button signals into tone signals corresponding to the desired number would be located inconspicuously near the telephone. These tone signals would then be transmitted to Sibyl where they would be converted into conventional dial pulses and forwarded to the local exchange.

Thus, the local telephone exchange would not detect that any unusual equipment was being tested, but Sibyl would have collected the desired information from the equipment under test. Such information might include time required to dial, dialing errors, number and duration of calls, and the like.

After it is collected, data may be "read-out" through a combination of direct-writing recorders, magnetic-tape recorders, paper-tape punches, electric typewriters or tabulating card punches. Statistical analyses of punched cards are done by a high-speed electronic computer. Visual displays, such as strip charts, are also available for immediate recognition of the information as it is being collected.

In essence, Sibyl permits the intensive study of new telephone devices, services or systems either in a laboratory with close observation and control, or in the more realistic and normal environment of the test user's office. Yet it saves the time and expense involved in perfecting and building some elaborate experimental devices.

The other aspect of simulation for research — the use of general-purpose digital computers to simulate new coding and transmission devices — has accelerated and broadened speech and television research, according to additional papers. In these papers, the authors stated that for studies of basic transmission or coding principles it is now possible to avoid the construction of very complicated experimental equipment through the use of computer simulation.

Complex, highly-instrumented equipment often must be built to test theories or design concepts in speech and video research. This construction is costly and time consuming. In addition, in the experimental stage, it is often difficult to distinguish equipment errors from deficiencies in the theory being tested.

Simulation of new devices by large-scale digital computers can greatly reduce expense and time lags, and thus make it easy to investigate the many approaches to coding and transmission problems. Also, it becomes feasible to investigate

H. S. McDonald, E. E. David, Jr., R. E. Graham and M. V. Mathews, left to right, of the Visual and Acoustics Research Department, work with audio playback equipment used in computer simulation.

highly speculative thoughts and proposals, which might otherwise be ignored. One of the greatest virtues of simulation, however, is versatility. The authors emphasized in their papers that computers can simulate any explicit operation on a speech or video signal.

E. E. David, Jr., M. V. Mathews, and H. S. McDonald, of the Visual and Acoustics Research Department, described the use of computers in speech research (*Experiments with Speech Using Digital Computer Simulation*). Here, sampling devices are used to quantize speech into ten bits, or 1024 possible amplitude levels per sample. This sampled speech is then recorded on tape, and the tapes are fed into the computer, where they are processed according to pre-assigned programs based on the coding or transmission scheme being investigated. The processed signals are then recorded, decoded, and played back for analysis and listener evaluation.

A speech-transmission scheme known as the "extremal" method, studied at Bell Laboratories extensively by simulation, illustrates the advantages of the new technique. Briefly, the extremes, or peaks and valleys, of a speech wave are sampled, and the amplitudes and time of occurrence of these points are then transmitted, instead of a detailed representation of the entire wave. At the receiver, an approximation of the speech wave is generated by interpolating a suitable mathematical function between these points. Listener evaluation of the simulated speech produced in initial tests showed that intelligibility is high — above 90 per cent sentence articulation — but that the quality is somewhat below that of commercial telephones.

Digital simulation has been applied to a number of other speech problems at Bell Laboratories. These include the design and evaluation of delta-modulation coders, pulse-code modulation systems, detection of vocal pitch, and automatic recognition of speech.

Picture-coding research has also been carried on by computer simulation. R. E. Graham and J. L. Kelly, Jr., also of the Visual and Acoustics Research Department, described a technique which has been used to evaluate a number of proposed TV coding schemes, and to improve others (*A Computer Simulation Chain for Research on Picture Coding*). In order to hold machine time and memory requirements to a reasonable level, their system has used an input picture of 100 x 100 elements, corresponding to an area about 1/25 that of a conventional TV frame. This 10,000 element "window" has proven to be of sufficient size to allow critical evaluation of the processed image.

A coding scheme which may have widespread significance in TV transmission, known as "predictive quantizing," has been studied by both simulation and conventional methods by Mr. Graham. This scheme takes advantage of the inability of the viewer to detect large brightness errors in a reproduced picture during periods of scene change or motion, and in areas of picture confusion. Computer simulation has provided a method for the investigation of a number of variations of predictive quantizing, as well as other methods of coding. Its use in picture analysis for pattern recognition, and for statistical computations as well, is also being studied.

These applications of simulation, which may well prove to be an important technique for experimentally evaluating concepts in other fields of research, were but a few of the many subjects covered by over fifteen papers presented by Laboratories scientists and engineers at WESCON. Some of the important facets of research and development at the Laboratories discussed in other papers were: microwave theory and techniques, parametric amplifiers, component materials, electron devices, solid-state electronics, and vehicular communications.

The Western Electronic Show and Convention this year featured 42 technical sessions on all phases of electronics and over 900 exhibit booths. WESCON is sponsored by the Los Angeles and San Francisco Sections (7th Region) of the Institute of Radio Engineers and the West Coast Electronic Manufacturers Association.

Shore operations, Clarenville, Newfoundland, form western terminal of the second transatlantic cable.

Shore Operations For European Cable Completed

Shore operations off Clarenville, Newfoundland, for the first submarine telephone cables that will link North America directly to the mainland of Europe, were completed recently by the cableship *Iris*.

The deep sea portion of the cable will employ the system developed by Bell Laboratories for the cable to the United Kingdom completed in 1956 (RECORD, *February*, 1957). This portion of the cable spans the Atlantic between Clarenville and Penmarch, France, a distance of 2,550 miles, and will form the main segment of a system for providing at least 36 voice circuits between the United States and continental Europe. Thirteen cable circuits are to serve France, 13 will serve Germany and the rest will be available for other European nations. A cable system using British Post Office equipment will connect Clarenville with the land network at Nova Scotia.

Earlier this summer the French cable ship *Ampere* completed the shore work for the eastern terminal at Penmarch on the Brittany Coast. Next summer the underwater cables will be laid and service is scheduled for late 1959.

H. A. Affel Retires

H. A. Affel, Assistant Vice President in the Switching and Transmission Development Department, retired from Bell Laboratories on August 1, concluding a 42-year career with the Bell System.

Mr. Affel, who with L. Espenschied of the Laboratories is the inventor of the coaxial cable system, has been granted 123 patents on wire and radio systems, and has written numerous technical papers on these subjects. He has had broad experience in communication work, particularly in the field of high-frequency transmission.

His most significant contributions have related to the problems of automatic gain control for telephone transmission and automatic volume control for radio. Many of his inventions dealt with carrier telephone systems and he also has made a number of contributions to the development of carrier telegraph systems and frequency diversity for improving the reliability of radio transmission.

Mr. Affel graduated in 1914 with an S.B. degree in electrical engineering from Massachusetts Institute of Technology, where he worked as a research assistant for the next two years. He then joined the A.T.&T. Company in the Development and Research Department. In 1934 this department was consolidated with Bell Laboratories. He was appointed Director of Transmission Development at the Laboratories in 1944, Director of Transmission Systems Development in 1949 and Assistant Vice President in 1951.

Mr. Affel is a Fellow of the A.I.E.E., the I.R.E., the Acoustical Society of America and the American Association for the Advancement of Science. The National Association of Manufacturers awarded him its Modern Pioneer Award in 1940 for his inventions.

NEWS BRIEFS:

Dr. Kelly to Receive 1959 John Fritz Medal

Dr. M. J. Kelly will receive the 1959 John Fritz Medal, the Medal Board of Award, representing four major national engineering societies, announced recently.

Cited for "his achievements in electronics, leadership of a great industrial research laboratory, and contributions to the defense of the country through science and technology," Dr. Kelly will receive the award at ceremonies to be scheduled by the American Institute of Electrical Engineers, of which he is a Fellow.

The John Fritz Medal is sponsored jointly by the American Society of Civil Engineers, the American Institute of Mining, Metallurgical and Petroleum Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. Presented not more than once in any year for "scientific or industrial achievement" in any field of pure or applied science, the medal was established in 1902 as a memorial to the great engineer and steel maker whose name it bears.

The roster of John Fritz medalists includes the names of some of the world's most illustrious engineers and scientists: Alexander Graham Bell, Frank B. Jewett, Edison, Marconi, Westinghouse, Goethals, Orville Wright, Sperry, Kettering and others.

New Hydrothermal Process for Growing Cultured Sapphires

A new hydrothermal technique for growing cultured sapphire crystals has recently been developed by R. A. Laudise, A. A. Ballman and A. J. Caporaso of the Chemical Research Department. Large sapphires — up to ¾-inch square by ¼-inch thick — have been grown by this technique. The grown crystals are probably almost strain-free.

Because of this freedom from strain, these sapphires should be optically superior to crystals grown by other available processes. Sapphire transmits light well out into the infrared and ultraviolet regions, and is thus a very useful material for such optical components as lenses, prisms, windows, and lamp envelopes.

The basis for the new hydrothermal process, which employs high-temperature, high-pressure conditions, is an increase in the solubility of the compound to a point where it can be crystallized on a seed. Aluminum oxide, normally considered insoluble in water, can be dissolved and recrystallized from aqueous solutions if the temperature and pressure used are high enough. For growing sapphires, pressures of the order of 20,000 to 50,000 psi, and temperatures of about 395°C and higher are used. Rate of growth varies with conditions, but typically it ranges from 0.002 to 0.010 inch per day. Even greater growth rates appear feasible with the hydrothermal process.

Sapphire is known as the "corundum modification" of aluminum oxide. It is extremely hard, and has applications in many industrial fields other than optics. Corundum is widely used as an abrasive.

If the nutrient solution of aluminum oxide is "doped" with small amounts of a chromate, the resultant crystal is synthetic ruby, with the color a function of the amount of chromate added.

This chromium-doped crystal has possible applications as a solid-state MASER.

Work Begun on New W.E. Building, '222 Broadway'

Work has started on Western Electric's new office building, located diagonally across from 195 Broadway, New York City. Crews are currently demolishing the four buildings now occupying the site. The new building will be designated "222 Broadway," and is expected to be ready for occupancy in early 1961.

In making the announcement, A. B. Goetze, Western's president, said that the Company found it "good business" to go ahead with this project despite the current lower level of general business. "Naturally we have given our plans a thorough review," he stated, "but we anticipate such substantial economies as a consequence of consolidating our general offices which presently are scattered in more than a dozen buildings in lower New York, that it is good business for us to go ahead."

About 3,000 employees will work in 27 floors of the new building. Executive offices of the Company will remain at "195."

C. C. Lawson Awarded Wire Association Medal

C. C. Lawson of the Outside Plant Development Department has been awarded the Wire Association Medal Award for the Non-Ferrous Division for 1957. The medal and a $100 honorarium were awarded to Mr. Lawson for his presentation of the best paper in this division published in the Association's publication, *Wire and Wire Products*, during 1957. The article was entitled "Buried Distribution for Telephone Circuits."

Formal presentation of the award to Mr. Lawson will be made at the Wire Association Convention in Atlantic City, N. J., in October.

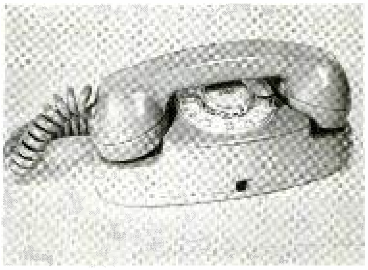
NEWS BRIEFS (CONTINUED)

New Telephone Design To Be Produced in 1959

A new, small-size telephone, similar to the one shown below, will go into production next year. G. A. Wahl, Station Apparatus Engineer at Bell Laboratories, was responsible for the preliminary design of the set.

A design suitable for large quantity production is currently being prepared, following the completion of a market test of 600 of the new telephones in Illinois and Pennsylvania. Design for production is under the direction of L. J. Cobb at the Indianapolis, Indiana, location of the Laboratories.

The new set will be offered in several colors, and later, in two models. The first model will feature a combined night-light and a dial-light. The second model will have, in addition, a two-line pick-up (with a "hold" button for the first line) and provision for use with home - intercommunication and speakerphone systems.



About 150,000 of the new telephones will be available by the end of 1959, and much greater quantities will be manufactured starting in 1960.

R. W. Hamming Elected President of A.C.M.

R. W. Hamming of the Mathematical Research Department was installed as President of the Association for Computing Machinery at the 13th Annual Meeting of the A.C.M. at the University of Illinois.

Mr. Hamming has been Vice President of the Association for the past two years, and was the New York Area representative on the A.C.M. Council for 6 years. He has been the Editor of the *Journal of the Association for Computing Machinery* since its founding in 1953.

TALKS

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

2nd INTERNATIONAL TELE-TRAFFIC CONGRESS, The Hague, Netherlands.

Barnes, D. H., *Statistical Methods for Administration of Dial Offices.*

Hayward, W. S., *Traffic Engineering and Administration of Line Concentrators.*

Wilkinson, R. I., *A Study of Load and Service Variations in Toll Alternate Route System.*

CONFERENCE ON MAGNETISM, Grenoble, France.

Bozorth, R. M., and Kramer, V., *Some Ferrimagnetic and Antiferromagnetic Materials at Low Temperatures.*

Clogston, A. M., *Optical Faraday Rotation in Ferrimagnetic Garnets.*

Dillon, J. F., Jr., *Optical Absorptions and Rotations in the Ferrimagnetic Garnets,* (Presented by A. M. Clogston).

Geschwind, S., Walker, L. R., and Linn, D. F., *Observation of Exchange Resonances in Gadolinium Iron Garnet at 24,000 mc,* (Presented by A. M. Clogston).

Jaccarino, V., and Walker, L. R., *NMR in Antiferromagnetic* MnF_2^{19}, (Presented by H. Suhl.)

Kramer, V., see Bozorth, R. M.

Linn, D. F., see Geschwind, S.

Suhl, H., *Nuclear Spin Interactions in Ferromagnets and Antiferromagnets.*

Walker, L. R., see Jaccarino, V., and Geschwind, S.

GORDON RESEARCH CONFERENCE, New Hampton, New Hampshire.

Douglass, D. C., see McCall, D. W.

Law, J. T., *The Surface of Semiconductors.*

McCall, D. W., and Douglass, D. C., *Diffusion and Relaxation in Simple Liquids.*

Slichter, W. P., *Nuclear Magnetic Resonance Studies of Some Stereospecific Polymers.*

OTHER TALKS

Bowers, K. D., see Mims, W. B.

Danielson, W. E., *Low Noise in Parametric Amplifiers at Microwave Frequencies,* Summer Meeting, Society of the Division of Electron Physics, Ithaca, N. Y.

Feher, G., *Application of the*

ENDOR Technique to Nuclear and Solid State Problems, Kamerlingh Onnes Conference on Low Temperature Physics, Leiden, Netherlands.

Feher, G., *The Application of the ENDOR Technique to Donors in Silicon*, *International Conference on Double Resonances and Multiple Quantum Transitions*, Paris, France.

Frisch, H. L., *Viscosimetric Polymer Dispersities*, College of Forestry, New York State University, Syracuse, N. Y.

Frosch, C. J., *Diffusion Control in Silicon by Carrier Gas Composition*, The Electrochemical Society, N. Y. C.

Geballe, T. H., *Investigations of Thermal Conductivity and Thermo-Electricity in Germanium*, Physics Dept., Univ. of Washington, Seattle, Wash.

Gohn, G. R., see Torrey, M. N.

Hamming, R. W., *A User Views Computers*, Digital Design of Electrical Equipment Conference, Pennsylvania State University, University Park, Pa.

Hamming, R. W., *Ideal Computers*, Association for Computing Machinery, Washington, D. C.

Harvey, F. K., *Voices of the Satellites*, Irvington Kiwanis Club, Irvington, N. J.

Herring, C., *Phonon Drag Thermomagnetic Effects in n-Type Germanium*, RCA Research Laboratories, Princeton, N. J.

Loomis, T. C., see Sinclair, W. R.

Maas, W. W., *History of Guided Missiles*, Allentown Lions Club; and Kiwanis Club of West Allentown, Allentown, Pa.

Mason, W. P., *Internal Friction Plastic Strain and Fatigue in Metals and Semiconductors*, A.S.T.M. Annual Meeting, Boston, Mass.

Mims, W. B., and Bowers, K. D., *Paramagnetic Relaxation in Nickel Fluosilicate*, Kamerlingh Onnes Conference on Low Temperature Physics, Leiden, Netherlands.

Purvis, M. B., *Creative Engineering at Bell Telephone Laboratories*, Pennsylvania State University, University Park, Pa.

Sinclair, W. R., and Loomis, T. C., *Diffusion in the System* TiO_2-SnO_2, Conference on the Kinetics of High-Temperature Processes, M.I.T., Cambridge, Mass.

Torrey, M. N., Gohn, G. R., and Wilk, M. B., *A Study of the Variability in the Mechanical Properties of Alloy A Phosphor Bronze Strip*, A.S.T.M., Annual Meeting, Boston, Mass.

Wilk, M. B., see Torrey, M. N.

Wolontis, V. M., *What Digital Computers Can and Cannot Do*, Armed Forces Electronics and Communications Association, San Antonio, Texas.

Wolontis, V. M., *What Is Automatic Programming?*, University of Texas, Austin, Texas.

PAPERS

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

Abrahams, S. C., and Geller, S., *Refinement of the Structure of a Grossularite Garnet*, Acta Crys., 11, pp. 437-441, June 10, 1958.

Anderson, P. W., *Coherent Excited States in the Theory of Superconductivity: Gauge Invariance and the Meissner Effect*, Phys. Rev., 110, pp. 827-835, May 15, 1958.

Ballman, A. A., see Laudise, R. A.

Beach, A. L., and Guldner, W. G., "The Application of Vacuum Fusion to Gas-Metal Studies," A.S.T.M. Book, *Determination of Gases in Metals*, STP 222, 1958.

Benson, R. J., *Fine-Pitch Gear Materials*, Machine Design, 30, pp. 121-122, June 26, 1958.

Bozorth, R. M., and Nielsen, J. W., *Antiferromagnetism of* CuF_2-$2H_2O$ *and* MnF_3, Phys. Rev., 110, pp. 879-880, May 15, 1958.

Bozorth, R. M., and Walsh, D. E., *Ferromagnetic Moment of* $CoMnO_3$, J. Phys. and Chem. of Solids, 5, pp. 299-301, 1958.

Bozorth, R. M., Kramer, V., and Remeika, J. P., *Magnetization in Single Crystals of Some Rare-Earth Orthoferrites*, Phys. Rev. Letters, 1, pp. 3-4, July 1, 1958.

Compton, V. B., *Crystal Structures of MgRh and ScRh*, Acta Crys., 11, p. 446, June 10, 1958.

Compton, V. B., see Wood, E. A.

Dearborn, E. F., see Nielsen, J. W.

Devlin, G. E., see Schawlow, A. L.

Dorsi, D., see Wernick, J. H.

Ferrell, E. B., *Plotting Experimental Data on Normal or Log-Normal Probability Paper*, Industrial Quality Control, 15, pp. 12-15, July, 1958.

Flanagan, J. L., *Some Properties of the Glottal Sound Source*, J. Speech and Hearing Research, 1, pp. 99-116, June, 1958.

Flanagan, J. L., and Saslow, M. G., *Pitch Discrimination for Synthetic Vowels*, J. Acous. Soc. of Am., 30, pp. 435-142, May, 1958.

Frisch, H. L., see Liehr, A.

Gallagher, W. J., and Nelson, C. E., *Drafting Standards for Microfilmed Engineering Drawings*, Filmsort Facts, I, pp. 3-10, June, 1958.

Geller, S., see Abrahams, S. C.

Gianola, U. F., *Switching in Rectangular Loop Ferrites Containing Air-Gaps*, J. Appl. Phys., 29, pp. 1122-1124, July, 1958.

Graham, R. E., *Communication Theory Applied to Television Coding*, Acta Elect., 2, pp. 333-343, July, 1957.

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Guldner, W. G., see Beach, A. L.

Heidenreich, R. D., see Miller, R. C.

Herrmann, G. F., Uenohara, M., and Uhlir, A., Jr., *Noise Figure Measurements on Two Types of Variable Reactance Amplifier Using Semiconductor Diodes*, Proc. I.R.E., 46, pp. 1301-1303, June, 1958.

Hobstetter, J. N., see Wernick, J. H.

King, B. G., McKenna, J., and Raisbeck, G., *Experimental Check of Formulas for Capacitance of Shielded Balanced-Pair Transmission Line*, Proc. I.R.E., 46, Letter to the Editor, pp. 922-923, May, 1958.

Kinsburg, B. J., *Distribution Requirement Specification*, A.S.Q.C. 1958 Nat'l Convention Trans., pp. 69-86, 1958.

Kramer, V., see Bozorth, R. M.

Laudise, R. A., and Ballman, A. A., *Hydrothermal Synthesis of Sapphire*, J. Am. Chem. Soc., 80, pp. 2655-2657, June 5, 1958.

Lax, M., and Levitas, A. (Syracuse Univ.), *Statistics of the Ising Ferromagnet*, Phys. Rev., 110, pp. 1016-1027, June 1, 1958.

Liehr, A., and Frisch, H. L., *Dynamical Stability Criteria for Molecular Motions*, J. Chem. Phys., 28, pp. 1116-1120, June, 1958.

Lovell, L. C., see Wernick, J. H.

Mays, J. M., Moore, H. R., and Shulman, R. G., *An Improved NMR Spectrometer*, Rev. Sci. Instr. 29, pp. 300-302, April, 1958.

Mayzner, M. S., and Tresselt, M. E. (NYU), *Consistency of Judgments in Categorizing Verbal Material*, Psych. Reports, 4, pp. 415-521, Sept., 1958.

McKenna, J., see King, B. G.

McNally, J. O., *Status Report on the Ceramic Receiving Tube Development*, Proc. of the 1958 Electronic Components Conf., pp. 168-185, 1958.

Meitzler, A. H., *Temperature and Frequency Dependence of Insertion Loss in Delay Lines*, I.R.E. Nat'l Convention Record, Part 2, pp. 153-160, June, 1958.

Miller, R. C., and Heidenreich, R. D., *Interaction of Low Energy Electrons with Ferroelectric Materials*, J. Appl. Phys., 29, pp. 957-963, June, 1958.

Moll, J. L., Uhlir, A., Jr., and Senitzky, B., *Microwave Transients from Avalanching Silicon Diodes*, Proc. I.R.E., 46, pp. 1306-1307, June, 1958.

Moore, H. R., see Mays, J. M.

Nelson, C. E., see Gallagher, W. J.

Nielsen, J. W., and Dearborn, E. F., *The Growth of Single Crystals of Magnetic Garnets*, J. Phys. and Chem. of Solids, 5, pp. 202-207, 1958.

Nielsen, J. W., see Bozorth, R. M.

Pearson, G. L., and Treuting, R. G., *Surface Melt Patterns on Silicon*, Acta Crys., 11, pp. 397-400, June 10, 1958.

Phillips, J. C., and Rosenstock, H. B., *Topological Methods of Locating Critical Points*, J. Phys. and Chem. of Solids, 5, pp. 288-292, 1958.

Poole, K. M., and Tien, P. K., *A Ferromagnetic Resonance Frequency Converter*, Proc. I.R.E., 46, pp. 1387-1396, July, 1958.

Raisbeck, G., see King, B. G.

Remeika, J. P., see Bozorth, R. M.

Riney, T. D., *A Finite Recursion Formula for the Coefficients in Asymptotic Expansions*, Trans. Am. Math. Soc., 88, pp. 214-226, May, 1958.

Rosenstock, H., see Phillips, J. C.

Saslow, M. G., see Flanagan, J. L.

Schawlow, A. L., and Devlin, G. E., *Intermediate State of Superconductors: Influence of Crystal Structure*, Phys. Rev., 110, pp. 1011-1016, June 1, 1958.

Schroeder, M. R., *An Artificial Stereophonic Effect Obtained from a Single Audio Signal*, J. Audio Engg. Soc., 6, pp. 74-79, April, 1958.

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Smits, F. M., *Formation of Junction Structures by Solid-State Diffusion*, Proc. I.R.E., 46, pp. 1049-1061, June, 1958.

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Tien, P. K., see Poole, K. M.

Treuting, R. G., see Pearson, G. L.

Uenohara, M., see Herrmann, G. F.

Uhlir, A., Jr., *The Potential of Semiconductor Diodes in High-Frequency Communications*, Proc. I.R.E., 46, pp. 1099-1115, June, 1958.

Uhlir, A., Jr., see Herrmann, G. F.

Uhlir, A., Jr., see Moll, J. L.

Walsh, D. E., see Bozorth, R. M.

Warner, R. M., Jr., *A New Semiconductor Component*, I.R.E. Nat'l Convention Record, Part 3, pp. 43-48, July, 1958.

Wernick, J. H., Hobstetter, J. N., Lovell, L. C., and Dorsi, D., *Dislocation Etch Pits in Antimony*, J. Appl. Phys., 29, pp. 1013-1018, July, 1958.

Wilkinson, R. I., *Queueing Theory and Some of Its Industrial Applications*, A.S.Q.C. 1958 Nat'l Convention Trans., pp. 313-330, May 26, 1958.

Wood, E. A., and Compton, V. G., *Laves Phase Compounds of Alkaline Earths and Noble Metals*, Acta Crys. 11, pp. 429-433, June 10, 1958.

PATENTS

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

Anderson, J. R. and Wolfe, R. M. — *Electrical Circuits Employing Ferroelectric Capacitors* — 2,839,739.

Belek, E. — *Tool for Stripping Wire and Making an Insulated Wrapped Connection* — 2,836,837.

Clary, W. T. Jr. — *Nonlinear Resonant Circuit Devices* — 2,838,687.

Critchlow, G. F. — *Electric Signal Transmission* — 2,840,648.

Cutler, C. C., Mendel, J. T. and Quate, C. F. — *Backward Wave Tube* — 2,840,752.

Duncan, R. S. — *Adjustable Inductor* — 2,838,737.

Goddard, C. T. — *Electron Discharge Devices* — 2,840,749.

Gustafson, W. G. and Harrison, H. C. — *Mercury Switches* — 2,837,612.

Haas, C. W. — *Pulse Rate Measuring System* — 2,839,725.

Harrison, H. C., see Gustafson, W. G.

Haugk, G. and Kennedy, K. K. — *Non-Saturating Transistor Circuits* — 2,840,728.

Hochgraf, L. and Koenig, W. Jr. — *Subscriber-Loop Carrier Telephone Ringing Systems* — 2,837,605.

Hoth, D. F. — *Electric Fault Location* — 2,838,604.

Kennedy, K. K., see Haugk, G.

Kent, R. J. — *Method of Welding Together Two Plastic Objects* 2,839,441.

Koenig, W. Jr., see Hochgraf, L.

Law, J. T. and Meigs, P. S. — *Method of Locating PN Junctions in Semiconductive Bodies* — 2,837,471.

Lozier, J. C. — *Encoder for Pulse Code Modulation* — 2,839,727.

Mason, W. P. — *Underwater Sound Detecting System* — 2,838,741.

McSkimin, H. J. — *Multi-facet Ultrasonic Delay Lines* — 2,839,731.

Meigs, P. S., see Law, J. T.

Mendel, J. T., see Cutler, C. C.

Quate, C. F., see Cutler, C. C.

Schenck, A. K. — *Pulse Rate Discriminator* — 2,837,642.

Southworth, G. C. — *Artificial Medium of Variable Dielectric Constant* — 2,840,820.

Thurmond, C. D. — *Method of Fabricating Semiconductor PN Junctions* — 2,837,448.

Thurston, R. N. — *Multi-Section Quartz Torsional Transducers* — 2,838,695.

Thurston, R. N. — *Torsional Transducers of Ethylene Diamine Tartrate and Dipotassium Tartrate* — 2,838,696.

Treuting, R. G. — *Method of Processing Semiconductive Materials* — 2,840,495.

Wolfe, R. M. — *Electrical Circuits Employing Ferroelectric Capacitors* — 2,839,738.

Wolfe, R. M., see Anderson, J. R.

THE AUTHORS

F. H. Winslow

F. H. Winslow, author of the article, "New Protectants for Polyethylene," in this issue, received the B.S. degree from Middlebury College in 1938, the M.S. degree from Rhode Island State College in 1940, and the Ph.D. degree from Cornell University in 1943. From 1943 to 1945 he participated in the development of new types of fluorinated polymers for the Manhattan Project at Columbia University. He joined the Laboratories in 1945, where his interests have been in polymer chemistry, deterioration of organic materials and the mechanism of carbon formation. Mr. Winslow currently heads a subdepartment in the Chemical Research Department concerned with polymer research and development. A native of Vermont, he is a member of the American Association for the Advancement of Science and the American Chemical Society.

John Meszar, author of "Janus and Switching" in this issue, is a resident of Basking Ridge, N. J., and is Director of Switching Systems Development II at Bell

John Meszar

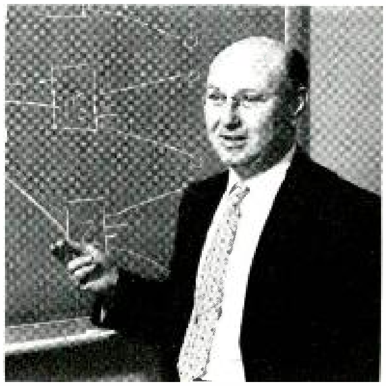
AUTHORS (CONTINUED)

Laboratories. He joined the Laboratories in 1922 as a technical assistant in toll switching circuits; five years later he became a circuit engineer for toll switching systems; and in 1936 became supervisor of his group. During the war he was supervising instructor in the Laboratories School for War Training, later returning to circuit design supervision, with particular attention to the automatic message accounting system. Mr. Meszar received his B.S. degree in E.E. from Cooper Union in 1927. A member of the A.I.E.E., he is on several of the Institute's national committees and is Chairman of its Communication Division Committee.

J. R. Harris

J. R. Harris, a native of Lockhart, Texas, received the B.S. degree in Physics from the University of Richmond in 1941. He joined the Chesapeake and Potomac Telephone Company of Virginia as a toll central office repairman, and later moved to Equipment Engineering, where he was concerned mainly with carrier systems. In 1942 he joined Bell Telephone Laboratories to develop airborne radiotelephone and navigation sets. Meanwhile he attended Polytechnic Institute of Brooklyn and received the M.E.E. degree in 1948. In 1950 he joined a group under J. A. Morton concerned with the development of transistors and transistor circuits to exploit that new invention in the field of digital techniques. When the TRADIC project was formed (Transistor Airborne Digital Computer) he joined it and was involved in the development of the TRADIC Phase One and Leprechaun machines. As Data Processing Development Engineer, he has been responsible for system aspects of the development of a new data processor intended for the automatic preparation of customer bills and similar functions. He is a member of I.R.E., A.C.M., Phi Beta Kappa, Sigma Pi Sigma, and an associate member of Sigma Xi. Mr. Harris is the author of "TRADIC: The First Phase" in this issue.

H. J. Michael, a native of Long Island, joined the Laboratories in 1929. He has engaged in studies relating to transmission quality including, the physical characteristics of speech and the structure of telephone conversation, signaling and switching development and, during the war, the design of underwater weapons. Since the war, Mr. Michael has engaged in the design and development of the No. 5 crossbar system. He joined the American Telephone and Telegraph Company in 1952 and, after two years in its Administration B Department, he rejoined the Laboratories in the Special Systems Engineering Department. He now heads a group concerned with studies of private line switching and signaling systems. Mr. Michael is a graduate of New York University with degrees of B.A. in mathematics and M.S. in physics. In this issue of the RECORD, the article "Selective Signaling for the SAGE System" is by Mr. Michael.



H. J. Michael

E. C. Thompson

E. C. Thompson, a native of Paterson, N. J., joined the Laboratories in 1935 and was initially engaged in field testing of the type K carrier system. Prior to World War II he was associated with various transmission engineering projects in the carrier telephony field, and with the development of voice spectrograph or visible speech techniques. During the war years he was concerned with special studies for the National Defense Research Committee. After receiving his B.S. degree from the Polytechnic Institute of Brooklyn, he became active in the development of automatic line-switching facilities for the L3 carrier system. More recently, his work has involved design of transistorized circuitry for special data transmission systems. Mr. Thompson is the author of "Automatic Line-Switching for L3 Carrier" in this issue.