Western Electric OSCILLATOR

DECEMBER 1945

Radio Relay for Voice and Vision

Thermistors

Lifesaver for Superforts

Western Electric
OSCILLATOR

DECEMBER 1945

DEVOTED TO DEVELOPMENTS IN COMMUNICATIONS AND ELECTRONICS

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THE COVER

This scene, photographed by N. Lazarnick, shows preliminary survey work at one of the sites along the new experimental radio relay system being built by A. T. & T. between New York and Boston. The photograph was taken near the summit of Jackie Jones Mountain — first of seven sites. The mountain is 35 miles from New York City and six miles from Haverstraw, N. Y. In this view, the transit man is giving alignment for establishing a point along the proposed road to the summit of the mountain. In the distant background may be seen the Hudson River. New York would be to the south and extreme right background of picture. The story of this relay system, "Stepping Stones for Voice and Vision", appears in this issue.

THIS ISSUE

Science In the Postwar World

Science — and particularly that branch of science called Electronics — has come out of this war bearing gifts — many of them strange and fascinating, some of them dreams of the future, more of them down-to-earth practical tools that will serve the modern world and its industries.

It is the task of any magazine attempting to deal with Electronics to assay this gold-bearing scientific ore and try to come up with solid information on practical uses and implications of this new knowledge. This — the first postwar issue of the Western Electric *Oscillator* — thus begins the continuing task of presenting, for the Communications field, Western Electric's postwar radio and communications activities and products.

These postwar activities and products are in many cases a direct outgrowth of techniques, developments and production born of the war. Slowly now the forms of these developments are taking shape in specific projects and apparatus. For example, great improvements in aircraft radio, in mobile radio and in radio for use at sea are being founded on these same radio developments for war. Newly designed battle announcing systems insure vastly improved public address systems for peacetime use.

Remarkable strides in war communications make possible equally outstanding improvements which can be applied to the Nation's great wire systems for telephone and for network program transmission. Radar and intensive microwave development have set the groundwork for possible revolutionary improvements in radio and television broadcasting, and a host of other developments, large and small, are in great part the legacy of war's speeded-up engineering and research processes.

In all of these fields Western Electric has played for many years — and intends to play — an important role, some aspects of which are indicated in the articles that follow on these pages.

Beaming Voice and Vision

Across the hilltops of New York and New England, a laboratory dream is becoming solid reality, as actual construction begins on A. T. & T.'s first experimental radio relay system. How far-reaching the effects of this experiment may be cannot, of course, be immediately determined, but many engineers are of the opinion it may well open a new world in sound and visual communications. The progress being made on this significant program and some of the problems involved are discussed in the article "Stepping Stones for Voice and Vision" beginning on page 20 and including three pages of photographs.

Radar

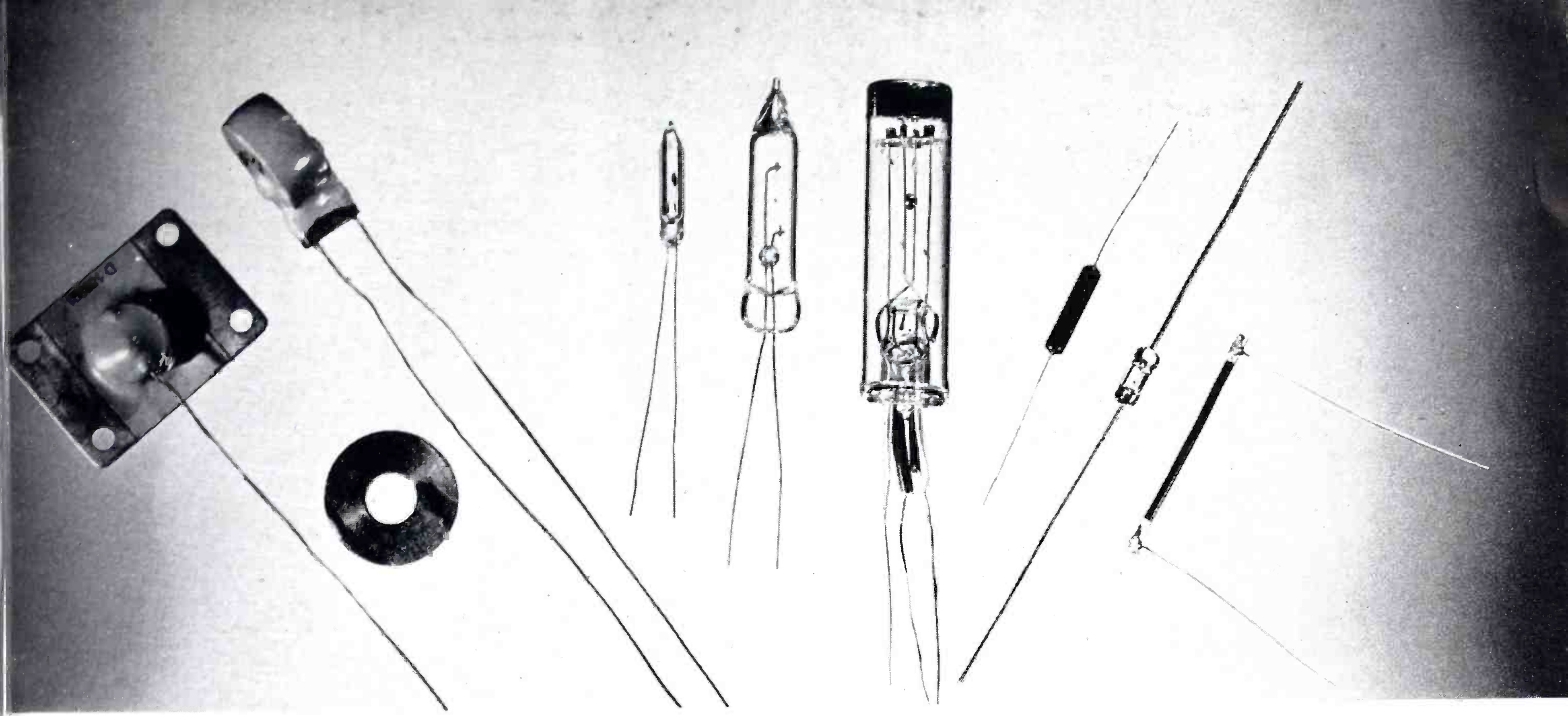
No other war-born development with the exception of the atomic bomb has created so much discussion and interest as has radar. Almost every aspect of its evolution and use in battle has been exhaustively treated, but curiously enough one feature of this triumphant radar story has not received equal attention—the remarkable account of its production. How U. S. industry was able to produce a wide variety of these intricate and delicate weapons of war in such quantities and with such speed that our radars literally "shadowed" the enemy in practically every part of the world is a story without precedent in electronic production annals. One part of this story is told in the article on page 6, entitled "Radar — A Production Triumph", outlining the contribution of the Western Electric Company — the Nation's greatest single source of radars.

Broadcasting's "Silent Partner"

With rapid advances in the art and techniques of FM broadcasting and television, the question of methods of knitting FM and television stations into regional and nationwide networks becomes increasingly important. The present foundation on which such networks can be built is outlined in a behind-the-scenes story beginning on page 10, entitled "And Now We Take You To —!", a picture of the wire network—Broadcasting's "Silent Partner" — which makes all present network broadcasting possible. This account of the Bell System's vast 130,000-mile web of circuits summarizes principles which must underlie all types of network operation and indicates how this experience gained by the Bell System may also be applied to the operation of FM and television networks.

Smaller than a Pinhead

Automatic gain control, accurate voltage regulation, time delay and control of temperature fluctuations in circuits — all these problems and many others that face communications engineers hold promise of being solved by a group of little devices having several forms and varying in size from smaller than a pinhead to no larger than a thumbnail. These devices are known as "thermistors" — thermal resistors, and their story is told in detail on page 3. One of the Bell Telephone Laboratories most interesting developments with a remarkable range of applications, thermistors may well become one of the major tools of the communications and radio engineer.



THERMISTORS

...they perform countless circuit control jobs

By J. E. Tweeddale

IN a variety of circuits, small beads, rods or discs, known as "Thermistors", ranging in size from smaller than a pinhead to no larger than a thumbnail, have been doing a number of vital jobs — many of them holding promise in the broadcasting field. Taking the place in many cases of more intricate and complicated apparatus these elements have often proved far more effective as circuit control units than former equipment.

Of principal interest to the broadcasting engineer may be cited their applications as automatic gain controls, volume limiters, expanders and compressors, voltage regulators, protectors, remote control resistances, power indicators, and time delay devices of which we shall speak more fully later. In other fields, they have been used effectively for temperature measurement and control, temperature compensation of electrical circuits and vacuum and flow measurement. Experimental studies have also indicated their possible use in some forms of filters and level equalized networks, and as oscillators, modulators, amplifiers and switching devices.

Thermistors — the word is a contraction of "thermal resistors"— are members of the family of solid variable conductors and have the property of varying their resistance greatly with changes in temperature, resulting in unique electrical characteristics. Made at the present time from a class of materials called semi-conductors, i.e., materials whose conductivity lies between that of conductors and insulators, they have relatively large negative temperature coefficients of resistance. In these thermistor materials — comprised of various combinations of manganese, nickel, cobalt, copper and other metallic oxides — the resistance increases rapidly as the temperature falls, and vice versa, the resistance decreases as the temperature rises. In some types, the resistance may be doubled with a temperature decrease of as little as 30°F. or even less.

Although knowledge of the behavior of semi-conductors is not new, experimental investigations having been made by Michael Faraday more than 100 years ago, no practical results were obtained until in recent years Bell Telephone Laboratories succeeded in developing combinations with reproducible and stabilized characteristics, and having indefinitely long life. At present the metallic oxides form the heart of thermistors. These are milled and mixed thoroughly and made into desired shapes by forming beads on fine wires, by pressing into discs or extruding as rods. After subsequent processing and firing under carefully controlled conditions of atmosphere and temperature, which give the elements a hard, ceramic-like structure, connecting leads are attached to the surfaces of the discs and to the ends of the rods. Bead thermistors are usually mounted in small sealed glass bulbs which may be evacuated or gas filled; disc thermistors are commonly soldered to mounting plates or other structures and provided with suitable protective finishes; rod thermistors are generally coated with glass or other electrical insulating materials. The specific shapes of thermistors and types of mountings employed are determined by the thermal-electrical requirements, as well as the mechanical requirements.

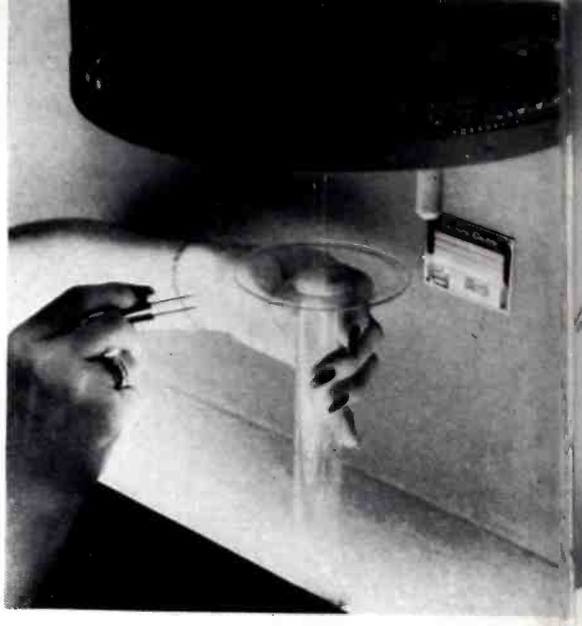
Numerous aging tests have been performed on thermistor elements to check the stability of their thermal-electrical characteristics. Some elements have been subjected to high temperatures for extended periods of time with no significant changes in their resistance values. In other tests, some types have been subjected to more than a half million heating and cooling cycles without change in their properties.

Thermistors can be constructed for use wherever temperature variations exist or can be produced. These variations in temperature may be brought about in three ways:

1) Externally — by changes in surrounding elements; air, water, etc.
2) Internally or Directly — whereby the current conducted through the

Skilled hands weld bead leads to the wire mount in an intricate operation in thermistor manufacture.

Thermistor aging: racks of Western Electric thermistors are here being placed in aging cabinet in manufacturing process.



Close-up of operator feeding thermistor beads into electric oven to finish hardening process.

thermistor causes self-heating and thus changes its effective temperature.

3) Indirectly — by means of a separate heating coil surrounding the thermistor element, producing a controlled ambient temperature condition.

Externally sensitive thermistors are usually of the disc or rod type. The directly and indirectly heated forms are usually of the bead type. The indirectly heated thermistors have particular merit in certain applications, in that the heater and thermistor element are electrically isolated, permitting them to be inserted in separate circuits. Resistance control is thus obtained thermally without electrical interaction.

The three fundamental characteristics of thermistor elements are briefly as follows:

Temperature Resistance Characteristics: Figure 1 demonstrates the change in resistance which can be produced in three of the more commonly used thermistor materials over a 500 degree Centigrade range of temperature, as compared to a representative metal. A variety of other thermistor materials have also been developed for certain types of applications where other characteristics were found desirable. Specific resistances ranging from 100 to 450,000 ohm-centimeters at 25°C. can be produced, thus permitting a wide latitude in design. As a measure of sensitivity, thermistors have been developed with temperature coefficients of resistivity as high as 5% per degree Centigrade at room temperature. This compares with 0.3% per degree Centigrade for platinum.

Mathematical Relationships

The development engineer will be interested in the mathematical relationships describing the temperature-resistance characteristics of thermistors. The resistance R of thermistor materials, in general, approximates the following relationships over limited temperature ranges:

$$R = R_0 e^{\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)}$$

and $\alpha = \frac{1}{R}\frac{dR}{dT} = -\frac{\beta}{T^2}$

where T = absolute temperature of thermistor

$R = R_0$ at $T = T_0$

α = temperature coefficient of resistivity

β = constant for a given material over limited temperature ranges.

e = 2.718 . . . . the naperian base

In Figure 2 which is the same as Figure 1 except that values are plotted against inverse absolute temperature, it will be observed that β is the slope of the curves. The values of β are approximately constant over a wide temperature range, decreasing however at low temperatures and increasing at high temperatures.

Static Electrical Characteristics: Current passing through a thermistor causes a self-heating effect which is readily shown by its static characteristic. A representative characteristic of one type of thermistor relating voltage, current, resistance and power is shown in Figure 3. At low currents, the effective change in temperature is small and Ohm's Law is obeyed, i.e., the

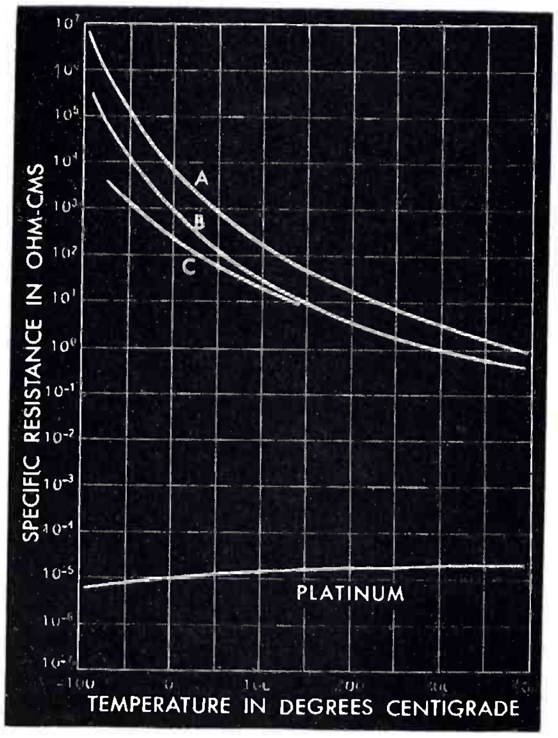


FIGURE 1 — Resistance-temperature curves of three typical thermistor materials over a 500 Centigrade range, as compared with a representative metal.

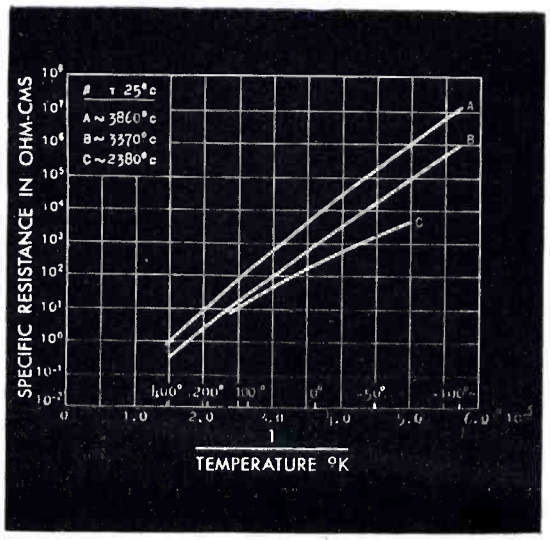


FIGURE 2 — A replotting of Figure 1 in terms of inverse absolute temperature. It may be noted slope of curves is fairly constant over wide range.

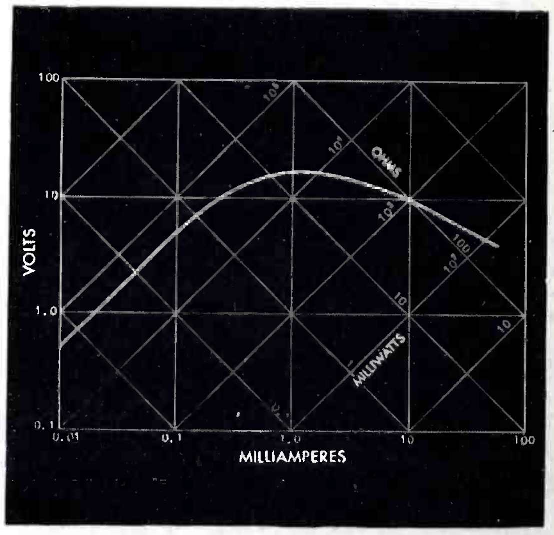
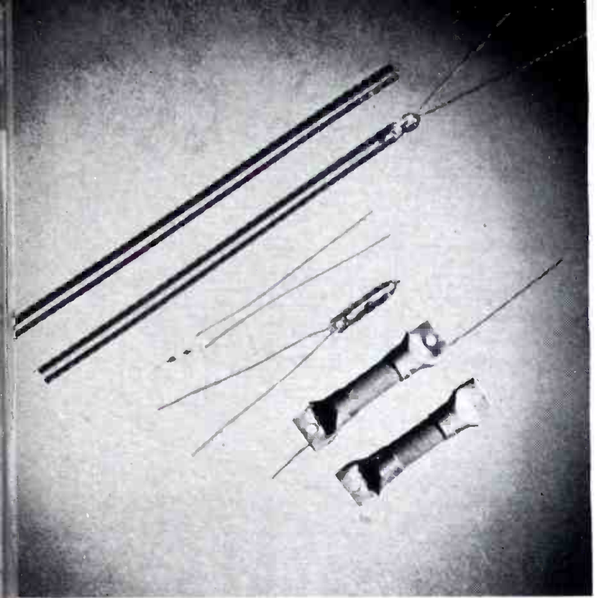
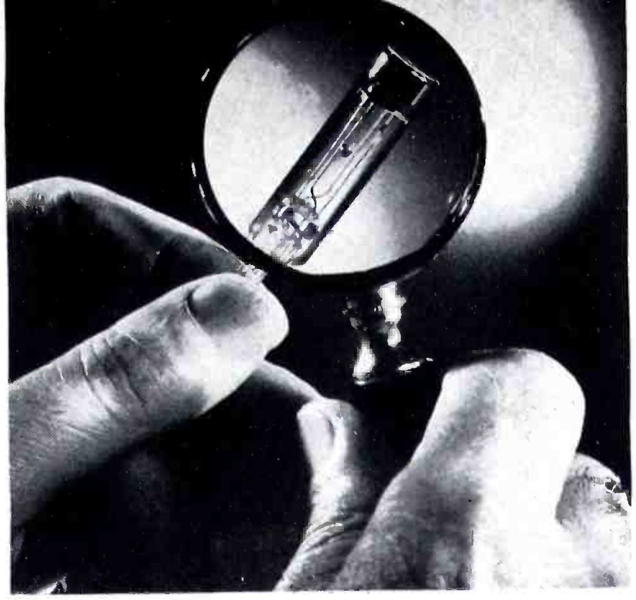


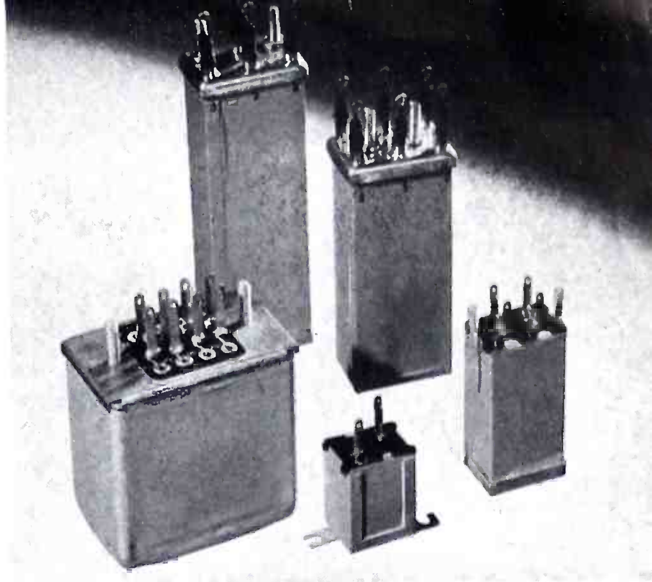
FIGURE 3 — Static characteristic typical of thermistors, relating current, voltage, resistance and power. Note negative resistance characteristic.



Directly heated bead type of thermistor — used for time delay — in various stages of assembly.



Indirectly heated bead type thermistor under magnifying glass. Note the small gilded bead with very fine lead wires.



Thermistor units encased in cans—a type used in telephone amplifiers for automatic gain control.

current is proportional to voltage and the characteristic is a straight line. With increasing current, the effects of self-heating become evident and the temperature of the thermistor rises with a resultant decrease in its resistance. Thus, as the current increases, the points for the steady state voltage deviate more and more from a straight line, until the voltage reaches a maximum value at which point the slope is zero. As the current continues to increase, the slope becomes negative and the voltage decreases rapidly. The falling portion of the curve, therefore, exhibits a negative resistance characteristic which has potential application in a wide variety of circuits of interest to the broadcast engineer.

It is of interest to note that the resistance-power characteristic is also shown in Figure 3. The magnitude of change in resistance brought about by power dissipation is demonstrated by the following example: With one type of thermistor at room temperature, if a small enough current is supplied so as not to heat it appreciably, it will offer a resistance of approximately 50,000 ohms. As additional power is dissipated, the element heats up and its resistance decreases. With 18 milliwatts dissipation the resistance value will be approximately 18,500 ohms and with a dissipation of 100 milliwatts a greater than proportional drop occurs, the resistance decreasing to approximately 800 ohms. The resistance-power characteristic makes thermistors useful as sensitive current and power measuring devices in a wide range of communication applications, particularly in high frequency measurements. The static electrical characteristic of thermistors is of fundamental importance in their application to the great majority of communication circuits.

Current-Time Characteristics: The change in resistance of thermistors with change in current does not occur instantaneously because of their inherent thermal inertia. If a thermistor is placed in series with a source of voltage, a delayed building up of current following closure of the circuit will be found. A representative characteristic is shown in Figure 4. The initial current which is determined by the cold resistance of the thermistor, is small, and rises slowly at first, then more rapidly as the thermistor becomes heated. The final current is limited by the circuit resistance. By a suitable design of a thermistor and choice of circuit it is possible to vary this time delay from a few milliseconds to several minutes. This time delay property is of distinct advantage in many applications, since it provides an action which, if obtained by other techniques, would undoubtedly be much more cumbersome and costly.

The thermal and electrical chracteristics of thermistors suggest a large number of circuit applications. In the following paragraphs, some basic applications will be presented to demonstrate their capabilities.

Automatic Gain Control

The applications of thermistors for automatic gain control and transmission level regulation are probably of greatest interest to the broadcast engineer. While the major applications have been primarily in wire communication circuits, the principles involved are applicable to a wide variety of other circuits.

In automatic gain control applications, the non-linear characteristics of a thermis-

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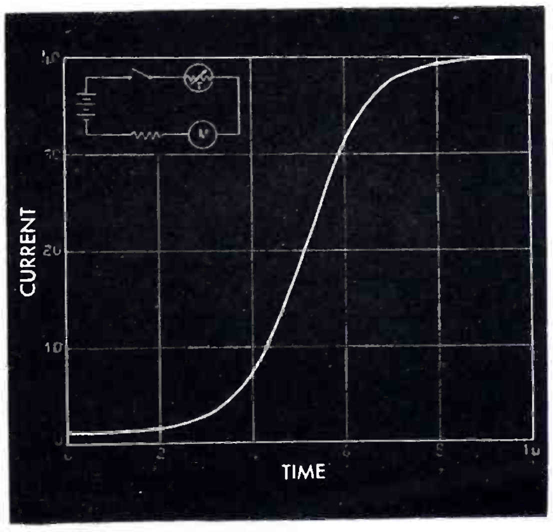


FIGURE 4 — Current-time characteristic showing the delayed build-up of current in a typical thermistor because of inherent thermal inertia.

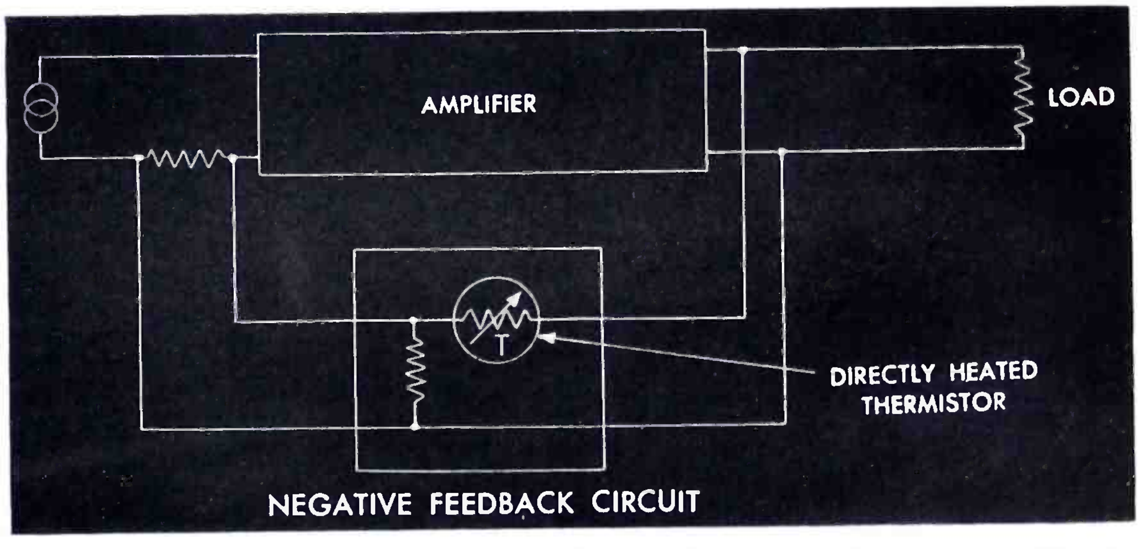
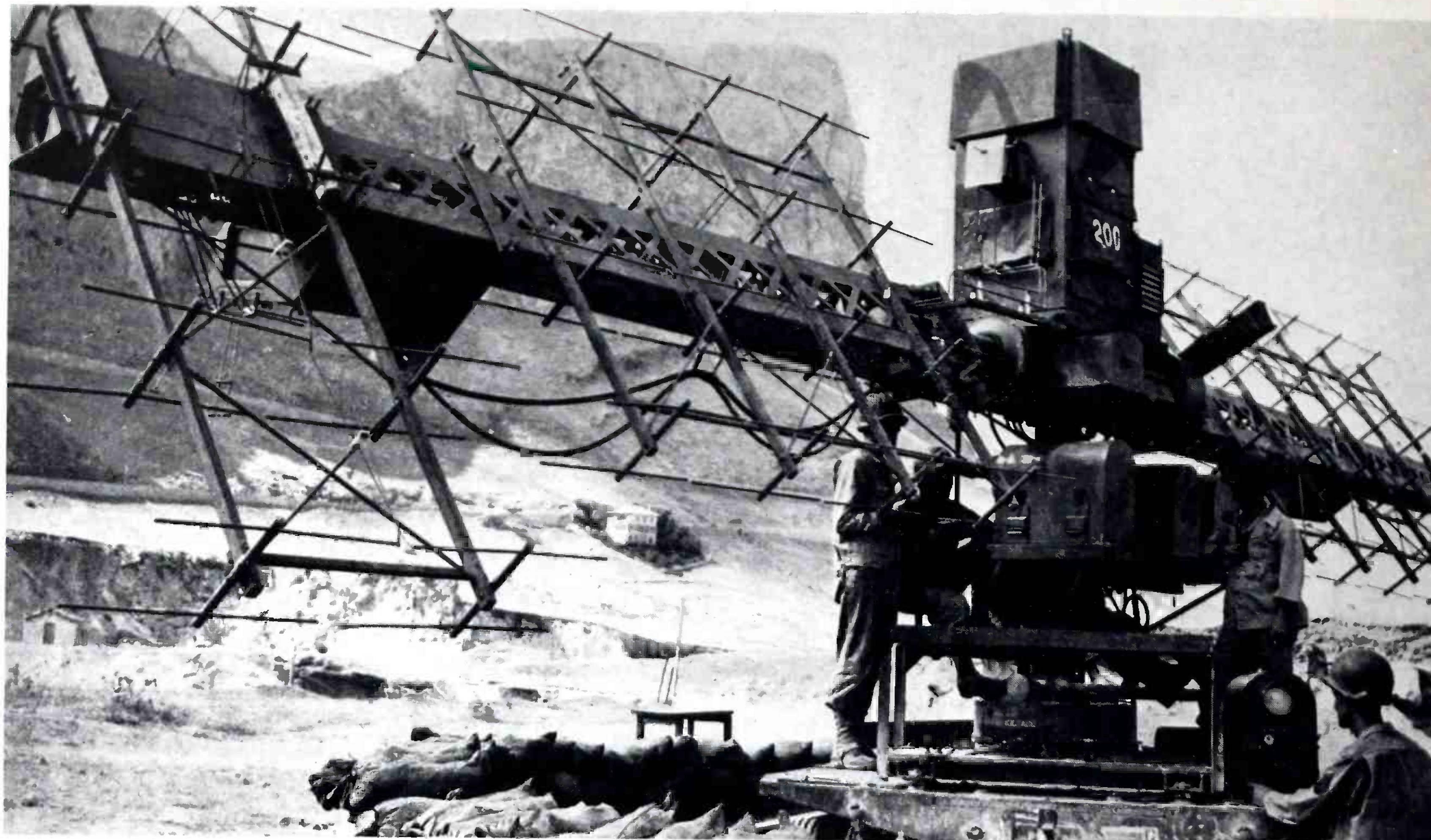


FIGURE 5 — A basic amplifier feedback circuit employing a directly heated thermistor to provide automatic gain control. In such applications, the non-linear characteristics of thermistors are used in the feedback circuits to provide constant output with negligible distortion for wide ranges of signal input.



Radar — one of the War's greatest secret weapons! Here against rugged background, an early type of search radar silently probes Italian skies for enemy planes.

RADAR — A Production Triumph

THE glare of well-merited publicity that attended the relaxing of restrictions on the war's most valuable and, next to the atomic bomb, most spectacular secret weapon, radar, overlooked to some extent one facet of radar's triumphant story — its production record.

Radar was a $2,700,000,000 development and production enterprise. The many stories of its achievements — from saving Britain during the fateful German air blitz, wiping out the Atlantic submarine threat, curtailing the V-1 menace, sinking the Japanese Navy to aiming the B-29 bombs on Japan — all have implicit in them not only the quality of the radar developed but the enormous quantity of it produced.

Many scientists contributed to radar's development from the early experiments of the group under Dr. A. H. Taylor and Mr. L. C. Young and their associates in the Naval Research Laboratory; the staff of Colonel (now Major General) R. B. Colton of the Signal Corps and in Britain the work of Sir Robert Watson-Watt and his associates to the modern improvements and refinements made by the scientists at Bell Telephone Laboratories and the Radiation Laboratories at Massachusetts Institute of Technology. Many industrial firms

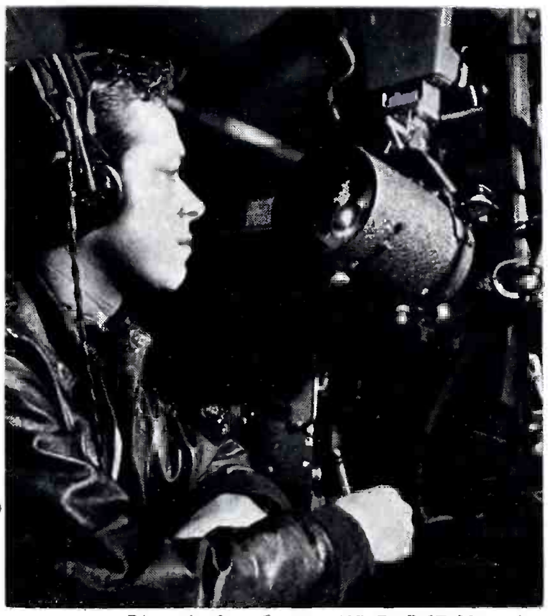


Photo by Sgt. Coster, AIR FORCE Magazine

On B-29s Western Electric radars aimed the bombs. Operator looks into PPI (Plan Position Indicator).

also contributed to the mighty production of this weapon, and the greatest of these manufacturing sources of supply for radar was Western Electric.

This brief report on the Bell System's — and particularly Western Electric's—contributions to the vast project will indicate the role played by all of industry in giving our fighters overwhelming superiority in radar development and production.

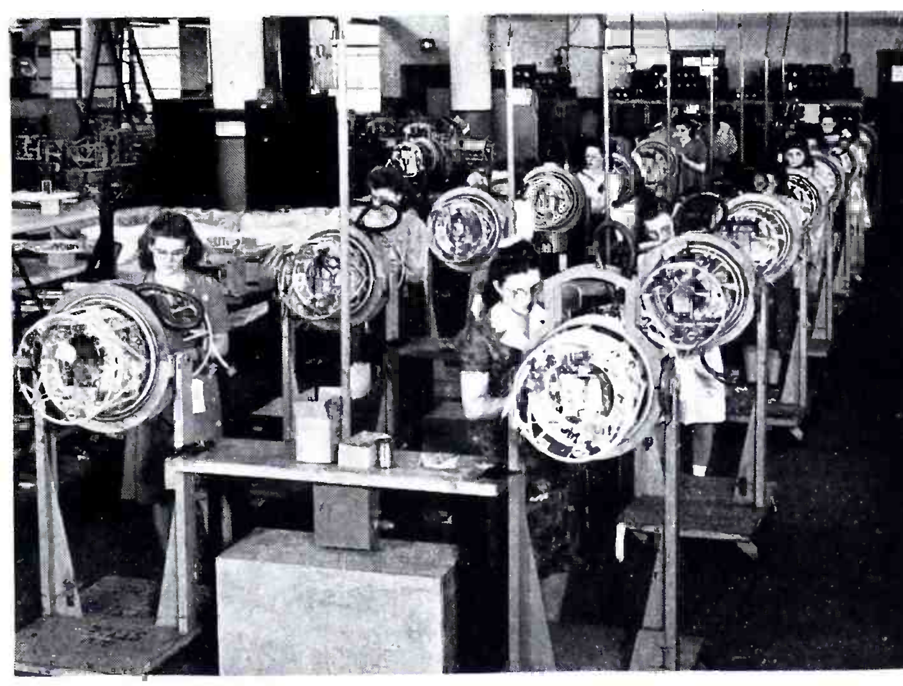
Western Electric had supplied to the United States as of June 30, 1945 a total of 56,000 radars; producing 64 different types of the more than 100 designed by Bell Telephone Laboratories. The value of those 56,000 systems reached a total of $900,000,000. In 1944 alone, the Company's output reached the yearly peak of 22,000 radars worth $340,000,000, but the monthly record was greatly exceeded during the first six months of 1945 when the Company turned out a total of 19,800 radars. In all, Western Electric was the Nation's largest single source of radar, supplying over 30 per cent of the value of the entire production program. In ground radars, the Company supplied 5,015 of the total of 11,887 produced in the United States during the war; in shipboard radars, 6,091 of the total of 22,983 produced, and in airborne search and bombing radars, 45,738 of the total of 162,731.

The above figures on development and production of radars mean a great deal more when the nature of the undertaking is considered. Because radar is such an intricate structure of vacuum tubes, transformers, electrical networks, rheostats, potentiometers, condensers and other circuit elements, each one is a manufacturing

(Continued on page 8)

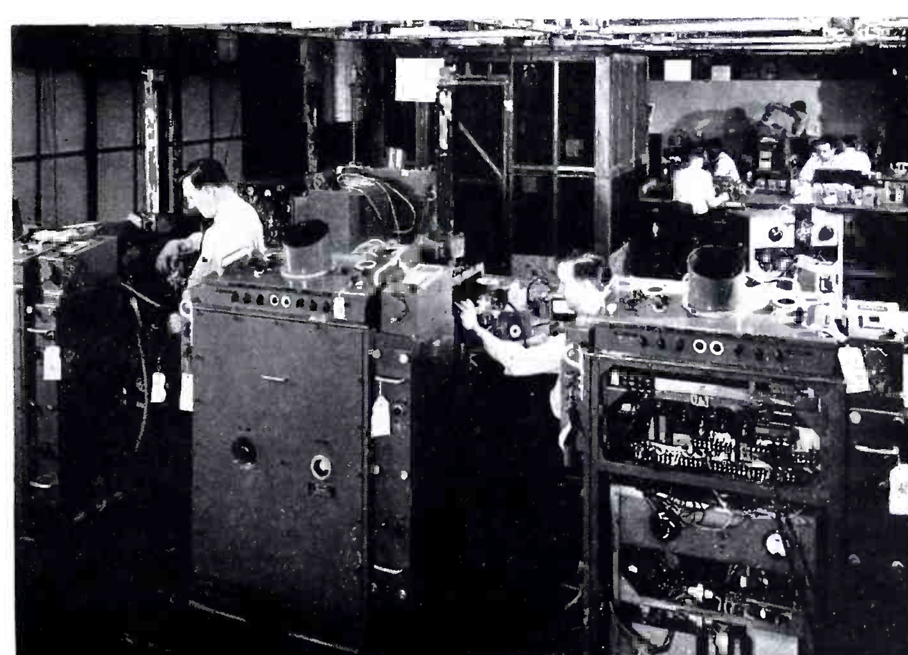
Production of the highly intricate Mark 20 anti-aircraft radar. This is assembly and inspection line of the step-by-step converter unit.

"All the large guns of the United States Navy were pointed by radars manufactured by Western Electric."—Above, view of one assembly department at Hawthorne Works.



"Many radars for the planes of the Army Air Forces, both bombers and fighters, were made by Western Electric." — Here radars for aircraft are being assembled.

Vital radar test equipment. Shown is a special type of Signal Generator receiving a final operation test at a Western Electric plant.



A total of 56,000 radars were supplied to the U. S. by Western Electric during the war. Above, experts give shipboard radars a final check before passing them.

On the desolate terrain of Okinawa, Western Electric field engineers see that this radar, used for searchlight control, is "open for business" in case of enemy attack. In such outposts, their skills are vital.

problem in itself. These elements are all interconnected by wires, coaxial conductors or wave guides of many varieties, and this complexity of radar systems may be indicated in the fact that in the total radar project, twice as many physicists were engaged as worked on the atomic bomb.

In addition to complexity of internal mechanisms, there are great varieties and types of radars. In general, according to use, radars fall into two major classes: the "search" type which sweeps wide and distant areas to detect the approximate position of the target, and the "fire control" type which uses a narrow beam to determine precisely the target's position so that searchlights and shells can pinpoint an object or aerial bombs can be properly aimed at ground targets. But in each general category, there are scores of varieties of radars and each must be designed and built for a specific purpose within these categories. One may have over 370 vacuum tubes, another only 80. By comparison, a moderate-size, console-model radio for home use may have eight tubes. A land-based radar may tip the scales at 70,000 pounds, while smaller, compact units built for fighter planes weigh only about as much as the pilot.

A radar may cost $87,000 or $6,000. It may require 40,000 labor hours to complete, or only about 4,000 labor hours, depending upon its size and the purpose it is to serve.

The war compelled the Government to call upon all the accumulated experience and talent Industry as a whole possessed. There was no time to build it up, little time to train or experiment. Western Electric was selected as the paramount manufacturing unit in the radar field because for 75 years the Company had been manufacturing intricate and precise communications equipment and had in later years made continuous progress in producing high-frequency radio apparatus.

This production skill combined with long experience and great resources was almost ideal for the sort of assembly-line manufacturing of extremely delicate and intricate systems involved in making radar sets. With the advent of War, the Armed Forces immediately poured their radar development production problems onto the Company.

From Zippers to Radars

So great were these orders that the Company's main works at Kearny, N. J., Baltimore and Chicago were swamped and it became immediately necessary to find more space to set up facilities for the enormously increased commitments. The Company was already loaded with orders for war communications equipment, and the radar program made necessary an expansion that eventually dominated the production facilities and skill of the entire organization. There was no time to construct new plants. Existing facilities were, therefore, leased in areas where manpower, transportation and other considerations were favorable.

Within a few months a zipper factory at Bayonne, N. J., was converted to radar and a shoe factory in Haverhill, Mass., was turned into a coil winding shop employing 2,000 persons turning out radar transformers and other high-priority items. A laundry in Jersey City was changed speedily into a radar assembly shop. In Eau Claire, Wis., Western Electric engineers revamped an ordnance plant, and in Baltimore an airplane hangar resounded to the whir of drills and air-driven screwdrivers in the radar production line.

Almost overnight, several floors of a huge Manhattan garage became the world's largest radar assembly plant. Its floor space was equal to six football fields. To get this big plant into production quickly was most urgent, because it was to turn out radar equipment for B-29 bombers, and the development of the planes themselves was well under way when Western Electric got its go-ahead. In rapid order, machinery and utility services were installed, and workers were recruited and trained into an effective production unit. It was so effective that not one B-29 had to wait for its radar unit.

In all, Western Electric set up 16 shops in nine cities to assist its main plants in turning out the land, sea and air radars. At the height of the program more than 4 out of 10 Western Electric plant people — 40 per cent of the manufacturing personnel — were engaged in the production of all types of radar.

Western Electric's wartime role was shaped in Washington in 1940 amid intensive study of defense plans. The Company became the principal prime contractor and pioneer manufacturer of most of the radar, secret electronic devices and other war communication equipment then in process of development within Bell Telephone Laboratories.

Western Electric also fostered a national subcontracting program aimed at mobilizing the electronics industry and a large sec-

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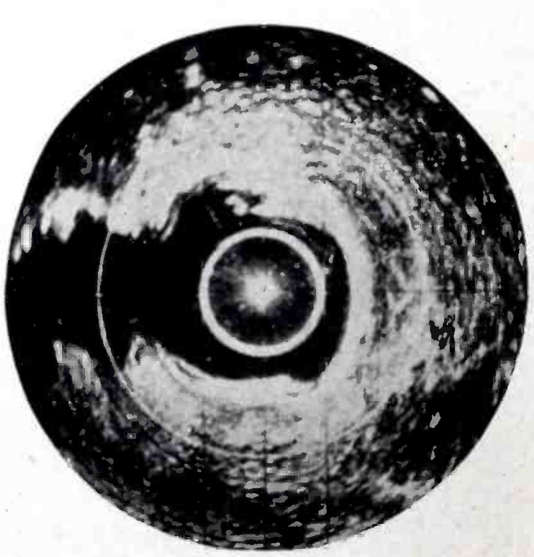
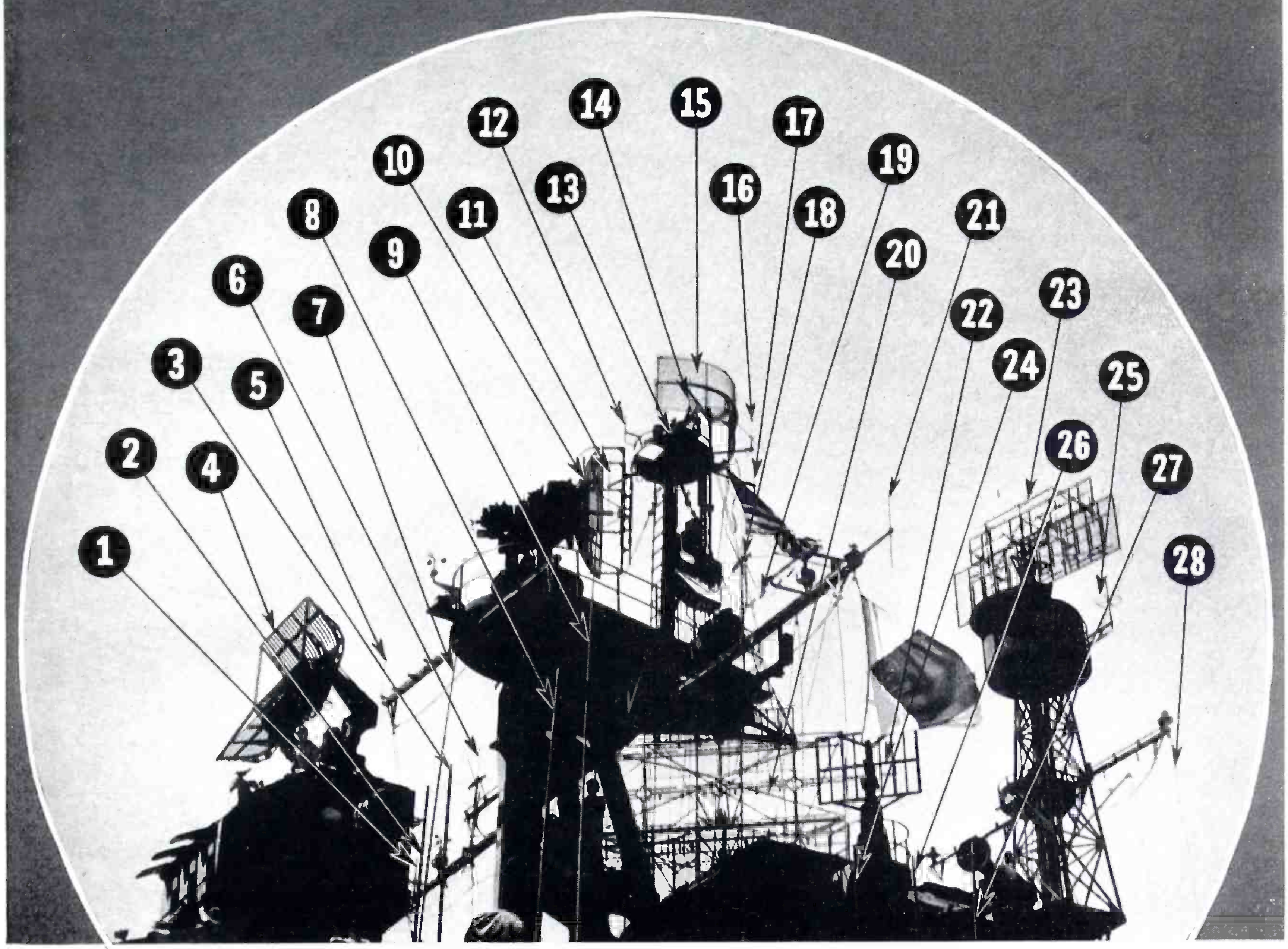


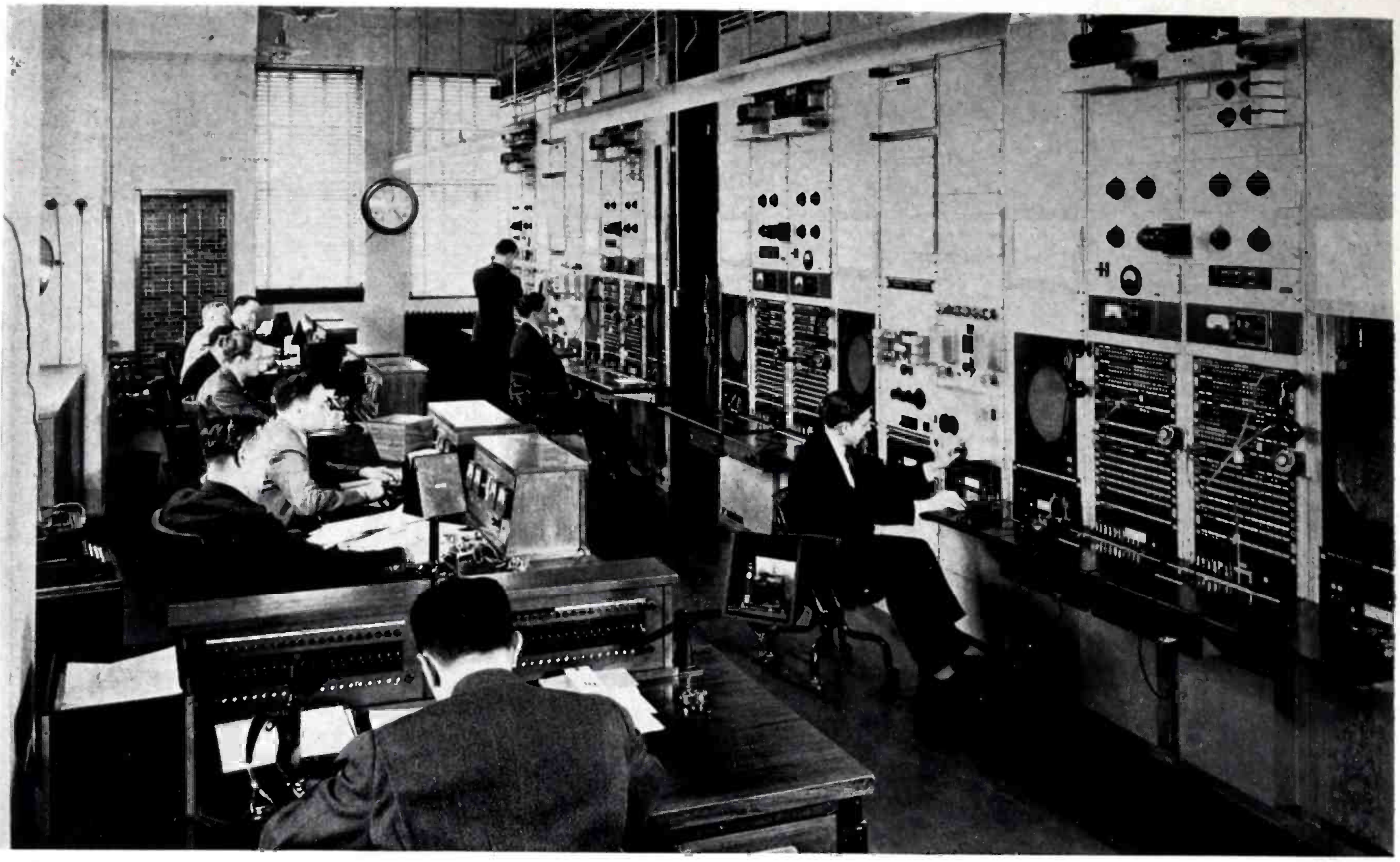
Pinpoint on Tokyo: unretouched photograph of radar PPI scope showing area including Nippon capital.

Eyes and Ears of a Carrier



THE extensive use of electronics in World War II is reflected in this complex array of antennas atop the "island" on a modern giant of our aircraft carrier fleet. In this view, at least 28 radar and radio antennas of different shapes and sizes are outlined against the sky. These may be identified by the corresponding numbers listed below. In the picture of an Essex-class carrier at the bottom of the page may be seen the identical area circled in the top photograph.

1. Rodio communications
2. Radio communications
3. Radio communications
4. Fire control radar
5. Radio communications
6. Radio communications
7. Rodio communications
8. Radio communications
9. Radio communicotions
10. Air search and height finder radar
11. Radio communications
12. Radar test equipment
13. Surface search rador
14. Rodio communications
15. Rodio homing beocon
16. Rodio communicotions
17. Radio communications
18. Radio communications
19. Radio communications
20. Air search radar
21. Radio communications
22. Radio homing beocon
23. Air seorch radar
24. Radio communications
25. Identification radar
26. Rodio communications
27. Radio communications
28. Radio communications



"NR" — Broadcasting network control room where A. T. and T. Long Lines technicians monitor nationwide network programs. From here, technicians are in constant touch with headquarters offices of the broadcasting companies and with key points along the networks, thus keep check on functioning of wire circuits.

"And now we take you to—!"

By George de Mare

• • A picture of the organization of the "wire network" behind broadcasting and what the experience gained in present program transmission may mean in the putting together of future FM and television networks • •

It is the end of the last program of the day — at one or two in the morning. The air, once filled with radio's evening programs, is silent now, but unheard by the great listening public a coast-to-coast program of tests and adjustments in preparation for the start of network broadcasting service in the morning commences. Radio is clearing its throat . . . and to assist in the process it calls upon its "silent partner"— the Bell System's vast wire network organization — to perform one of its most important functions. . . .

Everybody in broadcasting probably knows how network programs are distributed and something about this giant wire system — equal in actual money value to about half of all the equipment owned by the broadcasting companies it serves — but how many know how intricate is the organization necessary to keep network programs coming through at the level of performance Broadcasting demands, or how exacting are the problems which this wire network must solve? A more detailed review of the operation and organization of the wire network may be useful at this time in throwing some light on the problems that will confront broadcast engineers in putting together possible FM and television networks.

The present wire network service, the "silent partner" which makes all chain broadcasting possible, involves a great deal more than merely providing wire channels from studio to transmitter or from one broadcasting station to another. It means, among other things, maintaining great central switching and control points throughout the nation. It means having a staff of engineers to see that programs are going on the split-second schedules required. It means maintaining repeater stations all along the lines, operating a telegraph and teletype network totaling some 70,000 miles of circuits to transmit to all major telephone company offices information on every program — what stations are to be cut in and what switches are to be made, and it involves keeping a corps of "monitors" busy listening at key points for the faintest flaws in transmission. Finally, it means constant research to improve the quality, dependability and life of the lines and transmission equipment — research which draws constantly upon the great resources of the world's largest electronics and communications research center—Bell Telephone Laboratories.

As an example of the functioning of this "silent partner" let us go back for a moment to that program of tests and adjustments of which we were speaking and continue briefly the account of what happens on a typical network before the first announcer of the day signs on. . . .

This morning, for instance, amplifier tube tests are to be made at all offices between New York and Chicago from 2:00 to 3:00 a.m. These tests completed, still other tests must be made to assure transmission of program with unimpaired volume and quality. Each control office measures its own section, including the circuits kept ready for special services or emergencies, and sees that it is fit for broadcasting.

With section tests complete, the network is put together and New York pumps out a succession of different tones over the entire chain. Measurements and necessary adjustments are made at a score of places. Promptly at close of business, the telephone staffs send in by teletype reports on the service furnished, and yesterday's comments from the radio stations.

Let us say that an important news program is to start from New York at 8:00 o'clock in the morning over one of the networks. As usual it will be started on its way by the broadcasting station's technicians in the control room, from which it will be fed to the nerve center of the Bell System's web of broadcasting channels in New York's Long Lines Building, known by the call letters *"NR"*. There a corps of technicians will have already "lined up" the wires and equipment over which the show is to travel and have subjected them to certain exacting tests. From *NR*, the show is carried out over the great trunk routes of communication set up by the American Telephone and Telegraph Company's Long Lines Department and Bell System offices. These will carry it to the hundred or more stations that are taking the program in New England, the South, the Middle West and the West Coast.

Now, therefore, at 7:30 in preparation for this, each office checks its setup in accordance with the schedule sent out by the broadcasting company, to be sure the stations slated to receive the show are cut in. At 7:45 the New York studios of the network start transmitting test programs to their chain. By means of a control telegraph wire, New York receives telegraphic reports from along the line that a program of satisfactory volume and quality is being received. It is now 8 o'clock and the broadcasting network is ready for operation.

130,000 Miles of Circuits

This, briefly, is the bare outline of one of the major functions of the wire network during the silent hours, but it gives very little hint of the elaborate maintenance, the highly involved organization or the intricate equipment which must perform this essential function.

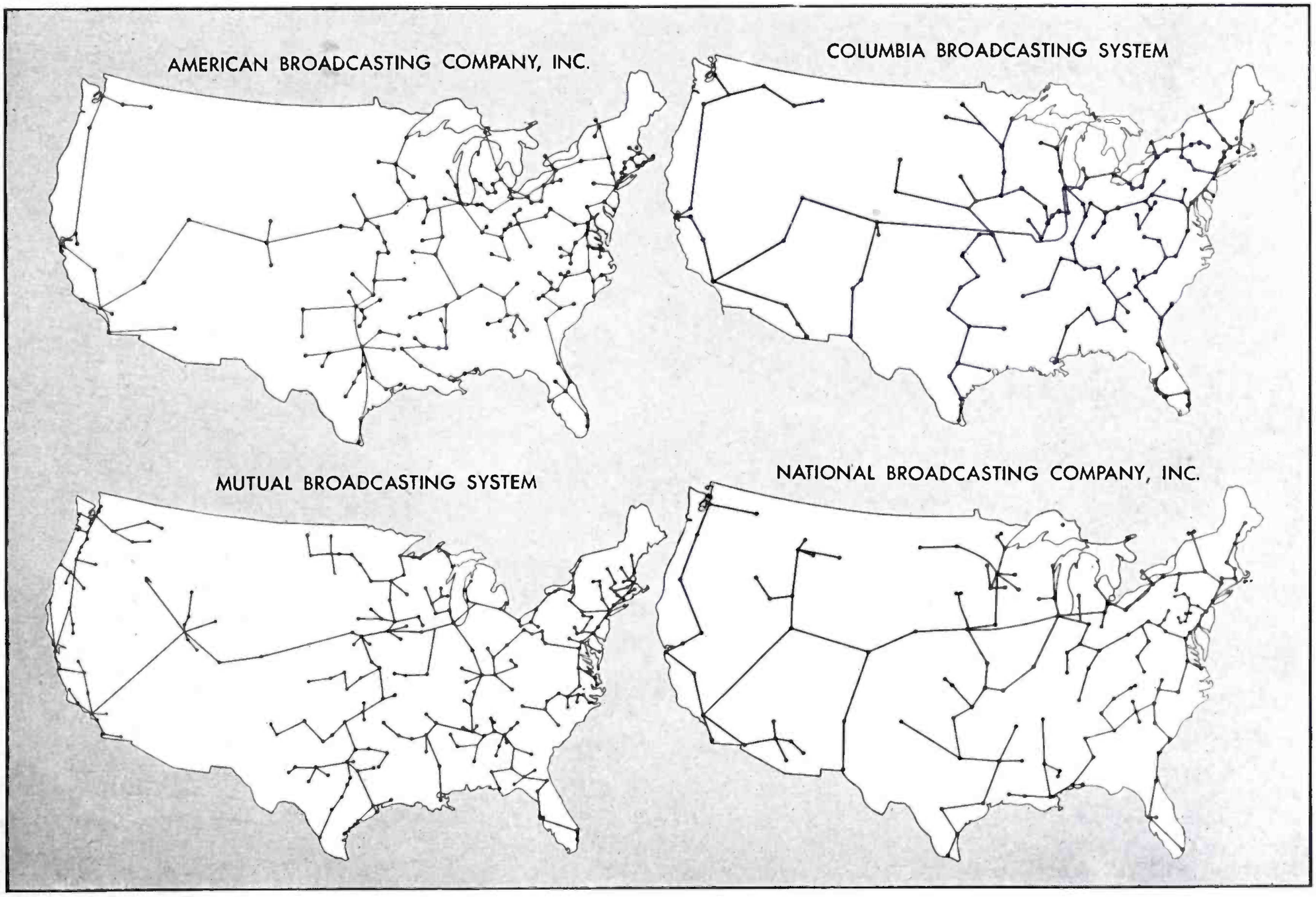
First, what is the "organization"?

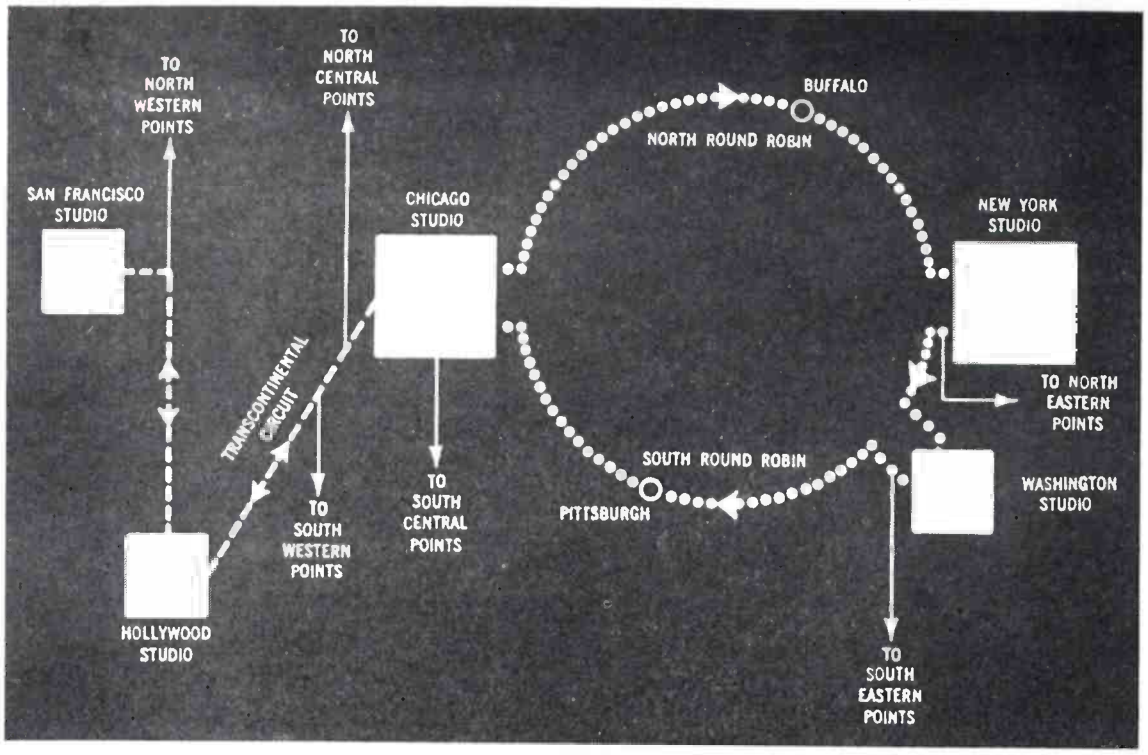
Physically, the wire organization consists of more than 130,000 miles of telephone transmission circuits linking into various networks over half of the 900 broadcasting stations in the United States. These circuits are permanently and exclusively devoted to this service, including some 31,000 miles of wire lines set aside for use in special features, "repeat" programs, unusual hookups and in such emergencies as storms, floods, fires and disasters.

Each major broadcasting company is provided with its own separate and complete network (see maps below). Circuits are one-way over special high-quality cable which will transmit a frequency band up to 5,000 or 8,000 cycles in width according to indicated preferences of the broadcasting companies under the circumstances. It may be noted that as early as 1933 the Bell System successfully transmitted frequencies up to 15,000 cycles over circuits between Philadelphia and Washington. In the postwar period this type of circuit will be widely available to serve broadcasters who may have a need for 15,000-cycle FM intercity channels.

The wire channels of the present network run through about 300 telephone offices; use over 2,500 of the special-type vacuum tube amplifiers designed for this network and in addition to the four major coast-to-coast chains, knit together approximately 30 regional webs. Hundreds of

Wire networks used to connect affiliated stations of the four nationwide broadcasting systems. These are part of 130,000 miles of Bell System program circuits in U. S.





Simplified diagram indicating the two essential elements forming the central nerve system of network broadcasting: the "round robin" from Chicago east and the "quick reversible" circuit from Chicago west.

Bell System transmission specialists are engaged in operating this nationwide system supporting the excellent engineering and monitoring facilities maintained by the broadcasting companies themselves.

The central nervous system for chain broadcasting in the case of three major networks (Mutual uses the quick reversible type exclusively) includes two important features. The first is the so-called "round robin" which is a major closed circuit running from New York to Washington to Chicago and back to New York. The second major element is the "quick reversible" or "Type 1 Reversible" circuit which links the round robin terminal at Chicago with Los Angeles and other points west (shown at top of page). These two elements, in fact, make network broadcasting possible, in that a progam originating anywhere in the network can be fed into the round robin and thus reach all points along the round robin circuit, and from the round robin circuit the program can be fed through the Type 1 quick reversible circuit to Los Angeles, any points along the way and north up the Pacific Coast. The quick reversible, as its name implies, although one-way, can be reversed in 15 seconds or less, depending upon the length and facilities involved. Thus a program originating on the West Coast can be carried east on the quick reversible to the round robin terminal at Chicago and from there fed through this central circuit to all points in the East. If desired, southern legs can be attached at the Washington or Chicago terminals of the round robin linking up the South Atlantic and Deep South regional circuits. The total effect is to make it possible to put together at any time in a matter of seconds a nationwide network into which a program from any part of the nation or the world may be fed.

Along this central nerve system, four major control point offices are set up: in New York, Chicago, Denver and Los Angeles. Offices controlling regional webs or parts of the main webs are set up in such cities as Boston and Washington; Atlanta and New Orleans; Cincinnati, Indianapolis and St. Louis; Minneapolis, Kansas City, Omaha and Dallas; Salt Lake City, San Francisco, Seattle and Portland and many others. These and subsidiary control and switching offices permit any desired combination of stations and quick changes from one hookup to another.

In the operation of this vast network, much skill and care are involved.

Two elements are perhaps most typical of operational requirements: "flexibility" and "speed". Broadcasters expect the organization to maintain standards that will permit quality transmission of a sufficiently wide frequency range, free from noise or interruption. Yet it is obvious that the specialists who operate any organization of this type are dealing in variables. Broadcasting networks vary in size from a handful of stations to more than a hundred. The number of programs varies. In a 17-hour day it is possible to have 68 fifteen-minute programs, and some stations approach that. Some programs are local shows; some regional and some coast-to-coast. In addition, there are last-minute changes: man-made, particularly during wars and elections, and finally there may be last-minute changes, caused by nature, when an aerial cable is blown down in a storm or a twister, a cloudburst or an explosion rips a line or two. Yet the major requirements remain the same, and the lines must never go silent.

Let's take typical examples of the problems that occur during a day in the operational life of the wire network. . . .

In all offices, switching schedules are constantly being received from the broadcasting companies. There are three classes of switches involved: (1) those at main studio points made by the broadcasting engineers (2) those in toll test rooms so set up that they can be operated by remote control from radio stations and (3) those in toll test rooms on the great national and regional circuits made by the wire network engineers. These operational orders covering the switching schedule may be more or less elaborate, and different offices will use different standard methods of handling them. They generally come in an abbreviated or code form. In offices where the schedule is heavy, the operations may be tabulated or charted and put on the bulletin board or in the order book. Vast improvements in facilities and the installation of much automatic equipment have made switching relatively simple in many offices. However, all orders must be carefully analyzed and carried out with split-second exactness.

"Army Hour" Set Travel Record

Switches are generally made during the 20 seconds or so allowed for local station identification or, as in "running switches" during the program, when the announcer gives the cue: "And now we take you to ——— . . ." Those little words may mean cutting in circuits from Manila, from European capitals, from Saipan, from Honolulu, from Alaska, from Tokyo, from anywhere our Armies and Navies may be, in all the corners of the earth. One program, the famous "Army Hour" presented by the United States War Department over NBC traveled during its first eighteen months on the air *within the United States alone* a distance of 560,000 miles — taking its listeners to Washington, D. C. a total of 140 times. The total number of miles the Army Hour traveled in switching *to points outside the United States* in those eighteen months was 1,061,000 — making a grand total of 1,621,000 miles traveled during the 78 hour-long broadcasts. This distance is equal to 65 times around the earth at the Equator or almost seven times the distance to the moon. The studio portion of the Army Hour originates at NBC in New York, and the switching setup operated by NBC and supported by the wire network is very elaborate. One example will indicate the extent of this setup. On October 24, 1943, Guadalcanal went on the air for the first time in history. To prepare for this entrance during the program, an NBC engineer spoke into his microphone in New York. His voice traveled over 3,000 miles of the wire network, then leaped by shortwave from San Francisco to Guadalcanal and issued from a loud speaker set up on the island.

A return circuit had been set up so that the production man on Guadalcanal could converse with the NBC man, but while the NBC man was giving his directions on cuing and timing for the broadcast to take place within a few minutes, checking quality and volume of signal and finally giving the correct time to within a fraction of a second, he could hear not only the production man's replies from Guadalcanal but *even the echo of his own voice* as it came from the loudspeaker on Guadalcanal and entered the production man's microphone set up nearby! Thus his words traveled out and back to him halfway around the world in that split-second of time. The only reason there was any difference of time at all was because of what is known as "delay" which occurs when telephone currents pass through complicated circuits and many units of wire.

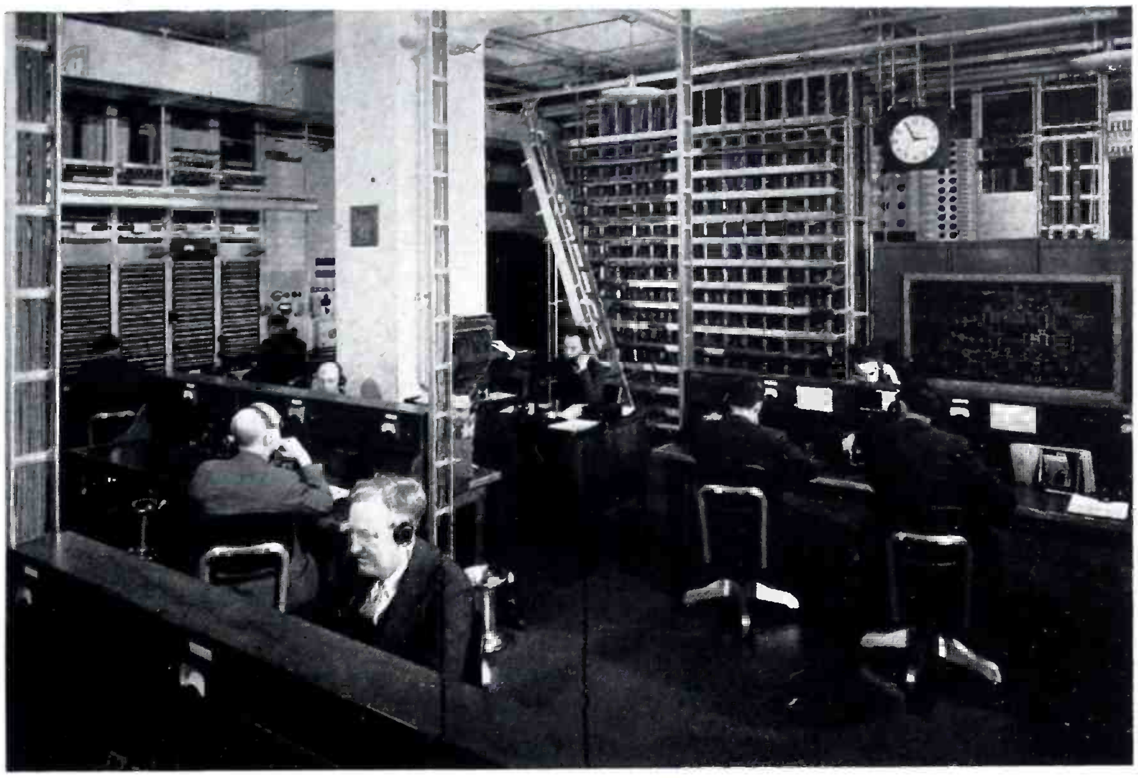
"Quick Reversible" in Action

Thus when the announcer finally said: "And now we take you to Guadalcanal!" the circuits were connected, the operation of switches reversed every amplifier along the line from San Francisco to Los Angeles, the operation of a key locked these amplifiers and as the words from Guadalcanal flowed in at the San Francisco shortwave receiving stations, they were carried by wire to the Los Angeles control room. Then they flashed along the quick reversible circuit to Chicago and the round robin and went to the NBC stations in the regional legs attached to the round robin. The network was functioning . . . and listeners all over the country could hear the voices of men and sounds of battle half a world away.

This might be one of the more complicated switching operations for the wire networks control offices during a typical day. There would be many others.

What does the experience of this wire network organization mean in the building of possible FM or television networks?

The answer involves several factors. One source for such an answer might be in the experience of the Bell System, for no matter whether telephone circuits transmitting 15,000 and more cycles or radio relay circuits, or both, are used, the same operating principles will hold. Based on this experience, these principles may be here briefly summarized:

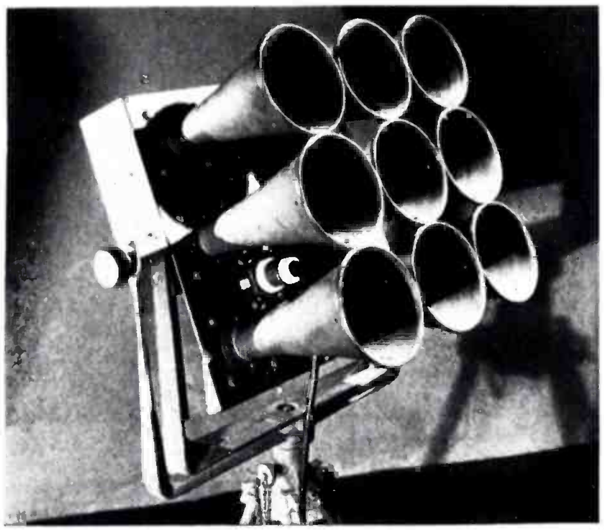


Chicago control room — a focal point in A. T. and T.'s intricate wire network for broadcasting — where important switching operations are made linking major circuits between Eastern and Western network stations.

1. To be suitable for network operation the transmission circuits must be kept at a very high level of maintenance. Interruptions or impairments in a single link may affect a large part of the entire network. Whether a nationwide network is made up of wire lines or radio relay circuits or part of each, a great deal of maintenance would be necessary. The coaxial system, for example, involves cable and equipment all along the route and repeater stations, including equipment and sources of power, at intervals of 50 to 150 miles. The radio relay system avoids line maintenance all along the route, but will involve repeater stations with sources of power and with their associated antenna structures at intervals of about 30 miles. In any case, a comprehensive and highly trained maintenance force is necessary for continued satisfactory network operation.
2. The standards of design applied to each link of the network must be much more severe than would be necessary for the operation of the single link by itself. Each link must be so designed that it will work satisfactorily with many other links in a wide variety of connections. The distortion effects are cumulative and the maximum distortion between any two points of the network must be kept within satisfactory limits.
3. Throughout the country bridging equipment must be installed to enable the reception of a program over one link of a network and its transmission at that point to a number of others with proper transmission levels on each. One bridging point may supply as many as 10 branches of a network.
4. Arrangements must be provided for instantaneous and often very complicated switching to rearrange the networks for successive programs. Much of this switching is done at the studios and a great deal is done at key points of the telephone system. In many places where the switching problem is complicated, arrangements are provided so that while one program is in progress the connection of the network for the next program is preset without interfering with the program. Upon the receipt of the proper cue, the attendant, by throwing a single remote control key, instantaneously completes the rearrangement.
5. It would be necessary to build an organization of engineers and attendants at key points to monitor the programs, and to carry out routine tests and adjustments to insure the continued operation of the network at broadcasting level. The amount of this work in the present wire organization is equivalent to about the full time of 400 men. The total involved is, however, much larger, as many men spend only a part of their time on this type of work.
6. To assist this operating force in making its work most effective, key points must be connected together by a network of telegraph circuits devoted entirely to network operation. In the present wire organization the Bell System calls on 70,000 miles of these telegraph circuits.

(*Continued on page 37*)

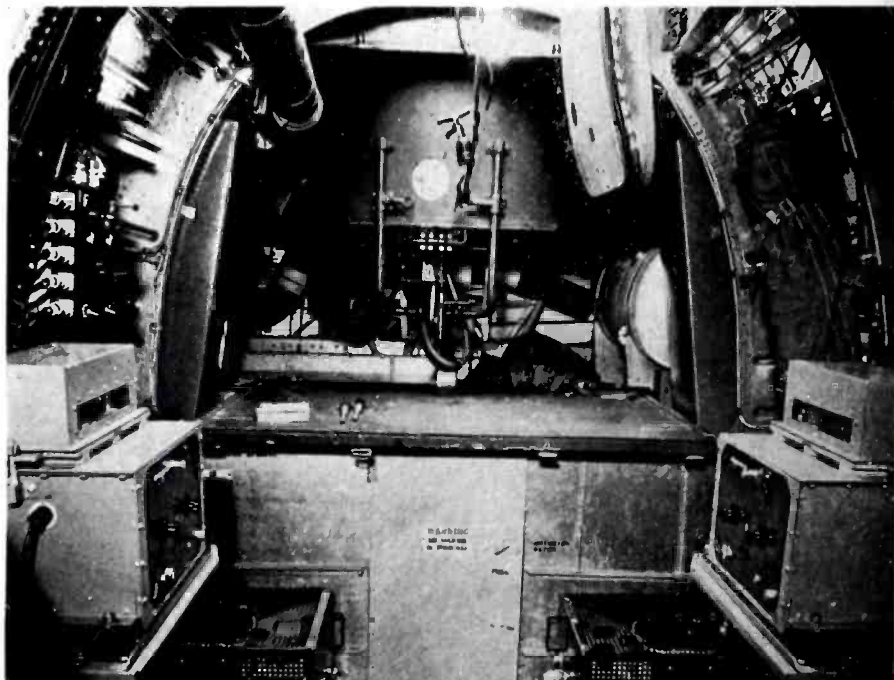
Used on invasion beaches of the Pacific, the Western Electric Beachmaster Announcing System landed with the first waves of fighters. Packaged in six watertight steel carrying cases, this system can be placed in operation in a matter of minutes. Above is the speaker for the powerful 500 watt system.



GIANT VOICES

250 watt Beachmaster Announcing System below includes generator, amplifier, microphone and nine-cell loudspeaker. Above is a close-up of the speaker unit.

The powerful announcing system mounted in this Navy Privateer bomber persuaded by-passed Japs to surrender. It was effective from a height of 10,000 feet.



Western Electric Flight Deck Announcing System on the Carrier Franklin D. Roosevelt provides over 4,000 watts of power for instructing personnel during take-offs and landings. Left: Amplifiers and control panels. Above: Movable bull horn, for talking to other ships, can be aimed like a searchlight.

THE requirements of modern warfare stimulated numerous important developments in the field of sound distribution. New and larger fighting ships, the severe demands of amphibious landings and the growth of psychological warfare, all called for something entirely new in the way of sound systems and gave sound engineers problems that were a real test of their abilities.

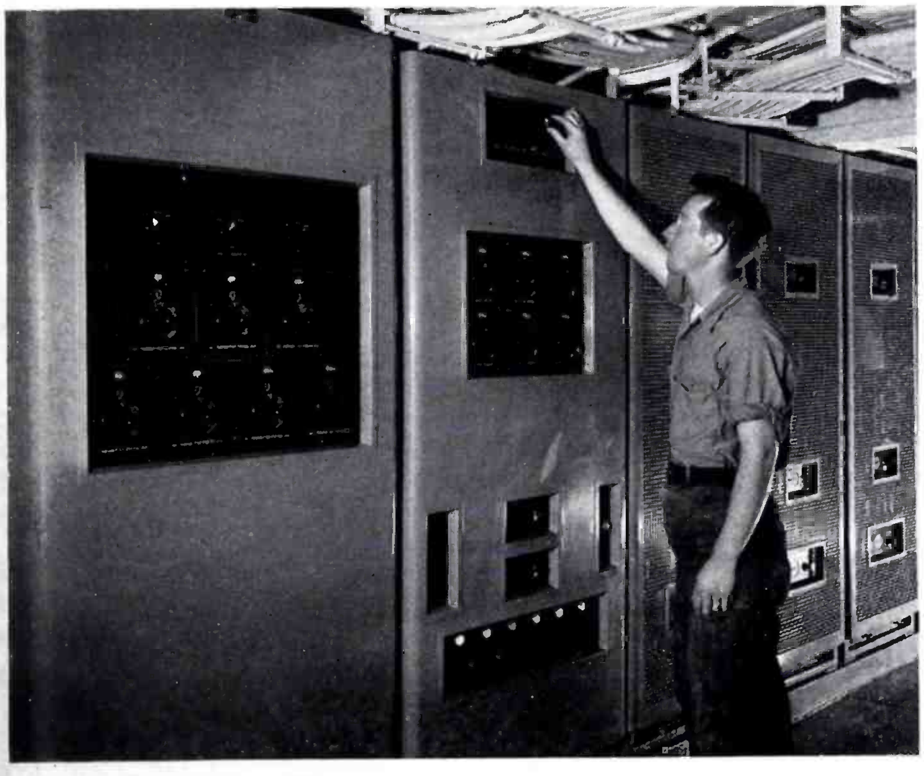
Some of the sound equipment required had to be portable and watertight so it could be moved ashore with assault troops. Other systems had to be extremely compact to fit in the cramped quarters of planes and warships. All types had to be unusually flexible in operation and just as powerful as it was possible to make them and still keep within the specifications.

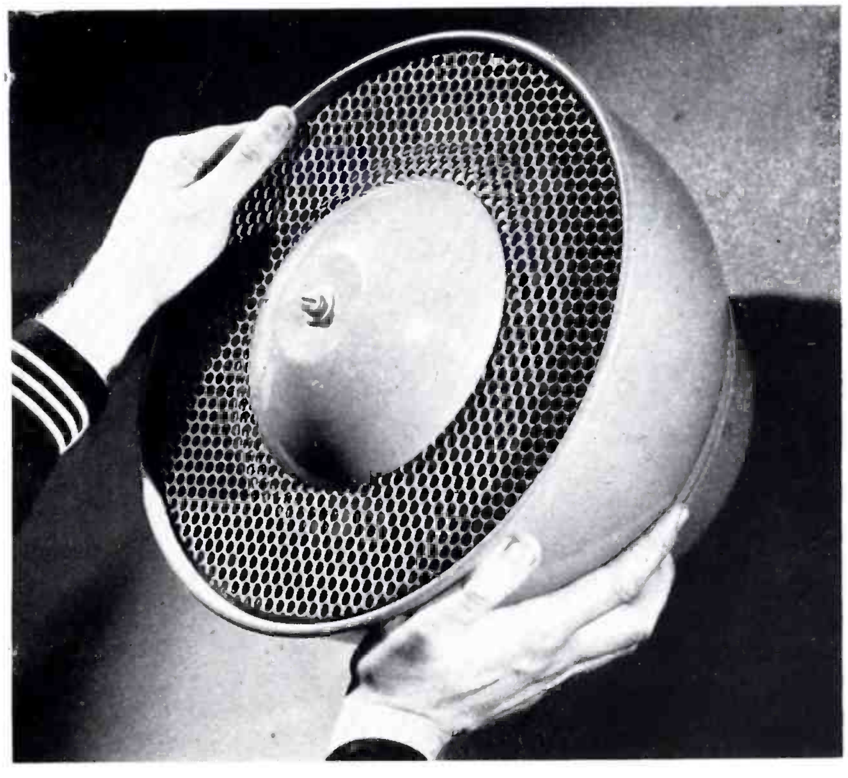
Examples of the results produced by the research facilities of Bell Telephone Laboratories and the manufacturing ability of Western Electric are shown on these pages. To the Navy went the greater proportion of sound equipment, for every combat ship had to have its battle announcing system to control and coordinate its fighting men.

The most spectacular use of such equipment on land was the employment of "Beachmaster" systems on invasion beaches. They provided the Beachmaster with a giant voice and enabled him to guide the vast flow of traffic in to an orderly landing. In psychological warfare, loudspeakers were often more convincing than guns in persuading the hidden enemy to surrender.

These combat announcing systems, which proved so successful during the war, and the lessons learned in designing and producing them, can now be turned into equipment for peacetime use which will be far superior to anything known before.

The Battle Announcing System on the Franklin D. Roosevelt carries orders instantly to every man on board through a total of 639 loudspeakers. Below are amplifier and control panels and one of the speakers. Another Western Electric system, not shown, sends orders and firing signals to the guns.

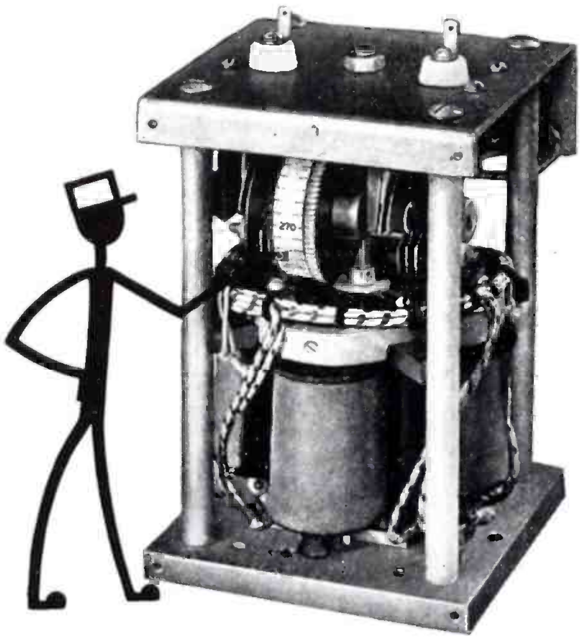




The Frequency Watchman

By R. H. Lindsay

Bell Telephone Laboratories



ORDINARILY there is very little of a striking nature about the workings of a radio transmitter that can be demonstrated to an interested observer, even when it is on the air. To be sure, you can listen to the program, but there is nothing about the transmitter to particularly impress you with the fact that a program is going through it, or even that the transmitter is actually putting out carrier current. These facts are largely matters of inference from meter readings, from the glow of vacuum tubes, or from the quiet hum of a cooling fan.

But there is something more than ordinarily impressive in a demonstration of the constant supervision that the "frequency watchman" of a Western Electric FM transmitter exercises over the carrier frequency. He is a very leisurely fellow or very active, depending upon the amount of work he has to do, and his supervision is no less effective while the carrier is swinging back and forth from 75 kc above the normal value to 75 kc below under the influence of modulation, than it is upon the steady carrier without modulation. It is no great trick to arrange both to watch and to hear him at work, although his movements are quite silent, and normally "behind the scenes." And just as you are wondering because of his apparent inactivity whether he is loafing or actually asleep, you are startled at how he springs into action if he is deliberately given a real job to do.

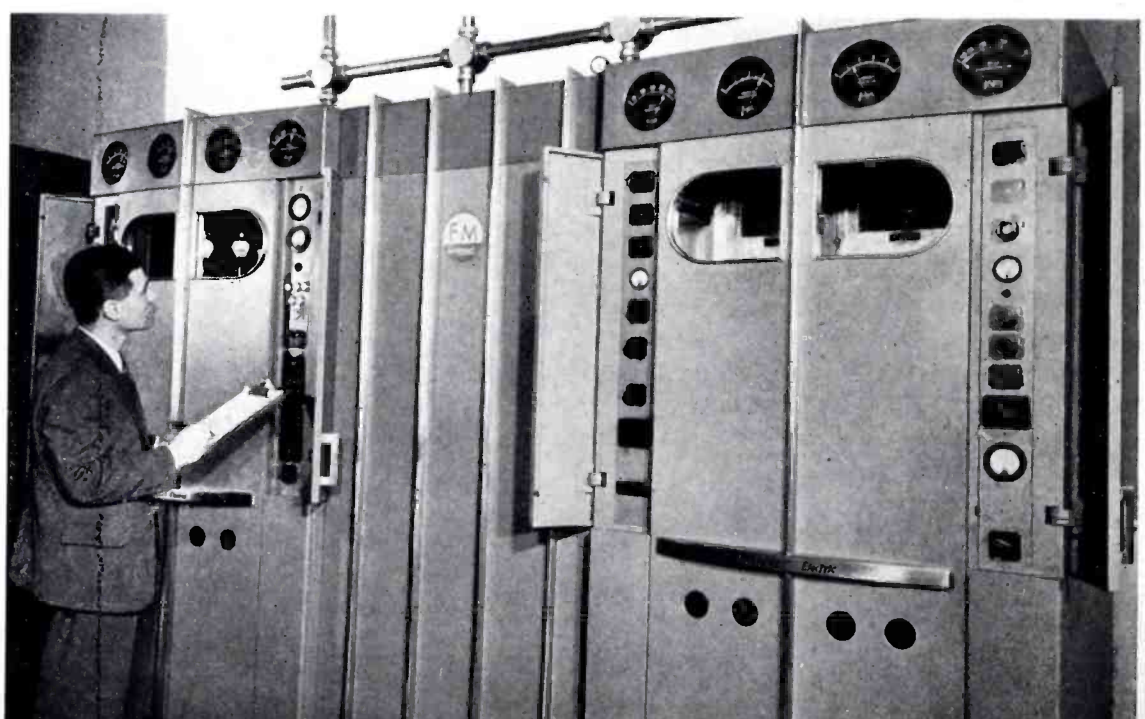
This "frequency watchman" is a small induction motor driving a tuning condenser in the plate circuit of the electric oscillator which generates the carrier frequency, or rather, one-sixteenth of the carrier frequency. This submultiple frequency is doubled four times in following stages, but ahead of these doubler stages a portion of it is fed through a frequency divider circuit which reduces it to 1×2^{-10} or 1/1024 of the frequency generated by the oscillator. This reduced frequency thus falls within the range of 5377 to 6586 cycles for the new carrier frequency range of 88.1 to 107.9 megacycles.

It is the job of our frequency watchman to compare this low frequency with a control frequency generated by a crystal oscillator which is exact with the amazing precision of quartz crystals. For example, at a carrier frequency of 99.3 megacycles, the frequency of the crystal oscillator is 6060.79 cycles. This frequency and that from the transmitter are both fed to the four stator windings of the induction motor in such a manner that if the frequencies are exactly the same no rotating field is produced and the rotor of the motor remains stationary. However, if the frequency of the transmitter differs slightly either high or low, as perhaps it may when the transmitter is started up after an idle period, the field produced by the stator rotates at a rate proportional to the frequency difference and in the proper direction. The rotor of the motor immediately starts to revolve at a proportional speed and changes the capacity of the tuning condenser in the electric oscillator in the proper direction to correct the momentary error. As the process of correction proceeds, the frequency difference becomes smaller, and so also does the speed of the motor until it comes imperceptibly to rest when the error has been eliminated.

So effective is this process of synchronization that the slow drift of frequency to which an electric oscillator is ordinarily subject from several short and long term causes, such as changes of temperature and aging of parts, can never accumulate but is gradually corrected as slowly or rapidly as it occurs. And so slight or so slow is the rotation of the motor required to make such gradual corrections that under normal operating conditions it always appears to the eye to be entirely at rest.

Frequency Watchman in Action

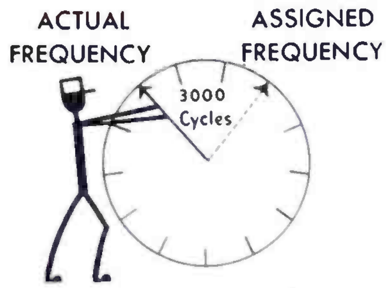
But, to return to our demonstration of how lively the watchman can be if thoroughly aroused, let us open the front door of the transmitter and remove the cover from the motor so that the armature is visible. So that our ears as well as our eyes can follow what is happening, we shall couple a heterodyne frequency meter loosely to the output of the oscillator-modulator unit by means of a single insulated wire. The frequency at this point is one-eighth of the carrier frequency, or twice that of the master oscillator. With the oscillator-modulator and frequency control mechanism operating (these functions not being



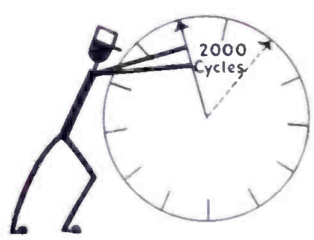
Synchronized frequency control is a feature found only in Western Electric's FM transmitters. This is the 10 KW transmitter, which consists of a high and low power supply and control unit (left); a 10 KW power amplifier (center); a one KW driver and synchronized frequency control unit (right).

How the Frequency Watchman Works

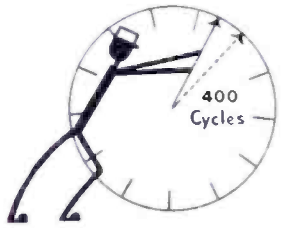
With the ***Frequency Watchman*** **on guard, stability of the Western Electric Synchro-*nized* FM transmitter is governed by the stability of the low frequency crystal, which varies less than 25 cycles per *million* for an ambient temperature range from 40° to 130° F. To demonstrate this split-second control, let's take an extreme case with a far greater deviation than would occur when the transmitter is on the air.**



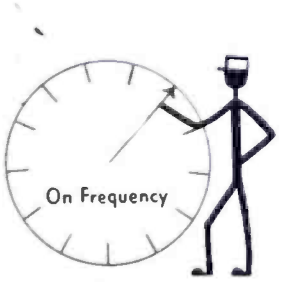
ZERO HOUR: *Starting up after a shutdown, transmitter may be 3000 cycles above or below assigned frequency.* ***Frequency Watchman*** *goes to work.*



ZERO PLUS 6/10 OF A SECOND: *The* ***Watchman*** *—in the fraction of a second —has reduced deviation to 2000 cycles.*



ZERO PLUS 3 SECONDS: Frequency Watchman *has now brought actual frequency to within 400 cycles of assigned frequency.*



ZERO PLUS 6 SECONDS: *Transmitter is on its assigned frequency and the* **Watchman** *will hold it there.*

disabled when the doors are open), the frequency meter is tuned to the desired frequency, fc/8, by adjusting its frequency until the beat note audible in the ear phones is reduced to zero. Then let us give the control for the oscillator tuning condenser a sudden twist, thus deliberately throwing in a frequency error of perhaps 10,000 cycles at the oscillator and 20,000 cycles where we are picking up our sample frequency. With a sharp "tweet" the audible beat passes up beyond the limit of audibility. At the same instant the motor has started to spin, fast enough this time so that we can also detect the slow movement of the tuning condenser plates which it drives through a worm and gear. And now the beat tone in the head phones is down again within audibility and rapidly drifting lower; and we observe the motor undergoing a corresponding reduction in speed. In another second or two the motor has lost all visible motion as the tone has fluttered out below audible frequency, and the transmitter is back on frequency again. The whole procedure has consumed only several seconds, the exact interval depending on how great a frequency error we introduced when we twisted the tuning condenser control.

The error of 10,000 cycles arbitrarily introduced for the purposes of the demonstration is many times greater than any which could occur except as a possible trouble condition. Yet it is still small as compared with that which the motor is capable of handling. A 10,000-cycle change at the electric oscillator corresponds roughly to a 10-cycle change at the motor, whereas the motor is well able to take care of 50 cycles per second or more.

But the question will now naturally arise: It is all very well to speak of the motor responding to a difference of a small fraction of a cycle between the frequency of the crystal oscillator and the corresponding reduced frequency from the transmitter, but what happens when this latter frequency is jumping up and down under modulation? The answer is that the motor is a practically perfect device for averaging such variations and responding only to the *mean* frequency from the transmitter. Let us see what happens. With the full 75 kc swing at 100% modulation, the corresponding swing at the reduced frequency applied to the motor will be 75000 x 2^{-14} or 7500/16384, which is equal to about 4.6 cycles per second. It must be borne in mind, however, that this frequency change takes place at a voice frequency rate. If it is a 400-cycle tone which is modulating the transmitter, the frequency difference at the motor will be changing from plus to minus 4.6 cycles and back 400 times a second. The inertia of

The Western Electric one kilowatt FM transmitter.

the rotor of the motor is far too great, even if the modulating frequency were as low as 50 cycles, to respond noticeably to such a rapidly oscillating torque. If, however, the modulation process were not symmetrical, so that the positive frequency swing were greater than the negative, then the *average* frequency would be higher with modulation than without it and the motor would definitely respond, attempting to adjust to some unsteady higher average frequency during program modulation, and returning to the normal position in the absence of modulation. On the contrary, the fact that the motor does in reality stand still during modulation demonstrates the symmetrical nature of that process in Western Electric FM transmitters.

No Need for Temperature Control

It will be seen that the accurate work of the frequency watchman causes the frequency stability of the transmitter to depend entirely on that of the low frequency crystal. This crystal is an X-cut duplex structure, and its range of frequency variation with temperature is less than 25 cycles per million for an ambient temperature range from 40° to 130° F. Thus, the range of frequency variation of a 6000-cycle crystal for the above temperature range would cover less than 0.15 cycle. Since the transmitter frequency is 2^{14} or 16384 times the crystal frequency, the transmitter frequency variation would cover a range of less than 2456 cycles. When it is remembered that the requirement of the Federal Communications Commission permits 4000 cycles (± 2000 cycles) it becomes evident why temperature control is not provided for the crystal. It is not needed.

With the resumption of delivery of Western Electric FM transmitters, many new owners will surely join those who already find great satisfaction in the alert frequency watchman.

"Experiences I Won't Forget"

Adventures of R. Morris Pierce during his assignments overseas by the Office of War Information

THIS is the story of two oustanding achievements that may serve as examples of the superb war jobs broadcasting engineers and radiomen have done at the world's battlefronts. It is also the story of a man and a transmitter. It begins on a night in August, 1943. . . .

It was 3:00 a.m. — one of those hot nights common in the Mediterranean. The Allied radio in North Africa had just gone off the air, and the time had arrived to try to put a brilliant idea to the test. The immediate job involved was the retuning of, and running measurements on, an old Western Electric 50 kw broadcast transmitter to modify it from 1226 kc to the Internation Distress frequency of 500 kc. Unfortunately the engineer and his two assistants, both Army officers, had not very precise tools to gauge the work; and even if it could be done, it seemed then a slim chance that the whole scheme would come to anything. In the first place the project had to be carried out in secret from sign-off to sign-on. Again none of the proper components for that frequency were available and it would have taken months to have them shipped over. Finally, the crew working on the job could not be taken into the engineer's confidence as to the purpose of the undertaking. Thus, it was not until 5:00 p.m. Middle East Time, 14 hours later, that the job was finished, and then the real test was yet to be made — the test that would determine whether the hunch had been a good one!

Now let us skip a few weeks.

In the early part of September 1943, a few weeks after this job on the transmitter, R. Morris Pierce, chief engineer of the Psychological Warfare Branch Radio Section attached to Allied Forces Headquarters in the Mediterranean, was waiting at Port Leauty to return home, when he heard that the Italian Fleet had steamed peacefully into Malta, and thus a great experiment — one of the best known radio feats of this war — had been successful.

There is a connection between these two events that adds up to a story of real ingenuity and goes back a long way to an afternoon of November 1942. Morris Pierce told it to me one afternoon not long ago. He is a modest man and it was not easy to pry out his own part in the big show "toward which," to put it in his own words, "all of us contributed and which none of us could possibly have done alone."

By R. Morris Pierce

Vice President and Chief Engineer
WGAR Broadcasting Co.

as told to George de Mare

"I was sitting in my office one day," Morrie said, "when the phone rang and Jim Weldon, OWI chief of Bureau of Communications Facilities, was on the wire from Washington.

Transmitters Are Lost

"How about going overseas, Morrie, to install a transmitter for us?" he said. That was the beginning. "My impression was," Morrie went on, "that the transmitter was to be set up in England, but in the early part of February 1943, we were dumped in Algiers after being flown by way of British Guinea and waiting two days on the Gold Coast. I remember it was about 4:30 in the evening when Paul Von Kunits of WINS and I arrived — hot! Paul also had a 50 kw transmitter to install. We spent three weeks trying to locate our transmitters. They had apparently been transshipped; some of the components were missing and some had rusted from the effect of salt spray on shipboard. Before leaving New York, I had dropped in at WABC to look over any drawings of the transmitter they might still have kept (it was one of their early Western Electric 50 kw models) and to find out any peculiarities it might have in operation. But we were completely unprepared for the job of setting them up. We finally found a farmhouse in the Algiers countryside that was suitable and took over the first floor in which to install the equipment. The antenna was another problem. It was supposed to be hidden. We finally located it in a swamp a mile from the transmitter — probably, though I wouldn't swear to this, the longest transmission line in medium wave broadcasting. There were lots of conduit to be laid in this job and very little help. We had to build our own cooling system and finally we got British construction engineers to come in and help. They helped us build the transmission line also.

"I was supposed to install a directional antenna at my transmitter but the towers didn't arrive until a month before I was ready to return to the States so we used a barrage balloon to support the antenna. Later Larry Stinson of KVOO completed the directional antenna and adjusted it so as to provide an effective signal of 250 kw towards France. However, we took to the air with the 'Voice of the United Nations' on June 12th. This is the station which had most to do with the story in which you are interested," Morrie said, "and it was the one I had come over for, but before returning to its part in that experiment, and the experiment itself, I might mention two other jobs that intervened. . . . One thing led to another and in July Captain Ellis of WFAA went to Tunis. There, a 120 kw station built by the French in 1939 had been damaged and dismantled by the Germans. It was an important station. The Germans had its 550-foot antenna completely dismantled because it had been a hazard to their air operations at the nearby flying field. Every part was unbolted and there were no blueprints available to show how the parts fitted together, so it was no wonder that the French had given up the station as hopeless. However, it was important to us as the most powerful station we could get at the time. I went to General Merlin, the French Chief Signal Officer at Algiers, and asked him for permission to try to put it in operation. 'It would take about a year to get that station together again,' he said, 'if it could ever be done before the war ends.' We can do it in two months, I told him, although I wasn't any too confident myself. 'If you can restore the station in two months,' he said, 'you are welcome to it.'

"We did it in nine weeks . . . and it was some job. Captain Ellis scouted around and found the Italian contractors who had originally put the antenna up for the French. The Germans had come in and hired them to take it down. We went to the Italian firm and asked them if they could put it up again. They could. Those men were perhaps the only people in the world who could put that antenna up, fitting piece to piece, bolts and all, without blueprints. That station became the most important one in North Africa. It was so badly destroyed that we had to rebuild about 50% of it."

Morrie leaned back remembering.

"Two of those jobs stand out in my memory," he said. "One was the first bombing of Rome. . . . You recall how much talk there was about the advisability of bombing the Holy City. . . . It was feared public opinion would not take kindly to the necessary job. Thus, we had to soften the blow and yet see that it was effective. We broadcast a warning to the citizens of Rome. We told them our bombers would hit only military targets. . . . We told them to take cover. . . . It was the best that could be done, and as you know there was very little reaction. . . .

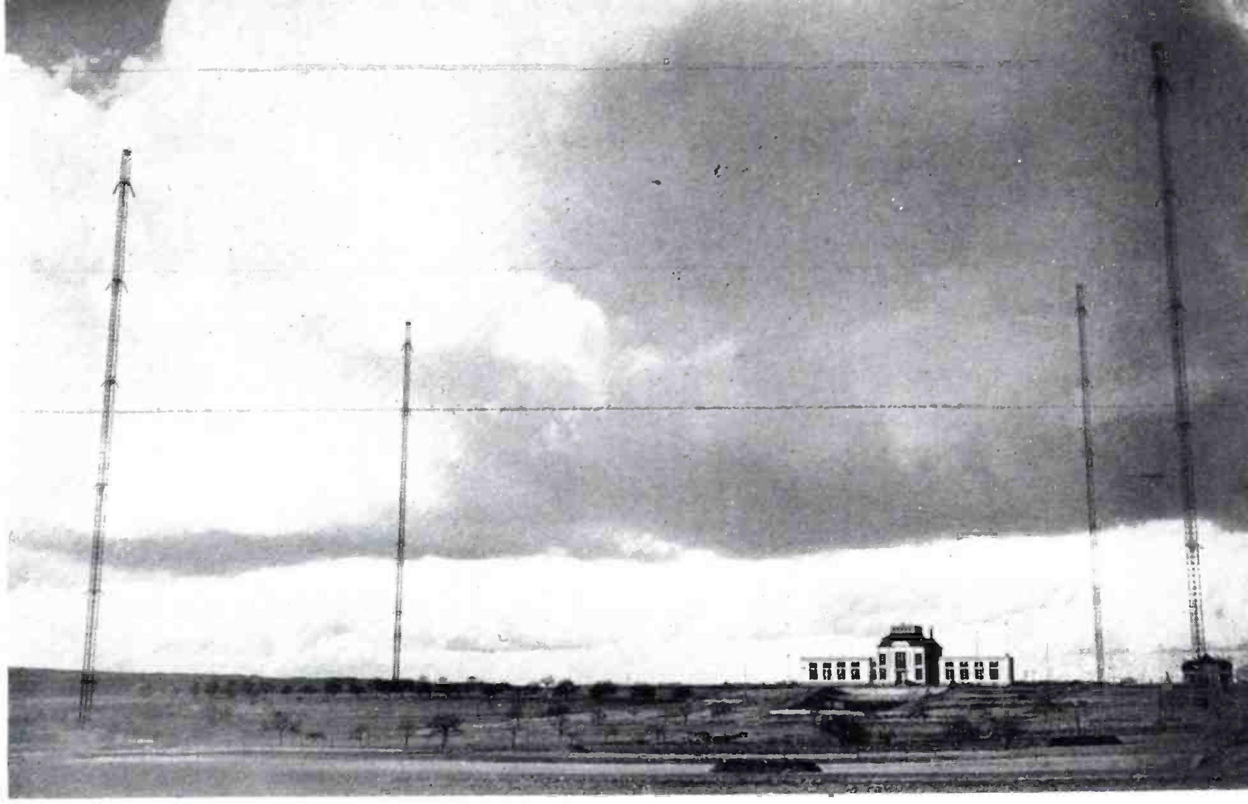
Preparation for Invasion

"Another interesting job was the broadcast preparing for the Sicily invasion in August 1943. . . . We knew about the invasion several days before, but naturally I could not tell my staff. . . . However, I called my technical men together about midnight and told them to stand by for important broadcasts sometime early that morning. . . . I knew that we probably wouldn't get much of an audience at 5:00 in the morning on our frequency. . . . So I worked up a little plan. At 5:00 a.m. we came in, but on Radio Rome's frequency and broadcast an hour's propaganda . . . then we went back to our own frequency. It worked pretty well. We got our barrage over with good effect as our troops were pouring in. The program staffs for all of our stations had begun to arrive in May — about 20 people. Of course we were in touch with OWI daily by cable. For construction and technical work we had the assistance of about 150 Signal Corps men off and on . . . but the work kept us pretty busy and it was hot and rugged . . ."

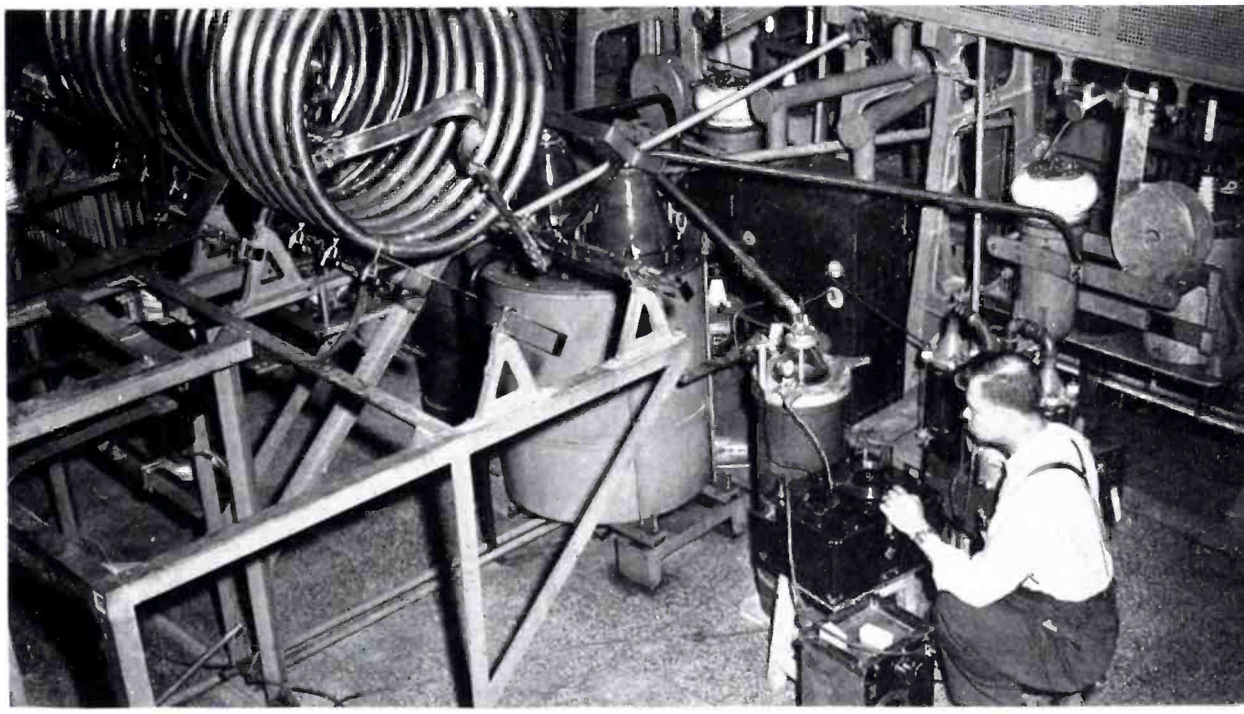
Morrie broke into his own train of thought here.

"This is where the event you wanted to hear about comes in. Plans for the Italian campaign had been going forward in August, when we got a request from the Admiralty to find some means of getting in touch with the Italian Navy which was then at sea. The Allied Navy was anxious that the Italian Fleet not fall into enemy hands, and the Navy instructed us to broadcast surrender terms and instructions which they would prepare to the Italian

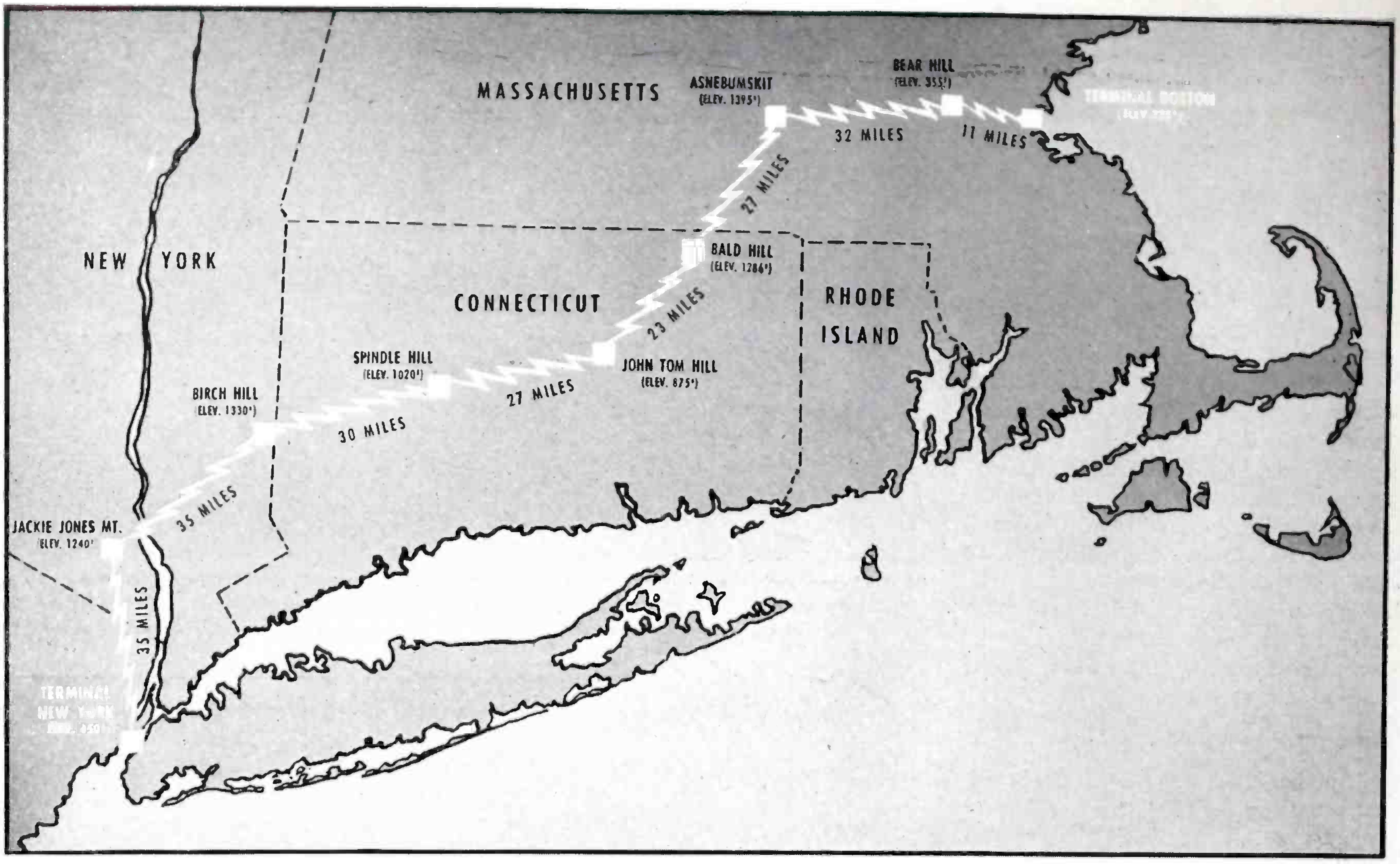
(*Continued on page 38*)



Radio Luxembourg — one of the most powerful broadcasting stations in Europe. Capture of this station by a small armored unit at night was one of war's dramatic feats and much credit for this achievement belongs to Robert Morris Pierce. This picture shows the transmitting station and antenna array towers, 590 feet high.



Above: View of tank circuit of 120 kw transmitter at Tunis — used as part of Psychological Warfare Branch radio transmitter network. Below: The old Western Electric 50 kw transmitter, formerly used by WABC, goes on International Distress Frequency to help capture Italian Fleet. Morris Pierce standing at controls.



May showing locations and elevations of the seven stations to beam microwaves along A. T. and T.'s experimental radio relay route from New York City to Boston.

Stepping Stones for Voice and Vision

A. T. & T's progress in building the Radio Relay "jump-jump" system — a landmark in communications transmission.

"Jackie Jones Mountain . . . Birch Hill . . . Spindle Hill . . . John Tom Hill . . . Bald Hill . . . Asnebumskit Mountain . . . Bear Hill" — chances are you never heard of these seven hills along the way from New York to Boston. Until recently, they were known best only by the rabbits and wildlife that lived on their slopes, but soon they may well be known as landmarks in communications and television history.

They are the seven hills on which are being built — for the first time on a carefully worked out and comprehensive scale — a radio relay system which will help to determine in practical operation the relative efficiency and economy of microwave radio transmission for sound and television programs and for long distance telephone messages, as compared with wire and coaxial cable methods of transmission. Many engineers feel that this experiment being undertaken by the American Telephone and Telegraph Company through its research organization, Bell Telephone Laboratories, may open a new world in sound and visual communication. This project has a special interest to communications engineers as a plan to handle long distance telephone messages by radio relay over land within the United States.

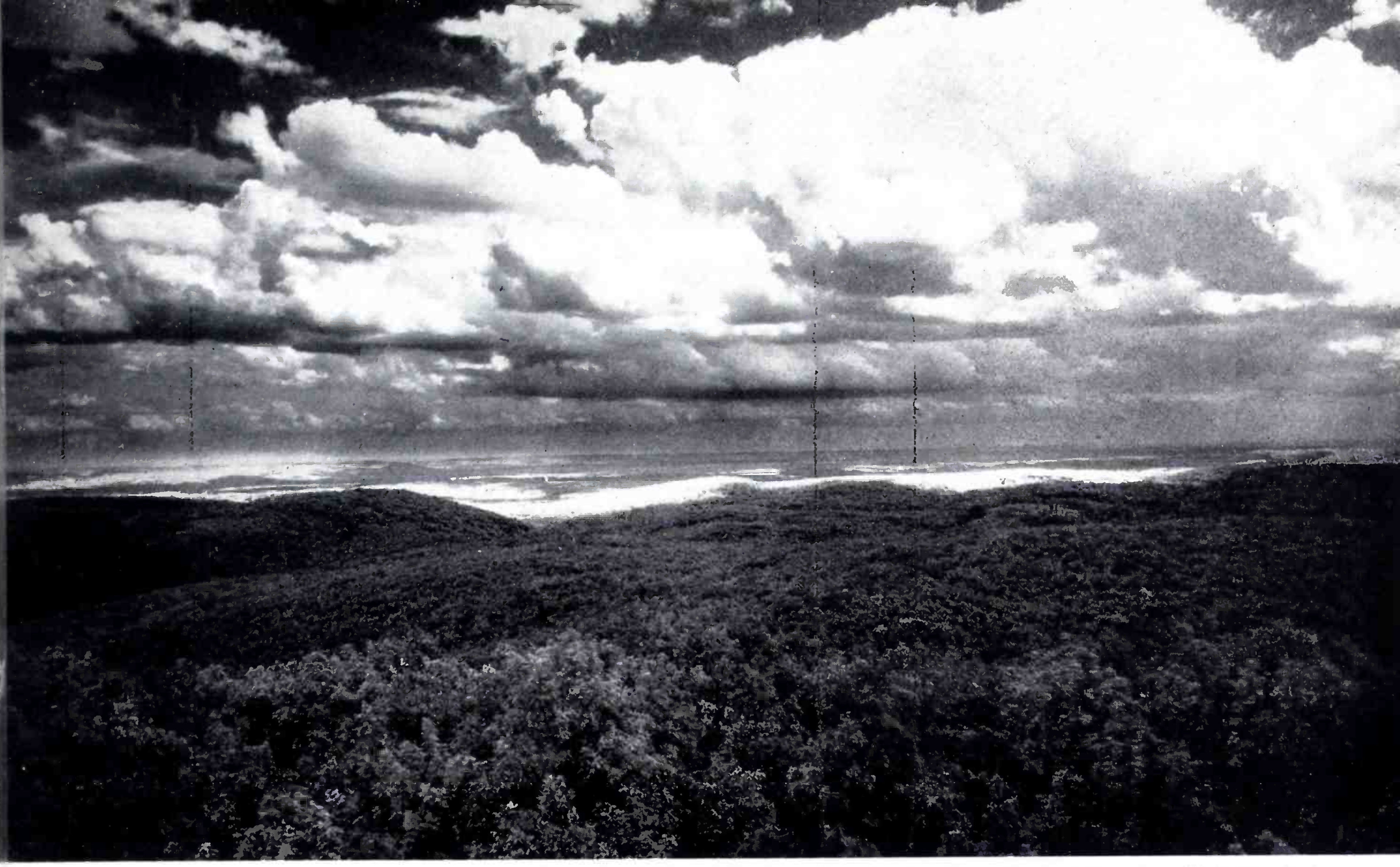
Work on the project actually began back before the war with intensive experiments on microwaves at Bell Laboratories. Its present physical development is an illustration of the problems encountered in trying to make a laboratory dream practical.

The F.C.C. has granted authority to begin construction at the two terminals and seven intermediate radio relay stations as covered in the A.T.&T. Company's applications. Authorization has also been granted to conduct experimental transmissions on eight 20 mc channels in each of the three parts of the radio frequency spectrum — near 2000, 4000, and 12000 mc. It is planned to provide initially a regular and a spare transmission in each direction, using different frequencies in adjacent relay sections. The radiated power that the transmitters will use at the terminals and radio relay points will not exceed 10 watts.

The present 220-mile New York-Boston route is convenient for the experimental trial of microwave radio relay because of its nearness to the Bell Telephone Laboratories in New York and because of the continuing need for additional facilities between these two cities. Also, with coaxial cable already in place between New York and Washington, completion of the radio relay system would provide broad-band transmission facilities all the way from Boston to Washington.

The physical work of building the relay system involves many factors. The first assignment was to make general surveys to find suitable locations for seven towers. For this purpose Mr. C. S. Borthwick of the A.T.&T.'s Long Lines Department was borrowed by the Bell Laboratories together with Mr. Kennedy Pope of the New Eng-

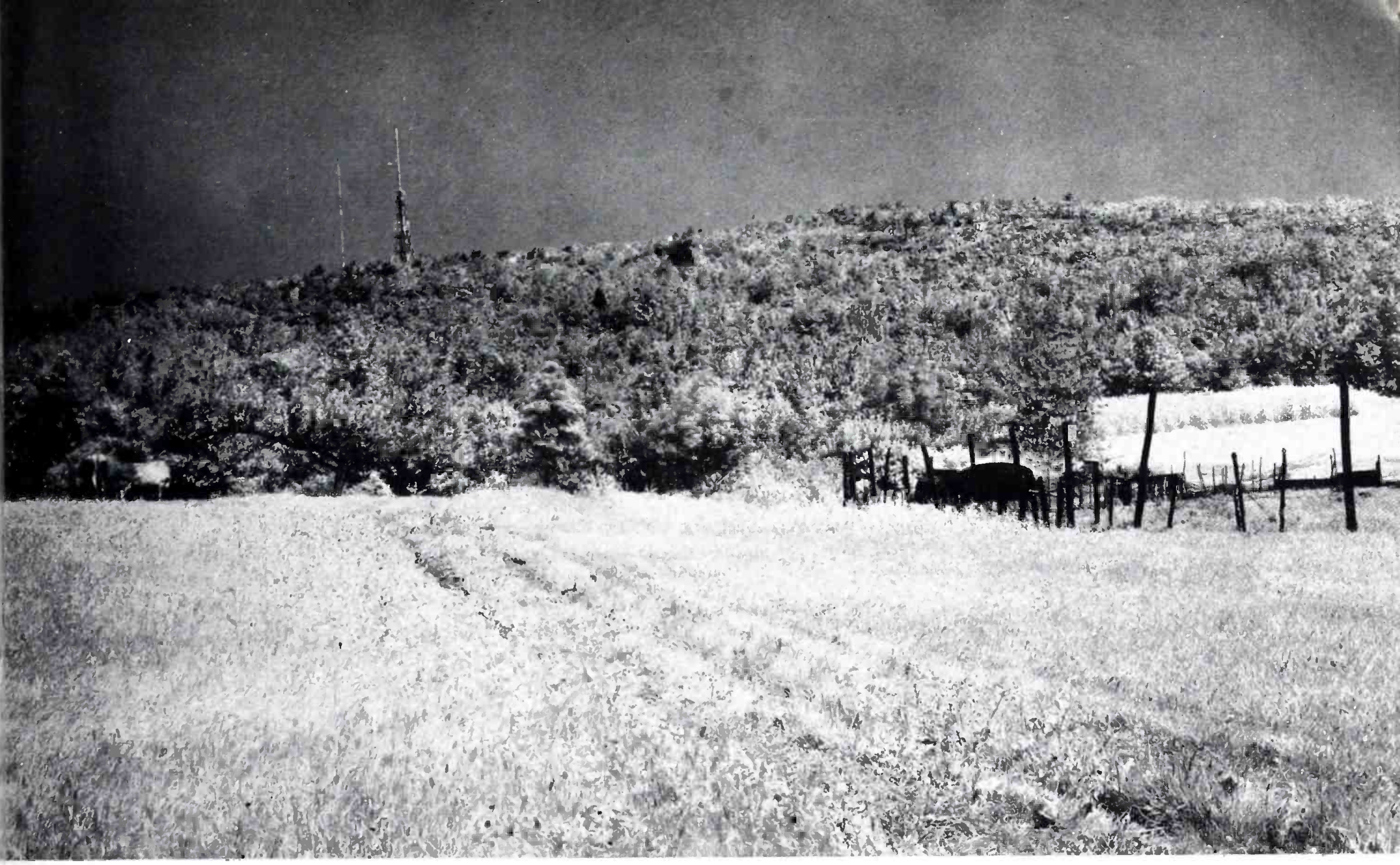
(Continued on page 24)



View looking south from site of first radio relay position of the A. T. and T.'s "jump-jump" line from New York City to Boston. This scene is from summit of Jackie Jones Mountain, six miles northwest of Haverstraw, N. Y. New York City terminal of the system is 35 miles away in right center of photograph.

Surveyors establish a bench mark on a rock on Jackie Jones Mountain, site of first of seven radio relay stations along A. T. and T.'s radio relay system from New York to Boston. This site adjoins Palisades Interstate Park and the tower for this position will be erected about 25 feet from State Park property.

Experimental radio relay antenna tower on Jackie Jones Mountain in position to test beam transmission from Long Lines Building in New York City. Beam will be relayed from here to Birch Hill.



View looking toward summit of Asnebumskit Mountain, site of the A. T. and T.'s sixth radio relay tower. Summit of mountain — elevation 1,395 feet — may be seen right center background. Tower will receive beam from Bald Hill, flash it east to Bear Hill. Antennas of broadcasting station WGTR are at left center.

Scene near summit of Asnebumskit Mountain, sixth of A. T. and T.'s seven radio relay sites from New York to Boston. Hill has been partially cleared by survey crew preliminary to running lines for construction of road to summit. From this position, surveyor is looking southeast toward Worcester, Massachusetts.

Stepping Stones

(Continued from page 20)

land Telephone and Telegraph Company and Mr. J. F. Cannon of the Southern New England Telephone Company. The specifications for these desired locations were severe. The stations had to be situated on hill tops which are within sight of each other directly or with the aid of towers of moderate height. The radio frequencies used by this system do not follow the curvature of the earth but travel substantially straight ahead into space.

Three months were spent in geographical and topographical research — amassing a group of detailed maps of New England covering in area a rough triangle bounded by New York, Albany and Boston. The three men then made a huge wall map, 12 feet by 14 feet, put together from United States topographical maps, which gave a clear picture of this area for study. From painstaking and detailed labor over these maps, approximately 70 sites were finally selected as possibilities for surveying in the field.

Surveying Required Six Months

The surveying was a formidable task and required about six months of intensive field work. In mapping and surveying, the problem was to select two points and plot the profile between them taking into account the curvature of the earth. At the center of a 40-mile path, the earth's curvature rises to 267 feet. Thus this curvature elevation must be added to any other elevations which lie at the center of the path. The sites finaly selected averaged 27.6 miles apart — which gave a rise of about 72 feet in the earth's curvature at the center. The shortest distance between two stations of the sites chosen was 11 miles, the longest 35 miles. A simplified profile map showing the elevations along the relay route between New York and Boston may be seen below.

The Long Lines Building in New York on which the New York terminal radio relay tower is being erected has an elevation of 450 feet above sea level. Sending voice and vision waves, the transmitter at this terminal will shoot its beam 35 miles to Jackie Jones Mountain, elevation 1,240 feet. Jackie Jones Mountain is located six miles northwest of Haverstraw and six miles east of Southfields, N. Y. The tract of land on which the relay tower is to be built is rocky with ledge rock outcropping in places and a very steep rock cliff along the southwest boundary. Medium growth hardwood trees 25 to 35 feet in height cover the area. There is one road in poor condition straggling up to the site.

The relay station on this tract of land when built will receive the beam from New York City and relay it to the next station 34.8 miles away at Birch Hill, elevation 1,330 feet. Birch Hill is located close to the New York-Connecticut state boundary line, four miles east of Patterson, N. Y. Since there was no local name for this hill, it was given the name Birch Hill by the surveyors for purposes of identification. This area also has ledge rock outcroppings, is uneven and covered with medium growth hardwood trees. Only a trail winds up to the summit of this hill.

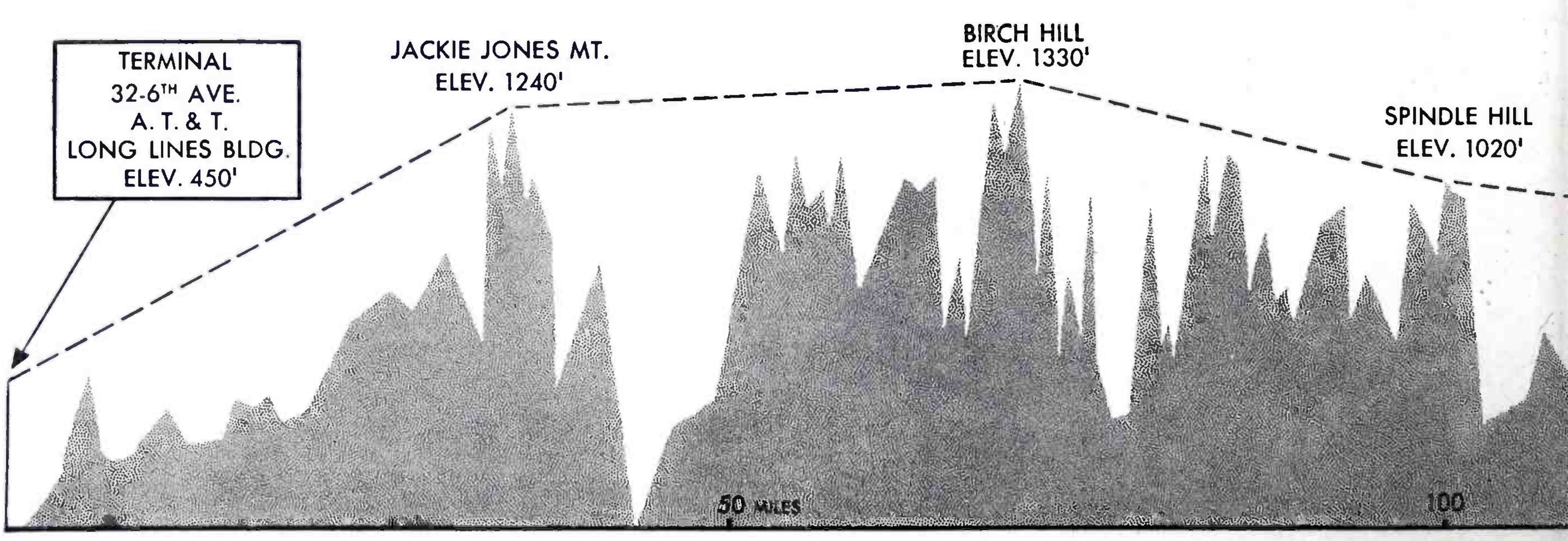
There, the relay station will receive the beam from Jackie Jones Mountain and send it on to the third relay tower site at Spindle Hill, in Connecticut, elevation 1,020 feet, 30 miles away. This hill, located four and one-half miles south of Bristol, Connecticut, is covered with thick small bushes and scattered trees that have been broken down by ice storms. No road leads to its summit.

From the Spindle Hill tower, the beam will flash to John Tom Hill, the fourth tower site, in Connecticut 26.5 miles away, elevation 875 feet. John Tom Hill located seven and one-half miles east of Glastonbury has a narrow dirt and gravel road running north across it past a forest fire observation tower. Other items of interest to engineers who will build the relay tower are: a power line with two-wire bracket telephone line running north along this dirt road.

New York terminal of radio relay system: A. T. and T.'s Long Lines building in downtown section.

From the John Tom Hill tower, the radio relay beam will flash to the fifth tower location on Bald Hill, 23 miles away — elevation 1,286 feet. Bald Hill, also called Ochepetuck, lies near the Connecticut-Massachusetts boundary line, five and one-half miles east of Stafford Springs, Conn. A poor dirt road extends from State Highway 20 to the top of Bald Hill. The area is covered with flat ledge rock outcroppings, some patches of grass and scattered bushes. Nearby along the State Highway power and telephone facilities are available.

From here the beam travels to the sixth and next-to-last relay station which will be atop Asnebumskit Mountain, elevation



Boston terminal of radio relay system: the Bowdoin Square building of New England T. and T. Co.

1,395 feet — 27 miles away. This hill is located in Massachusetts five and one-half miles northwest of Worcester. A U. S. Coast and Geodetic Survey triangulation station is nearby on the summit of the mountain, and to the north and further down is the radio station WGTR of the Yankee Network. Near this site are ample power and telephone facilities.

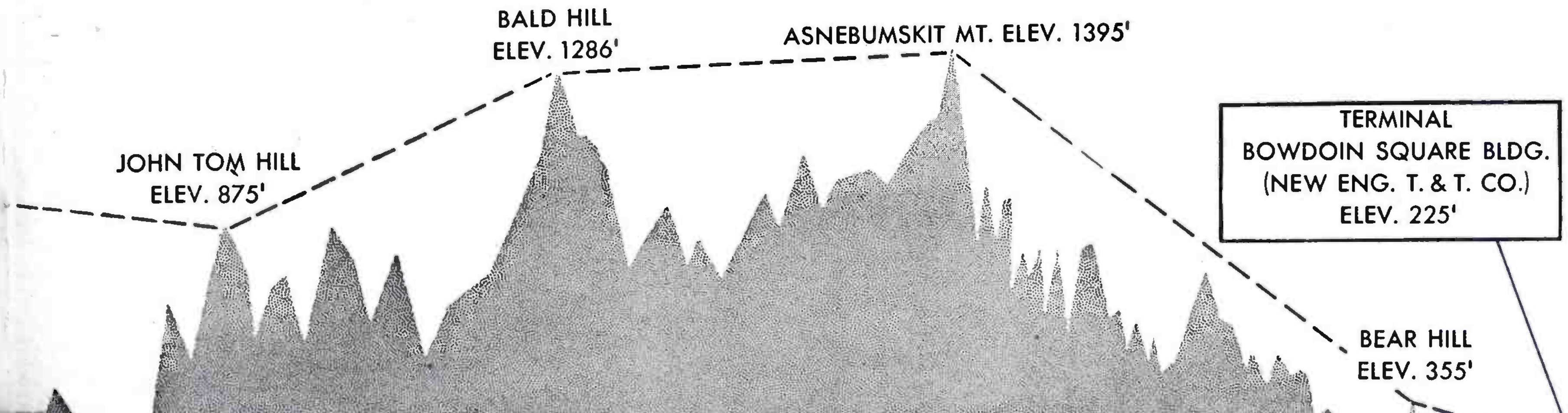
From Asnebumskit Mountain, the beam will be flashed to the seventh and last relay tower 32 miles away on Bear Hill, elevation 355 feet, one mile west of Waltham, Mass. Bear Hill has a gentle slope on the north and northeast sides and a steep decline on the south and southeast sides. The tract of 28 acres which has been selected for the tower includes all of the high ground of the hill. Main Street runs along the south end of the hill and Bear Hill Road (gravel and dirt) extends along its eastern side.

From the tower to be situated here, the beam will be sped on its final journey to the terminal tower in Boston atop the New England Telephone and Telegraph Company's Bowdoin Square Building — elevation 225 feet.

The next step involves building the roads to the sites and this work will be completed sometime this fall. Meanwhile, there have been certain tests by Bell Laboratories with portable towers to check the propagation of the beam.

A description of the towers and technical facilities must await the outcome of final experiments. The height of these structures will vary with locations, but will run from 50 to 70 feet on this project. A building will be erected at the foot of the tower to house the batteries and other power equipment.

If this experimental system proves as satisfactory as the radio engineers expect, and if this method of transmission is found to be economically feasible, apparatus will be standardized in order that the Bell System may be prepared to install similar systems on other routes throughout the country as the need develops.



Ingenious Test Sets Broke Mica Bottleneck

As a result of Bell Laboratories research during the war, the supply of mica suitable for use in capacitors has been increased by 60 per cent. For the better grades of capacitors, mica must be free from defects such as cracks and conducting spots, have very low dielectric loss, and must be able to undergo wide temperature cycles with only minor changes in electrical characteristics — and these changes must always be the same.

To be sure of satisfactory results only the better grades of ruby muscovite micas, imported from India, were formerly used in high quality capacitors and much of that was rejected as unusable.

Acceptance or rejection of each slab of block mica was based on a visual examination by inspectors. Mechanical defects such as cracks or foreign matter can be determined by eye. The real problem was how to determine the dielectric loss of the mica under the influence of the alternating voltages it would encounter in service.

When the mica shortage threatened to become acute, the War Production Board appealed to Bell Telephone Laboratories to devise a method of testing and classifying mica to give more positive results — a method that, while assuring that no defective mica could get into finished capacitors, would also insure that no good mica of any type was rejected. Such a procedure would not only increase the usable amount of imported ruby muscovite mica, but would also make available the large deposits of mica found in the United States, South America and Canada.

The Laboratories undertook an investigation which culminated in the design of two test sets; one to detect conducting regions in mica and the other to measure the dielectric loss of raw mica in block form. With the first set only a few seconds are required for each test. With the set designed to measure dielectric loss the time for testing a sample of block mica was cut from the 15 minutes formerly required to four seconds for each test. The operator merely inserts a sheet of mica between two contact plates, adjusts the control knob, and then reads the result on a voltmeter atop the set.

As proof of the value of the new test sets, a quantity of mica previously discarded as unusable was tested and approved, and was successfuly used to manufacture 40,000 capacitors.

THE FIELD ENGINEER

Industry's Battle-Tried Specialist

By Hollister Sturges, Jr.

BEHIND radar's outstanding contribution to World War II is the story of the field engineer, a little known industrial soldier who was as much the secret of radar's success as was radar itself the secret of many of our greatest victories.

The story of these unique war engineers — Industry's representatives in practically all of the world's battle areas — is a colorful one. These men served almost everywhere on earth that American troops served. They were stationed in 38 states of the Union and in war theatres in 34 foreign countries from Berlin to Tokyo. In many cases they saw action themselves — sharing with the G.I. or Bluejacket bombing attacks from the enemy and braving the dangers incidental to forward movements of the greatest fighting force the world has ever known. The capitals of the Axis and the occupied nations found them present within hours or days after their capitulation. Their color and contribution, however, can best be understood by other engineers because they carried the resources of the research laboratory and the manufacturer straight to the point of application against the enemy. And they have come back and told us what they have learned.

In the case of the Western Electric Company Field Engineering Force, it is of interest to go back to 1941 when Commander (now Commodore) J. B. Dow, of the Navy's Bureau of Ships, as early as June of that year, inquired as to whether this Company would consider supplying the services of a dozen specially trained engineers to render advisory engineering services to the Navy in connection with the installation, testing, maintenance and operation of radar and other electronic equipment supplied by Western Electric. These men were to furnish the industrial know-how to further the usefulness and effectiveness of this new and relatively untried scientific weapon of war. Thus the Western Electric Company's Field Engineering Force traces its formation to the urgent need of trained men to assist in the introduction and operation of the war's most intricate electronic devices, and in September 1941 this organization was born.

• • Little known to the general public, the field engineer — Industry's representative on the battlefields of the world — played a vital and dramatic role in "carrying the resources of the research laboratory and the manufacturer straight to the point of application against the enemy." • •

Its growth and performance made a significant chapter in the history of modern war. From a humble beginning, the force of 602 engineers served more than 150 Navy yards and Army bases, and were assigned to the Army Air Forces; the Bureau of Aeronautics; the Bureau of Ordnance; Marine Corps; Signal Corps; Ground Forces of the Army; the British Branch of the Radiation Laboratory, Office of Scientific Research and Development; the Aircraft Radio Laboratory of the Air Technical Service Command, and through lend-lease to the air forces and navies of Great Britain and Australia.

Traveled Twelve Million Miles

In performance of these assignments, Western Electric field engineers have traveled nearly 12,000,000 miles, worked 2,500,000 man hours and fulfilled 150,000 missions, and this Field Engineering Force was the largest of its kind in the field of electronics. One engineer — and his case was not unusual — traveled 62,000 miles during his assignment using as conveyances a gig, a whale boat, truck, jeep, duck, LCVP, B-26 bomber, C-47 transport, garbage wagon, alligator, destroyer, tanker, flying fortress, C-54, breeches buoy and a minesweeper.

The story of the field engineer is a thousand stories, but before telling some of them, it might be well to understand what kind of man the field engineer is, where he came from and what type of experience he possessed.

A field engineer occupies much the same position when attached to a fighting force as the war correspondent. He wears a uniform corresponding to the branch of service to which he is accredited and is accorded all the privileges due an officer. Men with the Navy or Marine Corps wore the uniform of the branch they served, with an insignia on the left breast displaying a spread eagle clutching an olive branch and tools, and the identification "U. S. Technician" embroidered upon it. Those with the Army Air Forces wore circular shoulder patches with "U. S. Tech Rep." embroidered upon them with propeller and wings in the center, while Army Ground Forces

Western Electric field engineers, attached to the Army Air Forces on Saipan, read headlines they helped create. These men prepared the radar program for first B-29 raid on Tokyo, Thanksgiving Day 1944. They are, l. to r. Harold A. DuChene, John Kreisheimer, Stanley M. Goard, Karl E. Zint, and Grant E. Makinson.

"Field engineers served almost everywhere on earth that American troops served." On this world map, each dot indicates where one or more Western Electric field engineers were stationed during the war — in 38 states of the U. S. and in 34 foreign countries from Berlin to Tokyo. One dot may represent field engineers attached to one or more of six branches of the Armed Forces: Navy Bureau of Ships, of Ordnance and of Aeronautics, Marine Corps; Army Air and Ground Forces.

wore an insignia consisting of a black square patch with "U S" in relief upon a white triangle.

A composite of the typical Western Electric field engineer may tell something more important about him. He was a mature, highly-trained, highly-skilled man, able to get along with all kinds of people under even the most harrowing of circumstances. Generally, he was married, had a family, averaged 35 years of age, had completed a college or technical school education or the equivalent, possessed an agreeable personality, had worked in an industry close to electronics or had a hobby of amateur radio, and, in most cases, left a good job voluntarily to devote his technical ability to the war effort.

As may be imagined, securing acceptable men with these characteristics was a difficult problem. Manpower demands by the Military and industry caused a unique recruiting program to be effected. A special recruiting force of engineers was established and its members soon became affectionately known as "bird dogs", for indeed this title was well earned as they traveled about the land over 700,000 miles in quest of talent, combing through over 15,000 names, interviewing 5,030 prospects, and accepting over 600 men who worked with the Force at one time or another. They were recruited from 38 states, and the District of Columbia of our country, Canada, and the British West Indies. By far the largest proportion of them were contributed by the Radio industry which furnished approximately 30 per cent of those selected; 20 per cent came from the Bell Telephone System, including 14 engineers from Bell Telephone Laboratories, 8 per cent from manufacturing industries, 5 per cent from the educational field, 4 per cent from the motion picture industry, 2 per cent from the power industry, and the balance of 31 per cent from nearly 200 miscellaneous vocations.

Many Were Former Hams

It is interesting to note that 163 had amateur call letters. One such former ham was assigned to an air squadron being formed by a high-ranking air force officer for a particularly important mission in the South Pacific. This squadron had been carefully chosen and trained for its assignment. The route to the main base in the Pacific was to be reached by a series of long, island-hopping flights. In the lead plane, with the commanding officer, was a field engineer. On the last lap of this crucial flight, the radio operator became critically ill and was unable to operate his equipment. The plane, low on fuel, became lost and overshot its destination. The field engineer took over and quickly put the radio equipment into operation, determined the plane's bearings by radio from other American planes in the area, and directed the plane back to its course so that the pilot was finally able to bring it down safely with only a few gallons of gasoline left.

When an engineer joined the Company, he was placed in a special radar school where he was first introduced to the principles of this new art. Although most engineers had been well trained in conventional radio, generally the change in concepts required between the low frequencies to which they had been accustomed and the high frequencies used in radar was so great that, at first, it seemed an entirely new subject. They were in a realm where copper — a good conductor — often acts like an insulator and polystyrene — a good dielectric — frequently acts like a conductor. As they became acclimated, however, they were prepared for the introduction to the various systems with which they would work. The length of courses depended upon the types of radar to be studied.

The engineer's initial assignment was a domestic one and here he learned the practical side of working with equipment under the guidance of experienced fellow-engineers. From this he was able to project his own talents and the results of his experience to the members of the Armed Forces with whom he would be later working. His own training, however, never ended. As major changes in design or new equipments were developed, the engineer returned to the classroom and laboratory for advanced training to keep abreast of these changes.

Battlefront Assignment

Within the year, the engineer was likely to be given his first overseas assignment to which he could bring the latest information on equipment being developed and manufactured for that particular location. Thus a Field Engineer was made.

It may be added here that it was found the training given was a tremendous asset to the engineer and to the command he was to serve, for, in most cases, the officers and men were not in a position to have learned at first hand all new developments. The very nature of the job required the field engineer to be ever attentive to a wide variety of problems met on assignments involving the supervision of installation and instruction in maintaining and operating the equipment, as well as advisory assistance. His broad experience was sought and relied upon by military personnel in the planning and solution of tactical problems involving the use of the equipment to optimum advantage. Many of these field engineers, because of certain qualities they possessed, became specialists in the matter of training. These extra talents made them extremely valuable in assisting both enlisted men and officers to a finer comprehension of problems of maintenance and performance, and, where required, of installation.

The B-29 program for the air offensive on the Japanese mainland, for example, was provided with field engineers even before the officers who were to direct these telling blows had arrived. Guam, Tinian and Saipan, and later Okinawa, were the bases of 45 engineers attached to the Army Air Forces during these months of offensive warfare. In this theatre, as in Europe against Germany, Western Electric precision bombing radars were introduced by field engineers to the pilots and bombardiers.

Occasionally, field engineers briefed the plane crews before their missions and interrogated them upon their return: a high compliment to the men and an acknowledgment of their value to the officers with whom they were working.

As a result of the creative ability of the engineers and of suggestions by military personnel, modifications or design changes were often recommended to the Force's headquarters. Such problems were turned over to the Bell Telephone Laboratories through an Engineering Department which, working in conjunction with the factories, originated desired changes for improved equipment to meet changing war conditions. It may be noted here that the engineers in the field had at the headquarters office a supporting staff of engineers whose functions were to provide the highly technical engineering information required by the man in the field, to analyze the many technical field reports originated by the field engineers and to act as a link between the Bell Telephone Laboratories, the manufacturing organizations and the field. The accepted recommendations of the field engineers constitute one of the primary contributions of these men who have played so many important parts in a war using electronics on an unprecedented scale.

The stories which follow of field engineers' adventures all over the world may, however, tell more about the scope of their unique usefulness, character and technical ability than any amount of explanation. Sharing the horror of the buzz bomb with Londoners; taking cover behind bags of rice with the Chinese; watching four torpedoes miss a vessel a distance measured in inches in Ulithi Lagoon; finding a piece of shrapnel in one's bunk where one had slept an hour before — these men have had a full share of war's hardships and dangers.

Two engineers flying from Calcutta to Kunming in China, were caught in a down draft while going over the Hump and their plane, dropping 1,800 feet in 30 seconds, fell parallel to the treacherous mountainside visible at 200 yards during the entire drop. The foxholes of the Pacific islands are as familiar to the engineers as to any Marine or G.I. One engineer experienced a total of 129 bombings and strafings, while another encountered 108 in five months.

J. S. Ward, Manager, Western Electric Field Engineering Force and Vice Admiral Wm. L. Calhoun, Comdr. Service Forces in Pacific, at Pearl Harbor.

Field engineers were among the first to record and help make possible the great effectiveness of radar.

One Western Electric engineer was present on the Anzio beachhead of Italy when a new fire-control radar was first used. After its initial night of action, the terrain was found to be strewn with the carcasses of Nazi planes. On the other side of the globe, the fabulous Battleship X (the *USS South Dakota*), through use of radar-controlled anti-aircraft guns, brought down 32 enemy planes in a single engagement. From bases in the China-Burma-India Theatre, bombardiers of the Army Air Forces stepped up sinking of enemy shipping with radar's help to exceed 100,000 tons monthly. Four nights after our forces landed at Leyte, a five-boat U. S. submarine pack intercepted a 27-ship enemy convoy off Manila Bay, and, with the exclusive use of surface search and torpedo-control radar, used all their torpedoes and sank 25 cargo vessels and tankers, left the twenty-sixth in flames, and only the twenty-seventh, a fast destroyer, escaped.

"Six-Inch Machine Guns"

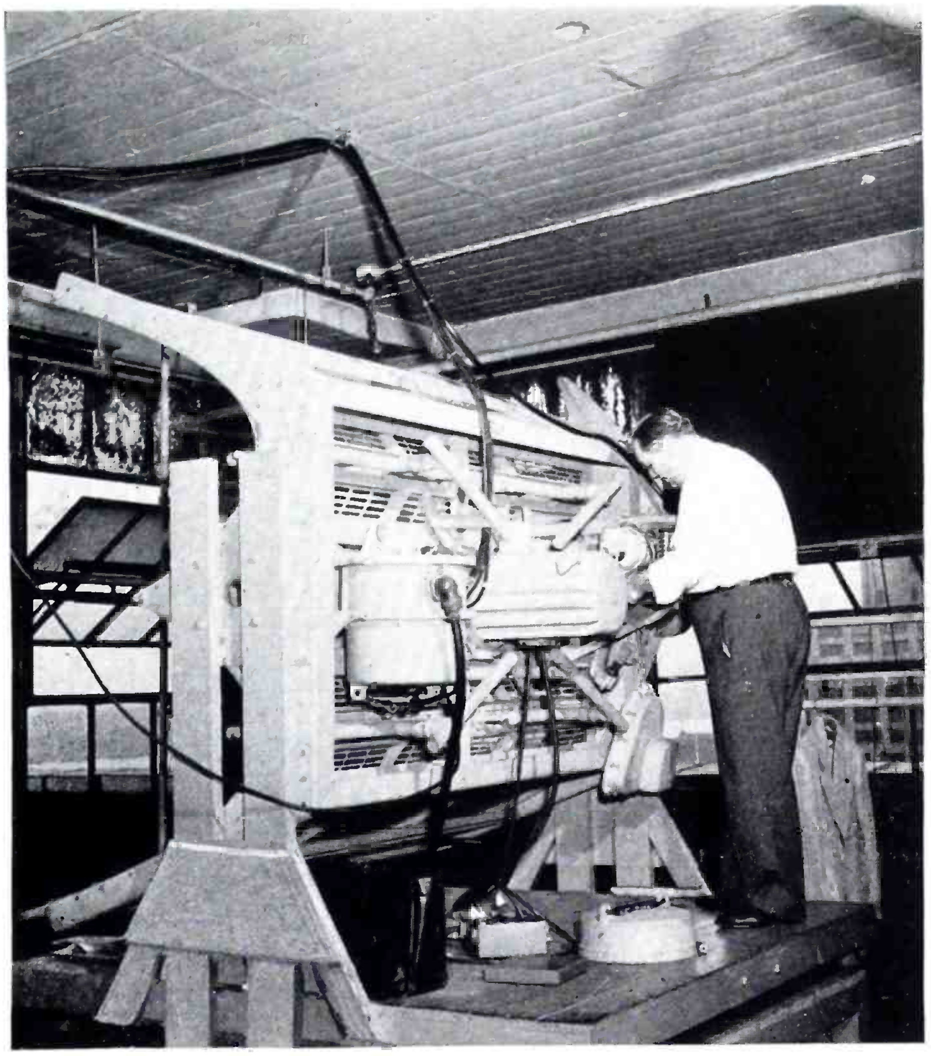
At another time a Japanese Naval officer, when fished out of the water off Guadalcanal after his and a number of other ships had been sunk, immediately asked, "May I see your six-inch machine gun with the electric-eye pointer?" He was referring to the guns carried by our cruisers, which had fired so fast and with such accuracy that he believed them to be some kind of super machine guns.

Engineers attached to the Marine Corps Section, while working with shore-based radar groups of the Corps, closely followed the Leathernecks as they advanced in the forward areas in the Pacific. At Okinawa, one individual landed with the third wave. Behind each of these incidents can be found the hand and skill of the field engineer.

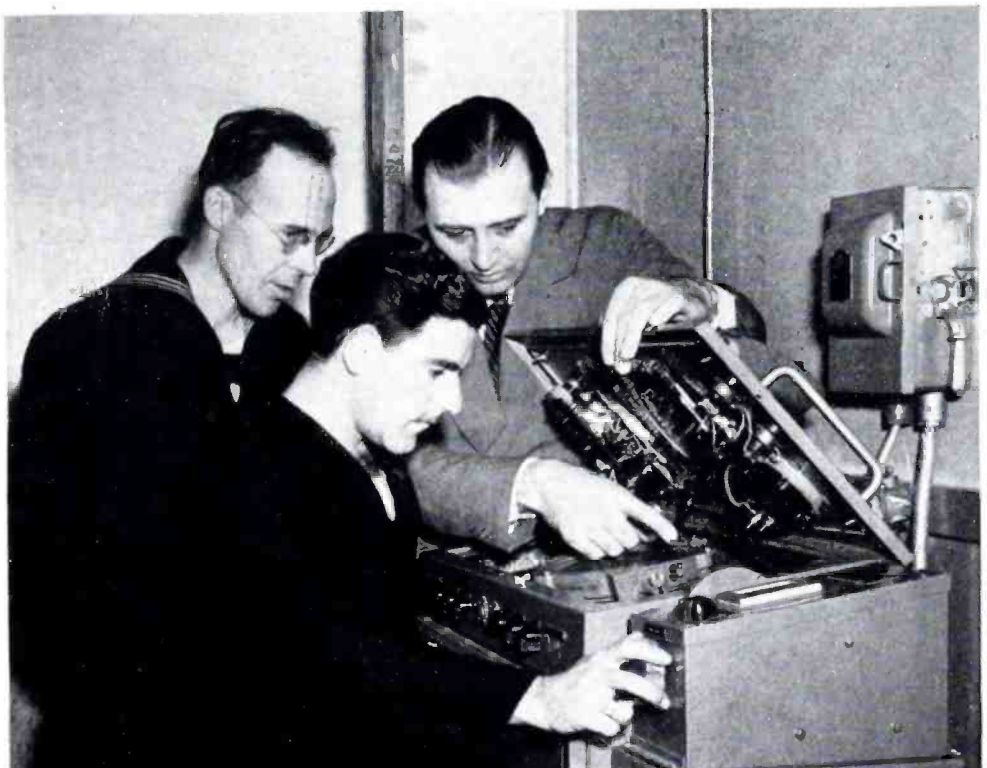
In communications, the work accomplished by engineers with the Army's Signal Corps and Ground Forces in the European Theatre did much to make possible adequate communication traffic between the American Armies as well as those of our Allies. To do this, much equipment was salvaged from existing material of German, French and English manufacture, supplemented by available stocks of Ameri-

(*Continued on page 40*)

Sonar — underwater sound detecting equipment — another secret war weapon handled by field engineers. Above: instruction in sonar.



Field engineer makes adjustment on Mark 12-22 radar antenna. Knowledge and skill of engineers in radar's proper use and care was part of secret of its success.



Instructing Navy radio technicians in intricacies of shipboard radar exemplifies one of field engineer's essential jobs. Here, technicians learn trouble-shooting at Casco Bay.

In answer to a trouble call, Western Electric field engineer is transported by breeches buoy to check radar on a destroyer.

Lifesaver for Superforts

ONE of the great and unexpected revelations of a single radio station's unique achievement to come out of this war is the story of how the Saipan station, known by the call letters KSAI — built by the OWI using a Western Electric 50 kw transmitter — saved 20 of the giant B-29 Superfortresses crippled over Japan and the lives of more than 200 fliers, almost as a sideline to its main and original purpose.

The story goes back to September 1944 when it was decided to put up a station on the north shore of the newly won outpost of Saipan, powerful enough to reach by medium wave the Japanese people. It was to be the first such medium-wave American station of this power in the entire Pacific area and its importance for waging psychological warfare was crucial. In November 1944, therefore, James O. Weldon, Chief of the OWI Bureau of Communications Facilities, and five members of his staff embarked for Saipan to undertake the construction of this major link in America's great overseas network. They started installation on November 20, 1944, and 31 days later on December 21, 1944, after working day and night, assisted by Army engineers, who helped construct the buildings and towers and Signal Corps men, who helped on the receiving antenna and transmission lines, the station was ready for programming. On the day after Christmas 1944, Radio Saipan went on the air.

The station operated on 1010 kc and consisted of four directional antennas which gave a 250 kw effective signal toward Japan, but there was still a question as to whether such a signal could reach the great Japanese population centers clearly and effectively. It was this problem which served to reveal the transmitter's extraordinary usefulness. First, however, two occurrences almost immediately gave some answers to the question concerning the station's effectiveness. Twenty minutes after the Saipan radio went on the air, the Japs began to try to jam it. The next evening after the Saipan radio had gone in on the Tokyo beam, the Tokyo radio advised listeners to turn off their radios, go to bed early and conserve their strength.

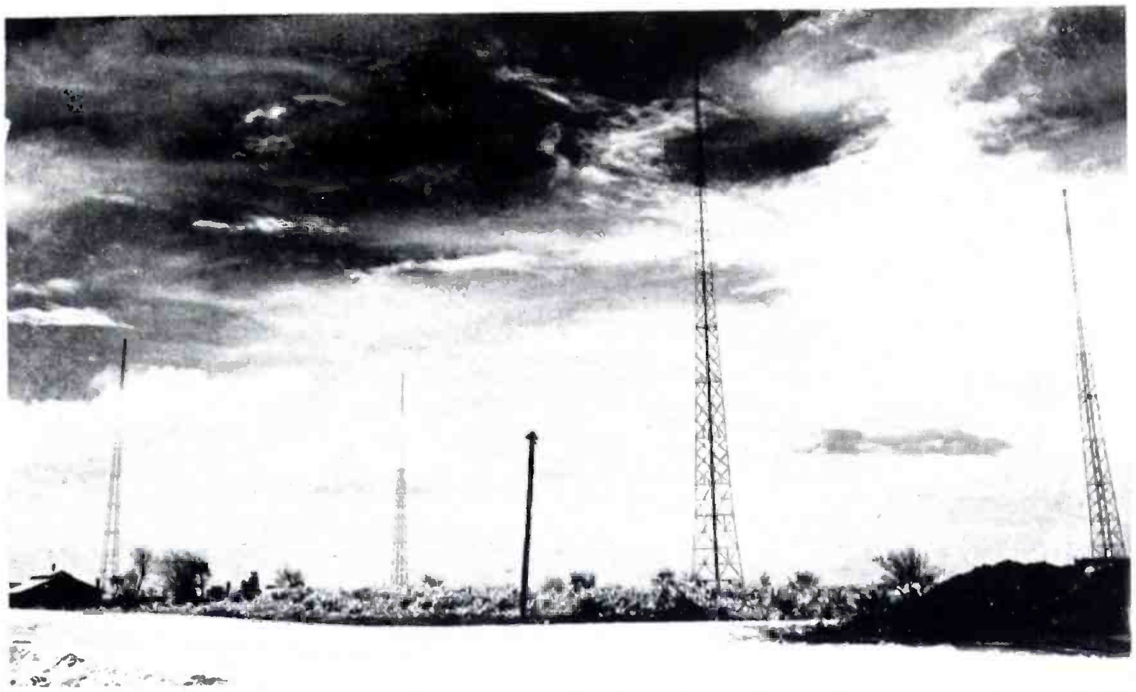
Request from Bomber Command

It was at this point that the OWI engineers received a request from the B-29 bomber command station on Saipan suggesting that the transmitter be left on 24 hours a day for four days as a trial so that the bombers themselves could check the signal over Japan.

Two days later an urgent order was received: "Keep that transmitter on 24 hours a day permanently from now on!" Gradually the story came out. A crippled plane, hopelessly lost, its navigating equipment smashed, had been able to pick up the Saipan transmitter signal so clearly that by using its radio compass it was able to ride in on the beam to its base. Some weeks later, the high point of this 'round the clock broadcasting to 'round the clock bombers was reached when four B-29's were saved in one week solely by following this beam. Within four months the station had been credited with saving more than 20 Superforts in this manner, and even when all other signals failed, the Saipan transmitter, according to reports, continued to come through clear as a bell. So important was the station considered that it was allowed only six hours per month off the air for maintenance and repair.

The station had been rebroadcasting OWI psychological warfare material relayed from a station, KRHO, especially constructed for this purpose in Hawaii, and it operated from 6:00 P. M. to midnight Japanese time skywave coverage. To keep on the air during the day for aerial navigation in accordance with the Bomber Command's orders, it rebroadcast at all other times troop shows and musical programs of the AFRS stations. Thus many a crippled bomber's crew winged its way home to such genuine and mellow American music as Bing Crosby crooning "When you're a long, long way from home", Dinah Shore coaxing "Come to mama, Come to mama, do!" and the King Cole trio reminding them to "Straighten up and fly right." There were also reports that Naval fliers returning from bombing missions tuned in on this beam and used it as an aerial signpost to guide them back to their bases.

From checks both by the bombers and by warships in the Japanese area, it is now known that this station was the most effective medium wave American station of that area on the air and easily rivaled the Tokyo radio. Thus, for the first time with the construction of the Saipan radio, a medium was secured through which psychological warfare men could be sure the man in the street in Japanese cities was being reached with such important information as the Potsdam unconditional surrender ultimatum which went out from Saipan, the warnings to specified Japanese cities of their impending destruction by air unless Japan surrendered and the recent historic development of the atomic bomb which was first dropped on Hiroshima.

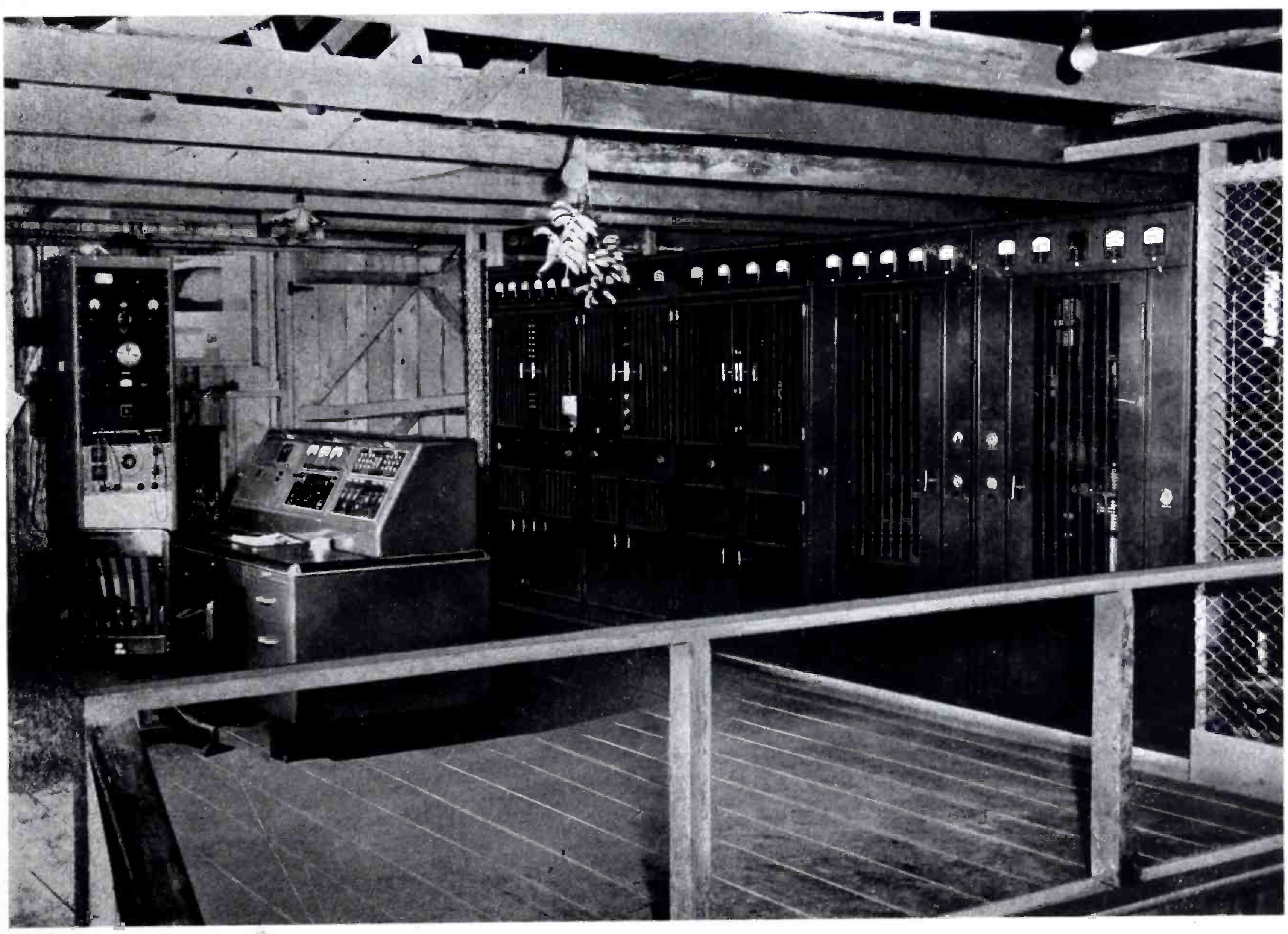


From this directional antenna array, KSAI beamed a 250 kw effective signal at the Japanese home islands.

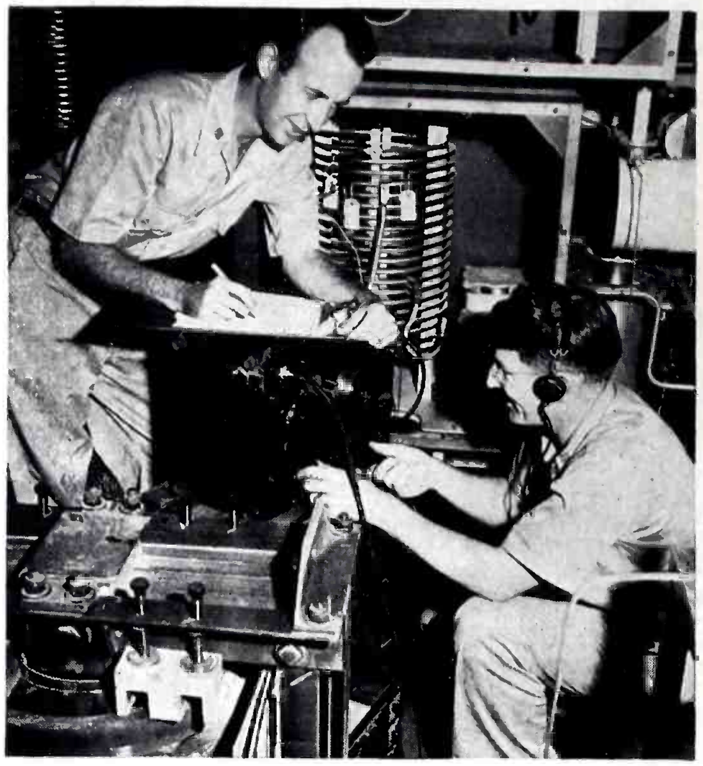
On the authority of Captain Paul Bosse, AFG Saipan, requests for "position" from homing crews over the B-29 communications system were reduced from an average of 140 a day down to an average of 20 per day as soon as this Saipan transmitter went on the air beaming its programs on a twenty-four hour a day basis.

As a sidelight on the coverage of this station, it may be noted that the crew received letters from persons all over the Pacific, from Australia, New Zealand, the West Coast and as far east as Tennessee—which may be some kind of medium wave

This is the transmitter at KSAI on Saipan which saved 20 crippled Superforts in four months — a Western Electric 50 kw with a control console. The bunch of bananas hanging from the rafter was included in the photograph to give it the proper tropical atmosphere, says George Chapman, chief engineer of the station.



Living conditions were rugged at Radio Saipan, for it was far removed from the established military bases. The Marine Guard pitched their tent in the shadow of the station's towers.



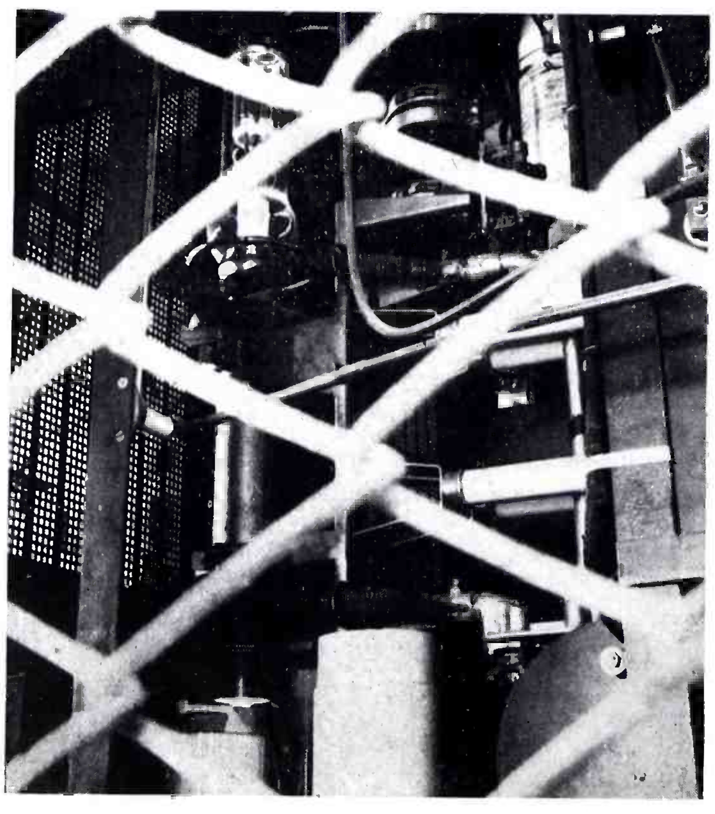
George H. Chapman, chief engineer, standing at left, and Harry Panchot make impedance checks on transmitter at station KSAI.

broadcast record, since such a signal beamed northwest toward Japan must have traveled half way around the earth.

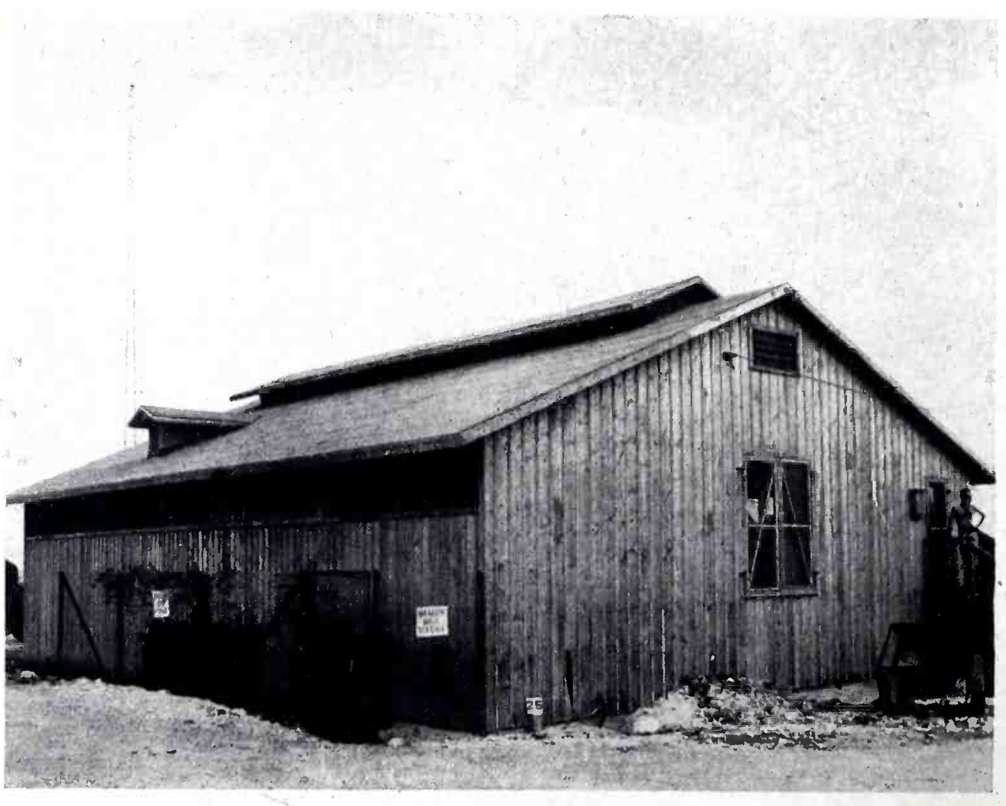
The transmitter itself, according to Chief Engineer George H. Chapman, formerly of KVOO, Tulsa, stood up heroically from its first signal to the end of the war without any major failures under the most severe conditions and operating a grueling twenty-four hours a day.

For one thing, whenever the anti-aircraft guns nearby on the island went off, in the words of Chief Engineer Chapman, "the sides of the building swayed like an accordion," and the tubes of the transmitter were given a terrific shaking. For another thing, it was necessary to change the frequency of the transmitter twice a day at 4:00 and at 5:30 a.m. switching from 1010 kc to 870 kc for a special broadcast and then back again to the regular frequency. This involved retuning the transmitter and the directional antennas twice a day, and it was so well worked out that two men could make the adjustments in 15 minutes. Moreover, the station was kept on the air chiefly by men who, with the exception of the supervisors, were not broadcast engineers; and, to top it all off, the transmitter was designed for 50-cycle operation while the only generators available were 60-cycle. Thus, at the start the engineers had many doubts about the ability of the rotating equipment to stand the strain of the increased speed due to this mismatched power supply. Ingenuity and close supervision on the part of the engineers overcame all these difficulties.

The Saipan station cost the United States approximately $180,000 to construct, not including the work done by Army engineers and Signal Corps men. In saving the lives of more than 200 bomber crewmen and $15,000,000 worth of B-29's within a period of four months, it would seem that few single instruments made by the Nation during the war paid such high dividends.

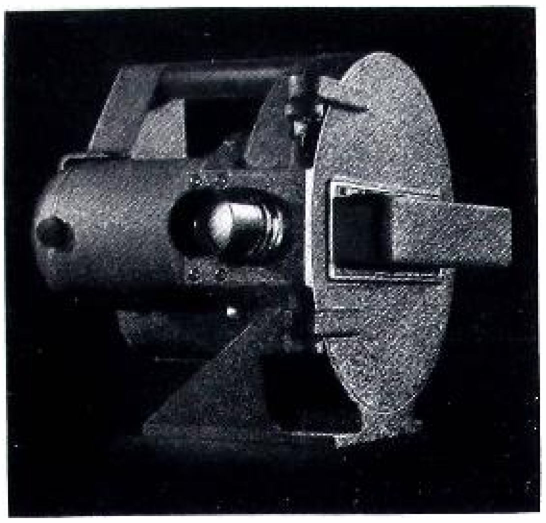


Tube and socket mounting in final amplifier stage of the 50 kw transmitter at KSAI. Photo was taken through wire screen.



Exterior of transmitter building, with towers in the background. To take advantage of overwater transmission, station was located in a remote spot near the coast in northern Saipan.

"Eight Thousand Winks a Second"



A NEW industrial tool that can photograph short-duration phenomena, such as the split-second action of high-speed machinery, is now playing a vital part in many essential war industries, in scientific research and in various branches of the Armed Services. This is the *Fastax* Camera,* developed by Bell Telephone Laboratories and manufactured by Western Electric, which can reach a top speed of 8,000 frames a second — an exposure period of 33 millionths of a second. Using 8 mm and 16 mm film, which travels at a maximum speed of 70 miles an hour, these cameras can shoot 4,000 pictures per second with the 16 mm film or 8,000 per second with the 8 mm film, as compared with about 128 pictures per second for the conventional "slow motion" intermittent type motion picture camera. A new 35 mm half-frame wide-angle Fastax which gives 3,500 pictures a second has also been developed. This has an angle of view of 40 degrees or a width of field of 71 feet when the camera is 100 feet from the subject.

Action photographed at high speed in this manner and projected at normal speed is retarded or "magnified". Thus if pictures taken at a rate of 8,000 per second are projected on a screen at a rate of 16 per second, a "time magnification" of 500 to 1 is obtained.

In this way, the innermost secrets of mechanical parts moving at high speed can be laid bare. The camera with its "8,000 winks a second" can "slow down" even the results of electrical phenomena and it is now being used to reveal to engineers frailties in vital moving parts never before beheld by the human eye. Also by means of this camera, studies are now being made of ballistic behavior, the movements of projectiles, particularly rocket propelled projectiles and their launchers, of muzzle velocities and the effects of explosives.

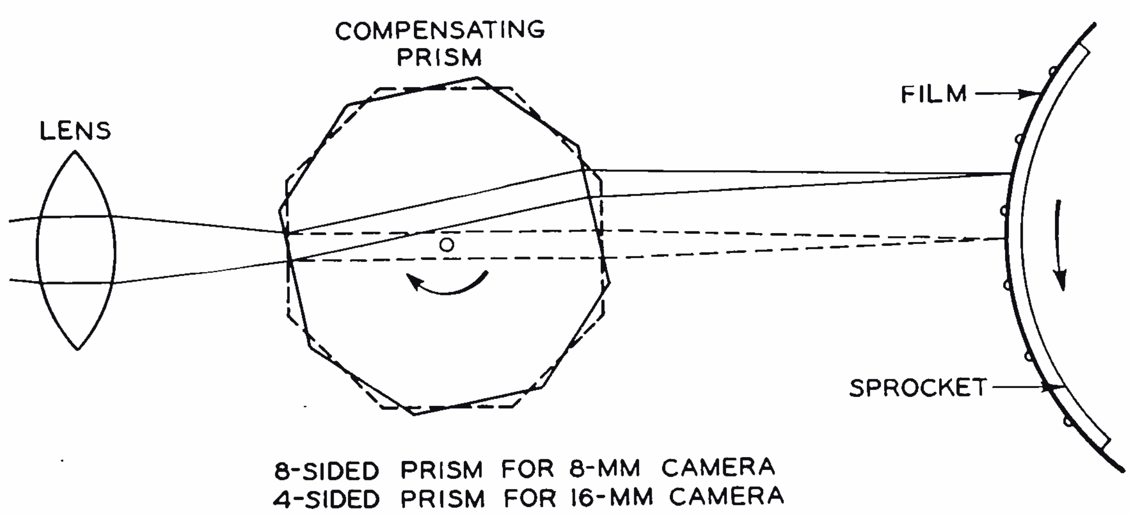
Color, black and white and polarized light pictures taken at the slower speeds (150 to 1,000 frames per second), have been invaluable in determining stress and impact conditions of new equipment designs. The middle speeds (1,500 to 4,000 frames per second) have been used to study automatic operations, laboratory-controlled breakage of parts and the causes of noisy operation in machines.

Bell Laboratories scientists, the camera's original designers, have made such diverse cinematic studies as the action of the human vocal cords in producing speech and the explosive short circuiting of wires carrying heavy currents of electricity. The first time the Fastax camera was used to make research films it revealed a heretofore undetected cause of false signals in telephone equipment.

A number of features distinguish the Fastax from other types of high speed motion picture cameras. The camera employs continuous film drive, as distinguished from the "stop-expose-advance" cycle of ordinary professional and amateur cameras. Exposure of successive frames in the new camera is accomplished by a revolving prism acting as an optical compensator. Hence the images travel in synchronism with the film past the film gate during the exposure period. It is adaptable for operating in any position on airborne, mobile, static or underwater equipment. It is equipped with a special type of glow-lamp timer which lays down a timing mark on the side of the film. This is a particularly valuable aid in military and industrial time and motion studies.

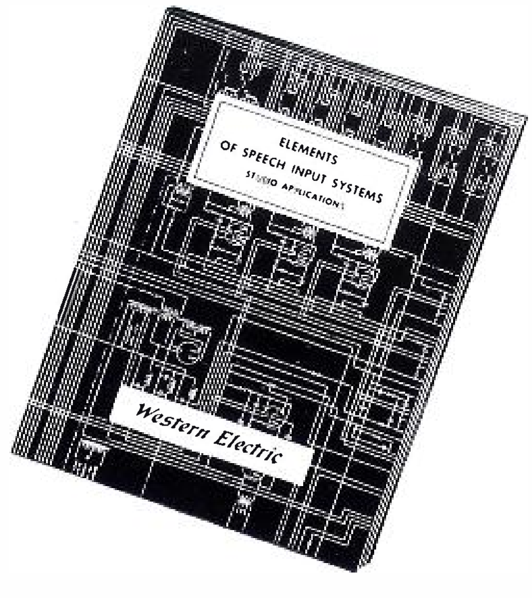
The object under study can be illuminated either by bright sunlight or by incandescent light of high intensity. This basic principle enables the Fastax to photograph self-luminous subjects such as a welding flame, or fusing lamp filaments, or to make high speed analyses by polarized light.

*Trade Mark Registered United States.



Schematic diagram of the optical system of the Fastax camera. This diagram shows rotating compensating prisms for 8 mm model, which correspond to the mechanical shutter in conventional motion picture camera.

New Speech Input Booklet



This 18-page illustrated Western Electric booklet "Elements of Speech Input Systems", has been mailed by Graybar Electric Company to chief engineers of all radio stations in the U. S.

The booklet summarizes certain basic Western Electric ideas regarding the components, desirable operating characteristics and functions of a modern speech input system for both AM and FM broadcasting, including both the basic, or program production unit and the master dispatching equipment. Its analysis of these concepts is intended as a help to an understanding of all Western Electric Audio System Equipment. The booklet also describes the principle of stabilized feedback and its advantages in audio system amplifiers. Included in the booklet are schematic drawings showing types of facilities used in a typical studio program production unit and in a master dispatching unit.

Copies of this booklet are available to radio station personnel upon request to Graybar Electric Co., 420 Lexington Ave., New York 17, N. Y.

Thermistors

(Continued from page 5)

tor are commonly used in the feedback circuits of amplifiers to provide constant output with negligible distortion for wide ranges of signal input. The elements of such a circuit are shown in Figure 5 (see page 5). In this case, the overall gain of the amplifier is regulated by the directly heated thermistor which varies its resistance with output in such a way that the amount of feedback voltage is varied to compensate for any change in input signal. The resistance-current characteristic of a thermistor used in a typical application is shown in Figure 6. It is evident that by choice of thermistor characteristic and circuit constants in the feedback circuit a wide variety of input-output relationships can be readily obtained.

In this type of application, it is evident that the directly heated thermistor being a thermally sensitive device, will react to the ambient temperature as well as the current passing through it. Where this is an important factor, it may be compensated for as shown in Figure 7, by using a heater type thermistor, with the heater connected in an auxiliary circuit containing a temperature compensating disc thermistor. The disc thermistor under the influence of the ambient temperature changes the heater current to overcome the effect of the ambient temperature on the bead thermistor element in the feedback network. Thus, a controlled and constant ambient temperature condition surrounding the bead is produced.

Another important form of thermistor gain control is shown in Figure 8. In this arrangement, the heater of a heater type thermistor is located in the output circuit of the amplifier, with the thermistor element in the input circuit. While the input and output circuits are electrically isolated,

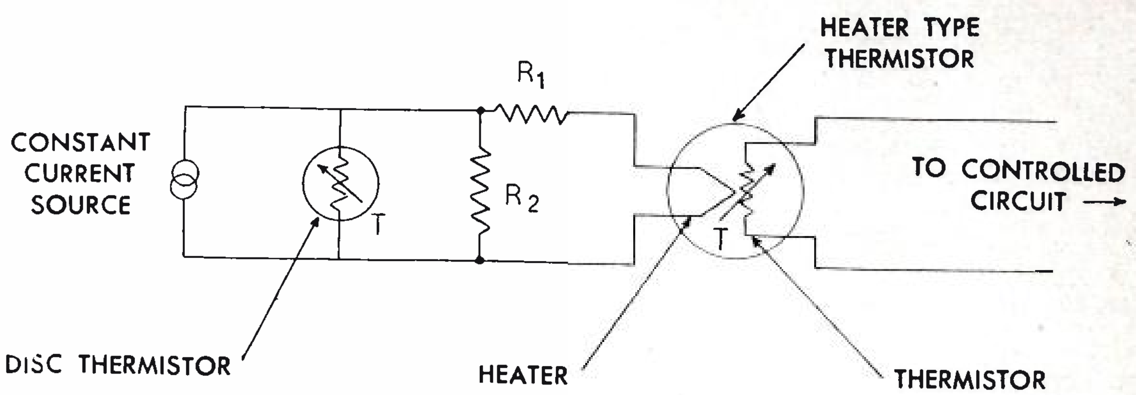


FIGURE 7 — One form of circuit employing an auxiliary disc thermistor to compensate for effect of varying ambient temperature on control thermistor. This latter thermistor in the main circuit is of heater type.

a form of feedback is obtained by thermal coupling. The heater current vs. element resistance characteristic representative of a thermistor used in a typical application of this form is shown in Figure 9. Other circuit adaptations and applications of heater type thermistors, particularly as remotely controlled resistances, will occur to the broadcast engineer.

Automatic gain control circuits using the preceding basic arrangements are used extensively in a variety of telephone carrier systems. In these systems transmission loss varies continually with weather conditions and other factors and the high quality of modern transmission demands that these variations be continually equalized to give constant transmission over the channel at all times. In these systems, the gain is controlled by sending pilot carrier frequencies over the channel and controlling the gain in accordance with the loss in level of the carriers. In one form of system, the variable gain is considered made up of three components: a "flat" component independent of frequency; a "slope" component, that is proportional to frequency; and a "bulge" component with a maximum at one frequency. Each of these components is controlled by its own individual pilot carrier and its own separate system of thermistors. Figure 10 shows a simplified schematic of a carrier telephone repeater station of this form.

Voltage Regulator

Thermistors also find important usage in stabilizing the output voltage in circuits in which the input voltage or load current may vary over a considerable range.

In this application, the negative slope part of the current-voltage characteristic is used. If an ohmic resistor and thermistor are connected in series and have slopes of equal and opposite sign, the voltage across the combination will be practically constant over a wide current range as shown in Figure 11. The series combination of thermistor and resistance will act as a variable shunt if placed in parallel across the load and will tend to maintain the load voltage constant. It is evident that a variety of characteristics can be obtained, depending upon the value of the series resistance. The effects of varying ambient temperatures can be substantially reduced by selecting network resistors of appropriate values and temperature coefficients of resistance.

This principle finds useful application in the voltage regulation of both a-c and d-c power supplies. As the power handling capacity of thermistors is limited, it is conventional practice in heavy duty power supplies to use this basic circuit to furnish a voltage reference standard to control in turn an electronic or other circuit to balance the output voltage and maintain it constant. This thermistor application has numerous advantages over conventional

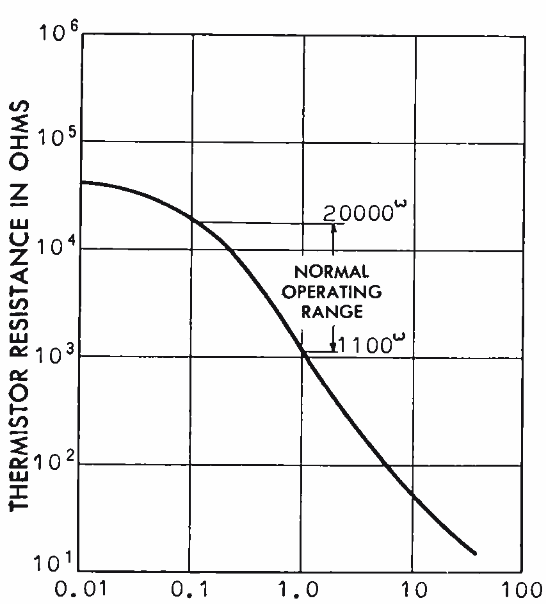


FIGURE 6 — Resistance-current characteristic of directly heated thermistor used for gain control.

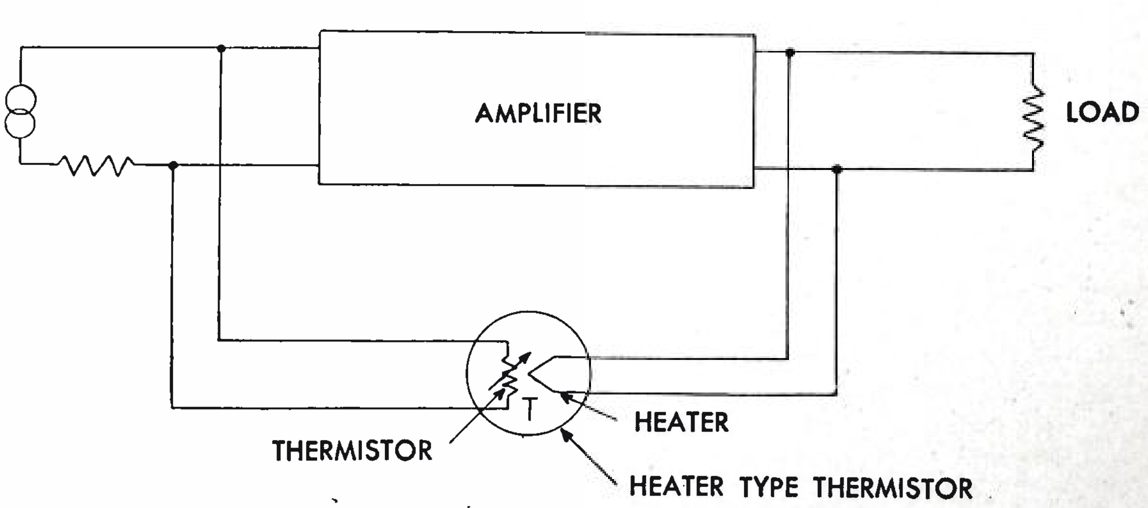


FIGURE 8 — "Thermal" feedback circuit for gain control using heater type thermistor. Also suitable as protective circuit for long duration overloads. The heater is located in the output circuit of the amplifier.

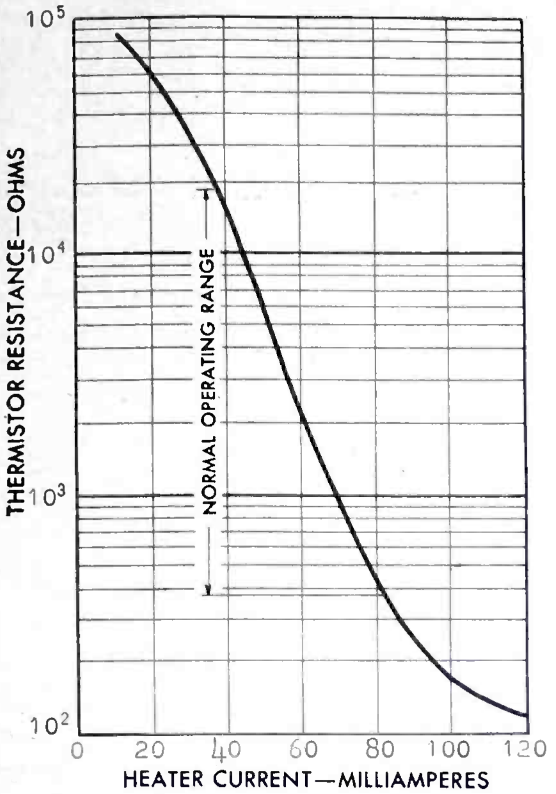


FIGURE 9 — Resistance-heater current characteristic of heater type thermistor used for gain control.

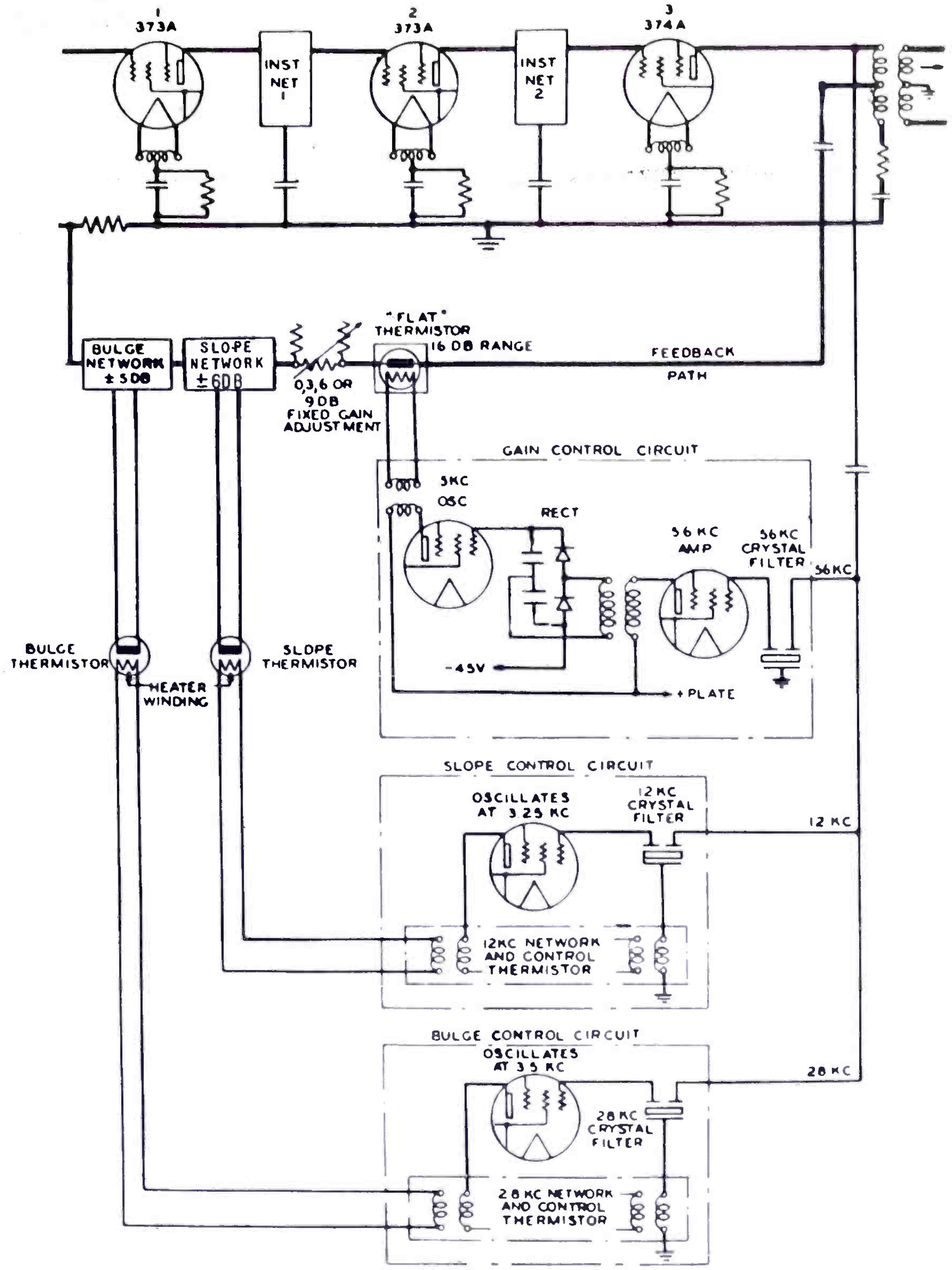


FIGURE 10 — Simplified schematic of carrier telephone repeater feedback amplifier employing thermistors to control flat gain, slope and bulge. Each of these components is controlled by individual pilot carrier.

voltage regulator circuits using constant voltage transformers or cold cathode tubes. Among other things, it provides better regulation with substantially negligible distortion and is independent of the power supply frequency.

Volume Limiters and Compressors

Upon further consideration of the preceding application, it will be evident that the same principle would be useful in speech and other circuits as volume limiters and compressors.

At low voltages and currents, the thermistor would act as an ohmic element and a linear relationship between input and output voltage would be provided over the lower levels. With increasing voltages, the output voltage would depart from linearity, and for appropriately selected circuit constants would rapidly approach a constant or limiting value as shown in Figure 12. Thermistor volume limiters of this type can accommodate large level changes without producing wave form distortion. In audio-frequency speech circuits this is an important advantage over conventional instantaneous volume limiters, which act as "peak choppers" with consequent serious distortion.

By proper choice of circuit constants, the departure of input and output voltage from linearity can be controlled over wide limits. Referring to Figure 12, values of R_1 greater than required for limiting action will produce compression characteristics. Expansion characteristics can also be obtained by placing the thermistor element in series with the source and load.

A different form of thermistor volume limiter circuit consists essentially of a hybrid coil arrangement as shown in Figure 13. Here the signal is divided into two paths by a balanced input transformer and continues through these two paths to a similar output transformer with the secondaries connected in opposition so that the currents of the two paths introduce opposing currents in the output line. If there were equal resistance in the two paths, there would be no output signal as the transformers are balanced. At low volume levels, however, the resistance in one path is very low and that in the other, very high. The bridge arrangement is thus unbalanced and the circuit introduces little loss. With increasing levels, the thermistor in the high resistance path heats, decreasing the resistance of the path. At input levels in the limiting range, the resistances in the two paths approach a common value, tending to balance the bridge and introduce more loss in the line. The variation in resistance is so designed that the change in loss is approximately equal to the change in input level which results in substantially constant output without noticeable distortion. The action of the variable elements of the circuit are shown in Figure 14.

It is to be observed in these volume limiter circuits, as well as in the preceding gain control applications, that an essential feature is that the control action is not significantly affected by the short time variations of level of speech or music, but follows the general level or average envelope. This is a result of the inherent thermal inertia of the thermistor elements. The time constants of the thermistors and associated circuits are selected to provide an appro-

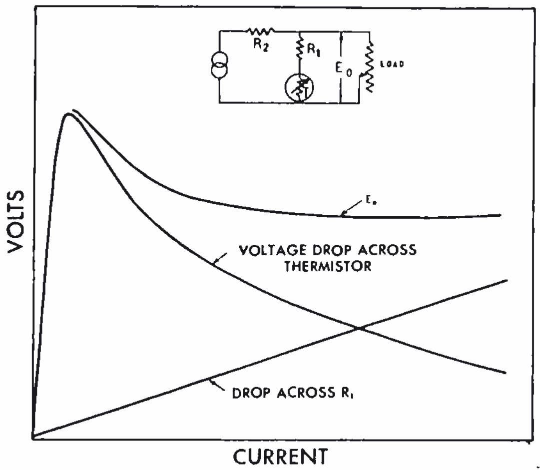


FIGURE 11 — Curves of current-voltage relationships in elementary thermistor voltage regulator circuits.

priate speed of response consistent with the type of application.

Time Delay Devices

The time-current characteristics of thermistors find numerous time delay applications. The automatic lowering of resistance which results when a thermistor is self or directly heated by passing current through it, can be employed to delay the operation of a relay or the functioning of other circuits. The magnitude of delay depends on the thermistor characteristics and the circuit constants. With a given thermistor material, the smaller the mass and the smaller the heat losses due to convection, conduction and radiation, the smaller the inherent time delay of the thermistor. By suitable design of the thermistor and choice of circuits, it is possible to vary the net delay time from a few milliseconds to several minutes.

In relay delay applications involving repetitive operations, it is evident that time must be allowed to permit the thermistor to cool off before reapplying voltage to it. The use of an auxiliary contact to short-circuit the thermistor after the relay has pulled up is common practice. With such an arrangement, if the relay remains closed long enough to permit the thermistor to cool the latter is available for immediate duty after de-energizing the circuit.

Thermistors as Protective Devices

The time delay characteristics may be used in a variety of ways to protect circuits against long duration overloads and also to prevent operation of relays or other devices by voltage surges of short duration.

In overload protection, the thermistor is bridged across the circuit and if the excess power is continued too long, the thermistor breaks down and protects the output circuits. Thermistors are also used as protective devices in circuits where a stray high voltage might be applied accidentally. The thermistor is normally in a high resistance state and does not interfere with the normal operation of the circuit. The continued presence of a high foreign voltage would cause the thermistor to break down and drain the power off to ground.

Thermistors may also be used in many circuits so their thermal inertia, together with their initial high resistance, discriminate against voltage surges of short duration. With lower potentials of longer duration, the current can build up to high enough values to operate relays or other devices. In telephone systems, this type of delay is used to prevent false operation of relays in the ringing circuits of private branch exchanges.

Power Meter

The resistance-power characteristic contained in the static E-I characteristic as shown in Figure 3, makes thermistors particularly useful as power measuring devices. As they can be designed to have extremely small electrical capacity, they are well adapted to the measurement of either low or ultra-high frequency power and have been used extensively for such purposes.

In this application, the unknown power to be measured is dissipated in the thermistor with consequent self heating and rise in temperature. The thermistor resistance which is dependent upon its temperature then becomes a measure of the power dissipated. The resultant resistance may be determined by means of a Wheatstone bridge, ohmmeter or resistance substitution circuit. When a-c or r-f power is measured, the resistance measuring circuit may be operated on d-c, and vice versa, with suitable isolating elements in the circuit. In cases where wide ambient temperature ranges are encountered, temperature compensating thermistors are commonly used in the measuring circuits.

Thermistors in Measurements

The temperature-resistance characteristics of thermistors suggest their use as sensitive thermometers, and also to compensate the effects of varying ambient temperature in electrical circuits.

In thermometry applications, conventional bridge or other resistance measuring circuits are commonly employed. Consideration must be given to keeping the measuring current sufficiently small so that it produces no appreciable heating and so that the thermistor resistance is dependent only upon the ambient temperature. As the thermistor elements have higher resistance compared to other electrical temperature measuring devices, they can be located remotely from their associated circuit and thus permit great flexibility in application. Numerous applications of thermistors have been made where temperature indications are automatically transmitted from remote locations by wire lines or radio to control points. The small size of thermistors, their simplicity, stability, high sensitivity and ruggedness adapt them to a wide variety of temperature measuring applications, and provide manifold advantages over other types of devices.

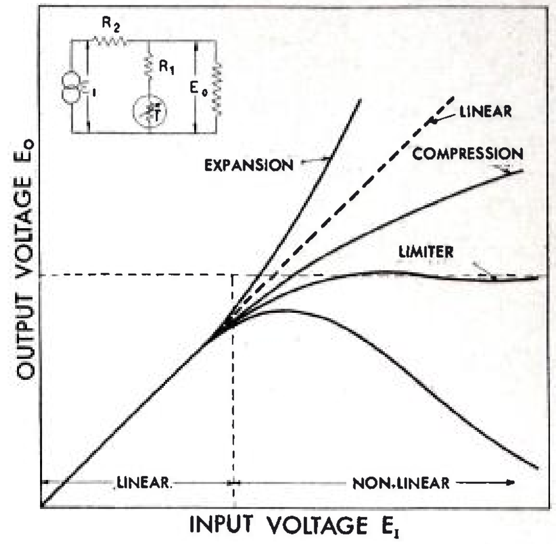


FIGURE 12 — Curves showing operation of thermistors in volume limiting, compression and expansion.

The applications of thermistors to compensate for changes in resistance of electrical circuits caused by ambient temperature variations are obvious. In practice, the compensating thermistor is associated with parallel and possibly series resistance, so that the combination gives a change in resistance exactly equal and opposite to that of the circuit to be compensated. Power dissipation in the thermistor element must be considered and limited to such values as will produce no significant departures from ohmic characteristics.

If a thermistor is directly heated by passing a constant current through it, its final equilibrium temperature, and thus its resistance, will be determined by the transfer of heat to or from it. This principle, already used in a variety of "hot wire" devices, is the basis for using thermistors for vacuum and flow measurements. The advantage of thermistors in such applications lies in the high temperature coefficients of resistance available over those of conventional "hot wire" devices. Conventional bridge circuits are used in these applications with the thermistor located in one bridge arm and exposed to the vacuum condition or the flow of gas or liquid. A second thermistor having substantially the same characteristics as the measuring thermistor is commonly used in another bridge arm to compensate for ambient temperature variations.

In vacuum measurements, suitably designed thermistors have been used satisfactorily over the pressure range from 10 to 10^{-5}mm of mercury. In flow measurements, the minimum measureable velocity will be limited, as in all "hot wire" devices, by the convection currents produced by the heated thermistor.

Experimental Applications

From the preceding applications there is ample evidence that thermistors as control elements have a place in almost every type of electronic circuit. Scores of other applications, however, remain to be tested and put into practical use. For example, the negative resistance characteristic exhibited by direct or self heated thermistors suggests their use as generators of low frequency alternating voltages and as low frequency power modulators for various purposes. Specially designed thermistors have been made to oscillate over the entire voice frequency range when placed in appropriate circuits. This characteristic also suggests their possibilities as amplifiers and in low frequency filters, replacing large and cumbersome components. Again, thermistors of the directly heated type have provided an effective method of amplitude stabilization of various high and low frequency oscillators. Details of this latter application will be found in papers by Meacham(1) and Shepherd and Wise(2).

Other promising applications of thermistors are as relays and switching devices. In such applications, use is made of the characteristic that the voltage drop across a thermistor passes through a maximum and then decreases with increasing current, thus having a pseudo "break down" analogous to that of a gas filled tube. This feature permits a thermistor, in a low voltage circuit, to be locked-in by the application of a higher voltage and to continue to pass a large current after the high voltage is removed. In a parallel arrangement of thermistors, it also permits any one thermistor to lock-out the other thermistors. It is evident that a wide variety of lock-in, lock-out and selective switching applications could be devised. However, at the present time, these applications are largely experimental, but do have a promising future.

Many other ingenious applications will occur to development engineers, and as they gain experience, it is anticipated that numerous other, as yet unconceived applications, will emerge.

(1) The Bridge Stabilized Oscillator, L. A. Meacham, Proc. I.R.E. Vol. 26 Oct. 1938 pp. 1278-1294.
(2) Frequency Stabilized Oscillator, R. L. Shepherd and R. O. Wise, Proc. I.R.E. June, 1943 pp. 256.

Ads Tells History of Musical Instruments

Do you know that Nero may have played the bagpipe — not the fiddle — while Rome burned? that the first xylophone had human legs? that Plato didn't approve of the harp? that the French horn was once used for hunting?

Filled with such little known facts about today's major musical instruments, a series of 25 unusual advertisements placed by the Western Electric Company in *Broadcasting* Magazine has elicited instant response from broadcasting people — particularly program directors and script writers who find the information the ads contain a useful addition to their file of program material.

The ads — one column in length — treat each instrument from its beginnings down through its various modifications and changes to its modern development. Starting with the violin, the "singing voice" of the symphony, each ad tells a story of the instrument's name, its use during major historical events in its evolution, and many colorful modern facts about it, including some of the names "hep cats" and other cognoscenti give their instruments, such as the term "licorice stick" for the clarinet, the "wood pile" for the xylophone and the "plumbing" for the saxophone. Also indicated in many cases are the frequency range of the instrument and the type of music it produces.

The research involved in securing the information for these ads was extensive. Many books and manuscripts on old musical instruments were pored over, and a mountain of background material was read to garner the most interesting facts. All the more common instruments are included, plus others less well known, such as the carillon, ocarina, bagpipe and xylophone.

For the convenience of broadcasting people, this series of 25 ads is available in a booklet entitled *Grace Notes*. The historical information contained in this booklet may be used freely for program material. A copy may be secured by writing to the Electrical Research Products Div., Western Electric Co., 233 Broadway, New York 7, N. Y.

"And now we take you to—"

(*Continued from page 13*)

7. At times of emergency the affected sections of network must be reestablished in the briefest possible time by stand-by circuits and by spare equipment or by the use of alternative routes. Under such circumstances the existence of a large program transmission network forming a part of a much larger telephone network — a telephone network having in service 10 million miles of long-distance telephone circuits terminating in 2,400 switching centers — has been of great importance. Numerous alternative routes were thus made available and stand-by circuits and spare equipment were used in common to meet the needs of any individual network.

Tests underway now will determine what methods, whether wire or radio relay or both are best suited to FM and television transmission, but whatever method turns out best, there is the vast experience in present network operation available to broadcasters everywhere to use as they will in building the FM and television networks of the future.

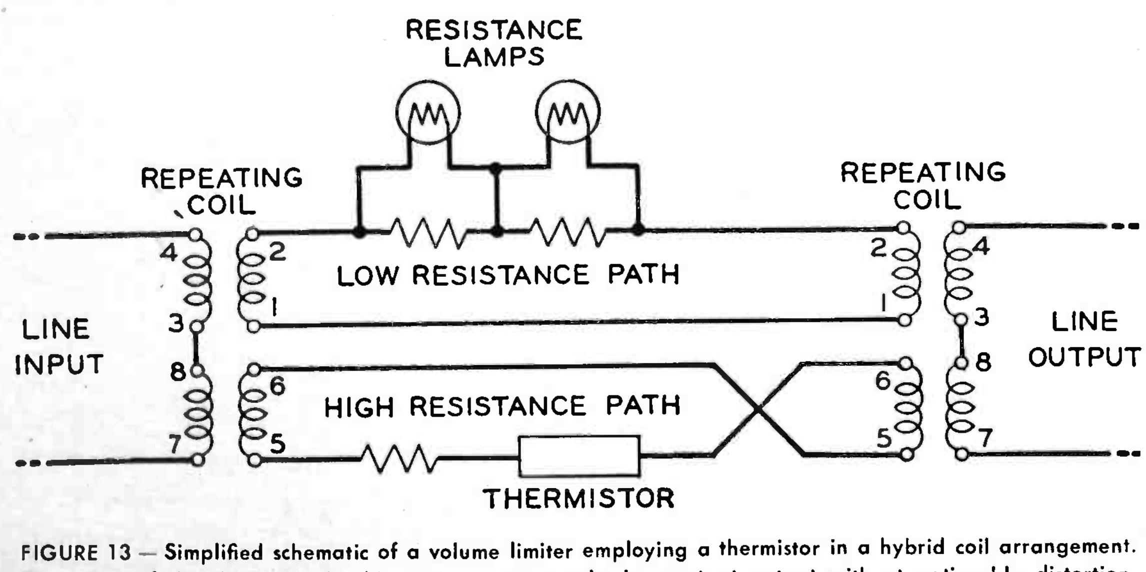


FIGURE 13 — Simplified schematic of a volume limiter employing a thermistor in a hybrid coil arrangement. Operation of the thermistor in this arrangement results in constant output without noticeable distortion.

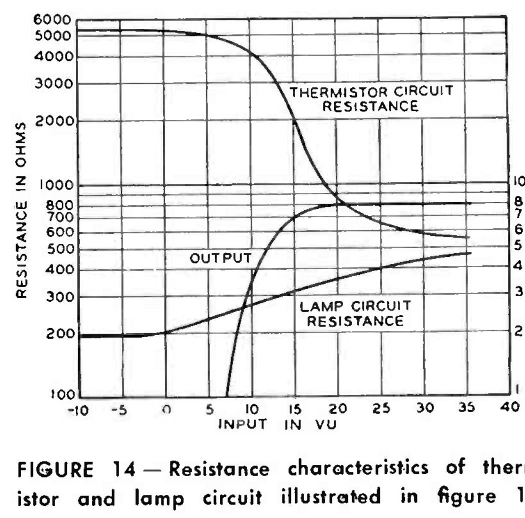


FIGURE 14 — Resistance characteristics of thermistor and lamp circuit illustrated in figure 13.

"Experiences I Won't Forget"

(Continued from page 19)

Fleet. We had a problem. We knew that the Italian Navy operating personnel was forbidden to listen to any radio other than its own. The recording giving the terms of surrender made by an OWI man in Italian was locked up in a safe ready for us to use if we could find a way of getting it over. Well, it occurred to me that we might reach them on the International Distress Signal to which all ships are constantly tuned. So now we come back to that old 50 kw commercial transmitter. We had the job of readjusting it from its normal operating frequency of 1226 kc to the SOS frequency of 500 kc. Too much has been made of the job and particularly of my part in it, I think," Morrie continued slowly. "We had a few difficulties and we were a little pressed for time. The first difficulty I had was that it all had to be done secretly and at night. I had two swell men to help me — Major Charles Carson of Peoria and Lt. Joel Keller of Cleveland — and they were tireless. The job itself is from a technical viewpoint not complicated. Of course we had none of the necessary components — crystals, coils or condensers. So first we made a little self-excited oscillator by winding up a coil, and used this in place of a crystal. The job from then on was to tune each succeeding amplifier and finally the antenna to operate at the 500 kc frequency. We had our standard frequency generator, the Signal Corps frequency meter and a radio frequency bridge to make the antenna adjustments. That's really all that was involved. However, we weren't too confident about that idea of the SOS frequency . . . and I was never sure it would work until I heard the news report of the surrender of the Italian Fleet while I sat waiting that afternoon at Port Leauty for a plane to go home. Several radio stations were used to transmit the message to the Italian Navy including Tunis so we have no way of knowing which station actually accomplished the job. The result is all that's important. . . . The publicity on our little stunt probably arose from the very generous remark, brought out at a House Committee hearing, reported to have been made by British Mediterranean Fleet's Chief Admiral Cunningham on seeing the Italian Fleet steam into Malta — perhaps one of the best tributes to radio propaganda ever received.

" 'Congratulate the Americans for me,' the Admiral is reported to have said. 'They've accomplished in one day with propaganda what I've been trying to do for three years with my fleet.' You can imagine how we who had been out there appreciated that remark!"

Almost equally famous is another feat in which Morrie Pierce was certainly the prime mover — the capture of Radio Luxembourg, second most powerful station in Europe and, as it turned out, the former center of Germany's principal propaganda network beamed to England. The capture of the Italian Fleet and that seizure of Radio Luxembourg are perhaps the two best known jobs performed by radio engineers in this war. I asked Morrie about this second great achievement — the inside story of how it was accomplished and something of his life as chief engineer for Psychological Warfare Division radio in the European Theatre.

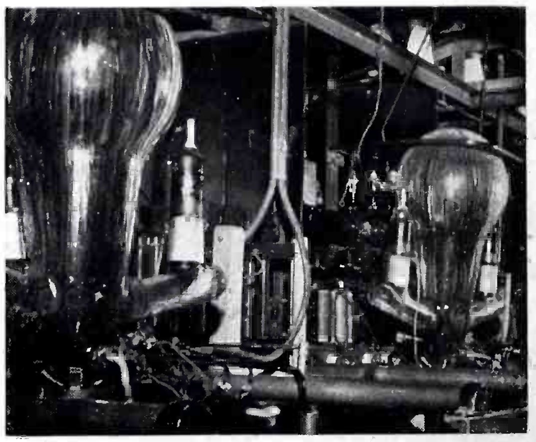
London Assignment

"Well," Morrie began, "I had been trying to get relief to return home to my family and the old station again (that's the WGAR-WJR-KMPC Richards stations) for a long time. But Colonel Hazeltine, head of the Psychological Warfare Branch in the Mediterranean, insisted he needed me. The station had allowed me to go on the understanding that I had only one job to do; then I would be back. At last, however, the break came and we got Charlie Topmiller of WCKY to take over so I finally reached home. But you know," Morrie said, "after you've been over once you sort of itch to get back. So when Jim Weldon called again even though I never did get complete authority from my wife, I went.

"I thought I was returning to North Africa and the Mediterranean area again but when I reached London, General McClure who was head of the newly made Psychological Warfare Division (formerly it had been merely a branch, but the success of psychological warfare in the North African campaign, where it was found that more than 80 per cent of the prisoners captured had been influenced by PW pamphlets and broadcasts, had apparently impressed General Eisenhower to such an extent he made it one of his staff divisions without a number but similar to the G-1, G-2, G-3 and G-4 divisions) — well when I reached London, General McClure head of this new division and his deputy C. D. Jackson suggested I stay on there for a job they had to do. . . . This was in September 1943. They were preparing for the big show. From January to May we were in London making our own preparations. These consisted of (1) analysis of all French broadcasting; (2) preparing a list of selected stations that we wanted to operate as soon as possible and getting permission from the Signal Officer and G-2 and G-3 to operate them. (In all areas, permission must be obtained from the military to take over any station for operation). (3) Issue memos to G-2 and A-2 (Air Force Intelligence) not to bomb those stations we had selected. (4) Train Army personnel in the rudiments of operating broadcasting stations.

"It was June 15 — D plus 9 — that we started out. But we sat all day in the harbor owing to the congestion and did not land until D plus 10. . . . The confusion was indescribable! Our first major job was Cherbourg. . . . This important area was served by the transmitter at Rennes. We had planned to rush up a mobile 250 watt transmitter, then if possible to install a 1 kw in Cherbourg. We intended to use these stations not only for propaganda but as a means of restoring order out of the chaos in newly liberated areas and of getting the vital news to troops thereabouts. This job we did five or six days after our troops had entered the city. We could get only the mobile transmitter operating and it was working by July 4th. The next step was to get the transmitter at Rennes into working order. There were really two transmitters there: the big 120 kw which the Germans had taken over for their troop entertainment and an old 40 kw left to the French. . . . The Germans had completely destroyed the 120 kw and had used a sledge hammer on the 40, smashing the meters, tubes and filament generators. One piece of luck favored us. The French had cached many of these valuable tubes from the transmitter in their homes and told the Germans the transmitter had never been finished, but still the station was in a pretty hopeless condition. We finally moved in two Army 'vans' as the English call trucks, with the 1 kw Western Electric mobile radio and got on the air in this fashion. . . .

"Our next enterprise was the network of stations in the Paris area. I had been assigned to a task force that was to enter Paris. We were perhaps the most miscellaneous task force ever assembled. We were about 30 per cent civilian, 70 per cent military, partly British, partly French, partly American and composed of radio engineers, intelligence officers and OWI



Unusual high voltage mercury vapor rectifiers in Tunis broadcasting transmitter used by Americans.

broadcasting men who knew French and German thoroughly, OSS (Office of Strategic Services) officers and men, and British military intelligence. We all got along very well. Our jobs were to pick up documents the Germans may have left behind, put into operation newspapers; set up poster and display outfits and take over radio stations. We always worked with the French themselves, acting generally as their assistants when we could. The French had done a good job. Three days before we entered Paris, the French FFI had started two transmitters in apartments. They would put up their antenna at night while the Germans were still in the city, run their stations then take down the antenna in the daytime. This was in the middle of the break-through and we were in the area dominated by French General Le Clerc. . . . Our troops were moving up fast toward the German border, and it was at this time that I had the idea we ought to try to get the great Radio Luxembourg, one of the most powerful stations in Europe.

"There was some confusion at that time as to whether Luxembourg would be in the 1st or 3rd Army area. . . . First I went to Major Huot in charge of Psychological Warfare for 3rd Army. He said this area would be under the 1st Army as soon as they reached it and that they wouldn't be there for a few days. The going was getting heavy and there was a lot of stuff in front of them. Meanwhile my travel orders which were dated September 5th were running out and I had to go back to Paris. With my orders changed I returned to the 5th Armored Division Headquarters. They had moved up to Belgium, and I had a hard time finding them. Our little group — now there were five of us — reached Palisseau where the Burgomaster put us up for the night and gave us a good breakfast in the morning, treating us with great kindness. Then we went out again to search for the 5th. We finally caught up with them at Arlon. When we finally arrived in the city of Luxembourg, the Luxembourgers went wild. They shouted and danced, and our cars were surrounded with overjoyed people. They threw papers out of the window — some of these papers, much to the distress of the Intelligence officer with us, were valuable German documents which he was supposed to pick up. This was a phenomenon we met everywhere — this demonstration of joy. Two or three of us went through several villages — the first Americans to enter and several miles ahead of the Army in one or two cases — and in each case, the people treated us with the most moving demonstrations of joy and relief. Well, in Luxembourg we found the studios of Radio Luxembourg. The master control room had been dynamited, but our real problem was getting the transmitters. The engineer in charge of the studios, a Luxembourger named Felten to whom we owe much, spoke English and volunteered to help us get to the transmitter which was 18 miles out near a little village called Yunglinster. We — a sergeant, this Luxembourger and I — drove out through four or five little villages in each of which, since we were the first Americans to get that far, we were plied with wine. About 18 miles out — northwest of the city — we ran into the forests. When we reached Yunglinster, we could see from a rise the five towers of the Radio, 590 feet high. At that moment a Luxembourger came bicycling by and went down to see if there were any Germans there. He came puffing back excitedly and said there were and their headquarters were in a school house. Night was coming on so we had to turn back.

"At 5th Headquarters again, I told my story and asked for an armored task force to take the station. The divisional commander couldn't spare the men, but the commanding general said: 'Do you really want to take that station, Pierce?' I told him I thought it was important. 'All right, Pierce,' he said. 'I'll give you an armored task force. We'll send for them down the line. You better send a courier though;' was his parting thrust at me, 'those damn radio circuits never work!'

Radio Luxembourg Captured

"The armored force consisted of eight tanks, two jeeps and a number of armored cars and troops under the command of Major Dey. We started off, a sergeant, an OSS man, an OWI Intelligence man whom we had picked up a a hotel in Luxembourg for the adventure, and I, in one jeep and Major Dey and some of his men in another. The going was slow. There were, of course, no lights and we crept along the narrow dirt road — a couple of soldiers on foot feeling the way out for us. It was Ardennes forest most of the way. We had not gone more than an hour out when we came upon a road block, two large trees felled in opposite directions across the path. The road block was examined for booby traps. Then the trees were hitched by chains to a tank. Just as the tank started up to drag them aside, a charge of dynamite went off. One soldier lost his eyesight and two others were seriously hurt. Major Dey dispatched a small group to take them back, and we dragged on, considerably depressed and nervous. Finally at 5:00 in the morning, we arrived at an open field and deployed. The station was only a mile ahead. On both sides, there was forest, rather creepy and quite dark. . . . Major Dey decided to send four armored cars to come in from behind. The station was in the center of open fields, but guarded by cross-hatch wire fence about ten feet deep. The soldiers used bayonets on the fence and felt around for more booby traps. Then we got out and followed two tanks in single file across the open field toward the station. Our hearts were in our mouths when we pushed in. I was the second man to step over the threshold. There was not a soul there. . . .

"That's all there was to it," Morrie said slowly, "We learned that the Germans had fled just that night, thinking perhaps that our task force was the American Army moving in. They had smashed tubes and broken a lot of relays, contactors and motor-starting equipment, but nothing that could not have been damaged in about ten or fifteen minutes time. They must have left in a hell of a hurry. There is little more to tell of this job. I went back to Luxembourg to cable that we had the station and sent a description of the tubes needed. We had one bit of the most wonderful luck when we discovered a complete set of tubes stored in the P.T.&T. (Postale Tel & Tel) building at Diekirch, and more luck in finding the chief engineer of the P. T. & T. who had been deported to Germany and just sneaked back the day before. The station itself had complete German files of all German propaganda, of the personnel the Germans had used and of those the Germans thought they could trust or felt they could not trust — each man listed as to reliability.

"Well, that's the story," Morrie said. "But just one thing if you tell about it. It may sound as if I played a bigger part in these events than I did. Remember there were other men without whom none of these efforts could have come off. Remember too that there were men like Captain Ellis of WFAA, Dallas who had the grueling job of taking over stations in ruined Naples and Captain Robert Woolsey of A. T. & T.'s Long Lines and WBBM, Chicago, who with two sergeants took over the important station at Palermo; got the chief engineer with complete plans for the destruction of the station still in his hands; then took not only the station but the town of Bari, Italy, singlehanded, coming in 15 miles ahead of the Army, driving up to the town hall, grabbing the mayor and saying: 'You're now an American prisoner,' and finally taking over the 2 kw station. . . ." Captain Hunter of KGER, Long Beach; Major Carlson and Lieutenant Keller and the civilians like Charlie Topmiller of WCKY, Larry Stinson of KVOO, Paul Von Kunits of WINS and so many others I couldn't name them all."

Morrie paused. Then he concluded slowly: "They were experiences I won't want to forget soon."

The Field Engineer

(Continued from page 28)

can make. Overcoming problems presented by lack of shipping space which limited supplies, securing facilities on the continent to manufacture needed tubes, repeaters and switchboards, and coordinating specifications to make the systems workable, were all a part of the tremendous task that faced the field engineers assigned to telephone reconstruction.

From the Normandy beachheads through V-E Day and even later, these engineers established communication systems in France, Belgium, Luxembourg, Holland, and then in Germany itself, with centers notably at Bad Kissingen, Wiesbaden and Munich. Appreciation of their efforts is reflected in high testimonials from the Director of the Communications Division of the European Theatre of Operations, Brigadier General C. O. Bickelhaupt. "Now that the eve of your departure for home has arrived," he wrote to one engineer last March, "I would be remiss if I should not try to express to you my sincere admiration for the job you did for us here during your term of duty with the Signal Corps in Europe. Not only have you made available to us your broad technical experience and knowledge, but you have given generously and for long hours at a stretch your personal efforts, under conditions which, at best, were in many cases very trying."

This and subsequent messages received the hearty indorsement of Major General W. S. Rumbough, Chief Signal Officer of the E.T.O., and of Major General H. C. Ingles, Chief Signal Officer at Washington.

The generals' messages may have in part repaid the engineer who wrote his office during an assignment:

"From early morning to late at night all kinds of questions are fired at us by generals, corporals and anyone else. Do we answer all of them? Yes, sir, we do (and I hope a fair percentage is correct). Would you like to have us engineer, say, 400 miles of open-wire line with carrier and all the trimmings from scratch? Give us fifteen minutes and we will hand you the layout all wrapped up and ready for service. Of course, we will survey the line for you. If you don't have the personnel to operate your equipment, we will train them in two weeks. If you don't have the equipment, don't worry, we will tell the French how to build the damned stuff for you. Some equipment may be German, some French, also British, and, of course, American. That's easy, just go ahead and modify — it works when we get through with it. How does it work? Well, we will discuss that later. When it comes to the finer points of transmission, you will find that there are two schools of thought over here. One groups works on the theory that you stretch a rope between two points, hang a 'phone on each end, and that constitutes a circuit. The other school (mine) is of the opinion that one ought to be able to talk between these two points."

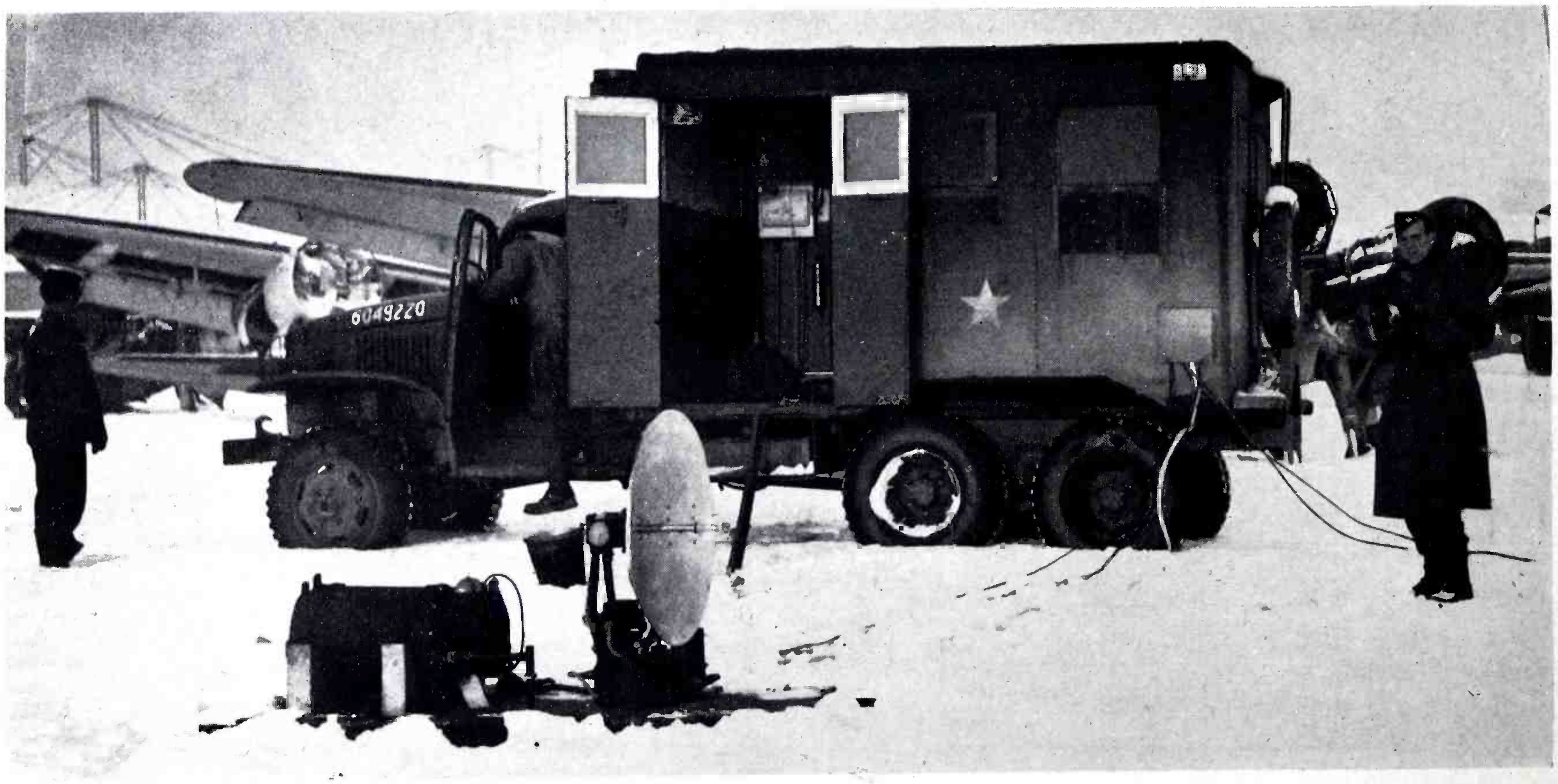
The author of this bit of humor, Mr. E. L. Pedersen, received the Bronze Star.

Field Engineer Turns Professor

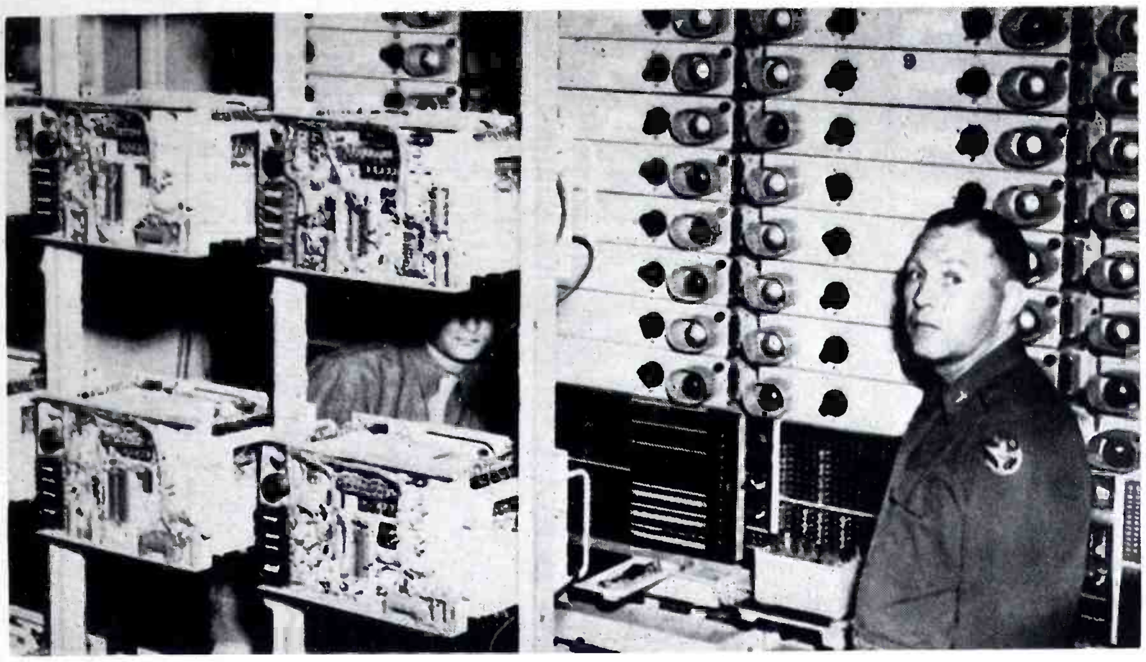
Another engineer, starting one midnight, had written by eight o'clock the next morning a textbook for Repeater men, who he was to recruit the next morning and train in a matter of weeks to operate the French Repeater stations. This ingenious individual, after requisitioning a building, managed to coax six G.I.'s, who had never before used a typewriter, to cut stencils for textbooks. He then set himself up as principal of an establishment known to the Signal Corps today as "Talberth's University on the Hill". The engineer was Harry Talberth, who in three days began a school which taught carrier equipment, carrier telegraph systems, plus duplex equipment and carrier frequency equipment. Altogether, there are over 2,000 "alumni".

Perhaps one of the most ludicrous dangers was experienced by an engineer on Saipan. After he had narrowly escaped from a crashing Jap Betty which fell in flames 40 feet from where he stood and threw burning gasoline outward singeing his clothing, a worse fate threatened him. For, a short time later, while crossing a field, he was chased by a wild bull and was saved miraculously when he tripped and so confused the beast that bystanders were able to rescue him.

At sea, how two engineers helped turn the tide against enemy shipping, is hinted at in a telegram to the Company's president, C. G. Stoll, from General H. H. Arnold. "I wish to express my own appreciation and that of the Army Air Forces for the invaluable assistance given by two of your



Field engineer stands at right of special portable radar used for tracking planes in over newly won military airfields. Radar equipment is transported in truck.



In Germany, Western Electric field engineer P. B. Fairlamb stands beside German telephone plant restored by his group. At left may be seen Western Electric toll ringers next to German telephone repeaters.

engineers who, under most difficult conditions, made it possible for the Army Air Forces to take the offensive with telling effect against Japanese shipping in the south and southwest Pacific areas, under conditions which normally would have made operations impossible."

Another engineer in the Norfolk Navy Yard was assigned to a ship for the purpose of testing and checking the fire-control gear and while on board, the ship left port. He was virtually shanghaied as far as New Caledonia before he could get transportation back to New York. "Due to unavoidable circumstances," apologized the skipper of this cruiser in a letter to the Home Office, "he was required to serve in a capacity far beyond that anticipated. He has been of invaluable service to this vessel at a great personal inconvenience." The engineer's wife, stranded in a Norfolk hotel without word from her "lost" husband for two months probably agreed heartily with this last statement.

During the war, besides the many unofficial expressions, nearly 250 official letters of commendation were received by the Force on behalf of its engineers. Typical are these sections from two of them which may serve to sum up the field engineer's role and his performance of it. One came from Rear Admiral A. H. Van Keuren, former Chief of the Bureau of Ships. He had received word from the Commandant of the Pearl Harbor Navy Yard concerning the work of an engineer assigned to that location when Japan struck.

"You have performed your duties in an exceptionally diligent and zealous manner," the Commandant advised the Bureau, to which Admiral Van Keuren added, "This example of good American spirit is typical of the manner in which Western Electric Company engineers have been undertaking their duties in connection with the installation and servicing of radar equipment in U. S. Naval vessels."

The second was contained in a report by Major General Curtis LeMay, Chief of Staff, 20th Air Force, (now Lieutenant General) to his Chief at Washington concerning six field engineers assigned to the C.B.I. Theatre early in 1944. General LeMay wrote of each field engineer:

"Although his primary assignment was maintenance of the equipment, he succeeded in raising the level of the maintenance of training in both a bombardment and service group assigned to this Command, to a point where even the most complicated problems were being efficiently performed by personnel of those units. His superb work becomes even more important as many of the lessons learned here will materially aid other VHB commands in the solution of their problems. The necessity for having Technical Representatives assigned to these organizations cannot, therefore, be over-emphasized."

Finally, a Navy guest at one of the Company dinners, held in honor of engineers upon completing their basic training, paraphrased the role of the engineer when he said, "We of the Navy are officers and gentlemen by appointment of the President and Act of Congress, but you engineers must be all this without official assistance."

The Armed Forces, which so benefited from the talents of these men, have thus expressed singular indebtedness to the role they played in World War II. The radio industry and the telephone companies deserve much credit for the success of the field engineering program, since they released many of their best men to this endeavor. These industries may now realize a measure of compensation for their sacrifices from the vast wealth of experience which the field engineers bring back as they return to important peacetime assignments.

Book Reviews

ELECTRONICS DICTIONARY. By Nelson M. Cooke and John Markus. 433 pp. New York: McGraw-Hill Book Co. $5.00.

Lt. Com. Nelson M. Cooke, Executive Officer of the Navy's Radio Materiel School and John Markus, Associate Editor of *Electronics* have combed the radio and allied fields and amassed a glossary of over 6,000 words and terms used in the language of electronics. These are contained in their new *Dictionary,* together with 600 illustrations of electrical and radio circuits, equipment and applications.

The glossary goes back in electrical history as far as the Leyden jar and the Faraday "ice pail," and is as up-to-date as radar and sonar. All the more common terms used in radio, television, industrial electronics, communications, facsimile and sound recording are included, as well as such unusual words as "episcotister," "electrokymograph," and "lumenophor."

According to the authors, the book endeavors to set up a complete and consistent abbreviating and compounding policy for electronic terms, and they suggest that some readers may wish to adopt the book as a one-volume style guide for engineering and stenographic use.

RADIO'S 100 MEN OF SCIENCE. By Orrin E. Dunlap, Jr. 294 pp. New York: Harper and Brothers. $3.50.

From the long list of scientists who have made radio and electronics possible, Orrin Dunlap, Jr. has selected 100 of the foremost and has written an absorbing narrative of their personalities and achievements. He writes from first-hand knowledge, for his wide experience as radio editor and executive has enabled him to know personally most of those men in this generation.

The biographies start with Thales of Miletus in 600 B.C. and cover the pioneers of electricity by touching on Galvani, Volta, Oersted, Ohm and others. By far the greater part of the book is devoted to pioneers of the Radio Age, such as Maxwell, Hertz, Edison, Bell, Heaviside, Tesla, Thompson, Steinmetz and Marconi. Forty-five of the scientists are still living, and the names in this group include Alexanderson, Langmuir, Ives, Zworykin, Armstrong and De Forest.

The sketches are short and concise, yet they go much further than the usual encyclopedia listing, for they tell something about the man himself — his personality, his likes and dislikes, and the force which drove him on to great discoveries.

Close-up of one type of antenna used in Western Electric fire control radar systems which point the guns of Navy ships from destroyers to battlewagons. Western Electric supplied more than 6,000 shipboard radars.

Radar

(Continued from page 8)

tion of the country's unrelated industrial resources to meet the Government's huge requirements in this field.

The subcontracting program began with a nationwide survey. While Western Electric's buyers were canvassing sources of supply, Company engineers sought out and classified potential subcontractors. This first survey by the engineers covered 500 plants in 28 states and Canada. It was the forerunner of other surveys that followed.

First subcontracts were for items of straight-forward manufacture, such as switches, condensers, motors and other apparatus already known to the subcontractors. Because of Western's intimate knowledge of the processes involved, the Government requested that the Company reserve for itself the job of producing the complex high-frequency components and other devices which had to be pioneered.

As the program got under way and Government requirements mounted, it became necessary for Western to train its subcontractors in virtually every phase of its own technique. A Western Electric engineer, for example, became the temporary foreman of one subcontractor's plant. In another plant, 11 Western employees were on duty at the same time, supervising technical methods, quality and assembly controls, expediting and generally helping the subcontractor to meet his commitments. Often, the engineers of these outside organizations were brought into Western's plants for training. In many instances, Western helped design, and usually financed, the new tools needed by subcontractors. Also, the Company frequently furnished them with critical materials.

Without skilled civilian technicians and trained military personnel to keep radar equipment functioning at top efficiency and to fix it if it goes wrong, this great technical weapon would have been far less potent. Here the Bell System's contributions have taken three forms: (1) training military personnel to operate and maintain the equipment, (2) furnishing detailed and illustrated instruction manuals with each radar unit, and (3) supplying the armed forces with Western Electric field engineers in the various war theatres.

Training in Military Electronics

The School for War Training, conducted by Bell Telephone Laboratories in New York City, instructed some 4,000 officers and men of the Army and Navy. In the aggregate they studied more than 100 courses in military electronics, chiefly radar. After graduation, most of the trainees became responsible for the training of additional men, either as instructors or as officers in command of maintenance units. Many went directly from the Laboratories' school to critical locations. The Navy required that every major combat vessel should carry at least one graduate of the Bell Laboratories' course on radar fire control (gun pointing) equipment.

Not only has Bell Laboratories furnished textbooks for its School for War Training, but it also has compiled and published instruction manuals in large quantities, to go along with each radar system. As a result, the Laboratories ranked as one of the largest wartime publishers in America, both for size of printings and number of titles.

Western Electric's Field Engineering Force (see article *The Field Engineer*, page 26) was born before Pearl Harbor when the Navy Bureau of Ships asked for 12 men trained in the installation of radar, to be stationed at the Navy yards. "It has been found," the Bureau stated, "where factory-trained experts are available to the Fleet, their efforts greatly facilitate the proper installation and assimilation of new equipment by the forces afloat."

By the end of the war, the Company's field engineers were serving all over the world with the Navy's Bureaus of Ships, Ordnance and Aeronautics, the Marine Corps, the Army's Air Technical Service Command and Ground Forces.

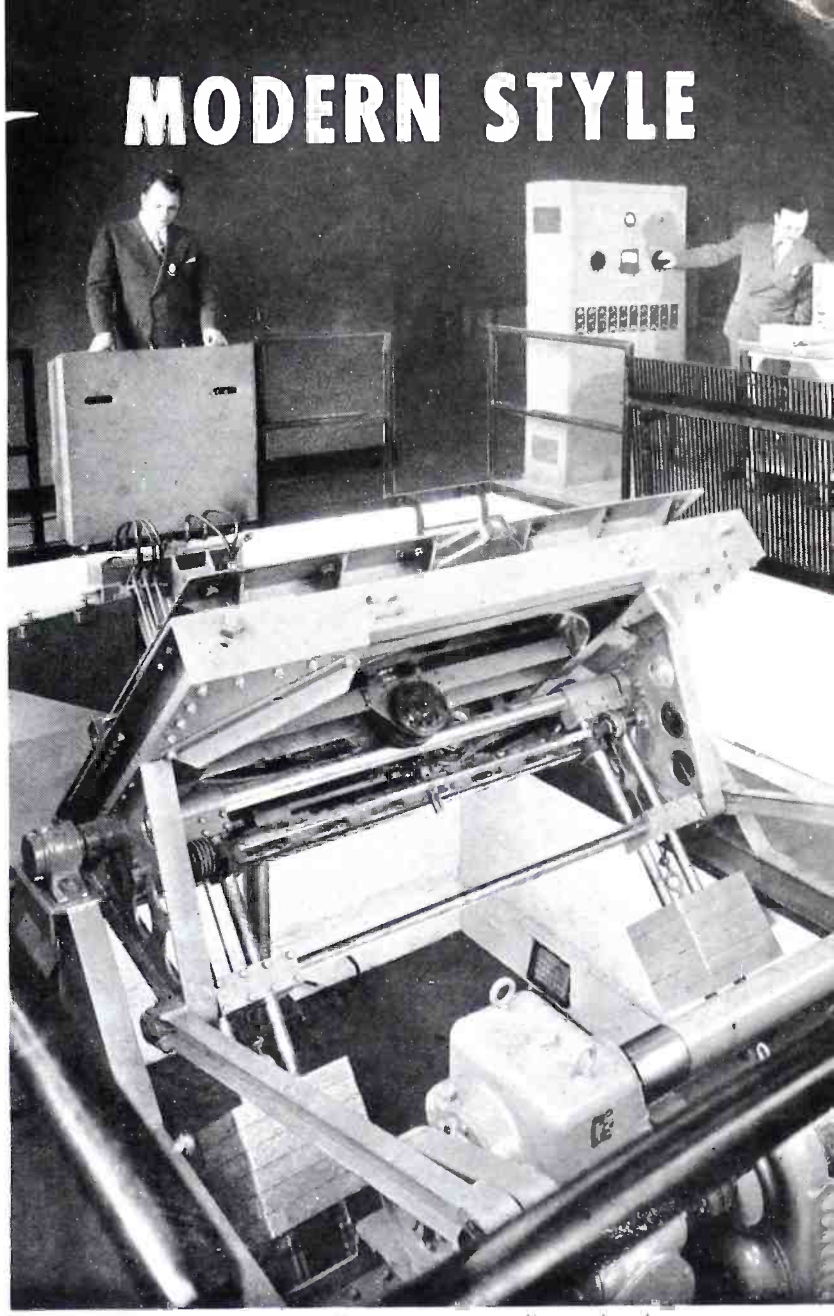
Precision test equipment is vitally important to the proper functioning of radar units. If no objects are perceived on the radar screen, it may mean one of two things: (1) that no objects are within the field of "vision," or (2) that the radar is not working properly. Thus facilities for testing the equipment regularly are obviously important in keeping it working at best efficiency.

Long before Pearl Harbor, Bell Laboratories undertook to develop test equipment for a few early radars. Commitments grew until Western Electric was carrying for the Government a major share of the manufacturing load of this vital equipment. The Laboratories developed more than 100 different test sets for different purposes. By 1944 Western Electric had made more than 40,000 units of 68 types, substantially all for use by our fighting forces at the war fronts or in their maintenance depots.

These test sets were more exact, precise and intricate than the radars themselves. Some of them were no larger than a loaf of bread. At the same time, since they must be used by troops right at the scene of action at the front, it was necessary that they be rugged and capable of withstanding airplane vibration, shock of gun-fire on shipboard, and the roughest possible ground transportation. Precision production, as it had for the vast radar program, did this job also.

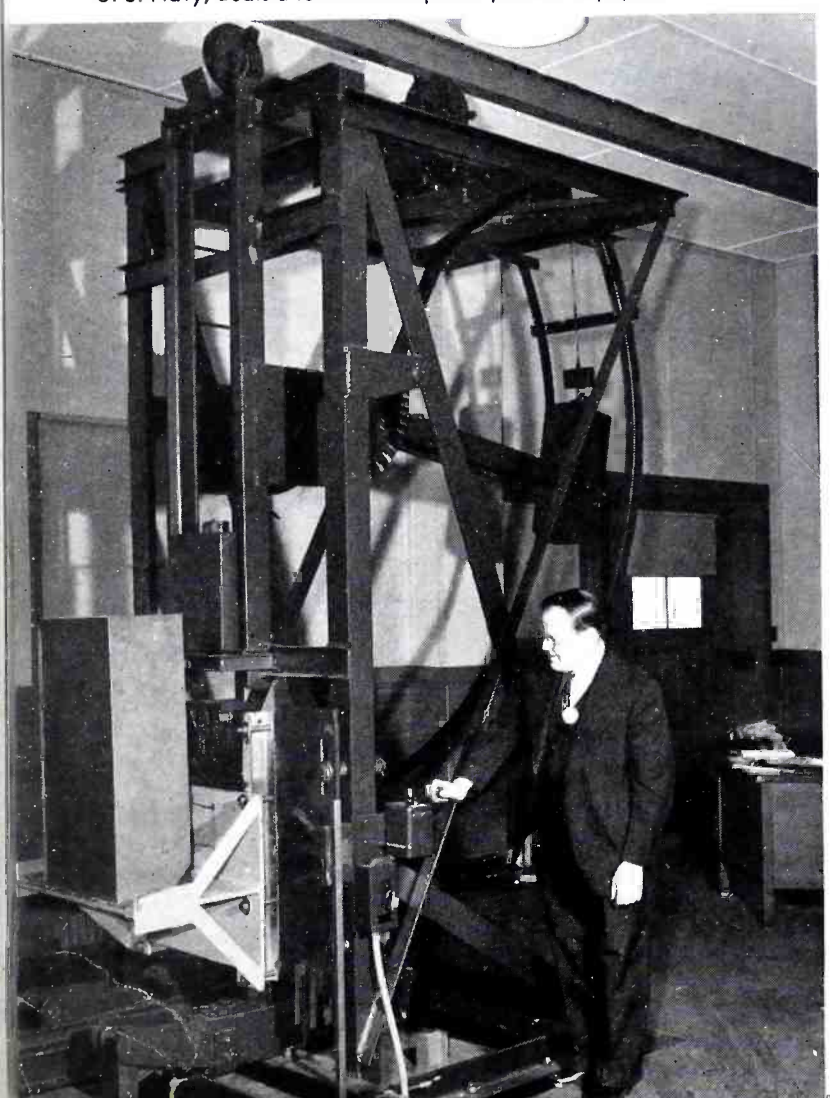
TORTURE CHAMBERS — MODERN STYLE

Wartime electronic equipment at Western Electric and Bell Laboratories was subjected to the most fiendish forms of torture which engineers could devise. This is the control for a stratosphere chamber where the temperature can be varied from —70 to 175 degrees F.

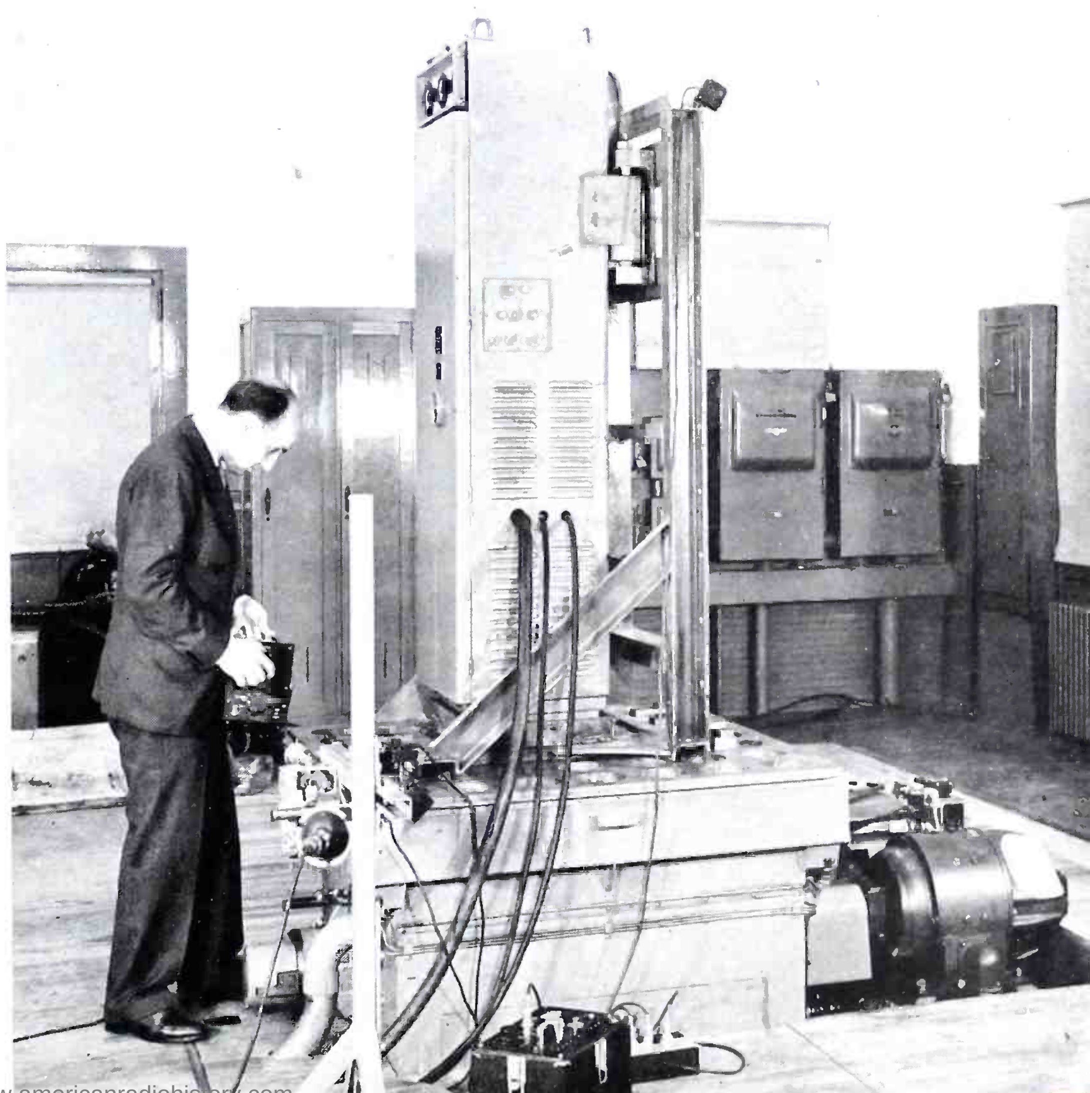


Only after passing these gruelling tests were radios and radars considered fit for military duty. This massive "rack" duplicates roll and pitch of a ship in a hurricane and the concussion of big guns.

The swinging hammer of this heavy shock machine, built for the U. S. Navy, deals a terrific wallop to a piece of equipment under test.



Apparatus gets the "shakes" on latest type of vibration test machine at the Whippany unit of Bell Telephone Laboratories. Torture tests were invaluable in designing war equipment.



"Firing" thermistors — This bank of three electric ovens is used to "fire" chains of tiny metallic oxide beads in one process during the manufacture of Western Electric thermistor elements.