# BENDIX RADIO ENGINEER


APRIL
Volume 1
Number 4
1945

*Volume I* *Number 4*

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The *Bendix Radio Engineer* is published quarterly by the Engineering Department of the Bendix Radio Division of Bendix Aviation Corporation, Baltimore - 4, Maryland; W. P. Hilliard, general manager; W. L. Webb, chief engineer.



Subscription rate: $2.00 per year; student rate, when subscription is entered through an instructor, $1.00 per year.




## The Cover

Video amplifiers must pass frequencies ranging from a few cycles to ten megacycles or more per second. The test set operated by Marie Rochester was designed by G. V. Rodgers to facilitate determination of frequency response characteristics. Its features are described in an article on the facing page.—*Photograph by Carl Gerber.*

BENDIX RADIO

*The significance of a person's creative ability goes beyond the immediate value of any object he may devise. For whether his work be based on a new concept, or on a new application of known principles, he adds to the store of knowledge and provides a foundation on which others may progressively build to heights limited only by man's ingenuity.*

## Editorial Staff

# VIDEO AMPLIFIER TEST SET

***A pulse test set for rapid determination of the frequency response characteristics of video amplifiers.***

**By G. V. RODGERS**
***Microwave Engineering***

Expansion in the field of television and similar projects which employ visual indicators, has led to the design of wide band amplifiers having substantially flat response characteristics and a minimum of phase distortion. These so-called video amplifiers are used to bring television signals, or other impulses, up to the level necessary for modulating a transmitter and for amplifying rectified signals from a receiver, so that they may be seen on a cathode-ray tube. Pulses of one microsecond duration or less are often used, so that the video amplifier may be required to respond equally to frequencies ranging from a few cycles per second to ten megacycles or more.

Assuming that an amplifier of this type has been designed and built, the engineer is confronted with the problem of determining the actual frequency response characteristic. Sine wave testing may be employed, but becomes an extremely tedious process, especially at the very high frequencies; and, if circuit modifications are being tried, considerable time is consumed in determining their effect over the complete frequency range. It is desirable, therefore, to determine frequency response by a more efficient method. Moreover, since the video amplifier is required actually to amplify pulses, the transient response is of prime importance.

## Pulse Composition

By Fourier analysis, a periodic rectangular pulse may be shown to contain an infinite number of components of different frequencies. Therefore, a wave of this form may be used to indicate instantaneously practically the entire frequency characteristic of an amplifier, with accuracy depending upon the capability of the user to interpret the results.

Practice in interpreting may be obtained by observing the distortion of a pulse when impressed on networks which have certain known limitations. The high frequency response can best be interpreted in terms of the transient response at the leading edge of the pulse waveform. Any decrease in the voltage rise time following amplification denotes poor high frequency response (see figure 1). Improper termination of cables, or certain combinations of circuit parameters, may cause oscillatory response or ringing, which is undesirable. Poor low frequency response is indicated by a sloping pulse top and by the appearance of the trailing edge.

The short-duration pulse described here is inadequate as an indication of response at the very low frequencies. The same testing method, however, may be applied, using a long-duration square wave, generated by a multivibrator, and observing the results with an ordinary oscilloscope.

The essential parts of a setup for pulse checking of video amplifiers are: 1) a pulse generator which will produce a rectangular pulse of variable amplitude with a duration of one microsecond or less; 2) an indicating device calibrated for pulse amplitude and duration, and having very low input capacitance in order to obtain a true picture of the pulse being observed; and 3) a means of synchronizing the pulse with the indicating device.

The author has incorporated these features into the design of a video test set with self-contained power supply. A block diagram of the setup is shown in figure 2.

The sweep generator causes push-pull deflection of the cathode-ray beam and at the same time furnishes a negative gate to turn on the cathode-ray tube during the sweep period. The positive sweep is also used to trigger the pulse generator.

Figure 4 is a schematic of the video test set, and figure 3 is a block diagram, which shows the waveforms obtained at various points in the circuit.

Both plate and bias supply voltages are obtained from a common power transformer rated at 860 volts center tapped, at 80 milliamperes. Half-wave rectification is used in the negative supply.

## Trigger Generator

The pulse repetition frequency of the set is determined by the time constant in the grid circuit of the trigger generator stage, V-1(a). This tube acts as a feedback oscillator which becomes inoperative for an appreciable time following each cycle of oscillation. Blocking is caused by the flow of grid current at the start of each cycle, at which time the grid is positive with respect to the cathode because of the signal fed back from the plate through the transformer. Electrons are attracted to the positive grid and store up a charge in the grid coupling capacitor. When the tube has reached saturation, the induced voltage no longer holds the grid positive and the capacitor applies

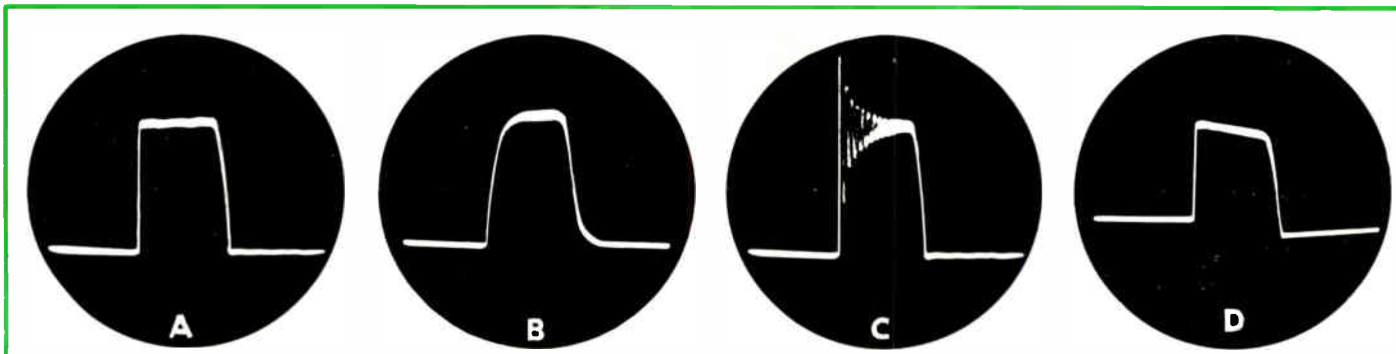



*Figure 1—Typical waveforms. A. Undistorted pulse; B. Poor high frequency response; C. Oscillatory response; D. Poor low frequency response.*

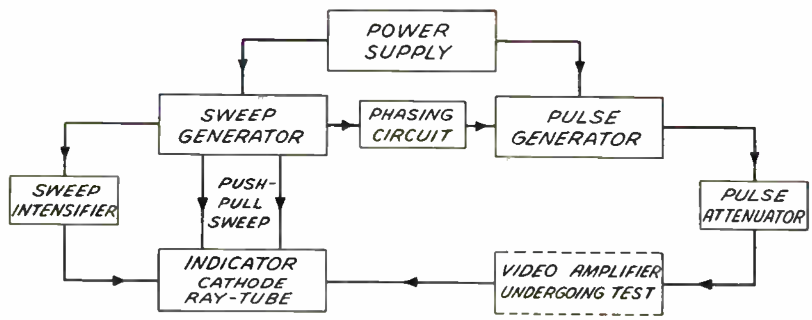



**Figure 2—Block diagram of setup for testing.**

a large negative bias, thereby preventing further oscillation until the charge has had time to leak off through the grid resistor. The time constant is therefore dependent on the product of R and C, but is altered somewhat by the presence of the transformer winding in the circuit. The exact repetition frequency is not important but, once selected, it determines, to a certain extent, the adjustment of succeeding stages. The values given here for R and C set the repetition rate at approximately 2000 pulses per second.

Following the trigger generator is a multivibrator circuit composed of V-1 (b) and V-2. Tube V-2 is normally conductive while V-1 (b) is non-conductive. When the negative trigger from V-1 (a) drives the grid of V-2 into the negative region, conduction abruptly ceases and a positive impulse is applied to the grid of V-1 (b), causing this tube to conduct. The plate of V-1 (b) in turn sends a negative impulse back to the grid of V-2 which drives the grid to a more negative potential. The drop in plate voltage of V-1 (b), however, causes the coupling capacitor to discharge through V-1 (b) and the grid resistor of V-2, and holds the grid voltage of V-2 sufficiently negative to prevent conduction. When the grid coupling capacitor voltage falls low enough to allow conduction through V-2, tube V-1 (b) is cut off abruptly, and the circuit assumes its normal operating condition. The time constant is determined mainly by the values of resistance and capacitance in the grid circuit of V-2.

The multivibrator circuit performs two functions: 1) it applies a negative pulse, taken from the plate of V-1 (b) and sharpened and clipped in the cathode follower, V-3 (b), to the cathode of V-4 to intensify the beam while the sweep is taking place; and 2) it provides a suitable time base or sweep voltage for the cathode-ray tube, since the leading edge of the positive gate, appearing at the plate of V-2, starts with a virtually linear voltage versus time characteristic.

The rise time of the gate is a period of a few microseconds, this time being required to charge the stray capacitances and the internal tube capacitances. Consequently, no actual capacitor is required in the plate circuit of the sweep generator. A change in gate amplitude is, in effect, a change in sweep speed, since the velocity of the cathode-ray beam across the tube face is proportional to the rate of change of the deflection voltage.

The sweep is applied directly to one of the horizontal deflecting plates of V-4 and, at the same time, is passed through the inverter tube V-3 (a), which drives the other horizontal deflecting plate. When the voltage at the plate of V-4 rises, the conduction of V-3 (a) is increased, causing a drop in plate voltage. Hence, a method of push-pull deflection is provided for the cathode-ray tube.

### Video Pulse Trigger

Synchronization and phasing of the pulse generator with the sweep are accomplished in V-5 (a). This stage makes it possible to trigger the video pulse after the sweep has started, so that the entire pulse may be seen on the cathode-ray tube. The circuit functions in the following manner: A part of the sweep voltage waveform is applied to the grid of V-5 (a). This tube is connected as a cathode follower and normally operates within the conducting region. If, however, the phasing control is turned so as to introduce a fixed negative bias into the grid circuit, the tube will not conduct until the sweep voltage has driven the grid above the current cut-off value. Consequently, part of the sweep time will have elapsed before a signal appears at the cathode to actuate the pulse generator circuit. The delay time is proportional to the amount of fixed bias and may be varied by adjusting the phasing control.

Tube V-5 (b) is a trigger generator similar to V-1 (a), except that it has a cathode bias resistor which prevents oscillation until a signal from V-5 (a) makes the grid sufficiently positive. Therefore, the trigger output from V-5 (b) operates in synchronism with the sweep voltage, but is delayed by an amount which is determined by the position of the phasing control.

Tube V-6 is a gas tetrode which is nonconducting until it receives a positive trigger from V-5 (b). When this happens, the tube fires and a negative voltage impulse is sent down a delay line, is reflected at the end of the line, and is returned to the anode causing a sudden drop in anode potential, thereby restoring the tube to nonconductivity. The delay line may be an actual

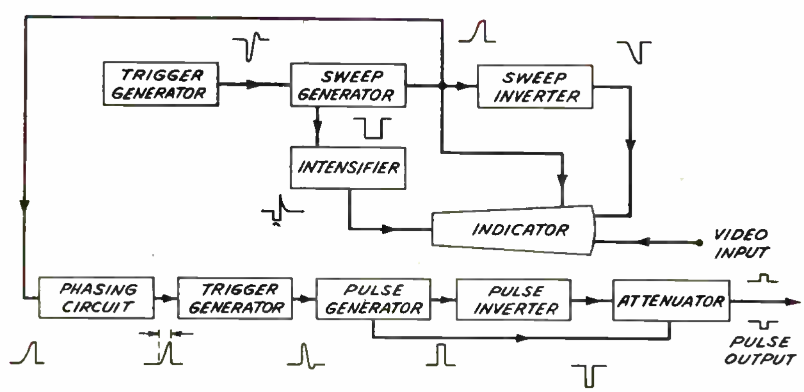



**Figure 3—Block diagram of the test set, showing the voltage waveforms at various points in the circuit.**

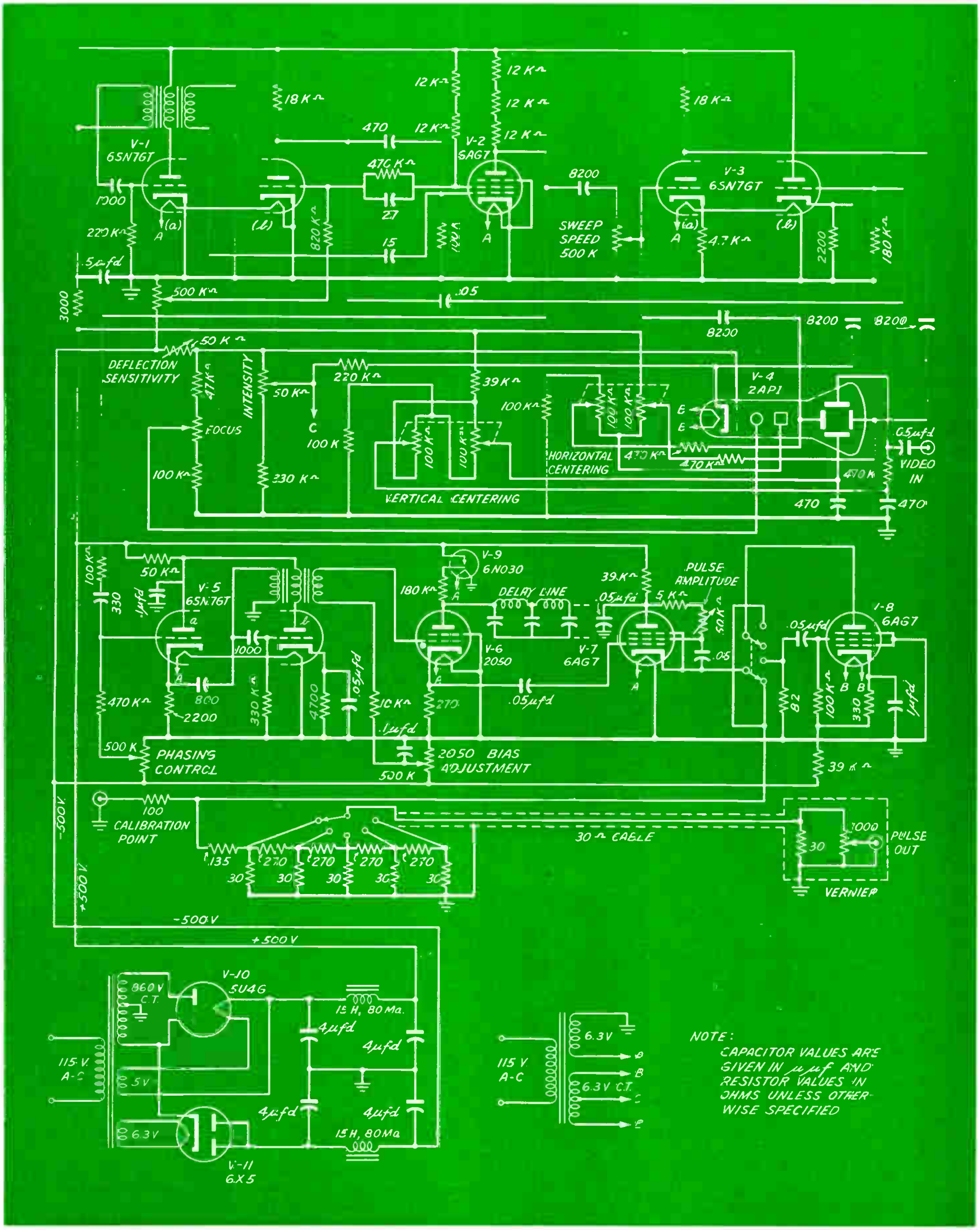



**Figure 4—Schematic diagram of video test set.**

cable having a length sufficient to give the desired pulse duration, or it may be made up of lumped parameters of inductance and capacitance calculated to give the required delay. Special spiral cable now is available, which, in one foot, contains the electrical equivalent of 15 feet of ordinary coaxial cable, making it possible to obtain the desired delay with lines of relatively short physical length. A 1/2 microsecond artificial line is employed in the unit described here.

A thermal time switch is provided to protect the gas tube from cathode disintegration, which would occur if anode voltage were applied before the tube is completely heated. This switch is a simple mechanical thermostat in an evacuated glass tube, with a heater winding designed to operate at 6.3 volts. A period of 30 seconds is consumed in heating the spring contact to the temperature required to close the circuit.

### Cathode Follower Stage

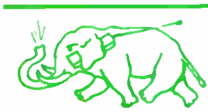
Tube V-7 is a pentode cathode follower stage, designed to clip the top and bottom of the pulse to assure rectangular wave shape. To accomplish this the tube is operated between cut-off and saturation. Coupling from cathode to screen increases the input impedance, thus decreasing attenuation in the grid circuit. By varying the series screen resistance this coupling is changed, and the pulse amplitude may be adjusted to the extent necessary for calibration purposes, without disturbing the wave shape.

An attenuator is used to step down the output pulse to a level which will not saturate the amplifier being tested. Steps of 10:1, 100:1, 1000:1, etc., are available, and in addition a calibrated vernier potentiometer is provided to determine the exact saturation level of the amplifier under test. If a negative pulse input is required, the attenuator is switched into the plate circuit of the pentode inverter, V-8. The switching action at the same time couples the puls output of the cathode follower to the inverter grid. V-8 is operated from the negative voltage supply, so that the attenuator may be used as the plate load. A rise time of .02 microseconds was measured for the positive pulse, and .01 microseconds for the negative. The input capacitance of the 2AP1 tube is approximately only 4 $\mu\mu$f, and hence does not affect the pulse shape. The combined potentials of the positive and negative supplies are employed to provide the high voltage necessary to operate the cathode-ray tube circuit. Dual potentiometers are used in both the horizontal and vertical centering circuits to prevent deflection de-focusing, which would occur if the d-c potentials applied to the deflecting plates were not symmetrical with respect to the second anode. Rotation of either of these potentiometers makes the corresponding pair of deflecting plates positive and negative in relation to the second anode by an equal number of volts. The horizontal centering control is arranged to move the trace on the tube to the left of center only, since the sweep will always deflect the beam to the right. The vertical deflecting plates, on the other hand, must reverse polarity with respect to the accelerating anode so that the trace may be shifted both above and below the center of the tube. Focusing is effected by adjusting the potential of the first anode, the proper setting being dependent on the beam intensity. Because of the fixed negative bias on the grid, the cathode-ray beam is normally cut off, except when the intensifier pulse drives the cathode in a negative direction. The manual intensity control sets the value of fixed bias, and thus determines the degree to which the beam will be turned on by the intensifier.

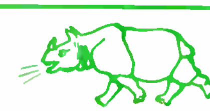
The deflection sensitivity of a cathode-ray tube varies inversely with the potential applied between the cathode and the accelerating anode. Hence, the adjustable resistor connected between the cathode of V-4 and the negative supply may be set to give the desired voltage calibration. To accomplish this a voltmeter may be connected between the vertical deflecting plates to show the change in voltage produced by moving the sweep trace a given number of divisions with the vertical centering control. A suitable calibration is 100 volts per inch. A lead connected from the calibration point to the video input terminal will project the full pulse amplitude on the screen of the tube. The pulse amplitude may then be set to 100 volts, making the steps on the attenuator equal to 0 to 10 volts, 0 to 1 volt, etc. The sweep calibration is 1 microsecond per inch, and may be set with sufficient accuracy by adjusting the sweep speed control until the 1/2 microsecond pulse occupies the correct portion of the screen, provided a reasonable amount of care is taken in selecting the delay line.

**G. V. Rodgers**

As Junior Engineer in the Microwave Laboratory, youthful, serious "Vic" (George Victor) Rodgers has been working on various applications of cathode-ray tubes and associated circuits, and designing an oscilloscope indicator for a microwave receiver. A native Baltimorean, he completed the "A" course at Baltimore Polytechnic Institute, devoting his spare time to servicing radios and building public address systems. Continuing to specialize in radio, he received his B.S. in Electrical Engineering at the University of Maryland in 1943. He helped in the erection of the campus broadcasting station at College Park, and managed to find time to construct recording equipment and make transcriptions of college orchestra music and other programs. During vacations he worked as a wireman at the Radio Division of Westinghouse Electric and Manufacturing Company. Joining the Bendix Radio staff immediately after his graduation, he had the advantage of four months in the Bendix engineering training course before assignment to the Microwave Engineering Section. Two nights a week he teaches Electronics in the adult education program at Baltimore Polytechnic Institute. When he has time to relax, he enjoys testing the speed of his outboard racing runabout, which he keeps anchored on the Magothy.



## The Ubiquitous Walkie-Talkie



Train crews want walkie-talkies for their own mysterious purposes; farmers' wives ask when they can broadcast dinner call to the men instead of waiting or screaming. Now, elephants wired for sound carry rescue crews to crash-landed planes in jungles. Only adventure occurred when a radio-equipped elephant, charged by an intrepid rhinoceros, trumpeted an impromptu program into the transmitter aboard and scared the daylights out of his passengers and the listening audience.

# The World Listens

YOUR TAXES MAY BUY a bargain in the Office of War Information. Present estimate is that, if the war is shortened by only five hours because of American propaganda, the OWI will have paid the complete cost of its operation from the time it was established in June, 1942. This cheerful conclusion is based on a comparison of the impressive cost of OWI with the astronomical costs of war—from bullets to bulldozers.

OWI radio operations alone, a five-million dollar project in 1944, are more extensive than NBC, CBS, Mutual, and Blue networks combined.

## New York Headquarters

The main radio center for OWI is in New York, the starting point of programs beamed eastward; propaganda for the Orient is sent from the San Francisco office, which expands as the need grows. Twenty-five hundred programs a week originate in the New York office. There, on a master control desk over 20 feet long, red lights show which of the 40 shortwave channels are in use at any one moment. Fourteen recording lathes—the largest recording setup in the country—grind out discs for these programs and for other broadcasts to be sent from foreign radio centers and from loud speakers in recaptured countries.

Contrary to popular belief, the subjects of the programs are not dreamed up in Washington. The OWI radio programs, sparked by practical radio men formerly in commercial stations, usually grow out of reports on the interests of potential listeners abroad. OWI outposts manned by civilian specialists in administration, research, Morse code, radio programming and engineering, follow at the heels of hostilities, find out what the inhabitants want to hear, and pass the word along to headquarters in the United States.

For example, when liberated Parisians wanted to know more about the United States, OWI went through a fairly typical procedure in turning out a program now popular on the continent. From OWI outposts came a flood of reports that the French were asking about the United States—about the TVA, aircraft factories, recipes for doughnuts, farms in Iowa, new music, Hollywood, and everything else. The Radio Executive Board of OWI decided on a weekly program, built around questions sent from French listeners to the Paris office and relayed to New York.

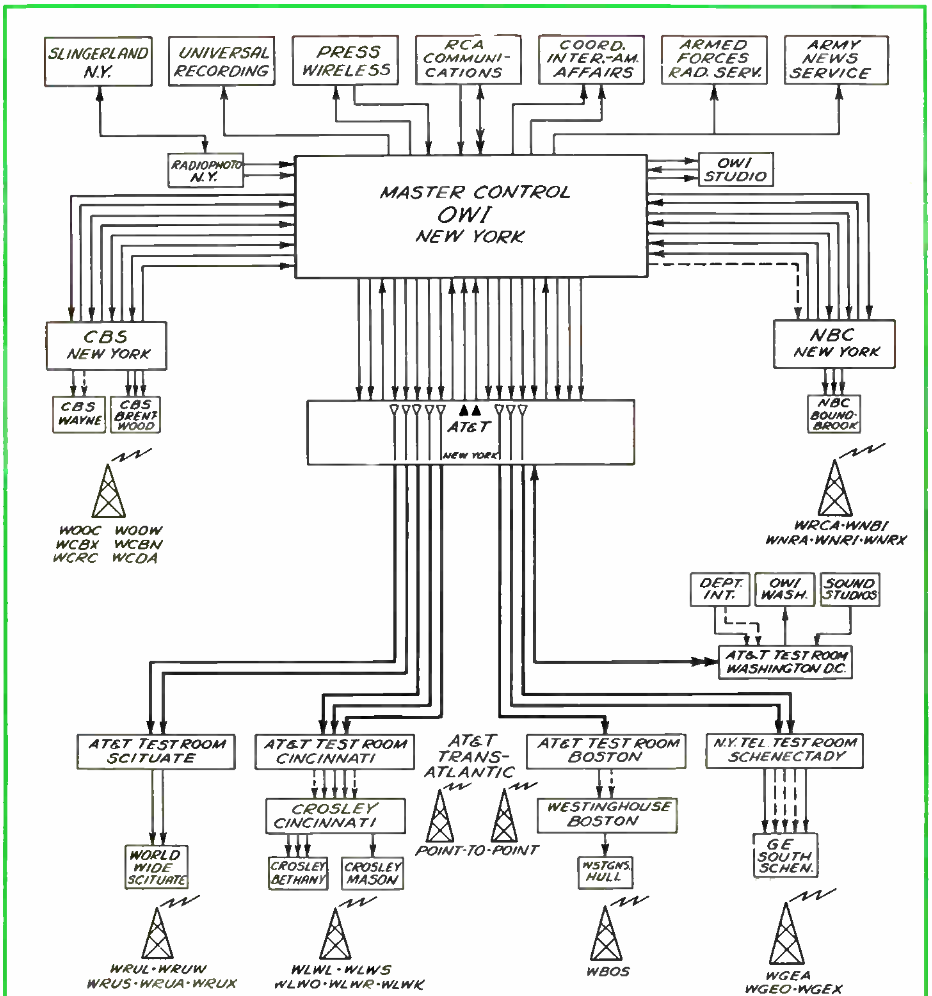
## Program Routine

Once the general plans were made, the Executive Board discussed the project with

***Master control unit provides channels for all broadcasts beamed east or south of the United States. Major networks and OWI studios feed programs on 60 incoming channels; programs go out on 20 channels. Switchboard at right connects with key offices in system. Recording room appears through window.***

***This section of the master control unit shows volume recorders. Panel at right permits monitoring of all studios, transmission lines, and receiving lines.***

*—Courtesy of OWI*




***Traffic facilities for international broadcasts through OWI in New York.***

the French Language Desk. Since then, a team of French writers and the executive producer for French broadcasts have had the entire responsibility for the script and the show from beginning to end. Each week they select the questions (though diplomatically touchy queries about the Polish border or the upheaval in Greece, are referred to authorities in Washington); and they compile the answers, which are translated and turned into a good radio script at the Language Desk. In its final form, this script must be approved by the OWI Control Office to satisfy its sponsor, the United States Government; and it must also be entertaining enough to appeal to its harassed listeners.

To get the program on the air, the executive producer arranges for the casting, announcing, rehearsals, and final production. He also requests clearance of the facilities needed to rehearse, record, and broadcast the program.

By virtue of the blood, sweat, and toil of the Facilities Office, the required equipment is cleared and assigned to the French program. With hundreds of shows being prepared simultaneously, the first problem is to provide a studio, even though commercial studios can be borrowed from the major stations if the twenty OWI studios are in use. Each of these twenty studios with its adjoining control booth is an unpretentious room equipped with a chair, a table, and a microphone—none of the luxurious lighting fixtures and leather upholstery of the commercial stations. From the assigned studio, a recording of the program is made well in advance of the actual broadcast.

Meanwhile, plotting the needed frequency is complicated by the fact that there is not a complete battery of antennas for each transmitter. An antenna beamed in the desired direction and a transmitter operating at the correct frequency must be free at the time scheduled for the program. To facilitate the shifting of frequencies, new antennas for overseas transmission have been rhombic in construction.

Next, the program must be routed through the master control which is large enough to feed all programs broadcast across the Atlantic from this country. In addition to OWI programs, all programs for international broadcast originating at NBC, CBS, Mutual, and Blue go through the master control at OWI. It is also large enough to feed forty groups of transmitters in specialized areas abroad.

After preliminary arrangements are complete, six or seven days of paper work are necessary to put the program on the air. Switching instructions, cues, notification of the telephone company, and instructions to the personnel in the program constitute part of this routine. The program, its destination, its language, the facilities it uses, and its span of time are noted on an elaborate chart which includes the same information about all other OWI programs of the week.

## Special Broadcasts

So much for one radio program on its way through the mill of production. Multiply this process by two thousand, and you have an idea of the weekly activity around the OWI radio offices in New York. In the swirl of all these projects, two special broadcasts stand out as colossal efforts to span the earth with news. The first began within minutes after the official announcement of the Normandy invasion, when the news went out from New York over 21 shortwave transmitters in 28 languages and 11 dialects. For 24 hours a day, listeners in Europe received the latest news in English on the hour, German at quarter after, French at half past, and Italian at quarter of the hour. With commendable shrewdness, many of them listened to make sure that Uncle Sam was saying the same thing in English that he directed to them in their own language.

The news for this program came into OWI over 11 teletypes carrying releases from press services here and abroad. It was supplemented by background material amassed weeks in advance about all possible invasion points. The Basic News Office sifted, checked, and edited news items before sending them throughout the OWI building on some 60 internal teletypes. Experts worked around the clock, verifying, interpreting, and shifting quickly from language to language. These experts are apologetic if they are fluent in only six languages; some of their colleagues, they tell you humbly, know thirteen.

Another special program lasted only four hours, but was so strenuous and nerve-wracking that one husky executive lost ten pounds. At nine in the evening of Election Day, OWI in New York began broadcasting early returns, and interpretations to make their significance understandable abroad. With each tabulation, announcers explained in English, French, and German

—Courtesy of Electronic Industries

**Recording room includes 14 cutting lathes (left) which produce records of constant quality. Memovox machines are lined up in the center.**

—Courtesy of OWI

**Operator uses microscope to check groove made by recording lathe.**

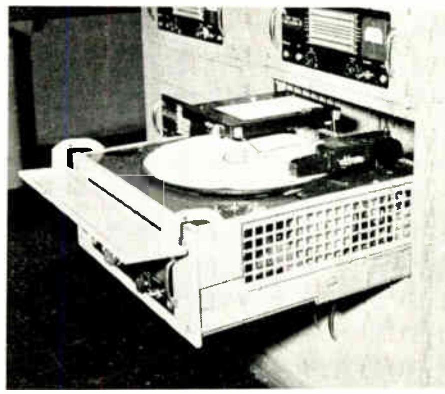
how the electoral vote differed from the popular vote, that the polls closed at different times in the various states, and that all bitterness would be forgotten the next day. This information was interspersed with music and with spot broadcasts from such places as Times Square and Ottawa, Canada. Four medium and six shortwave transmitters started the broadcasts which were relayed by BBC, the French national radio, stations in Algiers, Luxembourg, Stockholm, and other stations around the world. Two transmitters were reserved for the Army to carry election news to the troops.

## Facilities Expanded

Within the last year, the facilities for propaganda broadcasts have been increased first by the opening of ABSIE (American Broadcasting Stations in Europe), and later by the 200 kw high frequency transmitters near Cincinnati, Ohio. Capture of the powerful Luxembourg station last fall expanded the coverage of Europe by medium wave.

ABSIE uses 12 BBC transmitters and broadcasts from London on 5 shortwave frequencies, and 2 standard waves. The medium wave broadcasts have been particularly effective in reaching ordinary homes where radios are not equipped for shortwave reception. On D-Day, ABSIE helped the invasion by telling fishermen to keep the waters clear. Only one boat went out, and it was so pointedly boycotted by the Danes that its fish rotted on the docks. Next, civilians were told to stay away from war factories and danger areas, to watch where mines were laid, and to put up signs beside them. During the early summer, Europeans listened to ABSIE in terms of their lives, since the programs informed them of the exact line of behavior expected of them to help the advance of Allied troops. From the very beginning, straight hard news preceded and followed by a summary, made up most of the programs. After instructions lessened, entertainment relayed from the United States provided programs as American as the hot dog. They start with the first bar of Yankee Doodle which has become so popular in Europe that children now whistle it at play. Dance bands, symphonies, comedians, and speakers at such events as the *Herald Tribune* Forum, are given choice spots on featured programs. After hostilities end and the French broadcasting system is restored, ABSIE will silence its transmitters.

Programs sent to Germany and her satellites are very different because their sole purpose is to convince their listeners that the jig is up. Radio broadcasting is most



—Courtesy of Electronic Industries

**Open drawer of Memovox machine used to make a permanent record of all programs as they go over the air. Recording continues, automatically shifting from one drawer to the other until the program is over.**

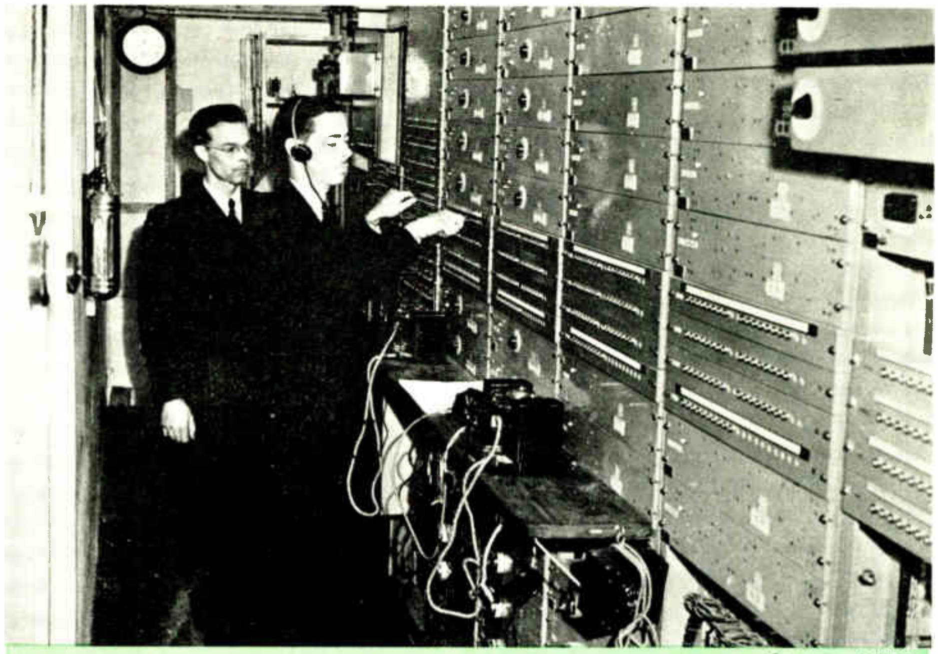
important during the tottering period of indecision when discouragement of the enemy may hasten the peace. To this end, German mail captured en route by the Allies is read in a popular program called "The Letterbag." In general, the letters complain of bad conditions and show concern about the civilians or soldiers to whom they are addressed. One solicitous frau wrote to her husband: "Wouldn't it be possible for you to get yourself surrounded like those we hear about?" German confidence in ABSIE is increasing because its reports prove to be accurate. There is something convincing about being told "The Allies are coming to your town," and finding them on the doorstep the next morning. A survey at Aachen showed that 70% of the civilians listened to ABSIE despite penalties, and some of them passed the word along to German soldiers.

The underground press and liberated press in Europe have been kept alive at times by Allied radio, almost their sole source of news. From New York are sent press releases (which are read three times at dictation speed) and radiophotos of recent events or facsimiles of whole pages of editorials and magazine features. Instead of the usual point-to-point transmission for this material, it is broadcast on schedule and picked up simultaneously by such scattered reception points as London, Paris, Rome, Ankara, Bagdad, and Aden. The results are very efficient, and the cost is considerably less than point-to-point transmission.

The brain of this farflung system is concentrated in New York. Here are installed a master control system, and also recording equipments which dwarf even the largest commercial setup. Each of the 20 sections of the master control can cover 60 incoming programs and 40 outgoing channels. Outgoing broadcasts are usually monitored just after each break, and then the channels are pre-set for the next programs. At one end of the master control is an automatic volume indicator which supplies an inked modulation graph for any channel to which it is switched. Reports that the audio level is too high or too low may thus be verified by this permanent record.

In an adjoining room are 14 recording tables, each set on a 700-pound cement base with an inch of rubber between the cement and the recording unit. Operation has been so simplified that one person can take care of as many as five tables. Pointed toward one side of the record is a shiny tube which sucks up the cutting threads and deposits them in the maw of an enormous machine, resembling a vacuum cleaner, in another part of the building. Attached to the other side of each lathe, a microscope is conveniently tilted so that the operator may inspect the width, depth, and condition of grooves. All machines cut laterally with constant quality, and produce a 14-minute, 40-second show on one side of each record. Parts of records may be dubbed in one disc to make a complete recorded show. For example, a record of the most popular selections from a series of Toscanini concerts was used as a master for pressings sent overseas for local broadcasts.

Twenty Memovox machines, each equipped with two turntables, record all programs leaving this country. One side of each 16-inch disc lasts one hour; then the recording is automatically shifted to the other turntable in a second drawer of the unit, and resumed at the break. If necessary, recording continues in the first drawer after the second span of one hour; and recording ceases automatically when the program is over. The records are flexible plastic discs which have no rich tone quality but are used for reference when the FBI or some other authority gets curious about a program. Once listeners reported that an excited German voice had broken in on a WOKO (Albany, N. Y.) broadcast, and the FBI traced it to OWI in New York. Careful checking of records and facilities cleared up the mystery. OWI and WOKO wires were shorted, and for 40 seconds Albany listeners were treated to a Jugoslavian program. Another time, London offices complained that code messages were in the background of programs sent to them. Reference records corroborated unusual noise, and it was traced to a workman doing some heavy construction near the studios. A Navy censor investigated his pounding, admitted it had an interesting rhythm, but assured London that it was not in code.



—*Courtesy of OWI*

***ABSIE switchboard connecting broadcasting headquarters in Great Britain with all their radio stations supplying programs to liberated and occupied countries.***

## *Enemy Also Active*

Impressive as this OWI equipment seems, our well-heeled enemies began with triple the shortwave broadcasting facilities that we now have in this country. In 1942, Japan controlled at least 48 broadcast transmitters, and Germany had about 80 shortwave transmitters with at least a dozen additional units of 200 kw output. At that time, the U. S. had 14 shortwave transmitters for international broadcasting; now there are 39, with the Crosley transmitters at Cincinnati supplying the only 200 kw power.

Recent expansion of facilities on the West Coast provides 1000 programs a week broadcast in 23 languages and dialects. Of the 12 transmitters there, the Army uses 7 for sending news and transcriptions of popular radio shows to the troops. Stations in Saipan and Leyte pick up, record, and rebroadcast these offerings. A shortwave transmitter in Hawaii extends the coverage to the interior of India and China. From the Aleutians to Australia, inhabitants and armored guests may listen daily to the news in their favorite language—whether it be Mandarin, Malay, or G. I.

# SIGNAL GENERATOR FOR UHF

***A new instrument that provides greater precision and convenience in ultra high frequency work than has heretofore been obtainable.***

**By ALFRED W. BULKLEY**
**Receiver Engineering**

THE MOST IMPORTANT REQUIREMENTS of a good uhf signal generator are negligible r-f leakage and absence of frequency modulation. The Bendix Radio IF-15A meets the first requirement by triple shielding of the r-f unit and careful design of the filter circuit between the shields. Frequency modulation is prevented by using three stages, consisting of oscillator, doubler, and modulated amplifier in order to isolate the oscillator from the modulated amplifier. The instrument is contained in a single, easily portable case (see figure 1).

### Features Incorporated

In constructing the IF-15A, the objective was to design an instrument convenient for reasonably fast production checking, yet of sufficient accuracy for laboratory use. To this end the following features were incorporated:

1) An over-all weight of only 70 pounds;

2) Outside dimensions 27 inches wide by 16 inches high by 12 inches deep;

3) Quick easy tuning, by means of a single-speed knob, and a low-speed vernier knob both geared directly to the condenser gang (no r-f trimming necessary);

4) Dial directly calibrated in megacycles, with vernier readings for accurate spot frequencies available on a roller chart mounted on the front panel;

5) A mask geared to the bandswitch knob so that it exposes only that portion of the dial covering the band in use; the limited exposure saves time and reduces chance of error in selecting frequencies;

6) R-f output fed through a coaxial line to a compact terminal cylindrical in shape, with the case at ground potential, and the r-f voltage available at a binding post projecting from the end; this arrangement makes it possible to apply the output to any part of a receiver by extremely short connections (an essential for accuracy in high frequency measurements);

7) A knob on the front panel which selects internal modulation frequencies of 200, 300, 400, 600, 1000, 1500, 2000, 3000, and 4,000 cycles per second, and terminals for applying any external source of modulation;

8) Percentage modulation read directly from a meter, with control from 0 to 100% provided by a knob below the meter face;

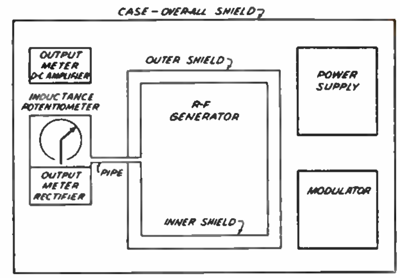



**Figure 2—Layout of signal generator; back view, showing shielding.**

9) R-f output voltage indicated by a meter with a semi-logarithmic scale calibrated from 1 to 10 microvolts, and controlled by a potentiometer (multiples of 1, 10, 100, 1,000, 10,000, and 100,000 are selected by a step attenuator); and

10) Careful mounting and shielding of the r-f oscillator, attenuator, and components of the output vacuum tube voltmeter to provide mechanical stability.

The first consideration in the initial layout of the instrument was minimum r-f radiation. Three factors determine the magnitude of the r-f leakage:

1) the arrangement of the shields,

2) a single ground lead between the shields, and

3) the r-f filters between the shields.

The r-f generator in the IF-15A is completely enclosed by a cast aluminum box

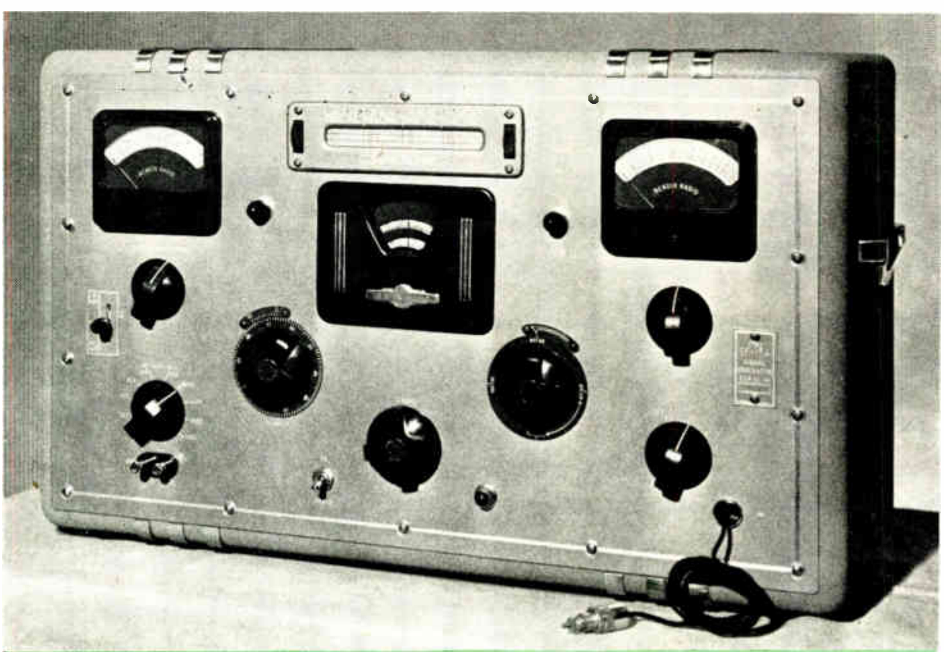


**Figure 1—IF-15A Signal Generator.**

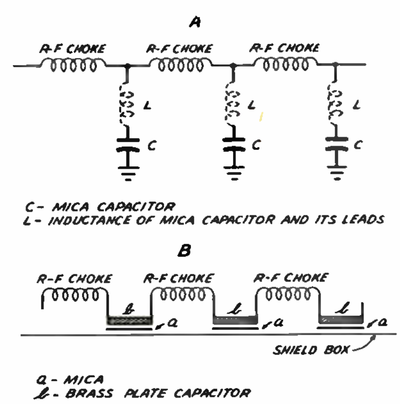



**Figure 3—A. Ordinary bakelite case mica capacitor is poor bypass at uhf because its inductive reactance is appreciable. B. Chokes and special flat plate capacitors used in IF-15A.**

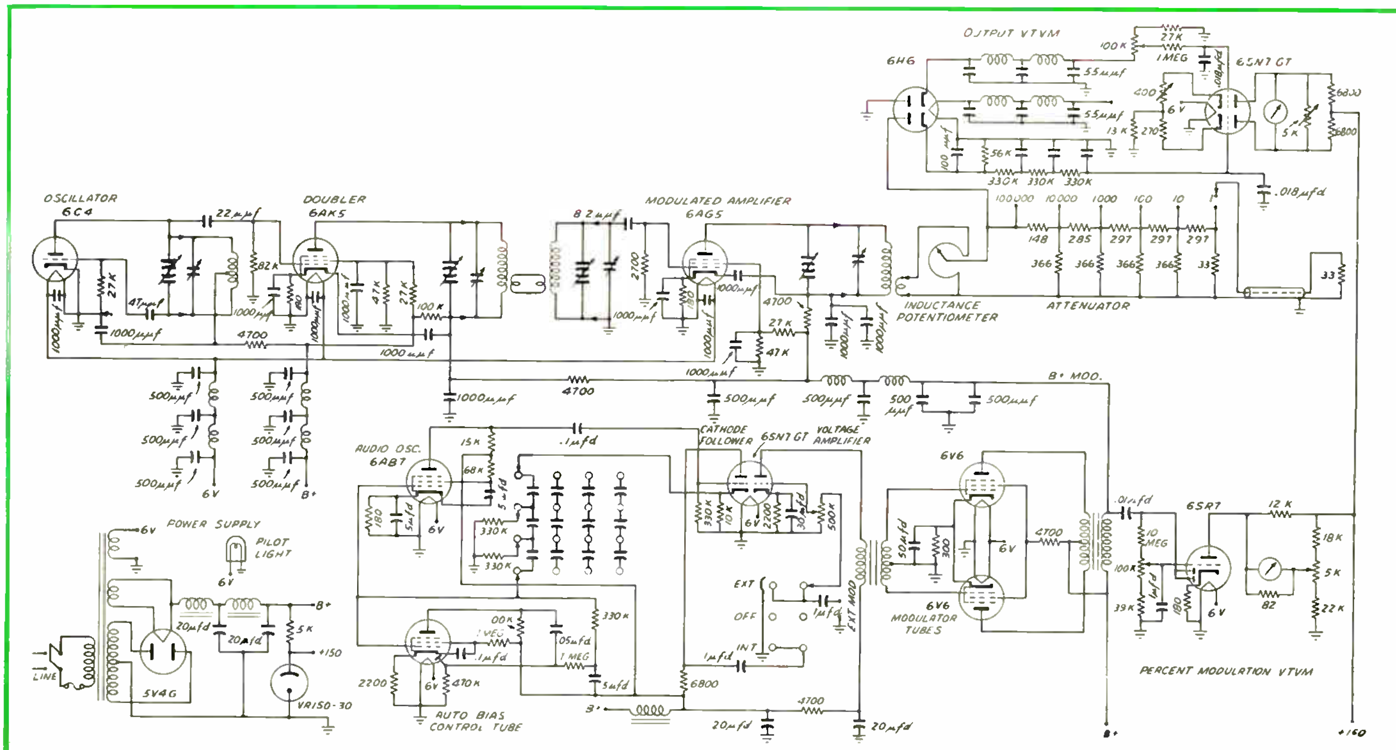



**Figure 4—Over-all schematic diagram of the uhf signal generator.**

which is supported inside another shield. The aluminum equipment case forms a third shield. Each shield is supported within the other by insulating pillars. The inductance potentiometer and the diode of the output meter are contained in another cast box which mounts to the panel with insulators. A pipe containing a concentric line carries the r-f signal from the inner shield, through the outer shield to the box containing the inductance potentiometer, and thence to the panel. This pipe constitutes the only ground connection between the units (see figure 2). Ventilation holes are drilled in the various shields, but their positions are staggered.

The plate and filament leads through the shields are filtered by a system of chokes and a special large flat plate capacitor mounted flat (figure 3). The leads, which are at ground potential with respect to the r-f voltage, are also grouped around the pipe which forms the common ground connection. The emphasis on single-point grounding is important because multi-point grounds mean that a difference of potential sometimes as great as several hundred microvolts can be measured between different points of the same case. The consequent radiation would defeat the purpose of the shielding.[3, 5, 7]

For convenience in discussing design details, the various subassemblies will be considered separately (see figure 4 for an over-all schematic diagram).

After the layout of the subassemblies, the next problem was the circuit and mechanical arrangement of the r-f generator. In this signal generator, the use of three stages overcame deficiencies of the widely used modulator oscillator types. In the latter:

1) it is not possible to make over-all measurements on a sharp tuning receiver,

2) changing the load on the oscillator changes the frequency, so that every time the attenuator is reset the frequency control dial must be readjusted, and

3) most of the currently available models are imperfectly shielded, making it necessary to dress the position of the leads for minimum signal.

The radio frequency generator in the IF-15A contains a 6C4 tube which generates a signal, a 6AK5 pentode which doubles the frequency of the oscillator, and a 6AG5 amplifier (figure 5). The four variable condensers are tuned by a common knob, and cover a frequency range from 20 to 160 megacycles in four bands. A four-position turret switches in the coils for each band.

Modulated voltage is applied to the plate and screen of the amplifier. The plate of the doubler tube also is partly modulated. This is done because the screen in the 6AG5 amplifier is not a perfect shield between the grid and plate since the lead between the shield inside the tube and external ground has an appreciable impedance at frequencies of the order of 100 to 160 megacycles. Therefore, some radio frequency voltage is fed through the amplifier tube even when the plate and screen voltage becomes zero during the modulation cycle. Plate modulation of the 6AK5 prevents frequency modulation of the oscillator when the screen of the doubler tube is maintained at a constant voltage.

The doubler plate coil and amplifier grid

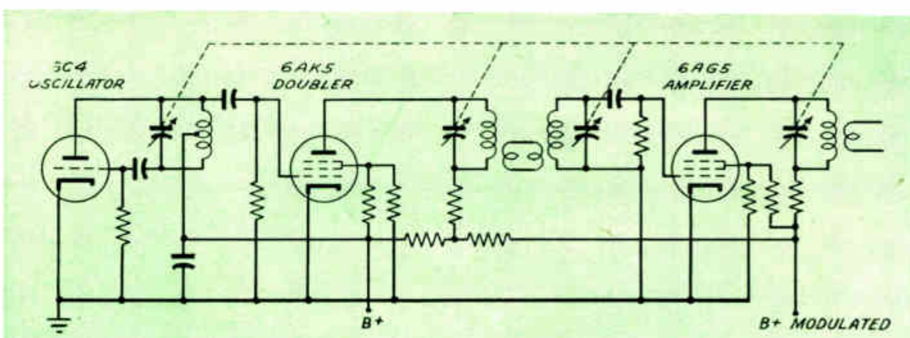



**Figure 5—Radio frequency generator.**

coil are inductively coupled but, on two of the bands, additional coupling in the form of a link is necessary.

All the components of the r-f generator, including the sockets of the miniature tubes, are mounted on the frames of two tuning capacitor gangs. A rotatable turret, carrying the coils, mounts between the gangs and is connected to them by spring clips. The layout is such that all r-f leads are extremely short. The tuning capacitors are of the split stator, insulated rotor type designed for low minimum capacitance and low inductance.

The use of miniature tubes helps to keep down the heat dissipation within the inner box, which must be almost completely enclosed to be an adequate shield.

One of the most difficult jobs in the construction of the r-f generator was the tracking of the four tuned circuits on each of the four bands. It was accomplished by holding the tracking tolerance of the capacitor gangs to one per cent and careful adjustment of the coils. Since any attempt to calculate or measure inductance or capacitance values gives results which are only a rough approximation, the determination of coil sizes for a model is a slow process of cut and try. The proper procedure is first to find from experiment which stage has the highest minimum capacitance, then to pad the other stages to it. In this design, the oscillator plate tank has a minimum capacitance of about 3 $\mu\mu$f more than the other three tuned circuits. Since this difference is within the range of the trimmers, no other padders are necessary.

One reason for using a tuned circuit in the grid of the amplifier is to make tracking easier. An early model used capacity coupling between the doubler and the amplifier so that the output of the doubler and the input of the amplifier were loaded across the same tuned circuit. The high minimum capacitance made tracking difficult.

## Modulator

The modulator supplies an audio frequency which is superimposed upon the radio frequency output of the r-f generator. A 6AB7 and one triode of the 6SN7GT connected as a cathode follower are used as a phase shift oscillator (figure 6). The frequency is varied in steps from 200 to 4000 cycles by a switch on the panel. A spare position on the switch connects to a small terminal board on the modulator chassis. By mounting three fixed capacitors on this board, it is possible to provide for any often used frequency between 200 and 4000 cycles.

The 6SF7 is an automatic bias control used to control the grid voltage of the 6AB7 oscillator. Controlling the bias of the oscillator maintains it just above the point of oscillation—the point at which the output of the oscillator is least distorted. The output of the cathode follower goes to a potentiometer, the per cent modulation control, which regulates the amount of audio frequency applied to the grid of the second triode of the 6SN7GT used as a voltage amplifier. A switch connects this potentiometer to binding posts on the front panel for external modulation.

The phase-shift oscillator with bias control tube and cathode follower is an adaptation of a circuit described by Ginzton and Hollingsworth.[9] It was necessary to hold the tolerance of the capacitors and resistors to ±2% to keep the modulation frequencies within 5%.

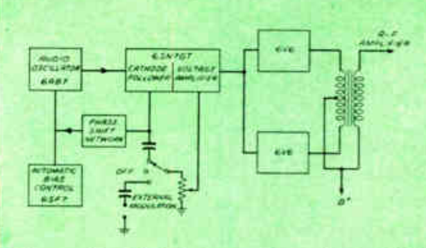


**Figure 6—Modulator using phase-shift oscillator.**

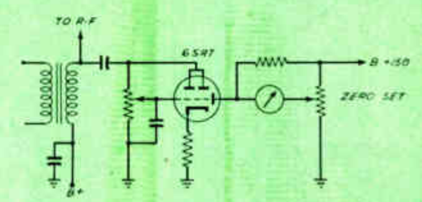


**Figure 7—Per cent modulation meter measures voltage across secondary of the modulation transformer.**

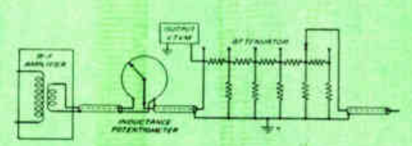


**Figure 8—Inductance potentiometer and attenuator.**

## Meter and Control Circuits

The voltage across the secondary of the modulation transformer is indicated by a VTVM called the "per cent modulation meter" (figure 7). A potentiometer on the input provides for calibrating the VTVM to read 100% at 170 volts rms, since this is the voltage required to modulate the r-f amplifier 100%.

The calibration of the VTVM is checked by observing the waveform of the modulated r-f signal on an oscilloscope.[1]

A pickup coil in the r-f generator feeds the signal through a concentric line to an inductance potentiometer, which consists of a circular shaped silver-plated strip around the edge of a phenolic disc (figure 8). The potential of the r-f signal appearing across the inductance potentiometer is of the order of 1½ volts. The arm of the potentiometer is used to set the voltage at the input of the attenuator to values between 0.1 and 1 volt. The voltage at this point is measured by the output VTVM. This voltage is subdivided by the attenuator into tenths, hundredths, thousandths, ten-thousandths, or hundred-thousandths; and the resultant is fed to the transmission line.

The inductance potentiometer has a special type of construction which makes it possible to reduce the r-f leakage through the potentiometer to a minimum. This feature consists of a kink in the rotating arm. Without the kink, the arm, together with the strap and shielded lead, would form a loop within the field of the larger loop consisting of the silver-plated ring and its connecting leads. Even at minimum setting of the arm, the small loop would have induced in it an appreciable r-f voltage so that it would not be possible to reduce the output of the potentiometer to zero. Adding the kink to the arm has the effect, at minimum setting of the control, of forming two small loops in the shape of a figure eight. The r-f voltage in one lobe of the figure eight cancels the voltage in the other lobe (figure 9).

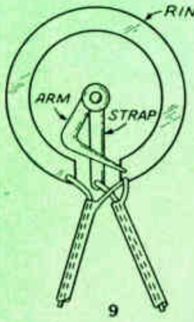
A characteristic of the inductance potentiometer method of controlling the signal generator output is that, with the stray capacitance shunted across it, the potentiometer resonates to some frequency within the range of the instrument. The effect is maximum output at some position other than the full "on" setting of the control. The disadvantage is slight, however, so this method has been retained.

A "swamping" resistor was tried across the potentiometer, but it reduced the output too much.

Some signal generator designs have used a pickup coil with variable coupling to the final amplifier plate tank—a system which is practical for a single band instrument, but which is awkward mechanically with a band change turret.

The ladder type of resistance attenuator in the generator is conventional. Each resistor is enclosed in a separate compartment of a bronze casting (figure 10). The shielding and grounding are important because the ratio between voltage across the input and output is 100,000 to 1.[3, 5]

A mutual inductance type attenuator was

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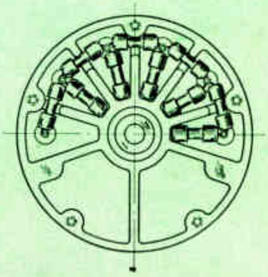

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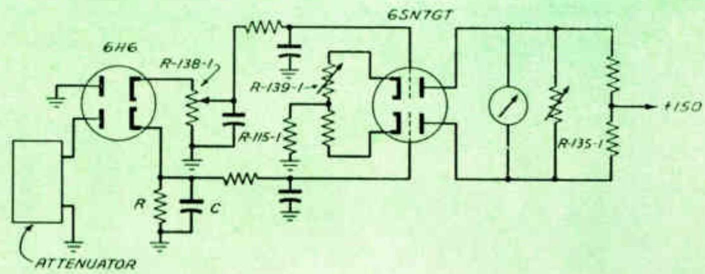


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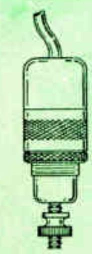

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**Figure 9—Rotating arm of inductance potentiometer is kinked to hold r-f leakage to a minimum. Figure 10—Attenuator with each resistor enclosed in a separate compartment. Figure 11—Output meter circuit. Figure 12—Output terminal housing contains 33 ohm terminating resistor.**

tested on this design, but the mechanical layout with a band change turret was too intricate.

The chief problem in constructing a resistance attenuator was obtaining resistors which would have a reasonably constant effective resistance over the range of 20 to 160 megacycles.[8] Only the "metalized filament" type was satisfactory. Several recent articles discuss the need for improved resistors for high frequency applications, and the necessity for more work on measurement methods. Some work is in progress at present on high frequency resistor development, so perhaps better designs will be available soon.

## Output Meter

The output meter contains two tubes. A 6H6 is located inside a shield box near the attenuator, with one diode acting as a rectifier to measure the voltage across the input to the attenuator and the other balancing out the effect of the zero signal current (figure 11). The rectified voltage across the diode load resistor is fed to the input of a 6SN7GT balanced d-c amplifier. The 6H6 and the inductance potentiometer are in a cast aluminum shield, while the 6SN7GT is on a small chassis mounted to the front panel. The leads from the 6H6 to the 6SN7GT are well filtered.

R139-1 is the zero set for the 6SN7GT d-c amplifier. R135-1 is a variable shunt which sets the meter to full scale at one volt input. This type of push-pull d-c voltmeter with a common cathode resistor R115-1 is quite stable.[6] The controls are inside the case, since they do not need frequent adjustment.

R138-1, the zero set for the 6H6 rectifier, is on the front panel. There is a slight drift in the zero set of the output meter, seemingly caused by a varying heater voltage on the 6H6, which must be corrected by adjusting this control. When the signal generator is connected to the power line through a voltage stabilizer, this drift is negligible. Except in locations where the line voltage fluctuation is extreme, a voltage stabilizer is unnecessary. None was included in the power supply, thereby reducing the weight. High frequency diodes having a smaller heater and cathode than the 6H6 are more subject to zero signal current fluctuation. The 6H6 is suitable for this circuit because it measures the voltage across a low impedance circuit.

## Output Lead

The transmission line feeds the signal from the attenuator to the terminal box which connects to the receiver under test. It is a flexible concentric cable with a characteristic impedance of 33 ohms. In the box at the end of the line is the 33 ohm terminating resistor. The box is small and cylindrical in shape so that it simulates a continuation of the concentric line (figure 12). The resistor is the "metalized filament" type. This line termination is a reasonably close approach to the ideal of a constant resistance, non-reactive load at all frequencies. Errors due to standing waves on the line are about 10%, but much greater errors might be caused by improper connection of a receiver to this terminal.[4]

Some signal generators are supplied with an unterminated line, which is useful for some applications. The terminated line, however, seems most convenient for general use.[4]

An attempt was made to terminate the line with two series resistors in order to provide a low resistance tap. Several objections appeared. When measuring receiver sensitivity at low inputs, radiation from the high tap binding post caused an erroneous indication. Moreover, no resistors were available which would maintain the same ratio and the same over-all effective resistance over the range of 20 to 160 megacycles when used as voltage dividers at the line termination. Finally, the two-resistor box was larger.

## Power Supply

The power supply furnishes 300 volts d-c to the plates of the tubes in the radio frequency generator and the modulator. It also supplies 150 volts regulated to the per cent modulation vacuum tube voltmeter and the output vacuum tube voltmeter.

Tests on the final IF-15A model indicate that it is a step forward in the attempt to supply the receiver design engineer with a tool which will give him the same degree of precision and operating convenience in making high frequency measurements that he has formerly enjoyed when working with lower frequency equipment.

*(For bibliography see page 16.)*

**Alfred W. Bulkley**

DURING MOST OF Alfred W. Bulkley's three years at Bendix Radio, he has been identified with the development of test equipment—power supplies, dynamotor test panels, and numerous other instruments—for the Receiver Laboratory. His electrolytic capacitor bridge was described in an article written by him in the October, 1944, ENGINEER. Building ham transmitters while he ran a successful radio supply and servicing business in Hannibal, Missouri, provided good background for his work on the signal generator discussed in the accompanying article. At present he is assistant project engineer in the design of a high-frequency ground station direction finder.

# TRANSMISSION LINE THEORY

***A simplified presentation of basic transmission line theory, which will be applied to the use of impedance charts in a second article.***


**By Lt. H. T. STRANDRUD**
***U. S. Signal Corps***


The solution of transmission line problems by means of mathematical formulas is often a long and difficult process. Certain such problems, however, are easily solved by the use of impedance charts, provided one is familiar with the significance of the terms involved. It is the purpose of this article and the following one to present in clear, concise, and practical form the development of basic line theory, and then to apply this theory to impedance charts.

The first article treats the general line theory, lossless lines, and short-circuited and open-circuited lines, an understanding of which is necessary for the intelligent use of the charts. Particular attention should be paid to the development and use of the terms "characteristic impedance" and "propagation constant."

### *Long Line Equations*

A transmission line is considered "long" when its length is an appreciable part of a wavelength of the electric energy it is designed to conduct. For example, a 250-mile line is a long line at 60 cycles, and a 6-inch length of line is long at 150 megacycles. Thus, if the frequency used is sufficiently high, any line may be classed as a "long" line.

In the treatment of a long line the characteristics which determine circuit behavior cannot be considered as lumped constants inserted at equally spaced points along the line. Instead they must be considered as being distributed uniformly along the line. In developing the transmission line equations, the following notation will be used:

R = series resistance (both conductors) per unit length;

L = series inductance per unit length;

G = shunt (leakage) conductance per unit length;

C = shunt capacitance per unit length; and

e and i = voltage and current, respectively, at any point on the line, and are functions of both time and distance traversed along the line.

The resistive drop is Ri and the inductive drop is $L\frac{\partial i}{\partial t}$ in unit length of line. The total voltage drop in an incremental length of line $\Delta x$ (figure 1) is therefore

$$\Delta e = (R\Delta x)i + (L\Delta x)\frac{\partial i}{\partial t}, \qquad (1)$$

where i and $\frac{\partial i}{\partial t}$ are average values in the interval $\Delta x$.

Leakage current is Ge and capacitive current is $C\frac{\partial e}{\partial t}$ between wires per unit length of line. The total current decrease in length of line $\Delta x$ is therefore

$$\Delta i = (G\Delta x)e + (C\Delta x)\frac{\partial e}{\partial t}, \qquad (2)$$

where e and $\frac{\partial e}{\partial t}$ are average values in the interval $\Delta x$.

Dividing equations 1 and 2 through by $\Delta x$, and passing to the limits,

$$\lim_{\Delta x \to 0} \frac{\Delta e}{\Delta x} = \frac{\partial e}{\partial x} = Ri + L\frac{\partial i}{\partial t}, \qquad (3)$$

$$\lim_{\Delta x \to 0} \frac{\Delta i}{\Delta x} = \frac{\partial i}{\partial x} = Ge + C\frac{\partial e}{\partial t}. \qquad (4)$$

Equations 3 and 4 describe e and i at any point along the line at any time and for any form of impressed voltage. It is desirable to develop the properties of the line for the more practical cases rather than to study all possibilities. Impressed voltages which are periodic are of greatest practical interest and Fourier Analysis proves that very general periodic functions can be expressed as linear combinations of sines and cosines of various periods. Therefore, a study of an impressed voltage having a simple sinusoidal variation with time is basic to the understanding of the entire transmission line problem. Simplicity of notation is obtained for sinusoidal functions by use of the exponential form $\epsilon^{j\omega t} = \cos \omega t + j \sin \omega t$, since the cos ωt or sin ωt effects can always be recovered by segregating the real or imaginary part of the equation. This is the complex or vector notation which really consists of two easily separated equations expressed as a single equation.

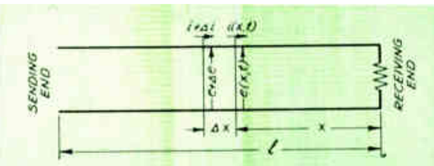


***Figure 1—Transmission line with distributed constants.***

To solve equations 3 and 4 for the case of a sinusoidal applied voltage, assume

$$e = E\epsilon^{j\omega t} \text{ and } i = I\epsilon^{j\omega t} \qquad (5)$$

where E and I are functions of x, and any difference in phase is absorbed in either E or I. Then, differentiating equation 5 with respect to t, we obtain

$$\frac{\partial e}{\partial t} = j\omega E\epsilon^{j\omega t} \text{ and } \frac{\partial i}{\partial t} = j\omega I\epsilon^{j\omega t}. \qquad (6)$$

Differentiating equation 5 with respect to x, we obtain

$$\frac{\partial e}{\partial x} = \epsilon^{j\omega t}\frac{\partial E}{\partial x} = \epsilon^{j\omega t}\frac{dE}{dx},$$

and $\qquad (7)$

$$\frac{\partial i}{\partial x} = \epsilon^{j\omega t}\frac{\partial I}{\partial x} = \epsilon^{j\omega t}\frac{dI}{dx}.$$

since $\frac{\partial E}{\partial x} = \frac{dE}{dx}$ and $\frac{\partial I}{\partial x} = \frac{dI}{dx}$ because E and I are independent of t.

Substituting equations 5, 6 and 7 in 3 and 4, we obtain

$$\epsilon^{j\omega t}\frac{dE}{dx} = RI\epsilon^{j\omega t} + Lj\omega I\epsilon^{j\omega t}; \qquad (8)$$

$$\epsilon^{j\omega t}\frac{dI}{dx} = GE\epsilon^{j\omega t} + Cj\omega E\epsilon^{j\omega t}. \qquad (9)$$

Dividing through by $\epsilon^{j\omega t}$ in equations 8 and 9,

$$\frac{dE}{dx} = I(R + j\omega L); \qquad (10)$$

$$\frac{dI}{dx} = E(G + j\omega C). \qquad (11)$$

Equations 10 and 11 are now ordinary differential equations for obtaining E and I. Simplify these equations by setting

$$z = R + j\omega L; \; y = G + j\omega C$$

Then

$$\frac{dE}{dx} = zI, \qquad (12)$$

and

$$\frac{dI}{dx} = yE. \qquad (13)$$

Differentiating 12, we obtain

$$\frac{d^2E}{dx^2} = z\frac{dI}{dx}. \quad (14)$$

Substituting 13 in 14,

$$\frac{d^2E}{dx^2} = zyE. \quad (15)$$

Likewise, differentiation of 13 and substitution from 12 yield

$$\frac{d^2I}{dx^2} = zyI. \quad (16)$$

Equations 15 and 16 show that E and I are functions whose second derivatives are multiples of themselves. Functions of this type are usually exponential, and it is apparent that the solution $E = K\varepsilon^{mx}$ can be made to satisfy equation 15. Assuming this solution,

$$\frac{dE}{dx} = Km\varepsilon^{mx}, \text{ and } \frac{d^2E}{dx^2} = Km^2\varepsilon^{mx}.$$

Substituting this solution and its second derivative in equation (15),

$$Km^2\varepsilon^{mx} = zyK\varepsilon^{mx}.$$

Then $m^2 = zy$, and

$$m = \pm\sqrt{zy}. \quad (17)$$

The constant K proved to have no effect upon the solution. Therefore,

$$E = K_1\varepsilon^{\sqrt{zy}\,x} + K_2\varepsilon^{-\sqrt{zy}\,x}, \quad (18)$$

is the general solution, since it checks and includes both values of m.

By applying the same type of analysis to equation 16, the solution

$$I = K_3\varepsilon^{\sqrt{zy}\,x} + K_4\varepsilon^{-\sqrt{zy}\,x}, \quad (19)$$

is obtained.

The final transmission line equations will be considerably simplified if they are expressed in terms of hyperbolic functions, which are defined as follows:

$$\sinh A = \frac{\varepsilon^A - \varepsilon^{-A}}{2}; \quad (20)$$

$$\cosh A = \frac{\varepsilon^A + \varepsilon^{-A}}{2}. \quad (21)$$

Adding 20 and 21,

$$\cosh A + \sinh A = \varepsilon^A. \quad (22)$$

Subtracting 20 from 21,

$$\cosh A - \sinh A = \varepsilon^{-A}. \quad (23)$$

Remembering that for trigonometric functions,

$$\cos A + j\sin A = \varepsilon^{jA}, \quad (24)$$

and (by substituting $-A$ for A),

$$\cos A - j\sin A = \varepsilon^{-jA}, \quad (25)$$

we obtain by adding 24 and 25,

$$\cos A = \frac{\varepsilon^{jA} + \varepsilon^{-jA}}{2}. \quad (26)$$

Similarly, by subtracting 25 from 24,

$$j\sin A = \frac{\varepsilon^{jA} - \varepsilon^{-jA}}{2}. \quad (27)$$

Comparing 21 and 26,

$$\cosh(jA) = \cos A; \quad (28)$$

and, comparing 20 and 27,

$$\sinh(jA) = j\sin A. \quad (29)$$

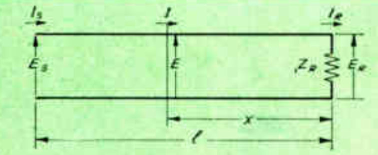

**Figure 2—Line terminated in complex impedance.**

It is this close connection between hyperbolic and trigonometric functions which makes it desirable to express the results in terms of hyperbolic functions. Using equations 22 and 23 for $\varepsilon^{\pm A}$, substitute hyperbolic functions in equations 18 and 19 for $\varepsilon^{\pm\sqrt{zy}\,x}$. Then,

$$E = (K_1 + K_2)\cosh\sqrt{zy}\,x + (K_1 - K_2)\sinh\sqrt{zy}\,x, \quad (30)$$

$$I = (K_3 + K_4)\cosh\sqrt{zy}\,x + (K_3 - K_4)\sinh\sqrt{zy}\,x. \quad (31)$$

As a convenience only, new constants may be used as follows:

$$K_5 = K_1 + K_2;\ K_6 = K_1 - K_2;$$
$$K_7 = K_3 + K_4;\ K_8 = K_3 - K_4.$$

Then

$$E = K_5\cosh\sqrt{zy}\,x + K_6\sinh\sqrt{zy}\,x; \quad (32)$$

$$I = K_7\cosh\sqrt{zy}\,x + K_8\sinh\sqrt{zy}\,x. \quad (33)$$

Again referring to the definitions, we obtain

$$d\frac{\cosh ax}{dx} = a\sinh ax$$

and

$$d\frac{\sinh ax}{dx} = a\cosh ax,$$

by differention of the exponential forms. We may write, by taking the derivative of 32 and 33 and substituting from equations 12 and 13,

$$\frac{dE}{dx} = (K_5\sinh\sqrt{zy}\,x + K_6\cosh\sqrt{zy}\,x)\sqrt{zy} = zI; \quad (34)$$

$$\frac{dI}{dx} = (K_7\sinh\sqrt{zy}\,x + K_8\cosh\sqrt{zy}\,x)\sqrt{zy} = yE. \quad (35)$$

Using subscript S for sending, subscript R for receiving, and the circuit labels shown in figure 2, we shall evaluate and give physical meaning to the equation constants. Letting $x = 0$ (see figure 2), then $E = E_R$ and $I = I_R$. Substituting in equations 32 and 33,

$$E_R = K_5 \text{ and } I_R = K_7. \quad (36)$$

Substituting in equations 34 and 35,

$$K_6\sqrt{zy} = zI_R \text{ and } K_8\sqrt{zy} = yE_R, \quad (37)$$

or

$$K_6 = \sqrt{\frac{z}{y}}\,I_R \text{ and } K_8 = \sqrt{\frac{y}{z}}\,E_R.$$

Here define $\sqrt{\frac{z}{y}} = Z_0$. The term $Z_0$, known as the characteristic impedance or surge impedance of the line, has a special significance as will be shown later. Re-writing equations 32 and 33,

$$E = E_R\cosh\sqrt{zy}\,x + Z_0I_R\sinh\sqrt{zy}\,x; \quad (38)$$

$$I = I_R\cosh\sqrt{zy}\,x + \frac{E_R}{Z_0}\sinh\sqrt{zy}\,x. \quad (39)$$

Since the term $\sqrt{zy}$ is complex, let us define it as,

$$\sqrt{zy} = \alpha + j\beta.$$

The term $\sqrt{zy}$ is the propagation constant of the line, to be discussed later.

At any point along the line (a distance x from the receiving end) the impedance is defined as

$$Z = \frac{E}{I} = \frac{E_R\cosh\sqrt{zy}\,x + Z_0I_R\sinh\sqrt{zy}\,x}{I_R\cosh\sqrt{zy}\,x + \frac{E_R}{Z_0}\sinh\sqrt{zy}\,x}. \quad (40)$$

By using $Z_R = \frac{E_R}{I_R}$, equation 40 may also be written

$$Z = Z_0\frac{Z_R\cosh\sqrt{zy}\,x + Z_0\sinh\sqrt{zy}\,x}{Z_0\cosh\sqrt{zy}\,x + Z_R\sinh\sqrt{zy}\,x}. \quad (41)$$

Also, since $\tanh A = \frac{\sinh A}{\cosh A}$, dividing numerator and denominator by $\cosh\sqrt{zy}\,x$ gives

$$Z = Z_0\frac{Z_R + Z_0\tanh\sqrt{zy}\,x}{Z_0 + Z_R\tanh\sqrt{zy}\,x}. \quad (42)$$

At the sending end of the line $x = l$ and $Z = Z_S$. Substituting these values in equation 42,

$$Z_S = Z_0\frac{Z_R + Z_0\tanh\sqrt{zy}\,l}{Z_0 + Z_R\tanh\sqrt{zy}\,l}. \quad (43)$$

### *Infinite Length Line*

If a transmission line approaches infinite length, as $l \rightarrow$ infinity, $\tanh\sqrt{zy}\,l \rightarrow 1$. In this case, using equation 43, the impedance as seen from the receiving end is

$$Z_S = Z_0\left(\frac{Z_R + Z_0}{Z_0 + Z_R}\right) = Z_0. \quad (44)$$

Thus we see that the term which was called $Z_0$ and defined as $Z_0 = \sqrt{\frac{z}{y}}$ is also the impedance which would be measured at the sending end of an infinitely long line.

### *$Z_0$ Terminated Line*

If $Z_R = Z_0$ the line is said to be terminated in its characteristic impedance and $E_R = Z_0 I_R$. Then, at any point along the line (at a distance x from the receiving end) equations 38 and 39 give

$$E = E_R(\cosh\sqrt{zy}\,x + \sinh\sqrt{zy}\,x) = E_R\varepsilon^{\sqrt{zy}\,x}; \quad (45)$$

$$I = I_R (\cosh \sqrt{zy}\, x + \sinh \sqrt{zy}\, x) = I_R \varepsilon^{\sqrt{zy}\, x}. \qquad (46)$$

Remembering that the propagation constant has components $\sqrt{zy} = \alpha + j\beta$,

$$E = E_R\, \varepsilon^{(\alpha + j\beta)x}; \qquad (47)$$

$$I = I_R\, \varepsilon^{(\alpha + j\beta)\, x}. \qquad (48)$$

At the sending end of the line, $E = E_S$, $I = I_S$, and $x = l$. Then

$$E_S = E_R \varepsilon^{(\alpha + j\beta)\, l};\ \text{or}\ E_R = E_S \varepsilon^{-(\alpha + j\beta) l} \qquad (49)$$

$$I_S = I_R \varepsilon^{(\alpha + j\beta) l};\ \text{or}\ I_R = I_S \varepsilon^{-(\alpha + j\beta) l}. \qquad (50)$$

The real term $\varepsilon^{-\alpha l}$ represents a change in magnitude and therefore shows that the voltage and current are attenuated by a factor $\varepsilon^{-\alpha l}$ in traveling from the sending to the receiving end. The term $\varepsilon^{-j\beta l}$, from the theory of complex quantities, represents a phase shift and therefore shows that the voltage and current are shifted $-\beta l$ radians in passing from the sending to the receiving end of the line. Also, from equations 47 and 48 the impedance at any point is

$$Z = \frac{E}{I} = \frac{E_R}{I_R} = Z_0,\ \text{or}\ Z_S = Z_0. \qquad (51)$$

Therefore, a line terminated in its characteristic impedance behaves as an infinitely long line. An infinitely long line cannot produce reflections which, in turn, cause standing waves and a loss in transfer of power to the load. If possible, lines are usually terminated in their characteristic impedance.

## Lossless Line

If $\alpha = 0$ in the propagation constant $\alpha + j\beta$, no attenuation is present. From the definition of $\alpha + j\beta$,

$$\sqrt{zy} = \sqrt{(R + j\omega L)(G + j\omega C)} = \alpha + j\beta, \qquad (52)$$

it can be seen that $\alpha = 0$ when, and only when, $R = G = 0$. Actually, this is not possible, but R and G may easily be negligible in comparison with $\omega L$ and $\omega C$. Then, approximately,

$$\sqrt{zy} = 0 + j\beta = \sqrt{(0 + j\omega L)(0 + j\omega C)} = j\omega\sqrt{LC}, \qquad (53)$$

$$\text{and}\ Z_0 = \sqrt{\frac{z}{y}} = \sqrt{\frac{j\omega L}{j\omega C}} = \sqrt{\frac{L}{C}}, \qquad (54)$$

a pure resistance.

From equations 28 and 29,

$\sinh j\beta l = j \sin \beta l$,

$\cosh j\beta l = \cos \beta l$, and

$\tanh j\beta l = j \tan \beta l$.

Then, for the sending end of a lossless line, from equations 38 and 39

$$E_S = E_R \cos \beta l + jZ_0 I_R \sin \beta l; \qquad (55)$$

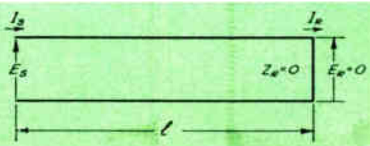


**Figure 3—Short-circuited transmission line.**

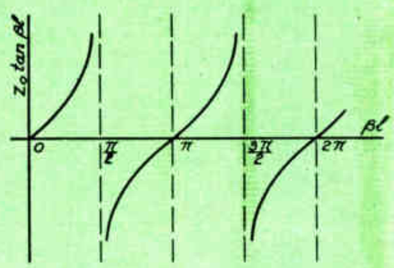


**Figure 4—Impedance variation in short-circuited line.**

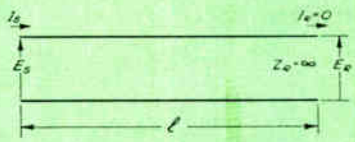


**Figure 5—Open-circuited transmission line.**

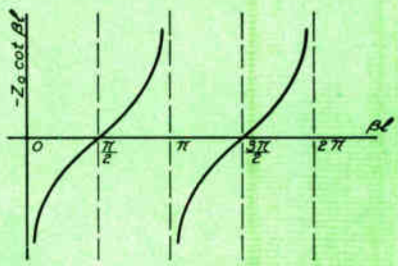


**Figure 6—Impedance variation in an open-circuited line.**

$$I_S = I_R \cos \beta l + j \frac{E_R}{Z_0} \sin \beta l. \qquad (56)$$

From equation 43,

$$Z_S = Z_0 \frac{Z_R + j Z_0 \tan \beta l}{Z_0 + j Z_R \tan \beta l} = Z_0 \frac{\frac{Z_R}{Z_0} + j \tan \beta l}{1 + j\frac{Z_R}{Z_0} \tan \beta l}. \qquad (57)$$

Equations 55, 56, and 57 give voltage, current, and impedance at the sending end of a lossless line terminated in $Z_R$.

## Shorted Lossless Line

For a lossless line short-circuited at the receiving end (figure 3), $Z_R = 0$, and equation 57 becomes

$$Z_S = jZ_0 \tan \beta l. \qquad (58)$$

Hence the sending end impedance is a pure reactance which varies through all values from $-\infty$ to $\infty$ as $\beta l$ varies (see graph of figure 4).

Impedance matching requires the use of the proper reactances at correct points in the circuit. Short-circuited lengths of line (stubs) are extensively used, therefore, as impedance-matching devices.

## Open Lossless Line

For a lossless line open at the receiving end (figure 5) $Z_R = \infty$ or $\frac{1}{Z_R} = 0$. Equation 57 becomes

$$Z_S = Z_0 \frac{Z_R + Z_0\, j \tan \beta l}{Z_0 + Z_R\, j \tan \beta l} = Z_0 \frac{1 + j\frac{Z_0}{Z_R} \tan \beta l}{\frac{Z_0}{Z_R} + j \tan \beta l} = Z_0 \frac{1}{j \tan \beta l} = -jZ_0 \cot \beta l. \qquad (59)$$

As shown by the curve of figure 6, $Z_S$ is a pure reactance that varies from $-\infty$ to $\infty$ for different values of $\beta l$. Open-circuited matching stubs are sometimes used.

## Wave Length

As defined, the propagation constant is $\sqrt{zy} = \alpha + j\beta$, where $\alpha$ is measured in nepers per unit length and $\beta$, which measures phase shift, is in radians per unit length. A wave length, $\lambda$, on a transmission line is that length in which total phase shift is 360° or $2\pi$ radians. Then $\lambda$ is defined by the equation

$$\beta\lambda = 2\pi. \qquad (60)$$

Hence,

$$\lambda = \frac{2\pi}{\beta}. \qquad (61)$$

## Quarter-Wave Lossless Line

For a line a quarter-wave long,

$$\beta l = 90°,\ \cos \beta l = 0,\ \sin \beta l = 1. \qquad (62)$$

Multiplying numerator and denominator of equation 57 by $\cos \beta l$,

$$Z_S = Z_0 \frac{Z_R \cos \beta l + j Z_0 \sin \beta l}{Z_0 \cos \beta l + j Z_R \sin \beta l}. \qquad (63)$$

Substituting equation 62 in 63,

$$Z_S = \frac{Z_0^2}{Z_R}\ \text{or}\ Z_0^2 = Z_S Z_R. \qquad (64)$$

Therefore,

$$Z_0 = \sqrt{Z_S Z_R}. \qquad (65)$$

Equation 65 may be applied in using a quarter-wave section of line as an impedance-transforming device. To match a source of

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**Figure 7—Quarter-wave short-circuited line.**

output impedance $Z_S$ to a load of impedance $Z_R$, the two may be connected through a quarter-wave section of line whose characteristic impedance is

$$Z_0 = \sqrt{Z_S Z_R}. \qquad (66)$$

### Quarter-Wave Support Stub

A special instance in which equation 65 has practical importance is $Z_R = 0$. This is the case for a quarter-wave support stub. Here $Z_S = \frac{Z_0^2}{0} = \infty$ (see figure 7). Such a stub may be used as an insulator to support the inner conductor of a coaxial line.

### Half-Wave Lossless Line

For a half-wave lossless line, $\beta l = 180°$. Then $\sin \beta l = 0$ and $\cos \beta l = -1$.

Equations 55, 56 and 63 become

$$E_S = -E_R, \qquad (67)$$

$$I_S = -I_R, \qquad (68)$$

$$Z_S = Z_R. \qquad (69)$$

Voltage and current are reversed in phase at points in a line a half-wave length apart, but impedance is the same. Thus, in an unmatched line, points of voltage and current maximum will be found one-half wave length apart.

### Basis for Use of Charts

Many practical transmission-line problems can be solved by means of the equations developed, but such solutions are often lengthy. A graphical solution based on charts is much quicker for certain problems, such as matching a line to its load, once the foregoing line theory is understood. The derivation and use of these transmission line charts, therefore, will be presented in a second article.

## UHF SIGNAL GENERATOR

*(Continued from page 12.)*

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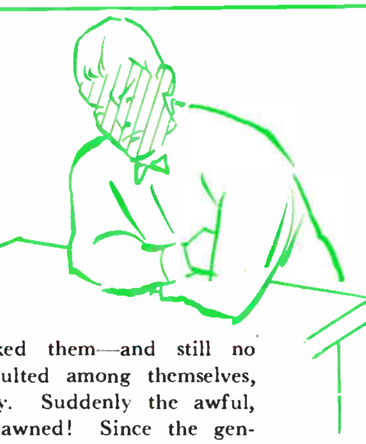
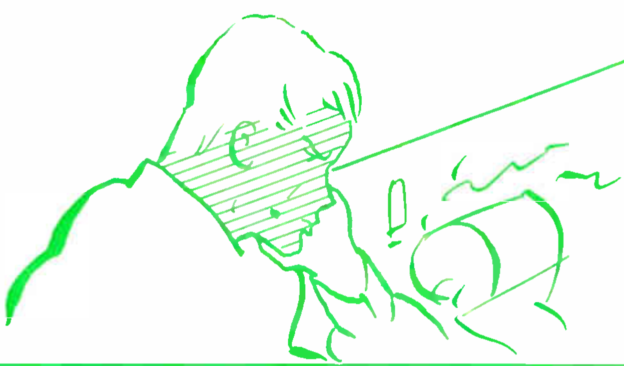
## Red Face



THE CHIEF SIGNAL ENGINEER of a railroad and a technical expert from Bendix scratched their heads. There was trouble with the generator which supplied the charging voltage for the radio equipment. They had made the routine adjustments.



But no results. Checked them—and still no charge. Pondered, consulted among themselves, tried again. Same story. Suddenly the awful, glaring, obvious truth dawned! Since the generator operates off the axle of the car, they could only expect results when the train was in motion. And here was the train at a dead stop! Well, maybe there's comfort in knowing that even the experts occasionally slip a cog.

# Voices in Flight

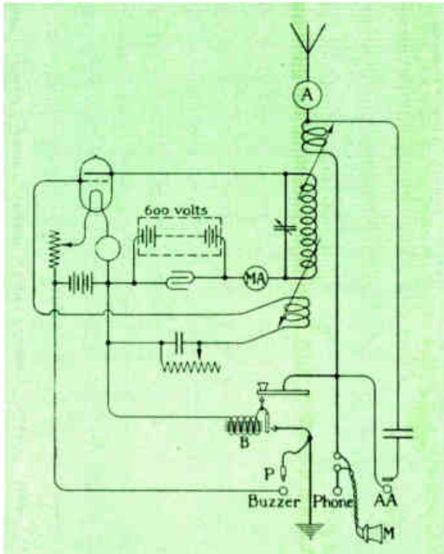
**By HARRYETTE CREASY**
***Technical Publications***

**This is the second in a series of articles on the history of aeronautical radio. The first, which appeared in the October, 1944, issue of the *Engineer*, dealt with the early attempts to adopt radiotelegraphy to the airplane. In this article, the early experiments with airborne telephonic sets are discussed.**

One fine October day in 1910, three Army officers watched a squadron of eleven monoplanes clatter over a grove of trees at Belmont Park and head toward the excited spectators attending the International Aviation Tournament. Concern for safety as well as interest in military formation flying may have prompted these officers to talk over the possibility of voice-commanded flight. Not two months before, one of them, Lieut. C. C. Culver, had heard the feeble clicks of the first radiotelegraphic message from a plane in flight, but his mind now leaped ahead to radiotelephony at the spectacle of so many planes in formation. For almost eight years, radio enthusiasts worked toward telephony for airplanes and finally, Lieut. Culver himself made the first official voice-commanded flight at Gerstner Field, La.

From 1910 until 1915, however, aeronautical radiotelephony remained a beautiful dream; then in the summer of 1915, the British broke the spell. In a careful understatement, they recorded that—though the "European trouble" hindered experimenting—some approximation to intelligible speech was received from a skeleton set in a plane in flight. This transmitter, which required six critical adjustments, was improved by Major C. E. Prince, OBE, and Lieut. McDougald, Royal Flying Corps, on the basis of earlier radio experiments by Capt. H. J. Round. The improved set had several virtues which appealed to the skeptical: it could be adjusted to transmit speech, continuous wave, or interrupted continuous wave; it weighed only ten pounds without batteries; and its telephonic range was ordinarily 20 miles. One interesting test demonstrated the alarming possibility of a range long enough to include enemy listeners. Lord Kitchener had arrived at St. Orme, France, in February, 1916, and consented rather unwillingly to listen for voice messages from a plane in flight. A sudden snowstorm kept Lieut. McDougald from flying higher than several hundred feet, but the messages came through and Lord Kitchener repeated them word by word. The report that the messages had also been heard clearly at Lowestoft a hundred miles away brought panic to Headquarters and resulted in limited experimentation for some time.

Although this first British set never failed in competent hands, it was superseded by a 20-watt choke control set designed by Major Prince to eliminate all critical adjustment and to provide greater power. Its added features were remote control, an airdriven generator, and an improved microphone. As late as 1920, this transmitter was still the accepted standard for the RAF.




***Schematic of 1915 British transmitter with an ordinary telephonic range of 20 miles.***

### *Early Experiments in U. S.*

In the United States, the problem of receiving and transmitting aboard an airplane had been complicated by the Army's change in 1913-14 from the low-powered pusher to the tractor type of plane. As soon as the motor was placed ahead instead of behind the pilot, the roar of the engine and the blast of the propeller engulfed him. All of this noise, in addition to the vibration of the plane, made the experts seriously wonder if human voice would ever be heard above the uproar. Their immediate job seemed to be the strengthening of Morse radio signals while preliminary experiments in voiced radio were carried on.

Lt. Col. Samuel Reber, another of the three officers who discussed aeronautical radiotelephony at Belmont Park, implemented this program when he became Officer in Charge of the Aviation Section of the Signal Corps. In August, 1915, he detailed Lieut. Culver to San Diego to work on the immediate needs of radiotelegraphy and the ultimate development of equipment for voice-commanded flight. That the idea of radio for aircraft was not fully accepted is suggested by Culver's added responsibilities; his official title was Meterological Officer and Radio Officer of the Aviation School. During the first year he concentrated on radiotelegraph and, as a result, hung up two records. For the first plane-to-plane radio communication which occurred on September 2, 1916, he went up in a ship equipped with a receiving set and piloted by Lieut. Herbert Dargue; then Lieut. W. A. Robertson took a message written after Culver's take-off by Congressman Kettner of California, flew to a height of less than 1000 feet in another plane, and transmitted the message in code. Captain Culver, who had remained in flight about two miles from the Robertson machine, descended first and handed Kettner a correct transcription of the message: "North Island makes new world record." His second achievement was the sending of signals for the unprecedented distance of 140 miles on October 27, 1916.

Nevertheless, radiotelephony had not been forgotten during these record-making events in Morse code. In October, 1915, America had thrilled to the headlines that a voice from Arlington, Va., had been heard simultaneously in Paris and Honolulu. At the same time Lieut. Dargue in San Diego made a spring-driven dictaphone record of speech shouted above the roar of a flying plane so that noise conditions of flight could be reproduced for laboratory work in radiotelephony. By 1916, E. J. Simon, de Forest, and Western Electric were tentatively but hopefully experimenting with radiotelephones for airplanes. On June 6 of that year, the first order for an airplane radiotelephone transmitter was placed with E. J. Simon by the Chief Signal Officer, and it was built during the summer according to specifications drawn up by Captain Culver. Finally, in testing this set during January and February, 1917, a spoken message was transmitted from plane to ground for the first time in the United States. L. W. Stevens operated the transmitter during the flight, and Captain Culver received the message on the ground. On February 7, 1917, the tests were officially announced as a success.

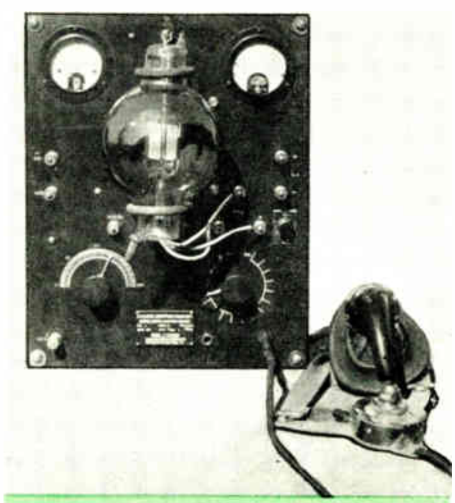
Suddenly, with our declaration of war, the further development of this first transmitter became a rush job. Having been detailed to Washington, Captain Culver conferred with members of the French Scientific Mission, and Colonel Rees of the British Royal Flying Corps. Then on May 22, 1917, Brig. Gen. George O. Squier, Chief Signal Officer, called Colonel Rees and Captain Culver into a conference with Western Electric engineers F. B. Jewett and E. B. Craft. After Gen. Squier's pep talk about the importance of voiced radio communication for airplanes, these specifications —notable for their brevity—were drawn up: "Minimum weight possible, maximum range 2000 yards, receiving set only and also a type for transmitting and receiving. The commander's set should be able to receive Morse also."

With this memo as a springboard, the Western Electric Laboratories on West Street leaped into furious activity. Their problems remained the same as those which had faced the San Diego experimenters, but solutions were now imperative. They were to eliminate dangling antennas which had always given the fidgets to pilots who wanted to loop-the-loop without wrapping themselves up in antenna wire. They were to lay the ghost of engine and wind noise by improving the transmitter and by soundproofing the helmet and earphone combination. The equipment was to be light, strong, easy to adjust and control—in short, to solve many problems which still beset radio engineers.

Six weeks later, the first laboratory models were tested at Langley Field, Va., by Western Electric engineers R. A. Heising who designed the transmitter and L. M. Clement who designed the receiver. Both equipments still used the unpopular 300-foot trailing wire antenna but—thanks to experiments by J. P. Minton—a new microphone appeared to be insensitive to noise though responsive to voice, and an improved helmet was being designed. On July 2, 1917, Heising transmitted from a plane to the ground station. On July 5, Clement was the first man in the United States to hear a spoken message in a plane equipped with a receiver. New models with mechanically improved connections and mounting details were started immediately. The new receiver, which included a coupled circuit and a tickler coil with one stage of amplification, was subsequently abandoned in favor of the simpler first model.

With the second transmitter and receiver installed in a Curtiss R-4, and the first ones in a Curtiss JN-4, the enthusiastic engineers won two "firsts" within three days. Heising at the ground station and Clement in the air carried on a two-way conversation August 18 at a distance of three miles. Two days later both planes went aloft and the two engineers chatted with each other over the intervening distance of two miles. A diluted version of this plane-to-plane communication was staged for Secretary of War Newton D. Baker, Chief of Staff Major General Hugh L. Scott, and other officers on August 22, 1917. One plane remained on the ground with these interested listeners while the operator in the other described the movements the plane was about to make in its flight.

In the meantime, tests of accessories showed that a 500-volt wind-driven generator mounted on the right wing was too noisy; that the interphone set using an antisidetone circuit and dry battery supply was good enough for Culver to phone the first order for 20 sets to Minton while the plane was in flight; that the lead-foil shielded earphones in heavily padded helmets, appropriately known as "Elephant B," shut out the wind noise more successfully; and that a counterpoise against the arms of the airplane to replace the trailing aerial lowered the range of communication to five miles, a loss of 50-80%. General Petain himself was so impressed with premature news about eliminating the trailing aerial that he sent a gracious communication of congratulations to Major Culver.



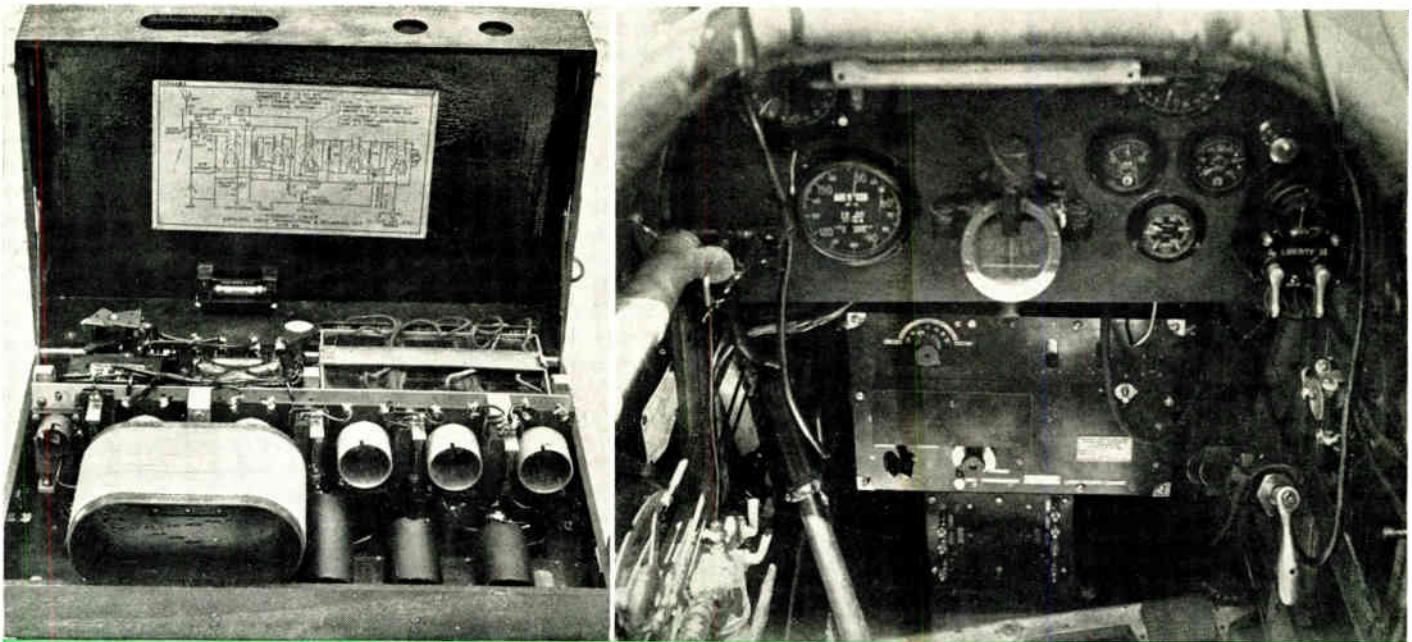
***In early 1917, first spoken message from plane to ground in the United States came from this transmitter built by E. J. Simon according to specifications of Captain C. C. Culver, Signal Corps.***

### Culver Sent Abroad

Officers in the A.E.F., however, showed little interest in the new aeronautical radio, and Signal Corps officers here decided to send Major Culver abroad to demonstrate the American equipment. Models were built incorporating all improvements, and tested at Langley Field. When General Foulois—the third of the group of officers originally interested in aeronautical radiotelephony at Belmont Park—was a spectator, moving pictures of the test flights were made with Heising in the airplane and A. A. Oswald, another Western Electric engineer, operating the radio equipment on the ground.

Final tests occurred on October 16, 1917, with Clement at the ground station, Heising in a seaplane, and Oswald in an airplane piloted by Major Culver who had earned his wings several months before. They established distance records of 10 miles for ground-to-plane transmission, 23 miles for plane-to-plane communication, and 45 miles from airplane to ground station.

The rest of the story about aeronautical radiotelephony during World War I veers from exhilarating demonstrations to persistent disappointments. Spectacular efforts to overcome the skepticism of the military were countered by kinks in production, and by failures of the equipments under the grueling tests which preceded acceptance. To sell the idea of this radiotelephone, a typical demonstration took place on December 2, 1917, before the members of the General Staff, key Army and Navy officials, and C. F. Kettering and other important civilians. On the eve of the demonstration, Western Electric engineers gathered in a hotel room and held a rehearsal. Heising and Clement represented the planes and sailed over beds, chairs and table, while ground station operators H. W. Nichols and E. B. Craft gave commands that they expected to use the next day. After a nearly sleepless night and a dull beginning to the show the next morning, the brass hats showed amazement and interest to hear from a loud speaker: "Hello, ground station. This is plane No. 1



*—Courtesy of The National Archives.* *—Official Photo U.S.A.A.F.*

***First standardized radiophone transmitter and receiver built for U. S. Signal Corps during 1917 and 1918 by Western Electric engineers. Installation in cockpit of Army plane shown at right.***

speaking. Do you get me all right?" Their enthusiasm was shortly reflected in orders for 110 receivers, 50 transmitter-receiver combinations, and accessories. Nevertheless putting these sets into production was a worrisome business since every decision stemmed from a dilemma. For instance, felt helmets admitted noise, but tight padded helmets which excluded noise were uncomfortable; batteries were too heavy, but a wind-driven generator could not deliver constant voltage when its little propeller varied, with the speed of the plane, from 4000 to 14,000 rpm.

In the meantime, Major Culver, Captain E. H. Armstrong and Captain Osborne tested British apparatus, French apparatus, and American apparatus before officials of the three Allies at Villacoublay, France. Subsequent reports on the equipment were cautious and described its possible use on various types of airplanes. Some of the officers were enthusiastic about two-way communication between a student pilot in flight and his instructor on the ground; they were even more enthusiastic over the interphone which would permit the instructor to talk to his beginner while they were flying in the same plane. They admired the oscillating system, the scheme of modulation, the simplicity of adjusting the transmitter, and the loudness of signal on the receiver. But they also pointed out the dangers of a dangling antenna in combat, and the advantages of a fan-driven generator as used by the British. They regretted that the modulator tube overheated, that the magneto made more noise than the wind, that the plugs often dropped out of the receiver, and that its condenser in the antenna short circuited.

## Success At Last

By the middle of February, 1918, preliminary production samples of the transmitters and receivers were delivered, and service and life tests began immediately at Langley Field. At about the same time, power from the wind-driven generator was steadied by the use of a vacuum tube in the dynamo. The tests culminated in the first successful voice-commanded flights at Gerstner Field, Lake Charles, La. About May 17, 1918, voice command was used by Colonel Culver, who, from his own plane, directed the movements of three other planes while a ground station recorded the conversation. The climax occurred on June 1, when 39 airplanes in two squadrons demonstrated voice-commanded flight for General Kenly and his staff. During 40 minutes, formation flying, routine maneuvers, and a mock battle in the clouds were carried on under the direction of Colonel Culver in the command plane. To prove the sturdiness of the radio equipment, each flyer performed an Immelmann turn, tail spin, side slip, and steep spiral—and only one antenna wound around the wing of a plane!

Tests continued at Lake Charles, at Dayton, Ohio, and at Camp Alfred Vail, New Jersey. J. R. Doolittle, who often acted as pilot, and others engaged in these tests apparently found some difficulty in making conversation as they put-putted through the sky. One recorded conversation ran like this:

F. Counting one, two, three, etc. Now if you hear me come in and let me know. Come in.

M. I hear you now. (This was at a point about half way to Lake Charles.)

F. We are tuned in now. Come up along side of me and talk to me. If you hear me come in right away and let me know.

M. I hear you clearly. I am flying with you now. How is your air pressure now? Let me know what it reads. Your air should not be over five pounds and not under two pounds.

F. (I turned to pilot and got air reading.) The air pressure is now about three pounds.

M. That is all right. Now let me know what your oil gauge reads. Your oil gauge should read over 20 pounds. Don't let the oil pressure get below 20 pounds.

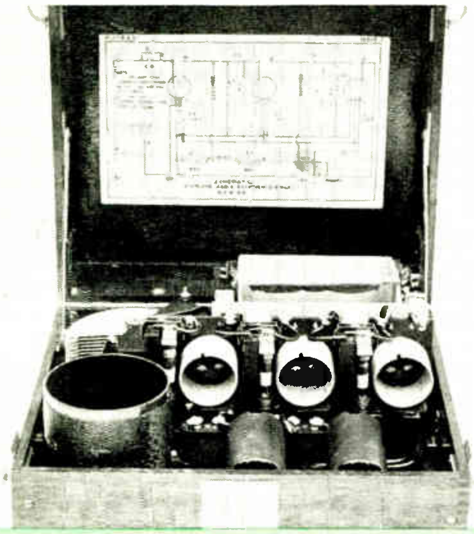
F. (I turned to pilot and got the oil gauge reading.) The oil gauge reads 25 pounds. Is that all right?

M. Yes, that is all right. Say you are on the front, aren't you? I thought you were on the back seat and could see those instruments. I was just asking about them to make conversation.

F. That's all right. I wondered if it was because I had a green pilot and you wanted to make sure things were O. K.

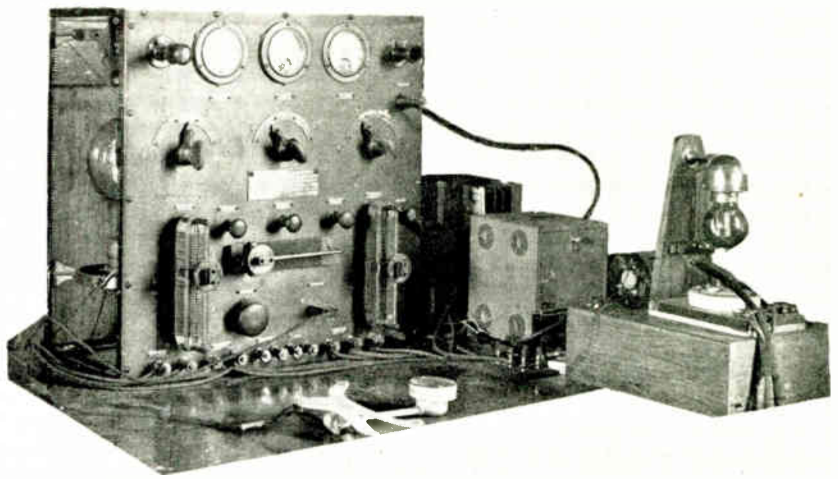
## More Difficulties

Across the sea, voice command faced more serious difficulties. Radio sets began to arrive in August, 1918, but many of them were damaged en route. A cable from General Pershing resulted in a flurry of official queries, reports, and improvements in packing. Nevertheless, the rigors of simulated combat at Orly, France, were even more damaging to these radio sets, since mechanical connections broke and electrical connections—particularly in the send-receive



—*Courtesy of The National Archives.*

**Rear view of Army airplane receiver built in 1918.**



—*Bureau of Aeronautics, Navy Department.*

**SE 1100, the first standard high power telegraph and telephone set, was manufactured by Marconi Wireless Telegraph Co. for the Navy. 1919.**

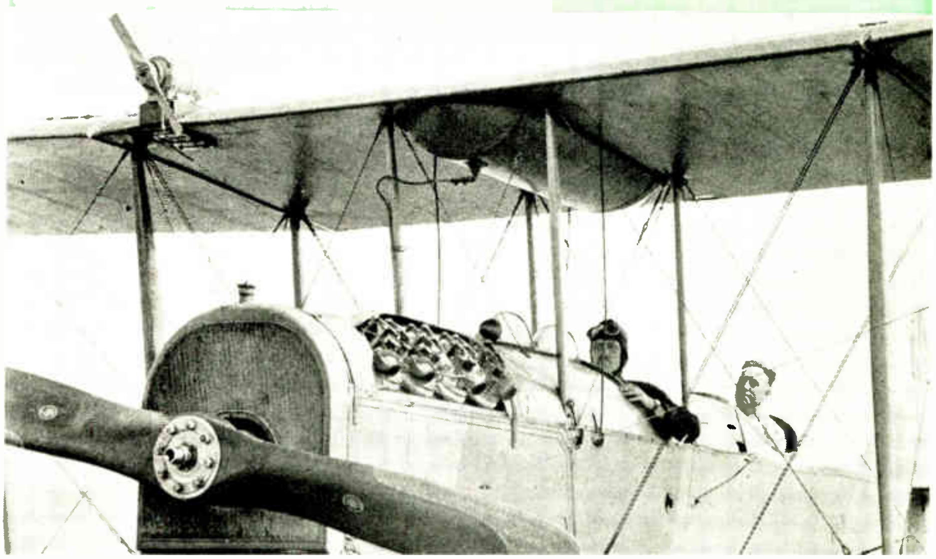
switch and the transmitter grid leaks—often failed. Beside its unreliability, the practical working range of the set was limited to about 1000 yards because of the weakness of the transmitter signal and the insensitivity of the receiver. The sad fact was that the sets would work in demonstration but that, as they came out of production, they could not be depended on to hold up in action. Bomber squadrons gradually lost hope of getting radiotelephonic equipment that would enable them to call for fighter escort when they found themselves in a hot spot. The American radiotelephone sets were installed only in training planes so that student pilots might know how to use them at the front later Not a set was used in actual combat.

Much of the disappointment in the performance of these sets came from comparison with the better British equipment developed earlier and installed on three squadrons of their planes. While American sets were depending on straight detection, the British used regenerative amplification on their detector to increase the receiving range. To be sure, they had piled up practical experience in the development of a highly superior set used by their Intelligence Division as early as 1916. With this equipment they could listen to the low-powered communication of German ships across harbors miles away; and in fact, their information thus gained contributed to the English victory in the Battle of Jutland.

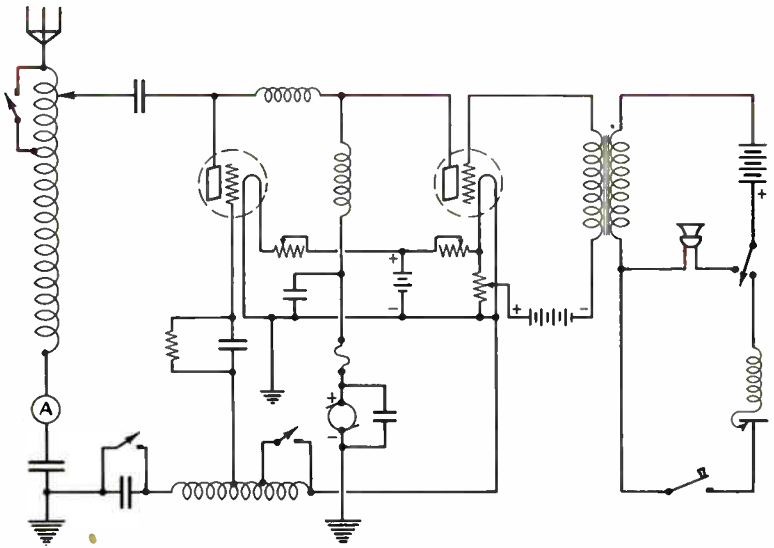
Captain E. H. Armstrong who was in charge of American radiotelephone development overseas, experimented with one of these British receivers at the Signal Corps laboratory in Paris. Not long before the Armistice, his adaptation of the British set was installed on a plane at Orly, southwest of Paris. With only one such receiver, the usual tests of plane-to-plane conversations had to be changed. A plane equipped with a transmitter flew on a predetermined route from Orly to Paris, reporting the passing landmarks, such as the Arc de Triomphe. Armstrong in a plane flying in circles over the field at Orly, operated the receiver which had a six-stage r-f amplifier. The installation was noteworthy because it had a fixed antenna in triangular form (instead of a dangling wire) that really worked. Continued tests showed reliable reception at fifteen miles, but the close of the war brought the experiments to an end.

The Navy, in the meantime, had promoted radiotelephony for airplanes by a different procedure. Lieut. Comdr. S. C. Hooper, in charge of the Navy Radio Division, set up an aircraft radio laboratory in the summer of 1916 at Pensacola under the direction of Expert Radio Aide B. E. Miessner. Specifications for a radiotelephone set weighing not over 30 pounds were sent to different contractors who agreed that such a light weight set could not perform according to specifications. While waiting for radiotelephone sample sets to be submitted, the staff at Pensacola went on with their other duties of testing radiotelegraph transmitters, and of developing an interphone, direction finder, and earphones. Several of their projects—such as the investigations resulting in Miessner's detailed reports on "Noise Conditions Affecting Radio Reception on Aircraft" and on "Radio Constants of Airplane Antennas"—recorded valuable experimental

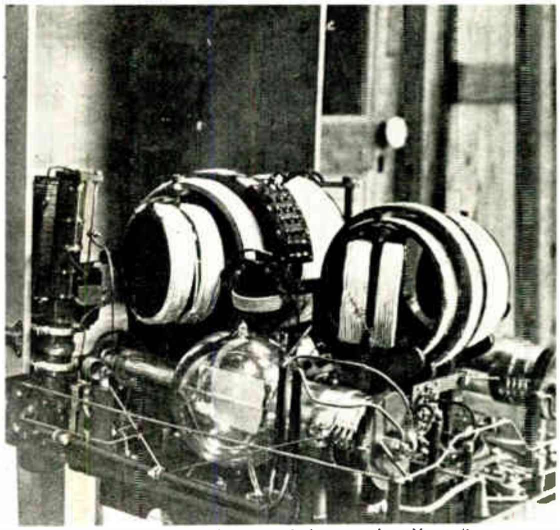
**Wind-propelled radio generator on Navy plane. May 3, 1918. On a test flight one such propeller flew apart and ripped the fabric on upper wing.**



—*Bureau of Aeronautics, Navy Department.*



**Schematic of the SE 1100 as developed by R. H. Langley. Its radiotelephone range was from 40 to 60 miles.**



—*Bureau of Aeronautics, Navy Department.*

**Rear view of receiver tested at Hampton Roads, May, 1918.**

research for radiotelephony. Another interesting development was an anti-noise microphone in which the back of the diaphragm was exposed; hence the engine noises which struck both back and front equally were at least partially canceled, while the voice carried through from the face of the diaphragm. Three years later, this microphone was acclaimed by Assistant Secretary of the Navy Franklin D. Roosevelt as the deciding factor in success or failure of long distance radiotelephony for airplanes.

After the United States entered the war, experiments in naval aircraft radio were shifted to Hampton Roads, Va., then a training station for pilots. Again, the idea was to invite companies to submit sample sets for test, to pay for the samples, and if satisfactory, to order in quantity from all manufacturers who had submitted them. When Frank King, who was in charge of the new laboratory, arrived at Hampton Roads on February 12, 1918, the equipment was limited to several old seaplanes that would hardly fly. S. S. Halliburton and C. D. Palmer, two crack pilots on King's staff, tinkered with the planes until they were reliable enough to use as test ships. Then company representatives began to arrive, at first with spark sets and a few months later with telephone sets. Soon Halliburton could anticipate the success of a set by looking it over before installation. His forthright "It won't work" at first infuriated any proud engineers who thought they had solved the problem of radio for airplanes. Actually, so many sets fell apart in the air that Halliburton could tell at a glance when equipment was not engineered to stand vibration. If the engineer insisted, he tested the set even though the plane ride shook it to pieces. At his advice, many sets were returned to the plant and made mechanically secure before they were installed and tested.

**Secretary of Navy Daniels telephoning the U.S.S. "New Hampshire," 1916—precedent for conversation from his office to Sadenwater in plane over Chesapeake, 1919.**

—*Courtesy of The National Archives.*

The first to be tested were combination radiotelephone-radiotelegraph models made by Western Electric. Since the Navy hoped for a range of at least fifty miles with a light weight set, these preliminary tests fell short. Dr. Lee de Forest also brought an early oscillion telephone and telegraph set to Hampton for trial. It was installed in a big flying boat and Halliburton took de Forest on the usual run from Hampton airport up the Potomac toward Washington. To relieve the tedium of testing, Halliburton climbed steadily during the entire trip, though every foot of altitude was a major achievement for the low-powered plane. Telegraph signals were transmitted 125 nautical miles, but the telephone was not satisfactory. Back over the airport, Halliburton went into a reverse control spiral and landed with a great flourish. De Forest was somewhat shaken by his accidental contact across the high voltage terminals of his set but thankful that the equipment had not shaken loose while the plane was upside down. When told that the plane had descended in a spiral not a loop, he was skeptical: "When I see battleships overhead, it's a loop-the-loop to me."

Of the low-powered radiotelephone transmitters accepted by the Navy, one by Western Electric was similar to the set developed for the Army. A 12-volt storage battery supplied the power instead of the wind-driven generator used by the Signal Corps. This substitution provided reliable power at the

—*Courtesy of Bell Telephone Laboratories.*

**Hand microphone for radio in Navy plane.**

time when a seaplane needed it most, since the generator would be useless after an unexpected landing on the water. Wind-driven generators were sometimes installed, however, in fighter planes. In one such instance, the generator propeller was to be tested at a speed of 110 miles to make sure it would not fly apart at the top speed of the fighter plane. But the little seaplane to be used for testing would not fly over 80 miles an hour. The solution of the ingenious pilot was to take the plane up to 10,000 feet, go into a dive, and read the meters on the way down to make sure the generator was functioning properly.

The earliest high power telegraph and telephone set standardized for the Navy was developed by R. H. Langley of the Marconi Wireless Telegraph Company of America. Known as the SE 1100, it was about the size of an overnight bag and weighed 40 pounds. It transmitted on wavelengths of 600 and 1600 meters, and telephone transmission during flight was within a 60-mile range at 600 meters, and 40 miles at 1600 meters. Two 12-volt batteries of the Willard lead type similar to those used for automobile starters supplied the filaments. Supplementary power sources were a 5-volt battery for the microphone, three 20-volt batteries for the grid, and two 20-volt batteries for the receiver.

The first standard naval aircraft receiver for voice messages was designed at the Radio Test Shop, Navy Yard, Washington, D. C., manufactured by National Electric Supply Company, and tested at Hampton Roads. This inductively-coupled vacuum tube receiver provided two stages of audio amplification, and had a wavelength range from 300 to 2500 meters. An innovation in its design was the use of a series primary condenser for shortwave, which could be paralleled to the antenna tuning inductance for longwave reception; an inductance changing switch in the antenna tuning circuit automatically made the change from series to parallel. Aviators liked this equipment because it was rugged enough to hold together during flight, and particularly because they could adjust its grooved knobs without removing their heavy gloves. This receiver together with a low-powered General Electric transmitter were in the NC flying boats on their dramatic trip from the United States to the Azores in 1919. Only in the harbors was telephony used on that trip, however, since the radio operators depended on the more powerful signals of their radiotelegraph.

All of these early radiotelephone equipments were tested at Hampton Roads, and their project engineers were advised and encouraged to improve the sets for the particular needs of the Navy. Not until the spring of 1919, did the Navy really pioneer in an application of the aeronautical radiotelephone. At that time, they decided to experiment with remote control of a flying plane by a combination of ordinary telephone and radiotelephone. On March 12, 1919, Secretary of the Navy Josephus Daniels, using his desk telephone, carried on a conversation with Lt. (j.g.) Harry Sadenwater who was flying a seaplane over the Chesapeake Bay 75 nautical miles from Washington. The arresting feature of this experiment was the connection between the lines of the Chesapeake and Potomac Telephone Co. and the ground transmitter and receiver at the Washington Navy Yard which relayed the conversation to Sadenwater.

To the layman of this time, however, almost any performance by radio seemed arresting, and in fact miraculous. Although radio equipment for both voice and code had reached the stage of standardized production, any unusual application of it was considered news. One report that made headlines was that Bonar Law and Lloyd George flew to the Peace Conference in a plane equipped with radiotelephone so that they could be in instant communication with their offices. Another spectacular event was the demonstration of voice-commanded flight for President Wilson on the White House lawn in November, 1918. His response to the experience symbolized the wonderment of the public: "Well, I have seen it, and taken part in it, but still I can't believe it possible."


#### ACKNOWLEDGMENTS

Many persons who helped in the collection of material for the first article in this series, have made valuable contributions to this story of radiotelephone for airplanes. In addition, the writer is grateful for material from the correspondence, old files, photographs, or vivid memories which have been so graciously shared by: Dr. E. H. Armstrong, Columbia University; E. J. Simon, Radio Navigational Instrument Corporation, New York; W. C. F. Farnall, Curator of the Bell System Historical Museum; W. A. MacDonald, Hazeltine Corporation, New York; J. V. L. Hogan, New York; Frank King, Secretary of the Radio Club of America, New York; Harry Sadenwater, RCA, New York; B. F. Miessner, Morristown, New Jersey; Rear Admiral S. C. Hooper, U.S.N., Retired, Washington; Dr. Lee de Forest, Los Angeles.

Searchers in many government offices have thumbed through miles of records in search of technical details, official dates, and photographs In particular, material was made accessible by the Historical Section and the Photographic Division of the Signal Corps, the Pictorial Library and the Historical Section of the Army Air Forces, the Navy Division of the National Archives, the Division of Photographic Archives and Research, and the Office of Public Relations, Navy Department.


**President Wilson directed flight of a plane above the White House lawn on November 21, 1918. Colonel C. C. Culver at his right.**

—*Courtesy of The National Archives.*

# ENGINEERS on the GO

O. L. PETERSON spent some time in New York City, Rochester, and Buffalo, interviewing personnel for employment in the Engineering Department.

J. P. SHANKLIN, G. F. SHRYOCK, and J. R. MASON were in Washington, D. C., to observe wind tunnel tests on an antenna. SHANKLIN visited the Naval Research Laboratories concerning a new antenna development.

D. W. MARTIN attended the first meeting of the Committee on Emergency Service, Transmitter Division, of the RMA Engineering Department in New York, and served as secretary, pro tem. He also conferred with engineers at Federal Telephone and Radio, then went to the Bureau of Ships in Washington for an engineering conference.

W. R. HEDEMAN conferred with officials at Camp Evans Signal Corps Laboratory at Belmar, N. J.

G. O. ESSEX was in New York for several State Department sponsored meetings concerning the postwar telecommunications conference. ESSEX is a member of the Engineering Subcommittee for the discussion of automatic distress signals. He also called at the General Aniline Works in New York, and at H. L. Crowley and Company at West Orange, N. J., concerning development work on an iron core loop.

H. K. BRADFORD, R. B. EDWARDS, C. M. SANFORD, M. FERNBACH, and D. W. MARTIN made a test run measuring field strength of a radio installation on the Baltimore and Ohio Railroad from Willard, Ohio, to Baltimore.

H. J. OOSTERLING visited P. R. Mallory Company in Indianapolis, Ind., on an inspection tour; attended a Magnetic Metals Committee conference at the Scintilla Magneto Division at Sidney, N. Y.; and visited the Electrical Industries Company and the Electronics Testing Laboratory at Newark, N. J., concerning hermetically sealed glass terminals.

A. A. HEMPHILL discussed ceramic trimmer condensers with officials at the Erie Resistor Corporation at Erie, Pa.

G. R. WHITE calibrated standard capacitors at the Bureau of Standards in Washington; then visited the General Radio Company at Boston, Mass., concerning the standardization of capacitance measurements.

W. G. JONES and M. W. MERICLE attended a lubrication conference at Camp Evans Signal Corps Laboratory at Belmar, N. J.

E. T. CARDWELL tested microwave equipment at Fort Hancock, N. J.

L. T. BARD attended a conference in Philadelphia called by the Army Air Forces for the standardization of manufacturing drawings, then went to a similar conference called by the Bureau of Ships in Washington. BARD also met with the Bendix Aviation Drafting Standards Committee in New York.

W. A. WILLIS visited manufacturers in Cleveland, Buffalo, Dayton, Detroit and Chicago concerning tooling for a new project.

T. A. WILD studied methods of testing dielectric properties at the Bureau of Standards.

D. C. HIERATH, A. D. WILLIAMS, and W. L. WEBB visited the Automatic Instrument Company at Grand Rapids, Mich., the International Detrola Company and the Bendix Aviation Research Laboratories in Detroit. HIERATH and WEBB called at the Columbia Recording Company at Bridgeport, Conn., and at the Columbia Broadcasting Company in New York City.

H. L. SPENCER and N. RAYMOND attended a conference on tropicalization called by the Signal Corps at Chicago, and a tropicalization conference called by the Air Transport Service Command at Wright Field for moisture and fungus proofing of Bendix designed ARL equipment. SPENCER also attended a conference at the Communications and Navigation Laboratories of the ATSC at Wright Field, then went to an industrial conference on tropicalization in New York.

R. S. BAILEY and P. G. CLICE visited the Bureau of Ships for tests and demonstrations of an ultra high frequency CFI model unit. They also visited Farnsworth Television Corporation at Fort Wayne, Ind., and P. R. Mallory in Indianapolis to investigate television components.

A. E. ABEL, W. E. MONROE, JR., C. M. McNEILLY, JR., and S. H. LARICK called at Hazeltine Corporation in New York.

Engineers who attended the winter meeting of the Institute of Radio Engineers in New York were W. L. WEBB, D. C. HIERATH, N. RAYMOND, R. C. MACARTHUR, G. O. ESSEX, R. V. LINDNER, A. HEMPHILL, L. T. BARD, H. L. SPENCER, R. S. BAILEY, A. E. ABEL, W. R. HEDEMAN, D. W. MARTIN, J. F. GORDON, A. C. OMBERG, D. CORNISH, A. L. BOHN, W. O. BRADFORD, and H. GOLDBERG.

V. MOORE attended a Bendix Aviation Lubrication Committee meeting in New York.

H. WALKER and W. A. WILLIS went to Federal Telephone and Radio Corporation in New York.

D. C. HIERATH visited Admiral Radio Corporation, Amphenol Corporation, P. R. Mallory Company, Webster Products Company, Oak Manufacturing Company, and J. P. Seebury Corporation at Chicago, Ill. He also called at Rola Manufacturing Company in Cleveland, Ohio, at General Industries at Elyria, Ohio, at Farnsworth Television Corporation at Fort Wayne, Indiana, then went to Benton Industries at Benton Harbor, Mich.

H. L. SPENCER and W. A. WILLIS attended a Bendix Aviation Materials Committee meeting in New York.

N. RAYMOND went to Wright Field concerning liaison work on a control panel and a receiver-transmitter equipment, then called at Zenith Radio in Chicago, Ill., and at Sparks-Withington at Jackson, Mich.

W. L. WEBB attended the Television Broadcasters Association convention in New York City, then went to Eclipse-Pioneer at Teterboro, N. J.

R. V. LINDNER went to Wright Field to demonstrate a new mobile service eight-channel transmitter which he designed in conjunction with R. B. Edwards.

W. H. SIMS, JR., called at the Bureau of Ships in Washington.

# VHF AND UHF POWER MEASUREMENT

***An adaptation of the calorimetric method of measurement by which high power readings can be made directly from a meter.***

**By H. M. HUCKLEBERRY**
***Transmitter Engineering***

POWER MEASUREMENTS, which at low and medium frequencies are most commonly made by determining circuit resistance and rms current, require different techniques at shorter wavelengths.

Until recently, most high frequency transmitters have been of sufficiently low power (below 100 watts) to permit the use of the photometric method of measurement. In this method, an incandescent lamp serves as a dummy antenna, and r-f output is found by obtaining the same luminous intensity with a source of known power as is obtained when the lamp filaments are coupled to the transmitter. Lamp brilliance is measured by means of a photometer.

Lately, however, applications have been found for vhf and uhf transmitters having power ratings greater than 100 watts. With these, photometric measurement is unsatisfactory, since it is necessary to use either a larger lamp or several smaller ones as a dummy load, and both introduce considerable inductive reactance at high frequencies. The lamps are consequently short-lived, and brilliance varies greatly.

Other schemes have been devised to overcome the difficulties introduced as both frequency and power are raised. Some produce acceptable results, but require elaborate equipment, and consequently are awkward for general use.

## Solution Found

An effective solution to the problem has been found in an adaptation of the calorimetric method of measurement, in which resistors, whose characteristics include constant resistance over wide frequency ranges as well as low distributed capacitance and reactance, are water-cooled for high power dissipation. Various sizes of small resistors may thus be used for measurements varying from 10 watts to 3 kilowatts, and, with the system set up in the Transmitter Laboratory, power can be read directly and accurately from a microammeter.

Resistors that approach the ideal for vhf and uhf work are now available commercially.[1] Physically, they consist of a hollow ceramic tube, cylindrical in shape, that is covered with a very thin coating of resistive material (see figure 1). A layer of silver plate at each end provides terminals to which contact is made by internal finger type connectors. Resistors are made in 4, 10, and 20 watt ratings, with outside dimensions of 2 x 3/16, 4½ x ¾, and 6½ x 1⅛ inches, respectively.

Experience shows that when resistors of this type are water-cooled, they will dissipate from fifty to eighty times the power dissipated in free air. Moreover, they function as a pure resistance over a wide range of frequencies when incorporated in the system to be described.

## System Components

The complete installation in Transmitter Engineering comprises a water storage tank, centrifugal pump, cold thermocouple junction, the resistor unit, hot thermocouple junction, direct reading wattmeter (microammeter), water flow meter and a control valve (figure 2). Probably the most interesting part of the system is the power indicating scheme comprising the thermocouple junctions and the calibrated microammeter.

**Figure 1—Constant resistance over a wide frequency range is provided by these 4, 10 and 20 watt units.**

Ordinary tap water is fed into an elevated storage tank where it is maintained at a reasonably constant level with a float valve. This arrangement permits air to escape before the water enters the cooling system and helps reduce pressure variations. From the tank, the water flows by gravity through the centrifugal pump, the use of which is optional but preferable both as a safety precaution, and to permit control of the flow rate by means of the valve at the outlet end of the system. The valve is so placed to prevent formation of air pockets due to syphon effects when a slow flow rate is required.

Immediately ahead of the resistor unit, the water passes through the cold junction of the thermocouple and, by means of rubber tubing, to the inlet of the resistor assembly. The resistor is enclosed in a glass tube, whose size permits a 1/16 inch column of water to flow (figure 3). The size of the water column is important, because it determines the flow velocity by restriction of the water circuit. Flow velocity has a direct effect on bubble formations, which if excessive, result in overheating and possible resistor failure. These bubbles are caused by breakdown of the water molecules and are independent of the presence or absence of air in the water supply. It is desirable, nevertheless, to hold water volume to a minimum because of the greater temperature differential obtained between the cold and hot thermocouple junctions. The 1/16 inch dimension has proved a satisfactory compromise, since sufficient velocity is provided to drive bubble formations off the resistor, and reasonable temperature differentials are maintained.

The glass tube is sealed at both ends with metal caps to which contact fingers are affixed, and the whole assembly is held together by a phenolic rod. Water from the cold junction of the thermocouple enters the unit at the center of the cap, goes through the hollow resistor form, and into the cap at the far end. Pressure forces it to flow back over the outside of the resistor form, through the outlet at the same end it entered, and thence to the hot junction of the thermocouple.

To prevent whirls and insure an even distribution of water over the resistor, the metal caps are made in two sections, with small holes spaced equally around the circumference of inner plates *a* and *b* (figure 4).

The thermocouple used in the system consists of a pair of parallel phenolic blocks drilled to permit the insertion of 22 junctions of a copper-constantan combination. When connected to a 100-microampere meter, a 10°C change is required for full scale deflection. Since in this application, the temperature rise will never exceed 10°C, it is well within the range of the system.

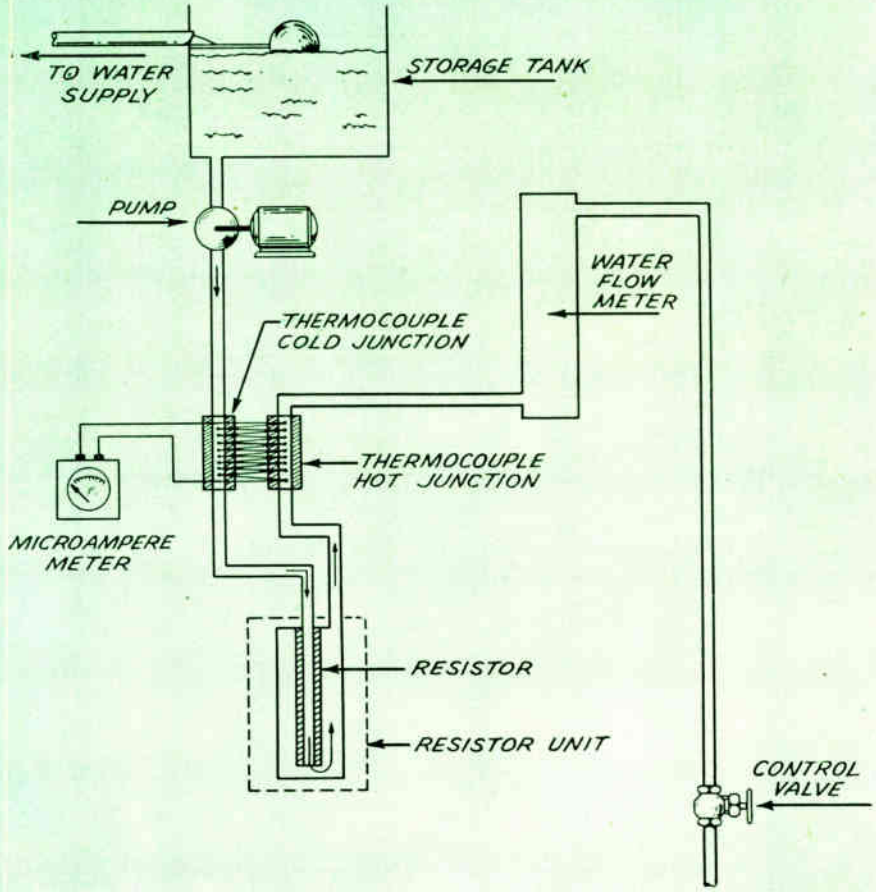



**Figure 2—Diagram of system set up in the Transmitter Laboratory for calorimetric measurement of r-f power.**

**Figure 3—Resistors enclosed in glass tubes for water-cooling.**

## Calibration Easy

The meter-thermocouple combination suggests an easy means of calibration in watts by application of known power to the resistor while maintaining the water flow at a constant rate. (Incidentally it was found that the resistors will withstand considerably more power at radio frequencies than at 60 cycles.) For some applications it is not necessary to calibrate the entire meter scale since the thermocouple is linear. A single reference point will serve just as well.

In the system now in use, the control valve is adjusted to .682 gallons per minute. This value is maintained on the flow meter which is accurate to better than 1%. If the resistor is dissipating 200 watts, a value of 10 microamperes is read on the meter. Hence, since the scale is linear, a full scale reading is equivalent to 2 kilowatts of power.

Once a calibrated reference point has been established, it is necessary only to control the water flow for any power rate which is a convenient multiple of the meter scale.

For example, a water flow rate of one gallon per minute is equal to 70.4 cc per second. By definition, one calorie is the amount of heat required to raise 1 cc of water 1°C. Hence,

.24 calorie = 1 watt/second.

$$\text{Watts for one gallon per minute} = \frac{70.4}{.24}$$

or 293 watts per degree C change.

Since power is proportional to the quantity of water flowing per unit of time,

$$V = \frac{P}{293},$$

where P = watts per degree C change, or (in the system just described) watts per 10 microamperes, and V = gallons per minute.

If a reading of 10 microamperes is desired for each 100 watts, then

$$\frac{100}{293} = .341 \text{ gal./min.}$$

Figure 5 shows an assembled unit used in the Transmitter Laboratory to measure from 1 to 1½ kilowatts output power from a transmitter operating between 100 and 156 megacycles. It is constructed in the form of a high loss line tank circuit.

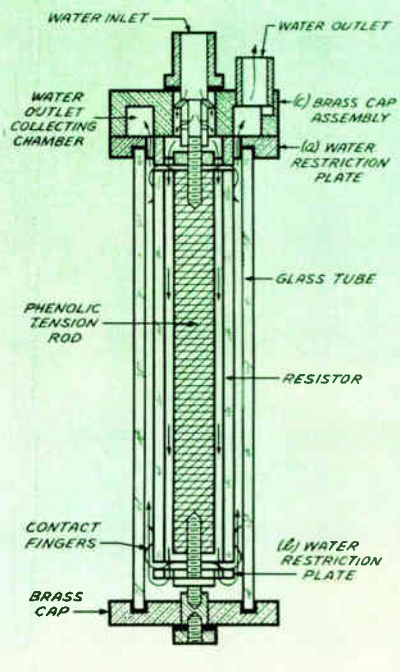
Because of the required resistor length at this high power level, the load is inductive and produces a standing wave ratio of 1.6 to 1 at 156 megacycles. The load may be resonated at this frequency by means of the variable capacitor so that, without further adjustment, the standing wave ratio over the band is not greater than 1.3 to 1. Since a short transmission is used, this mis-match is negligible. (For a description of a coaxial structure water-cooled unit having zero reactance, see the article by G. H. Brown and J. W. Conklin referred to at the end of this article.)

## Highly Accurate

From the experience gained in the Transmitter Laboratory, it seems that the degree of accuracy obtainable with the calorimetric setup is limited only by the tolerance of the meter movement and the introduction of human error. With reasonable care, errors can be held to 1% or less.

By interchanging and series-coupling resistor units, the same equipment has been

**Figure 4—Diagram of tube construction. Small holes are spaced around circumference of plates a and b to prevent whirls.**



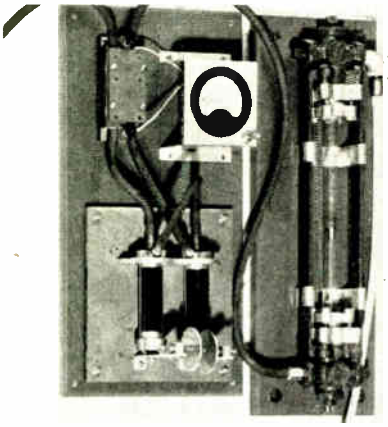


***Figure 5—Assembled resistor unit connected to microammeter and flow meter.***

successfully used to measure power ranging from 10 watts to 3200 watts, and is as adaptable to medium frequencies as it is to ultra high frequencies. It is true, that the original installation is somewhat elaborate, but once set up it is easily used in making almost any power measurement.

1. G. H. Brown and J. W. Conklin, "Water Cooled Resistors for Ultrahigh Frequencies," *Electronics*, April, 1941.

**H. M. Huckleberry**

HARD-WORKING, RESOURCEFUL Harry M. Huckleberry has been identified with Transmitter Engineering ever since his arrival at Bendix Radio in December, 1940. Born in New Albany, Indiana, he early became interested in radio and gained practical experience in servicing in Chicago and New York. He can scarcely remember a time when he has not been enrolled in some course in radio engineering or acoustics. For a number of years he made shipboard radio installations and reconditioned all types of marine radio equipment for Radiomarine Corporation of America. At Bendix Radio, as assistant project engineer on both fixed and mobile transmitters, he has acquired a reputation for tenacity which keeps him at grips with the most stubborn problem until a solution is reached.

# CMA INSTALLATION

***Radio installation designed by the West Coast Branch for CMA.***

**By DUDLEY KESSELHUTH**
***West Coast Branch***

COMPANIA MEXICANA DE AVIACION, Mexican Division of the Pan American Airways system, is now a 100% Bendix equipped line.

Last spring, Mr. Dowling, superintendent of communications of CMA, came to the west coast with sketches of a proposed radio installation for ten DC-3's. With him was Mr. Pedro Casteneda, who is in charge of radio maintenance for the company. After surveying requirements and discussing various possibilities, a complete conversion to Bendix equipment was ordered for all planes. Mr. Casteneda remained in North Hollywood to assist in the engineering of the installation which, with the exception of the transmitter and receiver units, was custom built from start to finish.

## *Special Jackboxes*

Each plane carries a dual automatic compass, a marker receiver, an RTA-1B transmitter-receiver, and an RA-10 auxiliary receiver. Selector switches are provided in specially designed pilot and copilot jackboxes (MS-87 and MS-88A), which also include a headphone volume control with a 12 db dropping range, a switch for selection of voice or range reception on any of three receivers, and an interphone switch. The latter controls the interphone circuit on the RTA-1B. In the first of four positions all functions of the transmitter are normal. When turned to "Interphone" or "Steward" position, the transmitter control circuit is broken for communication between pilot, copilot, radio operator or observer and steward. The fourth position is spring-loaded for call light and chimes that are universal on Pan American ships. The steward may signal for interphone, but cannot break in until his handset audio is completed to the RTA-1B through the pilot's, copilot's or radio operator's "Steward" switch. Headphone and microphone jacks complete the units.

Two selector switches, one for the communications unit and the other for the auxiliary receiver, are provided on the MS-89A radio operator's jackbox. The box also has the four-position interphone switch and, in addition, a cw key with the knob extending through the top. At the right of the box are three phone jacks by which an observer may monitor the pilot, copilot or radio operator.

Compass loop rotation can be controlled without changing the ADF function switch to loop position by means of special left-right switches on the sensitivity control box MS-86A. The box is mounted on the cockpit pedestal. In its center is the "Steward Calling" light, and at the top are volume controls for the two ADF units, the RTA-1B and the RA-10. Threshold sensitivity potentiometers are mounted internally.

All other radio controls are contained in an overhead box, MS-89A, and a dual ADF panel, MS-85A, which together with an antenna relay and a relay panel complete the installation. To make room for the ADF panel, electrical switches in a triangular shaped box mounted on the right V of the cockpit dome were removed to the left electrical panel. The MS-85A was made just small enough to fit in the available space with an LK-37 Cannon Plug added.

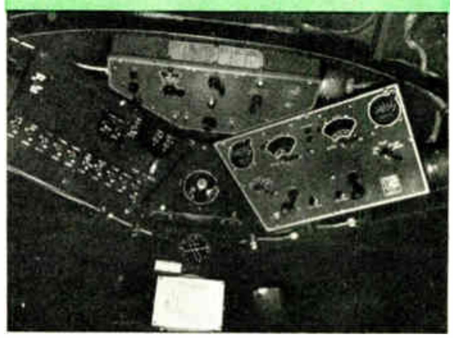
## *Installed by CMA*

The installation itself was done in Mexico City by CMA. When the first ship was completed, it was flown to Burbank on a regular run, and held there for three days so that we might go over it.

Mr. Gaines of the CAA was along one morning when the ship was flown. All functions of the ADF units were checked out, and the entire installation was given CAA approval. The plane is now in operation every other day on scheduled runs between Mexico City and Burbank.

According to Mr. Dowling of CMA, the installation has aroused a great deal of interest among other divisions of Pan American Airways, especially in the Central and South American divisions.

***Overhead control box, center, and ADF control panel, right, installed in DC-3.***



# Cross Sections

## Low Power Unit Built for Airlines

THE LOW POWER GROUND STATION transmitter being designed by R. C. MacArthur of Transmitter Engineering enters the competitive field of radio equipment designated primarily for South American airlines. It is versatile enough for wide use, especially by the smaller domestic branch lines which do not require transmitters of high power in aircraft control installations.

Three frequency ranges are covered: 200 to 400 kc and 2.5 to 15 mc for radiotelephone and radiotelegraph transmission, and 118 to 132 mc for radiotelephone only. R-f units are set up at a particular frequency in the range. If two channels in the same range are desired, two r-f units are necessary.

One hundred watts of power are provided for operation on the 118-132 mc radiotelephone band; 160 watts for radiotelephone on both of the lower bands; and 190 watts for radiotelegraph on both of the lower bands. Although there is a choice of several r-f units, the power supply is built to handle a maximum of one modulator and one r-f unit at a time, making the transmitter a one-operator station. Operation may be controlled either on the panel or at a point within approximately ¼ mile distance.

The modulator unit has a special limiter stage. The circuit consists of a tertiary winding on the modulator transformer across which a voltage is developed. This voltage is rectified by a 6H6 tube and impressed on the push-pull speech amplifier grids. With an audio output sufficient to produce 85% modulation, an increase of 20 db input will not result in more than 1.4 db increase in the modulator output. The limiter provides protection against excessive transient voltages in the modulator transformer in the event of loss of modulator load or excessive audio input.

The equipment is designed to operate at ambient temperatures from −40°C to +50°C, and under conditions up to 95% relative humidity. However, to operate at an ambient below 20°C, it is necessary to change the mercury vapor rectifier tubes to high vacuum type tubes.

The units will be installed in a standard relay rack, the size of which varies with the number of units used. A standard relay rack 68 x 22 x 18 will accommodate a power supply, modulator unit and three r-f units.

## New Squelch for King George Units

CURRENT ENGINEERING INTEREST in the widely used "King George" communication system is primarily confined to routine production follow-up. Certain modifications are made from time to time, however, to add to its efficiency. Production was recently started on a modified receiver introducing a rather extensive circuit change designed by C. B. Lau and T. G. Arnold, Jr., of Receiver Engineering.

Among other refinements there is an electronic squelch circuit to replace the relay type squelch circuit used on earlier models. Improved automatic gain control characteristic is obtained by the use of a circuit which might be called a "cascade" automatic gain control system. It uses two separate automatic gain control diode rectifiers in series. One rectifier, the conventional detector diode, is connected to the secondary of the last i-f transformer. The second, a shunt rectifier, is capacitively coupled to the primary of the last i-f transformer. The two rectifier loads are connected in series, with suitable r-f filtering between, thus providing nearly double the automatic gain control bias voltage obtainable from the conventional single diode rectifier.

## Climate on Order At Towson Plant

TO MAKE TEMPERATURE AND humidity tests on radio and radar equipment, three climate rooms have been built for the Measurements and Standards Engineering Laboratory at the Towson plant. D. C. Hierath and G. R. White, engineers on the project, provide liaison with the contractor.

Each room is 14.3 x 12.4 feet, and the inside surface of floor, ceiling, and three side walls is a continuous sheet of stainless steel. Almost the entire area of the other side wall is occupied with a 7-foot equipment door, control panels, and an air lock or vestibule permitting access for personnel during test runs.

The Temperature Room, enclosed by walls 18 inches thick and a door weighing 1800 pounds, automatically maintains any desired temperature between −60°C and +90°C by means of a two-stage freon 22 refrigeration system. In only six hours, the temperature of this room, with even as much as 1000 pounds of aluminum added, can be lowered from ambient to −60°C. Motors totaling 80 hp drive the compressors which, with the other machines, are installed beneath the floor of the climate rooms. Frequent starting and stopping of the motors is avoided by the automatic turning on of electric heaters (up to a total of 40 kw) to overcome minor "undershoots" of temperature.

The Constant Temperature and Humidity Room allows for tests at a constant temperature of 50°C and a constant relative humidity of 95%.

In the Cycling Temperature and Humidity Room, variations in both temperature and humidity can be controlled. Tests may be run providing varying degrees of temperature while retaining constant relative humidity, or humidity may be varied under constant temperatures. The temperature range is from ambient to 68°C and the controlled relative humidity may vary from 10% to 95%. The circuits for control of temperature and humidity in this room were custom built by Foxboro Instrument Company.

Fifteen thousand watts of power per room are available to drive equipment under test. Periods of test vary from 30 days to one year under conditions similar to those encountered in actual service.

# E. L. Borden Joins Engineering Staff

THE APPOINTMENT of E. L. Borden, formerly in charge of production control at the Fort Avenue plant, to the office of Administrative Assistant to the Director of Engineering and Research has recently been announced by W. L. Webb.

Mr. Borden's new duties place him in charge of engineering organization and procedure; preparation and control of engineering department budgets; assignment, classification and follow-up of all engineering projects. The scope of this new office is expected to relieve design personnel in the different engineering sections of much organizational detail.

# Greater Operating Range for Compass

THE NEW BENDIX COMPASS R-5A/ARN-7, now in production, retains all normal operating characteristics, while operating at temperatures varying from -55°C, encountered at high altitudes, to +70°C in tropical climates. Project Engineer A. A. Hemphill of the Receiver Laboratory designed the equipment under specifications of the Aircraft Radio Laboratory, Wright Field.

One of the problems encountered in building a unit whose performance is uniform over a temperature range of 140°C is misalignment of the set because of expansion and contraction of metal parts. It was solved by introducing sufficient negative coefficient capacity to balance circuit drifts over the temperature range.

For satisfactory performance at temperatures as low as -55°C, electrolytic capacitors had to be replaced with oil-filled, hermetically-sealed capacitors, which, along with added chokes, filled practically every available space left in the set. Since ordinary lubricants freeze solid in such intense cold, special free flowing types are used.

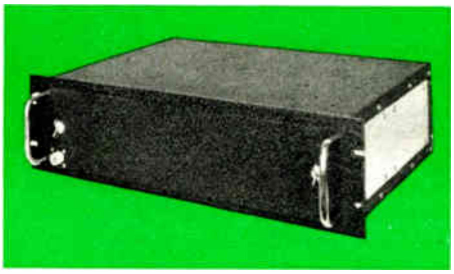
All audio units and large paper capacitors are hermetically solder-sealed in metal cans to insure operation in high humidity. Leads are brought out through insulating bushings which act as pressure seals between conductor and metal can. Particular care is taken to isolate circuits, and moisture-proof insulating materials are used throughout. R-f coils are made moisture resistant by filling coil shells with microcrystalline wax under vacuum pressure.

In addition to increasing the temperature range, the R-5A/ARN-7 incorporates improvements in fidelity, selectivity, audio regulation and operation under wide variations in supply voltage. Undesired coupling between circuits has been either greatly reduced or entirely eliminated.

# Build Production Set for Rail Use

AS AN OUTCOME OF TESTS conducted on various railroads, a production model railroad radio set is now being constructed under the general direction of R. B. Edwards, assistant section chief of the Transmitter Laboratory.

The new receiver, developed by D. W. Martin of Receiver Engineering, will mount on a standard 19-inch relay rack, occupying 5¼ inches in height and 12 inches in depth behind the panel. This particular type of construction makes it possible to use one unit interchangeably on either engine or caboose in special mounting cases, or in the dispatcher's office on a standard relay rack.



*Production model of railroad receiver.*

Design is such that the crystal harmonic generator string may be aligned without instruments. Since it is hoped that the receiver will find wide application aside from railroad use, the entire assembly, which includes the harmonic generator and r-f stages, is removable so that other stages covering different frequencies may be used.

The transmitter, on which H. K. Bradford of Transmitter Engineering is assistant project engineer, is crystal-controlled and will be about three times as powerful as present experimental equipment. Like the receiver, it will mount on a standard 19-inch relay rack, occupying 7 inches in height and 12 inches in depth, and may be placed in an office rack, caboose or engine installation. All adjustments, such as removing and replacing the crystals, operating the tuning meter, and measuring all necessary currents and voltages, are made from the front panel.

The entire system will be complete with remote control unit and will include mounted speakers and microphone. It operates on a frequency range of 155-170 mc.

The four kinds of power supplies are 32 volt, 64 volt, and 120 volt d-c, and a 115 volt a-c. The dynamotor supplied with any one of the d-c battery systems, and the a-c power supply for the 115 volt a-c system, will mount in the equipment rack with the receiver and transmitter.

Special short antennas of high efficiency and low angle of radiation similar to those successfully used in the mid-winter experimental run between Willard, Ohio, and Baltimore, are under development. An antenna relay will be provided in the transmitter for transferring the antenna from the receiver to the transmitter whenever the microphone press-to-talk button is depressed

# 225 Volunteer for Fungicide Tests

WHEN THE SURGEON GENERAL of the United States Public Health Service and the Surgeon General of the United States Army requested officials of Bendix Radio to furnish subjects for a patch test experiment to determine the possible toxicity of several fungicides specified for use in the "tropicalization" of Signal Corps equipment, 225 members of the Engineering Department immediately volunteered. Inasmuch as the tests will determine whether these fungicides are safe for use in equipment handled by our fighting forces, volunteers were assured they are making as great a contribution to the war effort as donors of blood for wounded soldiers.

Fungicides tested include phenol mercuric salicylate (1%), pentachloral phenol (10%) and salicylanilide (15%). Under the supervision of United States Public Health Service doctors, patches are applied for a period of forty-eight hours, followed by a twenty-four hour test after the expiration of ten days to determine any possible secondary reaction.

Similar tests have been made among Army personnel at Fort Monmouth, New Jersey.

# Components Group Aid to Engineers

ENGINEERS REQUIRING A NEW or unusual component for a specific application need no longer interrupt development work to find or design it as a result of a service initiated by the Components Engineering Section under Section Chief H. A. Cook.

The Components staff is coordinating information culled from trade advertisements, manufacturers' parts catalogues, and correspondence with suppliers so that it can quickly locate parts that are on the market. If the part is not available, the group will undertake its development in collaboration with a manufacturer.

At present, data is being assembled on hermetically sealed precision resistors, hermetically sealed meters, and grade one, class one resistors.

The Laboratory is also equipped to conduct tests on the quality of electrical parts. Projects under way include life testing of electrolytic capacitors made by various suppliers, and comparison of ceramic impregnating materials—wax, silicon liquid and GE Dri-film—to determine the effect of high humidity on electrical characteristics. Other activities of the Section are the preparation of specifications for the Electrical Standards Committee and individual engineers, correlation of certain difficult measurements, such as the temperature coefficient of capacitors, and a continuous check on the quality of parts as they are used in production.

# Plans Completed For 500 Watt Unit

A 500 WATT GROUND STATION radio transmitter planned by A. R. Perong, Transmitter engineer, will add to the Bendix Radio line a medium-power unit for aeronautical control stations. This equipment provides point-to-point and ground-to-air radiotelephone and high speed radiotelegraph operation, and automatic operation as a radio beacon modulated for station identification. The equipment is capable of 100% voice modulation with fidelity restricted to the voice range.

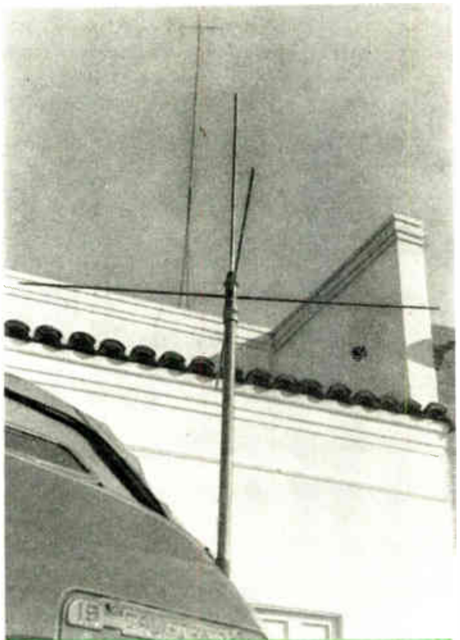
The design incorporates four individual r-f units equipped for adjacent channel operation having basic frequency ranges of 200 to 540 kc, 2.5 to 20 mc, and 118 to 132 mc. Instantaneous local and remote control of eight channels is possible, with combinations for simultaneous operation. Generally two radiotelephone channels are provided, or one radiotelephone and two radiotelegraph channels. Other combinations are also available.

The transmitter operates from a single phase, 220 volt, 50-60 cycle power line. Nominal power output for radiotelephone transmission is 450 watts minimum, and 500 watts for radiotelegraph. The power output of the vhf unit is 200 watts, for radiotelephone only.

The equipment is built to withstand rigorous service conditions of humidity and extremes of temperature and other conditions peculiar to tropical operation. The exterior of the 72 x 40 x 25 inch cabinet is gray with brushed chrome fittings. Materials used in construction are light enough to permit shipment by air.

# Tests Demonstrate VHF Effectiveness

VHF FIELD TESTS made in the course of the past few months in the Los Angeles metropolitan area for the Pacific Electric Railway are said by H. A. Varley of the West Coast Branch to have convinced both railroad and Bendix Radio personnel that reliable two-way communication can be provided within a thirty-five-mile radius, under all conditions, in at least 95% of the area.



***Antenna mounted on car used in vhf field tests.***

In these experiments the Bendix truck, equipped with ground-plane antenna, was parked on the summit of Mt. Hollywood at an altitude of 1600 feet, and served as the fixed station. The mobile unit was R. J. Moon's automobile with ground-plane antenna just above the top of the car or about six feet from ground level. Reliable two-way communication was established as far as fifty miles out as long as the mobile unit was not behind a range of hills or in a sharp depression.

The demonstration was particularly successful in giving reliable coverage in congested areas, freedom from noise, and excellent intelligibility of speech even under the most adverse conditions.

# Electron Microscope To Be IRE Topic

THE MEETING OF THE Baltimore Section IRE scheduled for April 24 will be in charge of Vernon D. Hauck, formerly of Bendix Radio and now chief engineer of the Friez Division. The paper to be presented on the Electron Microscope will include not only a theoretical analysis of its operation but also practical application data.

At the May 22nd meeting, the feature will be an exhibit of electrical and electronic radio components. Design and research engineers of the various component manufacturers have been invited to participate, with a view to an interchange of knowledge and ideas on components which are of general interest.

It is hoped that this demonstration may be made an annual IRE function and eventually serve to bring under the sponsorship of the Baltimore Section IRE the annual radio show for this area.

The final meeting of the season, including election of officers, will be held on June 26. The topic for discussion at this meeting has not yet been announced.

# Spencer Named to SAE Committee

H. L. SPENCER, Quality Engineer, has recently been appointed to the Aeronautical Committee of the Baltimore Section of the Society of Automotive Engineers, as representative of Bendix Radio.

The primary purpose of this committee is to coordinate and further the interests of all companies and organizations in the area connected with aviation. Recommendations on postwar development of local airports and world airline terminal facilities will be made by this committee and are promised consideration by the State Aviation Commission.

# New Maintenance Bulletin on MN-36

THE PUBLICATION OF Maintenance Bulletin M-121 on the MN-36 automatic loop is announced by W. L. Cunningham, head of the Service and Parts Department. This bulletin is the latest in a series prepared for distribution to customers to advise their maintenance forces on major engineering improvements and changes in equipment.

A customer who has bought an MN-36 may find that the current equipment varies considerably from his original. The bulletin covering the unit points out the changes made in the new model, gives information on spare and interchangeable parts, and suggests maintenance procedures.

A. T. Parker, who is in charge of the project, anticipates a great demand for the new bulletin, as well as for Bulletin M-120 on the MN-20 and MN-24 loops, and Bulletin M-119 on the RTA-1B microphone circuit, describing the changes made in all units subsequent to serial number 1060. He is particularly desirous that they reach users of Bendix Radio equipment whose maintenance personnel will profit by the information they contain. Correspondence is invited from those who wish to be placed on the mailing list to receive these bulletins and subsequent releases.

## Pulse Limiter For Queen Units

Because the pulse limiter on "King George" airborne equipment has given such good results in combat, a similar addition to the "Queen" ground station equipment is planned by Aircraft Radio Laboratory of the Air Technical Service Command at Wright Field.

While the device does not completely eliminate all pulse type interference, according to T. G. Arnold, Jr., Receiver Engineer in charge, it does limit the magnitude of the noise so that a signal, otherwise inaudible, can be read.

The limiter, provided in convenient kit form, will be available for installation by field personnel in all "Queen" ground station receivers in the field.

## Designs Portable Set for Railroads

In response to interest expressed by the railroads in portable communication gear, E. L. Crosby, Jr., of the Transmitter Laboratory, is designing a hand-held transmitter-receiver unit with integral microphone, receiver, antenna and power supply.

The following features are included: miniature tubes, an improved on-off switching arrangement, operation in the vhf portion of the communication spectrum, increased convenience in handling because of shape and weight, and sufficient transmitter output and receiver sensitivity to permit full practical use of the service range of the vhf frequencies.

## Omberg Appointed New Section Head

The engineering group engaged in special research and development at the Belvedere plant has been designated as a new section of the Engineering Department with Arthur C. Omberg as section chief. Prior to his association with Bendix Radio, Omberg was assistant director of the Signal Corps operational research group in Washington.

**Arthur C. Omberg**

The original staff has been augmented by two additional project engineers—Dr. S. B. Littauer, formerly of the Bendix Radio Receiver Laboratory, and Dr. Harold Goldberg, formerly chief of microwave research at Stromberg Carlson.

## Transformer Unit Moves to Towson

The Transformer Engineering group is occupying fine new quarters at Towson after several years in the Charles Street plant. Complete laboratory facilities for building and testing new models now make this section a self-contained engineering unit.

According to H. J. Oosterling, section chief, an ambitious program is in prospect to supplement the usual routine activities as soon as current investigations on Kovar-glass and ceramic terminals are concluded. Conversion from bakelite terminals to either glass or ceramic insulation has been specified on all Signal Corps equipment in tropical use because bakelite supports fungus growth. A special hermetically sealed Kovar-glass terminal has been successfully used in the construction of transformers for some recent radio compasses.

## Units Installed For PANAGRA

Installation of the Bendix Radio MN-31 Dual Automatic Compass and RA-2C Receiver on all PANAGRA planes in regular passenger service has recently been completed. R. L. Daniel, Sales Department engineer, assisted with the installations at Lima, Peru. There he was joined by Don Pomeroy, Bendix field representative, whose headquarters is at Montevideo.

Inasmuch as PANAGRA already used Bendix Radio Type TA-2J Transmitters, with the completion of the new installations all passenger planes on this airline are operating with 100% Bendix radio equipment.

## Ladies Must Wait


Nylon sheathing for electric wire may not have the enchanting possibilities of nylon hose, but its flame-resistant qualities will interest amateurs who turn on the juice to see whether they get sound or smoke from their homemade radios. The nylon coating, developed by DuPont, also resists all solvents except alcohol. Cable makers may use it as a sealing compound for spaces between wires in a multi-strand cable, and between materials in a cable that might contaminate each other.

Dielectric properties being measured on a General Radio 516-C R-F Bridge. Thomas Wild, who is operating the instrument, made modifications which permit use of the bridge for computing power factors from 1 kilocycle to 1 megacycle.

# MEASUREMENTS AND STANDARDS

THE GAMUT OF SERVICES RENDERED by the newly organized and splendidly equipped Measurements and Standards Section of the Engineering Department runs from unsnarling an engineering or testing jam to giving the curious a tip on tomorrow's weather.

Combining facilities that were formerly divided among Test and Inspection Department and the various Engineering sections, and adding a quantity of new equipment, the Measurements and Standards group, under the direction of G. R. White, has one of the finest setups for standardizing and checking test instruments that is to be found in any industrial laboratory in the country.

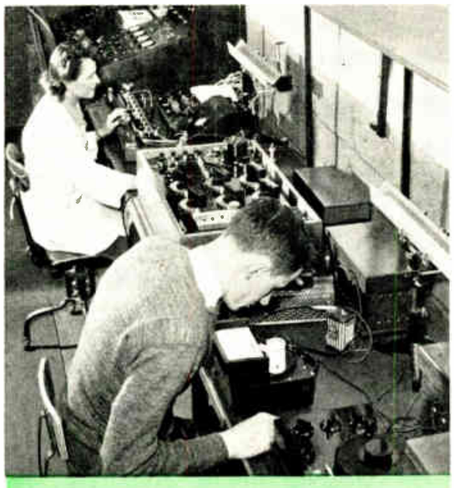
From the Cyclo-Stromograph, which the weather-wise note in passing through the corridor, to the six-foot General Radio Primary Frequency Standard, the latest types of equipment—some Bendix built, some custom built—give this section the appearance of a display room for all the famous names in test equipment design: General Radio, Leeds and Northrup, Boonton, Ferris, Weston, RCA, General Electric, Bausch and Lomb, Westinghouse, Brooks, Stoddart, and others.

## Important to Production

Accurate testing is part of the craftsmanship of turning out precision radio by mass production. It is essential, for instance, that a 1000 kilocycle note on a signal generator in Transmitter Engineering, where equipment is designed, and a 1000 kilocycle note on a signal generator in the Transmitter Test Department, where equipment is given its final performance test, are identical. Signal generators, of course, were regularly checked and standardized before the Measurements and Standards Section was formed. But the new organization centralizes instruments that were formerly scattered, and brings together personnel with a specialized knowledge of their operation and maintenance.

Measurements and Standards, being a service group, may be called upon to assist any department that has need of its facilities. Test and Inspection, for example, is responsible for keeping test equipment used in production areas in top working order. If trouble is encountered in getting radio equipment through the rigorous tests specified for it, it is quite possible that the unit itself is all right, but that something is wrong with the instruments used to test it. Without Measurements and Standards equipment it would be necessary to take the suspected test instrument to the Bureau of Standards in Washington or return it to the manufacturer to make absolutely certain that it is accurate. Any instrument, however, can be quickly checked against a primary or secondary standard in the new Section.

Incoming Inspection also relies upon the Section to act as final arbiter on the acceptability of purchased parts. It is not difficult to imagine the havoc that would be created with production schedules if a large quantity of defective components got into the stock bins. If a drawing calls for a 0.05 micromicrofarad capacitor, it is of the utmost importance that Production be supplied with capacitors that fall within the permissible tolerance. Tests made by Incoming Inspection can be double checked by Measurements and Standards. When inconsistencies occur, the source of trouble can be traced to the components themselves, or to the test equipment used by the inspectors. Not long ago, relays were rejected because they did not meet specifications. The vendor claimed that they had been tested before being shipped and had met all requirements. A check in Measurements and Standards revealed that the relays actually were defective, and the matter was settled.



Arborette Feehan, left, watches a mirror-reflected beam of light move across the scale in making resistance measurements with the Leeds and Northrup Kelvin bridge. John O'Gorman, right, checks the calibration of a meter with a Leeds K-2 Potentiometer.

To the design sections of the Engineering Department, the facilities of the laboratory are invaluable. Engineering test equipment, of course, is regularly checked. In addition, infrequently used but highly important instruments are available to any engineer who has need of them. A recent occurrence in Microwave Engineering illustrates the value of these services. A circuit designed for a microwave project failed to function properly. Careful checking of all other elements did not bring the trouble to light, so suspicion fell on the tube. A test on the Bendix-built transconductance bridge showed that the tube characteristics actually were not what they were claimed to be.

## Absolute Values

"Approximately" is not included in the professional vocabulary of the personnel of Measurements and Standards. Everything in the Section is calibrated to absolute values. The General Radio Primary Frequency Standard, for instance, is accurate to one part in five million. It contains a 50 kilocycle crystal which is mounted in a uniformly heated oven. Oscillator output is fed to a multivibrator which controls a 10 kilocycle multivibrator, which in turn controls a 1 kilocycle multivibrator. The 1 kilocycle signal drives a synchronous clock that maintains absolutely correct time when fed a pure 1 kilocycle signal. The clock is regularly checked against government time signals, and in a 24-hour period does not deviate more than a few millicycles.

Electrical values are assured with an accuracy that probably will not be found in any similar laboratory in the industry. A General Radio 821A Twin T Bridge contains a

Section Chief G. R. White measuring the conversion transconductance of a mixer tube on a Bendix-built bridge.

Sibyl Keener operating cathode-ray oscillograph in screen room of Standards and Measurements laboratory.

A precision meter is checked with a Brooks Potentiometer by Arborette Feehan, left, and Mary Haynes, right.

modified 722N air capacitor that is the finest variable capacitor for r-f work available. Its direct capacitance range is 100 to 1100 $\mu\mu f$; its frequency range 460 kilocycles to 30 megacycles. The bridge measures inductance in terms of capacitance over the same range. It has been used to check the Q of a set of coils built as standards for Boonton Q Meters, and a single measurement came very close to the average of about 15 different Q meter findings.

Among the many ways of measuring capacitance, the most difficult and tedious, but undoubtedly the most accurate, is an adaptation of the Maxwell method. Bendix secured the blueprints of the Maxwell bridge used at the Bureau of Standards, then commissioned Leeds and Northrup to build a similar model. The only difference between the two is in the polarity switch, which was not included in the original Bureau of Standards model, but was added later. Bendix specified that it be included in its design. Measurements made by the bridge are based on the charging and discharging of a capacitor at a known rate through a known resistance. The equipment utilizes platinum contacts seated in mercury cups. The contacts are placed on the prongs of an electrically vibrated tuning fork. The frequency of the fork is governed by the primary frequency standard. The bridge gives an accuracy of one part in a million over a period of several minutes.

Resistance of from five ohms upward is measured by the custom-built precision Wheatstone bridge. Though not new to the industry, the bridge is rarely found in industrial setups because of the prohibitive cost. It utilizes a Schone arrangement of ratio arms—two each of 10, 100, 1000, and 10,000 ohms. Each unit of 10,000 ohms consists of ten 1000-ohm coils to insure constancy. These manganin coils have a temperature coefficient of less than 0.00002 between 20°C and 30° C. The bridge is immersed in oil, which is kept at a constant temperature of 30°C. Low resistances are measured on a Kelvin bridge which has a range of 0.01 microohm to 1 ohm. It can be balanced to a precision of ±0.04% down to 0.000025 ohm. Deviation from a standard can be found in parts per million with a Wenner Ratio Box.

## Voltage Standard

The Section's primary standard of potential is provided by six Eppley saturated cells. These determine potential to an accuracy of six decimal figures, with the sixth figure the only variable. The drift per year is about 0.004%. A light beam galvanometer which deflects one centimeter for a current unbalance of a $5 \times 10^{-8}$ amp, indicates voltage balances, and is used with a Leeds and Northrup Type K potentiometer for measuring potentials from 1/10 microvolt to 750 volts. Another voltage constant, for checking meters, is an 850 volt wet battery supply. There are 17 batteries of 50 volts each in series, or in parallel, tapped every 50 volts.

Analysis, too, falls within the scope of the Measurements and Standards Section. Fungi growths, which plague the radio industry when equipment is sent to the tropics, is studied through a Bausch and Lomb Petrographical Microscope. With this instrument it is possible to determine whether a growth actually is a fungus. The instrument also is used to determine the optical properties of quartz crystals, exact index of refraction of small crystal grains, the polarity of crystals, and to find whether minerals are isotropic, uniaxial, or biaxial.

Other apparatus for analysis includes the General Radio 631-B Strobotac, which is used with a Type 549-C Synchronous Motor Contactor to measure the speed of rotating, reciprocating, or vibrating mechanisms, and for observing their operation in slow motion. Speed measurements for overload and underload tests can be made. The instrument is small, portable, and calibrated to read speed directly in revolutions per minute. The light source is a Strobotron neon lamp. Its flashing speed can be adjusted by a direct-reading dial to any value between 600 and 14,400 rpm. Speeds up to about 100,000 revolutions per minute can be measured.

Possibilities of using plastics in component manufacturing are constantly being explored. The Measurements and Standards laboratory has a Leeds and Northrup Insulation Tester which measures the electrical loss factor of plastics. It tests the value of wire insulation by measuring d-c surface resistance up to thousands of megohms. A special type of bridge also available is sensitive to temperature changes of 1/100°C by measuring up to a 1/10,000 variation in resistance of a platinum wire.

## Equipment To Be Added

Yet to be added to the equipment of the Section is a Westinghouse Electronic Oscillograph which, when installed, will be its largest single instrument. The oscillograph, weighing 1300 pounds, has a fluorescent screen for viewing electrical characteristics. Provision is made for recording on film single electrical transients of very short duration—about 1 to 15,000 microseconds. Rather than a cathode-ray tube, this equipment operates from a cathode-ray cell, which is energized by an oil vacuum pump and a molecular pump. The cell operates indefinitely, whereas a tube would have to be replaced periodically. The instrument will make possible the permanent recording of electrical phenomena on film, and will provide added accuracy for microwave research.

It has been possible to describe only a few of the instruments which are available in the Measurements and Standards Section, and to give only an incomplete idea of its activities. Many of the other instruments in the laboratory are unique, some fairly common—but all noted for extreme accuracy. The Section is well equipped to solve almost any problem that arises in connection with testing. Its value to the Engineering and other departments, already great, will increase as the facilities are further expanded, and as the personnel throughout the plant become better acquainted with the services it offers.

# As We heard it

## The Lighter Side

For the benefit of casual readers who may have the impression that radio engineers browse through Terman for relaxation and read blueprints at breakfast, we pass along this story.

In California on business, Eddie Wilbur of the Sales Department was the Christmas guest of Bob Moon, head of the Bendix Radio West Coast Branch. On Christmas Eve, in keeping with the custom of the house, stockings were hung for the visitor and members of the family.

When, well after dawn, the household yawned to life, and the booty was examined, it was found that St. Nick's presents included a catapult airplane for the guest and a popgun for the host. Quick as a wink the pajama-clad engineers were out on the back lawn, running tests on the new equipment.

Inevitably, the gunner took a pot shot at the plane, and the East Coast and West Coast were straightway plunged into noisy warfare. The ensuing uproar attracted the kids in the neighborhood who forsook their new wagons and bicycles to watch the progress of the battle. But not content to remain spectators, they soon were retrieving plane and cork, and eventually commandeered the entire outfit, forcing the engineers to retire.

Still filled with the spirit of the occasion, however, the two looked for other amusement, which they discovered St. Nick also had thoughtfully provided. For the next several hours they were on their knees in the middle of the floor shooting a hot game of—marbles.

## The Chinese Way

A new slant on the Chinese air raid warning system was given us by I. E. Morrison, Service and Parts, who recently returned from a tour of duty as Bendix technical representative in the China-Burma-India area.

While in Kukon, about 125 miles north of Canton, Morrison witnessed the heralding of enemy bombers by a method that is practical only in so thickly populated a country. Any person seeing or hearing Jap planes coming in over free China shouts what information he can get on the number and direction in which they are flying. People hearing the call repeat it, adding to it if the planes change direction or split into groups. The warning spreads to a distance of 20 to 30 miles each side of the course the bombers are taking. News thus travels well ahead of the planes and covers the entire area in which they are likely to strike.

When Morrison saw Kukon bombed, the people knew the Japs were coming 20 minutes before they arrived, and had ample time to close homes and shops and take shelter in the surrounding hills. As soon as the planes departed, their course was again relayed. Morrison says that, though he could not understand what was being shouted, the information was concise and spread across country like wildfire.

## Efficiency

Steve Holland of Sales Engineering, who has covered a large part of the eastern half of the country conducting railroad radio tests, now speaks as casually of riding an engine cab as he does of flying in a B-17 or the Martin Mars. But even the blasé Mr. Holland was impressed by a demonstration of efficiency that he witnessed at the Jacksonville Terminal Company.

The Terminal Company, whose operations cover 68 tracks, is the clearing point for most of the north, south, and west rail traffic entering and leaving Florida. It handles cars of highly perishable goods from an express loading terminal that is reputed to be the largest in the country, and uses 20 tracks exclusively for through passenger trains.

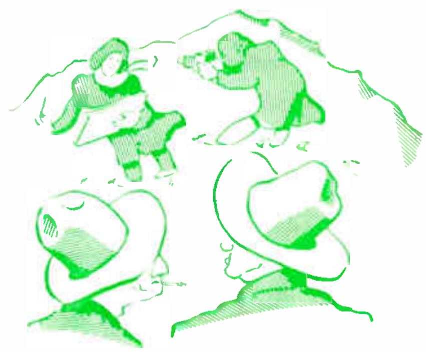
Steve timed a typical operation when an 18-car Florida East Coast Special pulled into the yard. A terminal crew removed the engine, express and passenger cars were uncoupled and other cars added, a new road engine was put on, a crew cleaned and serviced the train, passengers were unloaded and loaded without inconvenience to themselves, a new road crew went aboard and the train pulled out. The whole procedure took exactly 20 minutes.

## I Brung 'Em

"We want pictures of trains, lots of trains," said the boss. So John Sitton, artist, and Phil Morris, photographer, of the Technical Publications Section went west to get pictures.

In Chicago they bought fur caps with fur ear flaps, fur underwear as long as it comes, fur socks, and went farther west. At Denver they looked at movies of the Rio Grande Railroad's right of way, and picked 2000-foot Gore Canyon at Kremmling, Colorado, as the ideal spot for their work.

Kremmling, however, is 75 miles from Denver, and outside was a blinding snowstorm. But they had come for pictures, and their hosts of the Rio Grande were determined that they should get what they wanted. So Chancey VanPelt, the Town Marshal of Kremmling, was commissioned to drive them to the spot. The route was along the aptly named Shelf Road that was unmarred by tracks of any kind. They made it, although near their destination they had to dig the car out with the help



of a friendly cowhand. Their benefactor, curious to see what errand was important enough to bring them to the mountains in such weather, joined the group.

At the rim of the Canyon, John got out his sketch pad, Phil his camera, and they went to work. The cowhand looked at the two, then at the snow-covered countryside, and said, "Damn fools, ain't they Chancey!"

"No more than I am," said Chancey. "I brung 'em."

BENDIX RADIO

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