PHILCO

TECHREP DIVISION
BULLETIN

In This Issue...

Editorial . . .

A NEW CONCEPT IN COMPUTERS

by John E. Remich

Manager, Technical Department

Once again, the phenomenal advances in the electronics industry were revealed to some 40,000 visiting engineers who attended the recent annual convention of the Institute of Radio Engineers in New York.

With the accent on new developments in computers, transistors, printed circuitry, and miniaturization in general, one of the high spots of the I.R.E. meeting was the introduction of the new Philco TRANSAC. The device derives its name from "Transistor Automatic Computer," and it represents an entirely new concept of linking transistors in a miniature "electronic brain," or computer.

Space limitations preclude a detailed description of the TRANSAC; however, a few technical points will probably be of interest to Philco Tech Rep Field Engineers. The TRANSAC, packaged in a $5\frac{1}{2}$ inch cube, is one-third smaller and one-third lighter than any other announced transistorized computer. It may be operated on ordinary batteries, since it uses only about one thousandth of the power required for a comparable vacuum-tube computer.

The arithmetic section of the device, as well as the control circuits, are combined on a single replaceable unit—a printed wiring card, having on it only transistors and resistors. The section performs at an incredible speed (e.g., it will multiply two six-digit figures in 0.000048 second), and it signals when addition, subtraction, multiplication, division, or comparison has been completed. The output signal is converted into the type of electrical impulse necessary to activate whatever the computer is to operate, such as indicator lamps, mechanisms, autopilot, aircraft, guided missiles, etc. The high speed of TRANSAC is made possible by the Surface-Barrier transistor in conjunction with the newly developed Philco Direct-Coupled Transistor Circuits.

The development of the new computer is too recent to permit inclusion of a descriptive article in this issue of the BULLETIN; however, we hope to have more material on this subject in a forthcoming issue.

DESIGN AND INSTALLATION OF GROUND SYSTEMS

by Harley N. Stoleson

Philco Field Engineer

A comprehensive and practical approach to the design of efficient ground systems.

(Editor's Note: One of the most important and often neglected parts of an electronics installation is the associated ground system. This article is intended to guide installation planners in the installation of equipment required to make grounds under all conditions. Also covered are the methods by which the electrical resistance of a ground may be reduced to specified limits. It is felt that this article will be of great value to the field engineer.)

THE IMPORTANCE OF INSTALLING and maintaining a proper ground cannot be overemphasized. Any protective device is no better than the ground through which it is connected to the earth. The most approved protector is practically worthless when the bypath to ground, offered to foreign currents by its operation, is unreliable or of high resistance. Reliable ground connections of comparatively low resistance are, therefore, an essential requirement of any protective system.

Resistance to the flow of current through a grounded electrode or ground connection into the surrounding earth is made up of three component parts:

1. Resistance offered by the electrode itself.

2. Contact resistance between the electrode and the earth adjacent to it.

3. Resistance of the surrounding earth.

Rods, pipes, and structures commonly used for electrodes or grounds offer negligible resistance.

The diameter of the ground rod, as well as its contact area, have very little effect upon the resistance of a ground. Experience has shown that if the ground rod is free from paint or grease, and the earth is packed tightly around it, the contact resistance is negligible. A curve which illustrates the effect of electrode diameter on ground resistance for single driven grounds is shown in figure 1. It will be observed from the curve that increasing the diameter of the ground rod from ½" to 2", which is equivalent to increasing the contact area by four times, reduces the ground resistance by only 25%.
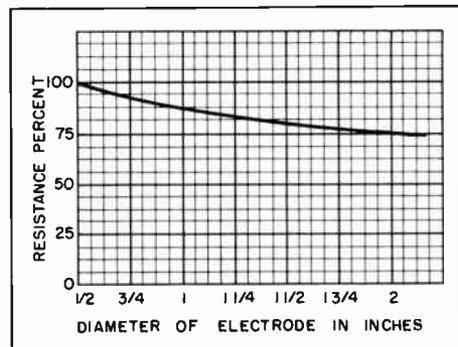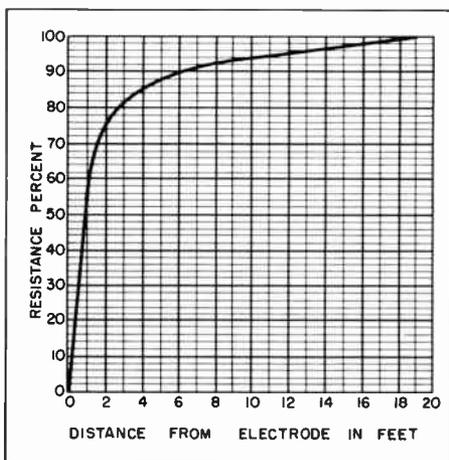

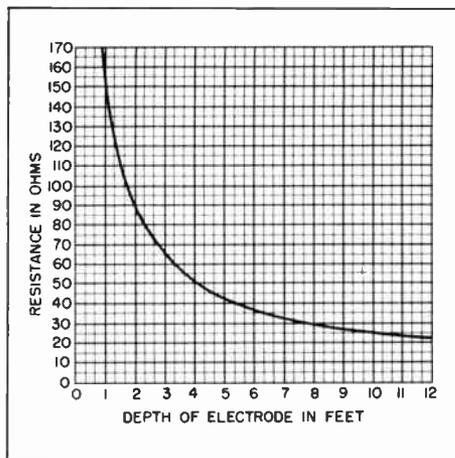*Figure 1. Relation of Electrode Diameter to Ground Resistance (Soil of Uniform Resistivity)*

It is now a well established fact that the resistivity of the soil or surrounding earth, as determined by its composition and moisture content, is the important factor governing the resistance of a

ground. About 90% of the total resistance to earth is generally encountered in the first 6 to 10 feet from the ground electrode, and about 60% of the total resistance to earth is encountered in the first 12 inches from the ground rod. In other words, the soil adjacent to and surrounding a ground electrode has a predominant effect on the ground resistance of that electrode. If the soil is assumed to be of uniform resistivity, then the resistance offered to flow of current decreases as the inverse square of the distance from the ground electrode. A curve illustrating the relation of resistance to distance from the ground electrode is shown in figure 2.

As the composition and moisture content of the soil are important in determining the resistance of a ground, it will be observed that the depth to which the ground electrode penetrates the earth will have a considerable effect upon the ground resistance, other conditions remaining the same. To reach permanent moisture level where the resistivity of the earth is low, is a most desirable condition, and a ground rod having a minimum length of 8 feet has been found by experience to be the most suitable. A curve illustrating the rela-

Figure 3. *Relation of Resistance to Depth of Driven Ground Electrode (Soil of Uniform Resistivity)*

tion of resistance to the depth of driven ground electrodes is shown in figure 3. It will be seen that the curve begins to flatten out at a depth of about 8 feet, and beyond this depth, the decrease in resistance accomplished by increased depth of the ground rod can usually be neglected. Another factor which must be considered in connection with the depth of a ground is that the resistance of soil rises rapidly at temperatures below the freezing point. In most parts of the United States, the depth of the ground electrode, when placed 8 feet below the surface of the earth, will generally be below that at which the soil naturally freezes.

Grounds may be required at a particular location for more than one purpose, such as protection of communications equipment, a-c power supply ground, and cable ground. For protection reasons, it is best to connect all grounds to a common bus, particularly when lightning is prevalent. This will prevent excessive potential differences when one of the grounds is carrying large currents, as may happen during a lightning storm. Such potential differences, unless avoided, may cause insulation failures and hazards to personnel.

Figure 2. *Relation of Resistance to Distance from Ground Electrode (Soil of Uniform Resistivity)*

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For a similar reason, it is advantageous from the protection standpoint to interconnect grounds of different communications systems installed at one point. In some cases where the resistance of the ground is high, it may be necessary to use separate equipment grounds to avoid transmission difficulties; however, wherever practicable, a single low-resistance ground should be used, and the ground conductor should be as short and direct as possible.

CHOICE OF GROUNDS

The best grounds available are water pipe grounds. A water pipe ground is defined as one obtained by connection to a system of water pipes, gas pipes, or other extensive underground metallic structures. In cases where there is a water pipe in the building, or where it can be readily reached by a short length of buried wire, that water pipe may, if its resistance is satisfactory, be used as the sole ground. Where the run to a nearby water pipe must be of considerable length, that piping system should not be the only ground. In such cases, a driven ground should be provided and located as close as possible to the protected equipment. The ground conductor from the protected equipment should be connected to the driven ground. A bond conductor from the water pipe should then be connected to the driven ground.

In places where no water pipes are available, driven grounds should be installed. They should consist of one or more rods (or pipes) driven, where practicable, at least 8 feet into the earth.

STATION GROUNDS

All stations should be equipped with a ground connected to a ground bus. The ground should preferably be a water pipe ground. Where the resistance of the ground exceeds the value specified in TABLE 1, supplementary driven grounds should be installed and con-

nected to the ground bus. The ground bus provides facilities for the convenient disconnection of the main ground or the supplementary grounds for the purpose of measuring ground resistance.

If the resistance of the ground cannot be reduced to a value below that specified in TABLE 1, a "counterpoise" consisting of a network of conductors buried to a depth of 2 feet or more should be employed. The effectiveness of the "counterpoise" depends primarily upon placing sufficient wire in the ground to attain the required conductance. If the moisture content of the subsurface soil is low, the "counterpoise" should be very extensive. It may require thousands of feet of wire, laid out in a network of interconnected groups of radial and/or lateral conductors, as described in a later paragraph.

CABLE SHEATHS

Sheaths of lead-covered cables should ordinarily be grounded where they terminate at switchboards. Sheaths of underground and aerial cables should be bonded where both are used. Sheaths of aerial cables should be electrically continuous from end to end to prevent large differences of potential, which would otherwise occur at sheath discontinuities during lightning storms.

METHODS OF DECREASING GROUND RESISTANCE

There are two general methods which may be applied to the problem of lowering the resistance of driven grounds. The chemical treatment should be tried first, and if not satisfactory, a system of parallel ground rods may prove effective.

SALTING

Treating the soil surrounding a driven ground is generally recognized as an effective means of lowering ground resistance. Its success depends chiefly upon the characteristics of the soil, the chemical treatment used, and the method

of applying the treatment. In general, the higher the resistance of the soil, the greater will be the percentage of improvement in electrical resistance after treatment. Thus, a driven ground resistance of 30 ohms may be reduced about 50% by treatment, whereas the same treatment may reduce a 1000-ohm resistance ground by about 90%.

Treating the soil with coarse rock salt has been found to give very satisfactory results. Driven grounds should be salted immediately after installation unless an immediate test shows that its resistance is less than the maximum allowed, as shown in TABLE 1. A basin 1 foot deep, and 2 to 4 feet in diameter is dug around each rod or pipe, and 40 to 60 pounds of coarse rock salt poured into each basin. At least 5 gallons of water is then poured into each basin over the salt, and the earth replaced and packed tightly.

MULTIPLE GROUND RODS

If satisfactory low ground resistance is not obtained with one rod, after salting as outlined above, a second rod should be driven and salted at least 20 feet away from the first, in a location which will permit a buried bond conductor to be run without difficulty. Ad-

Figure 5.   Ratio of Resistivity of Ground Rods in Parallel in an Area to That of Isolated Rods

ditional ground rods may be driven, salted, and bonded to the others at a uniform separation of at least 20 feet, if the ground resistance is still found to exceed the maximum. Where three ground rods are necessary, they should form an equilateral triangle; if four ground rods are used, they should form a square.

The reduction in resistance, accomplished by adding ground rods in parallel with a single driven ground, can be fairly accurately predicted by referring to figures 4 and 5 and employing the formula:

$$RT = \frac{R1 \times K}{N}$$

where RT = approximate total resistance of ground rods in parallel

Figure 4.   Ratio of Resistivity of Ground Rods in Parallel to That of Isolated Rods

R1 = measured resistance of a single driven ground rod

K = ratio of resistivity as read along vertical axis of figures 4 and 5 for number of rods, and spacing as read along horizontal axis and on curves

N = number of rods

Where necessary, more than four ground rods can be driven, salted, and bonded together, provided that, having employed the method outlined above, it can reasonably be expected that the resistance will be reduced to a value below that given in TABLE 1. The proper arrangement of the rods is that of a square bounded by the outer rods. In the interest of economy, no more than 25 rods should be installed as described. Where a need for more than 25 rods is indicated, a "counterpoise" should be installed.

MEASUREMENT OF GROUND RESISTANCE

The approximate resistance of a ground can be determined with a resistance bridge or an ohmmeter by the method described below. The accuracy afforded by this method is sufficient for all practical purposes.

1. Designate the ground under measurement as ground A.

2. Drive a ground rod vertically into the earth approximately 50 feet from ground A. Call this ground rod B.

3. Drive another ground rod vertically into the earth approximately 50 feet from ground A and 50 feet from ground B. Designate this ground rod C.

4. Secure two leads of wire long enough to reach from A, B, or C to the location of the resistance bridge or ohmmeter.

5. Measure the resistance between ground rods A and B. Take several readings. Then reverse the connections to the resistance bridge or ohmmeter and take several additional readings. Take an average of these readings, and record.

6. In a similar manner, measure the resistance between ground rods A and C, and between ground rods B and C.

7. The approximate ground resistance may then be determined by substituting the values obtained in the formula:

$$R = \frac{AB + AC - BC}{2}$$

where R = approximate resistance of ground under measurement

AB = resistance between rods A and B

AC = resistance between rods A and C

BC = resistance between rods B and C

INSTALLATION OF WATER PIPE GROUNDS

Water pipe systems form the most satisfactory grounds and should be used wherever practicable. Where a ground connection to such a system is made inside a building, it should be located as near as possible to the entrance of the main pipe into the building, and between that entrance and the first valve, meter, or similar fitting, if possible. When this cannot be done, as in a case where the ground conductor would have to pass through premises not available for such use, it is sometimes feasible to install bond conductors around meters, valves, or other fittings which might possibly be removed or cause high-resistance joints.

Connections made outside of build-

ings to water pipes should be so located as to be near the apparatus to be grounded, and yet be free from liability to mechanical disturbance. It is preferable to locate such connections at least 12 inches below the surface of the earth.

For connecting ground or bond conductors to a water pipe, a ground clamp should be used. Before attaching the clamp, the entire outer surface of the pipe must be thoroughly cleaned for a length of 2 inches, using a file or emery cloth. Around this cleaned section, lead foil should be wrapped. The ground clamp is then tightly fastened over the lead foil after the ground or bond conductor has been properly connected to the clamp. A flexible-type clamp should be tightened as much as possible and then rapped with a hammer to make it conform more closely to the contour of the pipe. After hammering, the clamp is again tightened as much as possible. Ground clamps employed for this purpose should be of good grade; they must make good electrical contact, and must be mechanically secure.

INSTALLATION
OF DRIVEN GROUNDS

Driven grounds should be so located that the ground conductor will follow the shortest practicable run. Special care should be taken to locate such grounds, intended for use with arresters, at the nearest point to the protective equipment. Preferable locations are those in which the ground will be moist. Abundant vegetation usually indicates underlying moisture and favorable conditions for grounds.

At locations where the surrounding earth is mostly gravel, sand, or other material of doubtful conductivity, it may be necessary to drive grounds to a depth greater than 8 feet to obtain the resistance specified in TABLE 1. If the ground conductor is to terminate in a building or on a pole, either of which

is located on an embankment, it may be necessary to drive the ground at the foot of the embankment, and in some cases some distance from it, in order to ensure that the rod reaches a sufficient depth in moist soil.

Unless a rod or pipe is driven within or under a building, a hole should be dug about 18 inches deep and the rod driven until the top is at least 12 inches below the surface of the earth. Grounds should not be driven closer than 2 feet to the base of a pole, or to the face of a building wall.

In general, each driven ground should be so located as to minimize the possibility of interruption to the buried ground conductor connected to it.

"PERMA-FROST" AND ROCK

At locations where no water pipe systems are available for grounds and the nature of the earth is such the ground rods or pipes cannot be driven economically because of "perma-frost" and rock, special methods of obtaining grounds must be considered.

Bodies of water usually form satisfactory grounds. Extending one or more ground conductors to a nearby body of water will normally give satisfactory low ground resistance. The ground conductor should be no smaller than #6 AWG when this method is employed, and the near edge of the water should be no farther than 3000 feet from the protected equipment. The conductor should be extended sufficiently far into the body of water to ensure its reaching a depth below that at which the water will normally freeze.

Where bodies of water are not within the specified distance, a "counterpoise" may be laid on top of the earth to serve as a ground. This "counterpoise" is constructed as outlined below. At least one ground rod must be driven, salted, and connected to the "counterpoise" at the

TABLE 1.   MAXIMUM ALLOWABLE GROUND RESISTANCE

TYPE OF SERVICE		PROTECTOR GROUND		CABLE SHEATH	RETURN & PROTECTOR GROUND		MAX. RESISTANCE (OHMS)
		WATER PIPE	DRIVEN GROUND		WATER PIPE	DRIVEN GROUND	
Pole and Tower Arresters (including horn gaps)			Xb				2
Neutralizing Transformer	Multiwire	Xa					5
	Individual Line		Xb				25
Arrester Relays	On more than 40 wires	Xa					3
	On 40 wires or less	Xa					5
Telephone Subscriber Stations						Xa	25
Cable Protectors				X			—
Messengers & Guard Screens			X				—
Antenna Tuning Units			X				—
Stations (see Note 1)							
Low Frequency (see Note 2)	Transmitter Station		Xb				10
	Homing Beacon Station		Xb				10
	Receiver Station		Xb				10
Medium & High Frequency (see Note 2)	Transmitter Station		Xb				25
	Receiver Station		Xb				10
	Direction Finder Station		Xb				10
VHF & UHF (see Note 2)	Transmitter Station		Xb				25
	Receiver Station		Xb				10
	Direction Finder Station		Xb				10
	Omni-Range		Xb				5
Microwave Stations			Xb				25
Tape Relay Centers			Xb				25
Communications & Message Centers			Xb				—
Control Towers (see Note 2)			Xb				25
Radar Stations			Xb				25

X = ground normally to be provided.

Xa = ground preferred if obtainable without a material increase in cost over that of a driven ground.

Xb = ground to be used when run to water pipe is uneconomical.

Note 1. Where two or more stations (facilities) are to employ a common ground, the ground resistance should be below the lowest value specified for any one of the particular facilities.

Note 2. If control circuits employ the earth as a conductor, the maximum resistance should not exceed 1 ohm. A ground to serve satisfactorily as a return ground should be free and remain free of any appreciable earth potentials.

most advantageous location. Where "perma-frost" is encountered, driving can be accomplished with the assistance of a steam drill. If rock is found, blasting will probably be the most satisfactory method of driving.

"COUNTERPOISE" GROUNDS

When satisfactory low resistance cannot be obtained by installing deep-driven ground rods, as otherwise specified herein, a "counterpoise" should be installed. "Counterpoise" grounds should consist of at least 18 radials (#8 AWG wire or larger), 100 feet long, spaced 20 degrees apart and interconnected at 25-foot intervals along their lengths with wire laid in a circular pattern. All connection points should be mechanically strong and soldered so as to ensure good electrical conductivity.

Except where "perma-frost" or rock is encountered, the "counterpoise" should be buried to a depth of at least 2 feet. Buried "counterpoises" should have a ground rod, 5 feet or more in length, driven and connected at each connection point of the mesh.

GROUND CONDUCTORS

A ground conductor which extends between equipment and the ground connection or main ground bus bar should be run as directly as possible, without kinks, coils, or sharp bends. The ground conductor should, if practicable, contain no splices, except at its connection to the tie wires of the ground rod or pipe.

In no case should the ground conductor between the equipment and the ground connection pass through an iron or steel duct or conduit. Where protection against mechanical injury is necessary, wooden molding or fiber conduit should be used.

No T-splices or other branching connections should be made in the ground conductor between the equipment and the ground connection or main ground bus bar.

Sufficient slack should be left in the ground conductor at the ground connection to ensure against possible breakage of the conductor due to vibration, but care should also be taken to see that no sharp bends or loops are left in the ground conductor.

MATERIALS

Standard commercial ground rods of iron, copper-clad, or copper-weld construction 8 feet long, should be used for all driven grounds, except as otherwise specified.

Pieces of new or old galvanized, or black iron pipe of a size at least as large as standard 1-inch water pipe, and from 8 to 12 feet long, may be used for grounds when the nature of the soil is such that it is impracticable to use a standard 8-foot rod. If it becomes necessary to reach a greater depth than 12 feet, two or more sections of pipe joined together may be used. Driving points of a commercial grade should be fitted to pipes before they are driven into the earth.

Except as otherwise noted in this article, ground conductors should be no smaller than #8 AWG wire, or ½" wide if flat braid is used.

Ground buses should be of flat copper braid, 1 inch or greater in width, flat bus-bar copper, 1/16" x 1" or greater, or round conductors no smaller than #2 AWG.

Ground conductors between an equipment and a ground bus should be of ⅜" flat copper braid or larger.

Bond conductors should be no smaller than #8 AWG. Flat copper braid, ⅜" wide, may be used to bypass meters, valves, etc., in a water pipe system.

Clamps, straps, lugs, and other devices of standard commercial types should be used in making connections for a ground system; they should be mechanically secure and make good electrical contact.

DEVIATION METER FOR AN/TRC-1 TRANSMITTER CALIBRATION

by Robert E. Vogt
Philco Field Engineer

A simple and accurate method of adjusting the modulation level of the T-14/TRC-1 transmitter.

(Editor's Note: The author of this article has constructed and used the deviation meter to be described. The fact that several of these meters are being constructed for use at other AN/TRC-1 sites is indication of its considered worth.)

AN/TRC-1 maintenance personnel have long desired an easy method of checking and adjusting the modulation level of the T-14/TRC-1 transmitter, a method which would be standard and suitable for use at all installations. Procedures outlined in equipment operation manuals are too involved and complex for normal field or on-the-job maintenance levels, even when the test equipment required for such adjustment is available. Once a deviation meter has been constructed and calibrated, however, the job becomes so simple that it can be performed at any installation without the use of other test equipment.

THEORY OF OPERATION

The deviation meter is designed for use in conjunction with the R-19/TRC-1 receiver, which provides most of the necessary signal gain and signal limiting for proper operation. It is essential that the R-19/TRC-1 receiver be properly tuned; it must receive a signal of sufficient level to cause its own limiting circuit and that of the deviation meter to operate at saturation.

The 5-mc. modulated signal, present at the control grid of the second limiter tube (V108) in the R-19/TRC-1 receiver, is applied to the input jack of the deviation meter, as shown in the schematic diagram of figure 1. Input transformer, T_1, is tuned to 5 mc. and the resultant signal is applied to the

grid of limiter tube, V_1. After being amplified and limited by V_1, the signal is applied through transformer T_2 to the conventional discriminator circuit of V_2. The audio output of the discriminator circuit is amplified in the first section of V_3, and then applied to the grid of the second section of V_3. The latter section is connected as a cathode follower, the rectified output of which is applied to a meter movement through a switching arrangement. When the deviation meter is constructed according to the schematic diagram, and then calibrated accurately, the circuit affords the following provisions:

1. A means of adjusting its B+ voltage, obtained from the TS-32 power socket in the R-19/TRC-1 receiver. This is important because of the d-c voltage differences which exist between different receivers.

2. An accurate means of balancing the meter discriminator circuit.

3. An accurate means of setting the input signal level before any adjustments are made. This is required because the discriminator circuit is amplitude-sensitive.

4. A means of interpreting the output of the deviation meter in terms of transmitter deviation (the final step).

Many of the parts used in the deviation meter are the same as those used

Figure 1. Schematic Diagram of Deviation Meter

in the R-19/TRC-1 receiver. For example, transformer T_1 and T_2, the entire discriminator circuit, the meter movement, and the meter switch are all parts of the R-19/TRC-1. The remaining parts are standard and all easily procurable.

CALIBRATION PROCEDURES

As stated previously, the deviation meter is designed to be used in the field as the sole instrument for calibrating the T-14/TRC-1 transmitter. However, the meter, itself, must first be accurately

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calibrated. The necessary calibration procedures must be performed at a location where the following radio and test equipment is available:

1—S-36 u-h-f receiver
1—BC-1032A panoramic adapter
1—R-19/TRC-1 receiver, properly tuned
1—T-14/TRC-1 transmitter, properly tuned (this is to be calibrated and adjusted for correct deviation)
1—CF-1A (or 1B) carrier bay
1—A-C voltmeter, VTVM, I-166, etc.

The calibration of the deviation meter requires the use of a T-14/TRC-1 transmitter which is known to be operating at the correct modulation level. Therefore, the first phase of the calibration procedure is concerned with the adjustment of the transmitter, by means of the following steps. (The procedure may be performed on normally operating equipments by removing them from use for a short period of time.)

1. Connect the BC-1032A panoramic adapter to the S-36 receiver at the plate of the mixer stage.

2. Using a short piece of wire as an antenna, tune the S-36 to the T-14/TRC-1 frequency, and note the sig-nal as observed on the panoramic adapter. (Caution should be used in tuning the S-36 because of the backlash in the tuning mechanism.) Identify the observed signal as originating from the T-14/TRC-1 by turning the transmitter signal off and on again, while watching the pattern on the panoramic adapter.

3. With the T-14/TRC-1 unmodulated, the signal observed on the panoramic adapter should be adjusted in height by the adapter gain control, and in width by the adapter frequency control to 500 or less, as shown in part A of figure 2.

4. Send a tone through the T-14/TRC-1 via channel 4 of the CF-1A carrier bay. This will be the 10.8-kc. tone originating in the CF-1A bay. The pattern observed on the panoramic adapter should have a configuration as illustrated in part B of figure 2. Adjust the oscillator calibration control on the CF-1A bay by a clockwise rotation and note the pattern on the panoramic adapter. The carrier should decrease in amplitude and the first sidebands increase; the second sidebands should appear (if not present before) or increase.
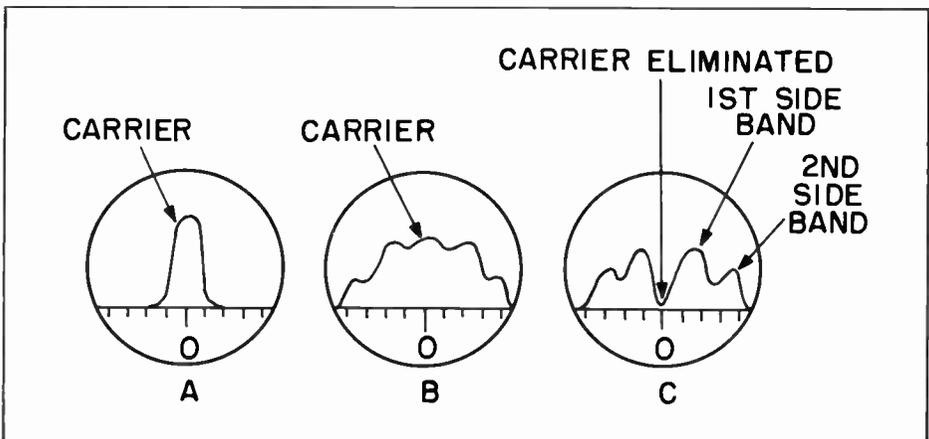

Figure 2.   Panoramic Adapter Presentations Used in Calibration of T-14/TRC-1 Transmitter

Continue to adjust the calibration control until the carrier is completely removed and all the power is in the first and second sidebands. (It may be necessary to increase the cable compensator adjustment, R_4, on the T-14/TRC-1 to obtain this pattern.)

With the completion of the procedure above, a condition exists where the carrier power is entirely removed and all the power is in the sidebands. Referring to Bessel functions, it is understood that when the carrier power is completely removed, a modulation index of 2.4 is achieved (a constant for this condition). Thus, from the formula,

$$\Delta F = FA \times MF = 10.8 \text{ kc.} \times 2.4$$
$$\Delta F = 25.9 \text{ kc. deviation}$$

where ΔF = frequency deviation
FA = audio modulation frequency
MF = modulation index

The next phase of the calibration procedure involves the use of the R-19/TRC-1 receiver, which is properly tuned to the T-14/TRC-1 frequency.

1. With the panoramic adapter presentation corresponding to the pattern shown in part C of figure 2, connect an a-c voltmeter to the output terminals of the R-19/TRC-1 receiver. Using a low scale of the voltmeter, so that a fairly accurate reading can be obtained, measure and record the voltage. This voltage corresponds to a frequency deviation of 25.9 kc.

2. Using a graph of the type shown in figure 3, plot coordinates for the values obtained in the preceding calculation and measurement. Assume, for example, that the measured voltage is 4.3 volts. From the point of intersection (4.3 and 25.9 kc.), draw line X to the O point, and extend X in the opposite direction as shown in the figure. It can be seen from the graph that 30-kc.

Figure 3. Graphical Representation Showing Frequency Deviation Versus Arbitrary Values of R-19/TRC-1 Output Voltage

deviation in this case would be equal to 5 volts. (At 100% modulation the T-14/TRC-1 has a 30-kc. deviation.)

3. With the audio control of the R-19/TRC-1 undisturbed, restore all controls on the CF-1A bay to normal (OSC CAL to — 4 db.).

Send tone on all four channels and adjust the cable compensator (R_4) to zero. While observing the voltmeter connected to the R-19/TRC-1, adjust calibrating potentiometer R_{44} in the T-14/TRC-1 transmitter until the meter reads 5 volts. If this cannot be done by adjusting R_{44} alone, then the cable compensator may be set to obtain the desired 5-volt reading. The T-14/TRC-1 transmitter output deviation will now be ± 30 kc. Cable compensator R_4 and calibrating potentiometer R_{44} *should not be moved* after this adjustment has been made.

4. Record on graph paper all pertinent values, along with equipment serial numbers, for future reference.

5. Set the T-14/TRC-1 on low power and connect to an AS-19/TRC-1 antenna. Connect an AS-19/TRC-1 antenna to the R-19/TRC-1 and
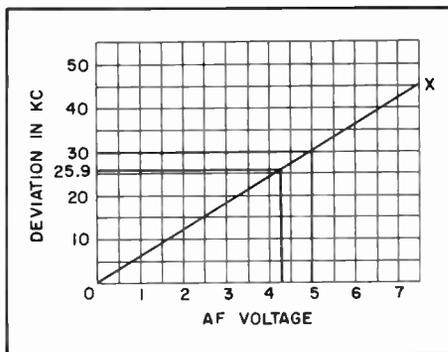
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align (preferably with a signal generator).

NOTE: The deviation measurement cannot be made unless the limiters of the R-19/TRC-1 are saturated, a condition easily met if the R-19/TRC-1 and the T-14/TRC-1 are located in the same room or local area.

6. Connect the deviation meter power plug to the TS-32 power socket in the R-19/TRC-1 receiver, and allow the meter to warm up for 15 minutes.

7. Connect coaxial cable RG-8 (part of the AN/TRC-1 equipment) to the deviation meter and couple to the control grid (pin 4) of the second limiter tube (V108) of the receiver through a 200-$\mu\mu$f. capacitor.

8. With the deviation meter switch in position 4, adjust B+ control R_2 until the meter indicates a reading of 66.

9. With the meter switch in positions 2 and 3, tune the discriminator for a reading of zero on the meter for both positions. (This is the same procedure as for the R-19/TRC-1 discriminator tuning.)

10. Place the meter switch in position 5, and set input level control R_1 for maximum indication.

11. Adjust primary and secondary of transformer T_1 for maximum meter indication.

12. Adjust R_1 for a reading of 40 on the meter.

NOTE: This adjustment is very critical and must be exact before further adjustments are made.

13. (It is advisable at this point to recheck the discriminator tuning.) With the meter switch in position 1, adjust calibrate adjustment R_3 for a mid-scale reading of 50. This control, which is a screwdriver adjustment, is then sealed with glyptal or similar material and is not to be moved except for re-calibration. The meter is now calibrated; it will have at most a 6% margin of error (2 kc. in deviation).

CALIBRATING A T-14/TRC-1 TRANSMITTER

With the deviation meter in use in the field, a T-14/TRC-1 transmitter may be calibrated for the proper level of modulation by using the following procedure:

1. Tune a spare R-19/TRC-1 receiver to the frequency of the T-14/TRC-1 transmitter to be calibrated.

2. Set the OSC CAL adjustment on the CF-1A carrier bay to — 4 db., and send tone on all four channels of the bay.

3. Connect the deviation meter as previously explained in steps 6 and 7, above.

4. Make the adjustments for positions 4, 2 and 3, and 5 of the meter switch, as previously explained.

5. Set the meter switch to position 1. The meter now indicates the degree of modulation of the T-14/TRC-1 transmitter, with a reading of 50 being equivalent to 30 kc. deviation. Set cable compensator R_4 to zero, and adjust calibrating potentiometer R_{44} on the transmitter for a reading of 50 on the deviation meter.

It is possible for the modulation level of a T-14/TRC-1 transmitter at one site to be checked at another site; however, caution should be taken in using this method as r-f fades can make deviation measurements inaccurate if the limiter stages of the R-19/TRC-1 are not saturated.

The deviation calibration for the T-14/TRC-1 transmitter can be performed on a weekly basis, or as directed. It can be seen that once the deviation meter is built and calibrated, the time and effort required to calibrate a T-14/TRC-1 transmitter are negligible.

WEATHER EFFECTS ON AIRBORNE RADIO

by Robert G. Nevitt

Philco Field Engineer

**A discussion of tropospheric propagation conditions and
their effect upon VHF communications reliability.**

ATMOSPHERIC DISCONTINUITIES have a pronounced effect on so-called "line-of-sight" radio propagation, and have caused much distress in communication work. The ability to predict in advance the effects of weather on very-high-frequency propagation has long been desired, and recent work in this field indicates that this may soon be a reality. The troposphere (earth's lower atmosphere), where weather conditions form, is not as stable as the stratosphere or ionosphere; as a result, any predictions of tropospheric propagation conditions will be less accurate, and cannot be made so far in advance as ionospheric propagation predictions.

This article was prepared after a study was made of weather effect on airborne radio and radar communications at Eniwetok, MI. During the winter months at Eniwetok, there is a condition known as trade wind temperature inversion which persists until springtime (April). Multiple temperature and humidity inversions often exist simultaneously during this period. These inversions are relatively stable with respect to time, which is an unusual feature, and which makes Eniwetok an ideal location for such study.

ELEMENTARY LIGHT PHYSICS

At very high frequencies, radio waves behave in a manner similar to light waves. Because of this similarity, a brief review of the physics of light is presented here as an aid in understanding the effects of the earth's atmosphere on radio propagation.

Light waves travel in straight lines at a speed of 186,284 miles per second in free space (vacuum). When light waves travel at an oblique angle from one medium into a medium of different density, bending occurs. This bending effect was noticed by primitive man when spearing fish. Fish were not where they appeared to be, and the spear when partially immersed in water appeared bent.

The bending characteristic of light when going obliquely from one medium into another is due to a change in its velocity of propagation. The light-bending (refracting) characteristic of a substance is indicated by a ratio known as the index of refraction, which is defined as follows:

Index of refraction =
$$\frac{\text{Velocity of light in vacuum}}{\text{Velocity of light in substance}}$$

The index of refraction of a vacuum is 1, and for most applications it is considered to be the same for air; however, in this discussion the difference (at normal pressure and temperature, air has an index of refraction of 1.00029) is an important factor. The index of refraction of water is approximately 1.33, which indicates that the velocity of light through water is 140,063 miles per second. The light is bent abruptly when passing at an oblique angle from water to air, or vice versa; because of the abrupt change in velocity no bending occurs, of course, when the light entering a different medium is perpendicular to the surface of the medium.

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The amount of bending that a light wave experiences in traveling between media of different densities depends on the frequency (color) of the light wave, the densities or indices of refraction of the media, and the angle at which the wave approaches the boundary of the two media.

Figure 1 illustrates the effects produced when a light wave traveling through water reaches the surface. The beam of light will either bend and emerge from the water at an angle, bend and skim the surface, or bend completely back into the water, depending upon the angle at which the beam meets the boundary discontinuity. If the water is replaced with another medium having a different density, the degree of bending in all three cases will be different.

VHF PROPAGATION CHARACTERISTICS

Very-high-frequency radio waves are not ordinarily refracted and reflected back to the earth by the ionosphere, with the result that reliable long-distance communication is impossible. If the troposphere, through which these radio waves travel, were homogeneous, the radio waves would travel in straight lines, and communication would be limited strictly to straight-line transmission. The troposphere, however, is heterogeneous, and its density at any point depends on temperature, atmospheric pressure, and water vapor con-

tent. The density of the normal atmosphere decreases exponentially with altitude, a condition which results in an increase in the velocity of propagation gradually with altitude; however, the rate of change of velocity decreases with altitude, indicating that the greatest bending occurs near the earth. Figure 2 illustrates the bending effect caused by this variable velocity of propagation. The radio wave leaves the earth tangent to the surface, and as the altitude increases, the velocity increases. Since the distance that the radio wave can travel in a unit of time is equal to the product of velocity and time, the distance between the line of tangency and the radio line of sight increases with altitude. (The path of the radio wave assumes the arc of a circle having a radius approximately 4/3 that of the earth.) Radio waves are therefore bent with the earth's curvature, increasing the range of transmission beyond the line of tangency. (Light waves also exhibit this characteristic, with the result that we can see the sun before it is above the horizon at dawn and after it is below the horizon at dusk. For this reason optical line of sight is not used in this article as a reference.)

A radio wave propagated perpendicular to the earth's surface has a velocity which varies with the density of the atmosphere, but no bending occurs. Airborne electronic equipment such as radio altimeters, which radiate radio energy perpendicular to the earth's surface, are
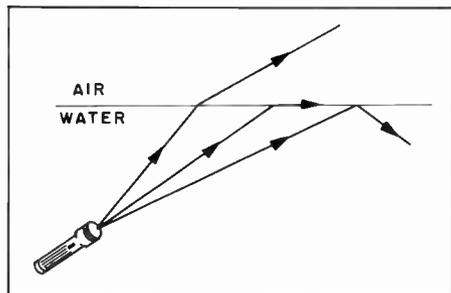

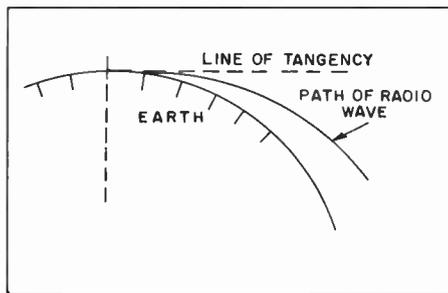*Figure 1. Bending of Light Wave Upon Meeting a Boundary Discontinuity*

Figure 2. Bending Effect of Radio Wave Due to Variable Velocity of Propagation

therefore unaffected by the bending effect (refraction) of the earth's atmosphere.

RADIO WAVES AND THE ATMOSPHERE

Atmospheric discontinuities (changes in propagation medium) are responsible for greatly increased ground communication range. Sharp changes in humidity or temperature with altitude produce discontinuities which can refract radio signals back to the earth very similar to the way that lower-frequency signals are refracted by the ionosphere. Normally the temperature of the air decreases with an increase in altitude; however, occasionally a temperature inversion exists which results in a mass of less dense, warm air being trapped between two cold air masses. One of the ways that a temperature inversion forms is by the movement of a cold or warm air mass which results in the formation of a front. Figure 3 illustrates a warm front and the temperature inversion thus formed.

Often a sharp change in humidity will be present at the base of the temperature inversion. Water vapor content of the atmosphere has a primary influence on tropospheric propagation due to its high dielectric constant. The greatest change in the atmospheric index of refraction results when a humidity inversion is present at the base of a temperature inversion.

Upon meeting a discontinuity radio waves are both reflected and refracted, and the amount of each depends upon several factors, among which are the frequency and angle of propagation of the radio waves. The change in the medium of propagation extends for a finite altitude differential, and the smaller the differential for a given change in temperature and humidity, the greater the reflective qualities of the discontinuity. The refractive qualities
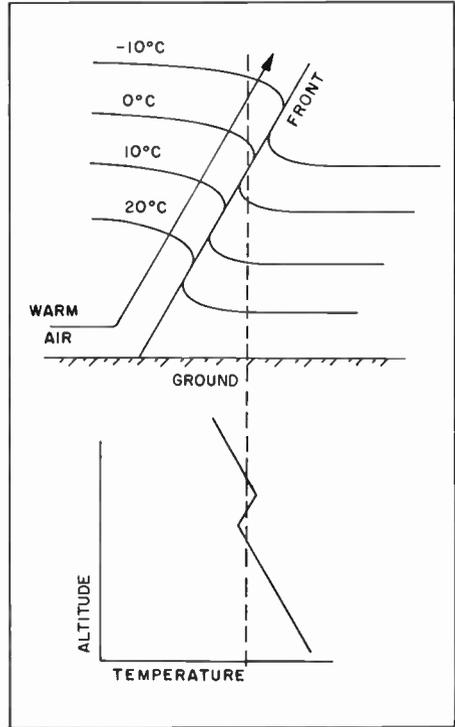

Figure 3.   Warm Front and Corresponding Temperature Inversion Chart

depend upon the rate of change of pressure, temperature, and humidity.

If an atmospheric discontinuity were to act as a perfect reflector of radio waves, it would likewise act as a perfect shield or barrier to radio propagation between airborne stations above the barrier and stations below the barrier. The communications range between stations beneath the barrier would be greatly increased, but the range between stations above the barrier would be decreased. With normal atmospheric conditions, the radio range would increase with increased altitude; however, with the condition cited this would not be true. The greatest communication range between an aircraft and ground stations would exist when the aircraft was immediately below the discontinuity.

In practical cases an atmospheric discontinuity never acts as a perfect bar-

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rier. A certain percentage of the energy is returned by reflection and refraction, and the remaining energy passes through. When the percentage of returned energy is small, the attenuation existing between stations above and below the discontinuity is also small. Even though the radio wave in passing through such a medium is not bent back toward the source, it is bent sufficiently toward the horizon to increase the communication range between air and ground stations as shown in figure 4.

Radio waves are often trapped in a duct and guided in a similar manner to waves propagated through a waveguide. The duct can exist between the earth and an inversion, or between inversions of different heights. The duct thus formed has a definite cutoff frequency depending upon the duct's dimensions and the electrical properties of its boundaries. Ductual propagation seldom exists below 50 mc. and usually only for frequencies above 100 mc.

In some locations, especially over still water, very low atmospheric inversions often occur. In order to take advantage of ductual propagation for ground-to-ground communications, the height of the antenna would have to be kept low, since the height of the inversion can be as low as 10 feet. For air-to-ground communications an antenna located above the inversion would be most desirable. Ductual propagation has often been experienced with ground radar equipment, resulting in target detection at distances which far exceed the normal range.

Radar waves from high-altitude aircraft must penetrate all the atmospheric discontinuities between the aircraft and ground, and after being reflected by the earth, they must return through the same discontinuities before being received. The radar antenna tilt can be varied and the receiver sensitivity and contrast can be increased, to obtain the best picture possible under the prevailing conditions; however, the radar range indications will be slightly in error as a result of the atmospheric bending.

Temperature inversions are usually found in conjunction with wind discon-
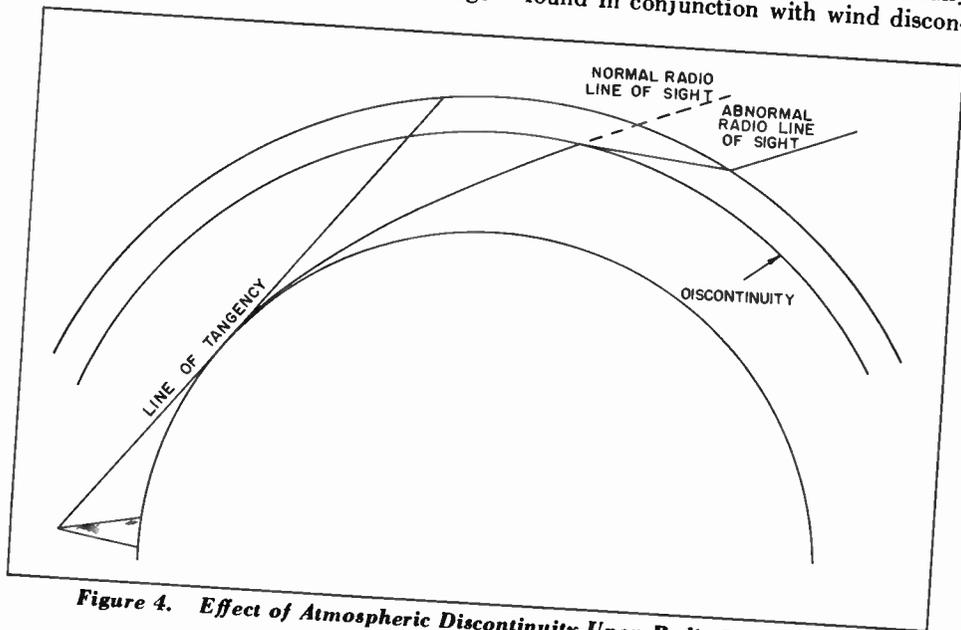

Figure 4. *Effect of Atmospheric Discontinuity Upon Radio Line of Sight*

tinuities, where both the velocity and the direction of the wind are different above and below the inversion. Reception at an aircraft immediately above an inversion may be subjected to violent fading caused by multiple-path transmission and variations in signal strength. Under these conditions a top-mounted antenna, which was shielded by the aircraft from radio signals emanating from immediately below the aircraft was found to be far superior to an antenna mounted on the bottom of the aircraft for receiving constant-strength signals.

Atmospheric discontinuities vary constantly and differ with location, season of year, and time of day. Atmospheric data were collected at Eniwetok two to four times daily by means of meteorological instruments carried by balloons. The meteorological instruments included a small radio transmitter, known as radiosonde, which automatically transmits atmospheric data from
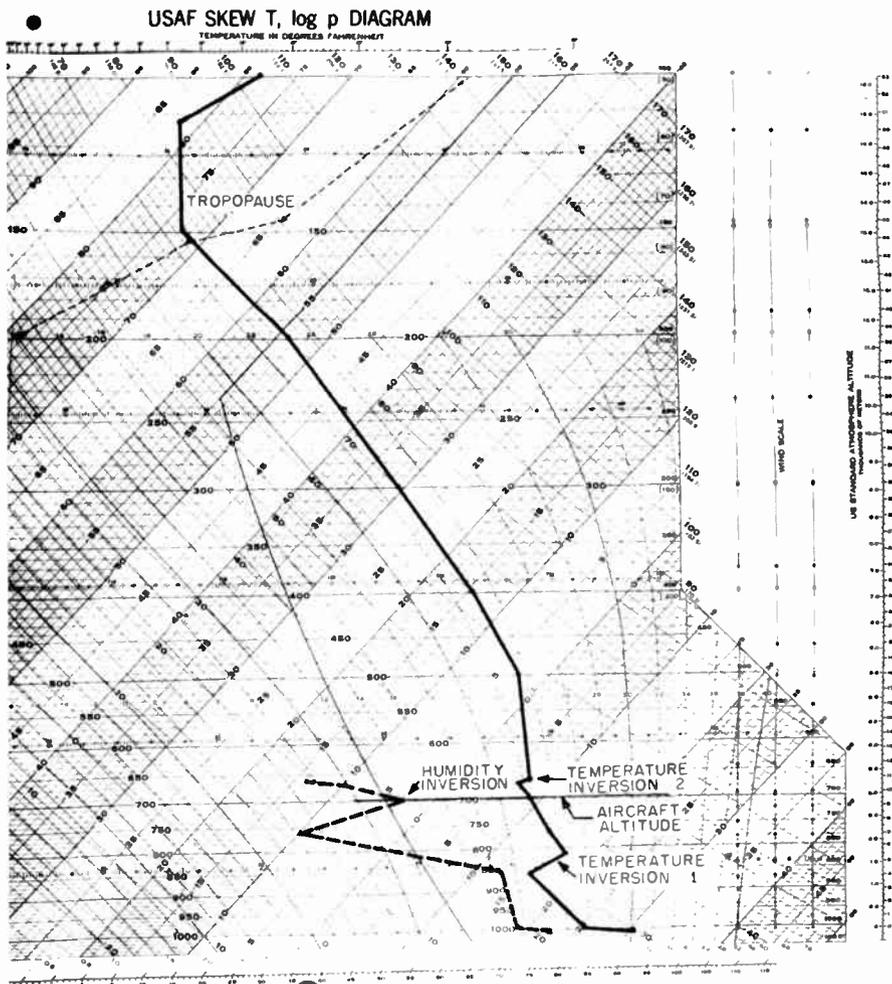

Figure 5. *Adiabatic Chart Showing Two Temperature Inversions and One Humidity Inversion*

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various altitudes as the balloon rises. These data, which deal with temperature, humidity, and pressure, were used in the preparation of adiabatic charts for weather analysis. Radiosonde data from other weather stations were also obtained and correlated with the data obtained locally.

The two adiabatic charts in figures 5 and 6 give a graphic presentation of atmospheric discontinuities. The solid-line graph on these charts presents temperature versus atmospheric pressure or barometric altitude, and the dashed-line graph presents dew-point temperature versus barometric altitude. The dew-point temperature is a measure of the vapor content of the atmosphere. The vapor content may exist in layers at various altitudes—a fact which accounts for the discontinuity of the humidity graph in figure 5. Temperature lines on these charts slope upward from left to right, and are marked in degrees centigrade but can be read in degrees Fahrenheit by projecting them to the Fahrenheit scale at the bottom of the chart. On the right side of the chart is an altitude scale graduated both in meters (left) and in feet (right).

Very good VHF communications (150 mc.) were obtained by flying under the conditions illustrated in figure 5. The aircraft was flying at an altitude immediately below a sharp humidity discontinuity and a temperature inversion, and above another temperature inversion which undoubtedly exhibited ductual propagation characteristics. Data on the two inversions are as follows: Temperature inversion 1 — temperature differential, 1.4°C.; altitude differential, 1400 feet; rate of change, 1000 feet per degree centigrade. Temperature inversion 2—temperature differential, 1°C.; altitude differential, 300 feet; rate of change, 300 feet per degree centigrade. Comparing the two inversions, it can be seen that a 1°C. change in temperature exists for a smaller altitude differential for temperature inversion 2 than for temperature inversion 1; therefore, temperature inversion 2 would be the sharper. The
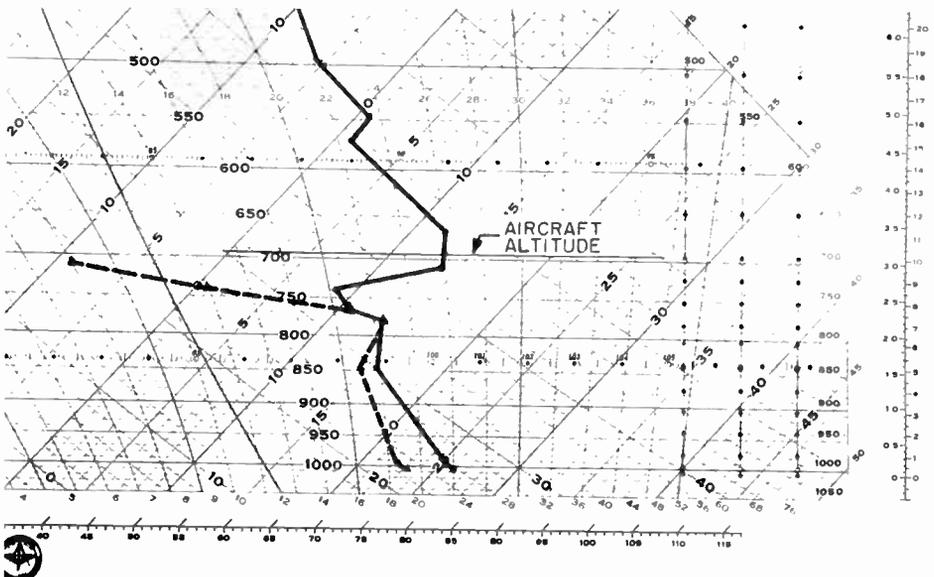

Figure 6. *Adiabatic Chart Showing One Temperature Inversion and One Humidity Inversion*

temperature inversion below the aircraft bent the radio signals toward the horizon, and the humidity and temperature inversions above the aircraft reflected and refracted the energy back toward the earth, increasing the range far beyond the normal optical line of sight.

Very poor VHF communications (150 mc.) were obtained by flying under the conditions illustrated in figure 6. A bottom-mounted antenna was used for the reception of the radio signals, and the aircraft flew above the temperature inversion. The signal faded violently and was very weak even when the aircraft flew very close to the transmitter site. The data on this temperature inversion are as follows: Temperature differential, 5°C.; altitude differential,

1000 feet; rate of change, 200 feet degree centigrade. This is a sharper change than either of those shown in figure 5.

Although a large number of complex variables determine the exact behavior of very-high-frequency radio propagation, it has been established that for a given location, radio frequency, and equipment there is a definite correlation between equipment performance and meteorological data. The relationships that exist can often be found by carefully compiling and studying these data as this article illustrates.

The same procedure can also be used to determine whether reported airborne radar malfunctioning was due to adverse atmospheric conditions or to equipment failure.

Solution to . . . January-February "What's Your Answer?"

The voltage across the 3-μf capacitor is 47 volts. This answer may be verified as follows:

Since the voltage across the 91-ohm resistor is 91 volts in the steady state, then,

$$E_1 + E_3 = 100, \text{ or } E_1 = 100 - E_3 \tag{1}$$

$$\text{and } E_2 + E_3 = 91, \text{ or } E_2 = 91 - E_3 \tag{2}$$

$$\text{let } Q_1 = I_1 t_1 = C_1 E_1$$

$$\text{let } Q_2 = I_2 t_2 = C_2 E_2$$

$$\text{then } Q_3 = I_1 t_1 + I_2 t_2, \text{ or } C_3 E_3 = C_1 E_1 + C_2 E_2 \tag{3}$$

By substituting in equation (3) the expressions for E_1 and E_2 given in equations (1) and (2), we have

$$C_3 E_3 = C_1 (100 - E_3) + C_2 (91 - E_3)$$

Substituting all known values in this equation gives

$$(3 \times 10^{-6}) E_3 = (1 \times 10^{-6}) (100 - E_3) + (2 \times 10^{-6}) (91 - E_3)$$

Dividing by 10^{-6},

$$3E_3 = 100 - E_3 + 2(91 - E_3)$$

$$6E_3 = 282$$

$$E_3 = 47v$$

REDUCING MOTOR FAILURES IN THE M2A2 MOTOR DRIVE

by Robert Fritsch
Philco Field Engineer

An analysis of the principal causes of motor failure in the M2A2 Motor Drive, together with recommended corrective procedures.

(Editor's Note: For authorization to make the modifications outlined in this article, see MWO ORD AE F274-W3, Changes No. 2. This is a USAREUR Change to DA MWO ORD F274-W3.)

THE D-C MOTOR in the M2A2 Motor Drive is the final component in a servo loop which acts to position an output shaft bayonet. The Combination Fuze Setter-Rammer M20 can then automatically set the shell fuze to a number which corresponds to the fuze number calculated by the antiaircraft director. In operation, the armature of the motor is supplied with approximately 1.3 amperes from a constant-current d-c source, while the split field coils are energized by the output current from the M1A2 Amplifier. When the fuze numbers at the director and the gun do not correspond, an a-c error voltage from a synchro control transformer appears at the input to the amplifier, an unbalanced d-c current flows through the split field coils from the output of the amplifier, and the d-c motor turns in the proper direction to reduce the fuze error (and consequently the a-c error voltage) to zero. In the balanced condition, the two field currents are equal.

Many of the motors (F274-5659410) in the M2A2 Motor Drive fail because they develop a winding-to-winding short circuit or a winding-to-frame short circuit within the stator fields. These short circuits are caused by destruction of insulation due to overheating and/or excessive coil-to-coil voltage.

In investigating the overheating, it was found that the excessive tempera-

tures were caused by the average current of 40 milliamperes from each of the four 6V6 output tubes, which flows through the field coils at all times. This current causes the coil temperature rise to exceed the maximum allowable value of 65°C (Class A insulation) after only 25 minutes of operation. After 90 minutes of operation, the coil temperature rises to 125°C, with no "leveling off" of the temperature-time curve in evidence. When the value of the common cathode resistor, R16, is increased from 250 to 500 ohms, the plate current drops to 30 ma. per tube. This decrease in field current seems to solve the problem of overheating, since tests now show an acceptable coil temperature of 70°C after 90 minutes of operation.

The excessive coil-to-coil voltage is the result of repetitious transient voltages of approximately 1000 volts, caused by an excessive a-c signal passing through the amplifier and overdriving the final stages (the last two stages of the amplifier are d-c stages). In explaining the production of these transient voltages, it will be recalled that the M1A2 Amplifier is composed of four basic sections — preamplifier, phase-sensitive detector, compensating network, and power amplifier. The phase-sensitive section functions to detect the phase and amplitude of the a-c error signal, and to convert this voltage to a push-pull d-c error signal for the suc-

ceeding sections of the amplifier. Any 60-cycle ripple remaining in this signal is supposed to be removed by the tuned filter section in the compensating network stage. Unfortunately, however, a 3-volt peak-to-peak signal still remains at the grids of V1B. This signal, when amplified in V1B, becomes a 70-volt peak-to-peak signal at the grids of the 6V6 power tubes, overdriving these tubes from cutoff to saturation. The resulting square waves of current, flowing through the high inductance of the field coils (44 henrys), cause the high transient voltages. (Any rapid change in the current through an inductance results in a high induced voltage whose
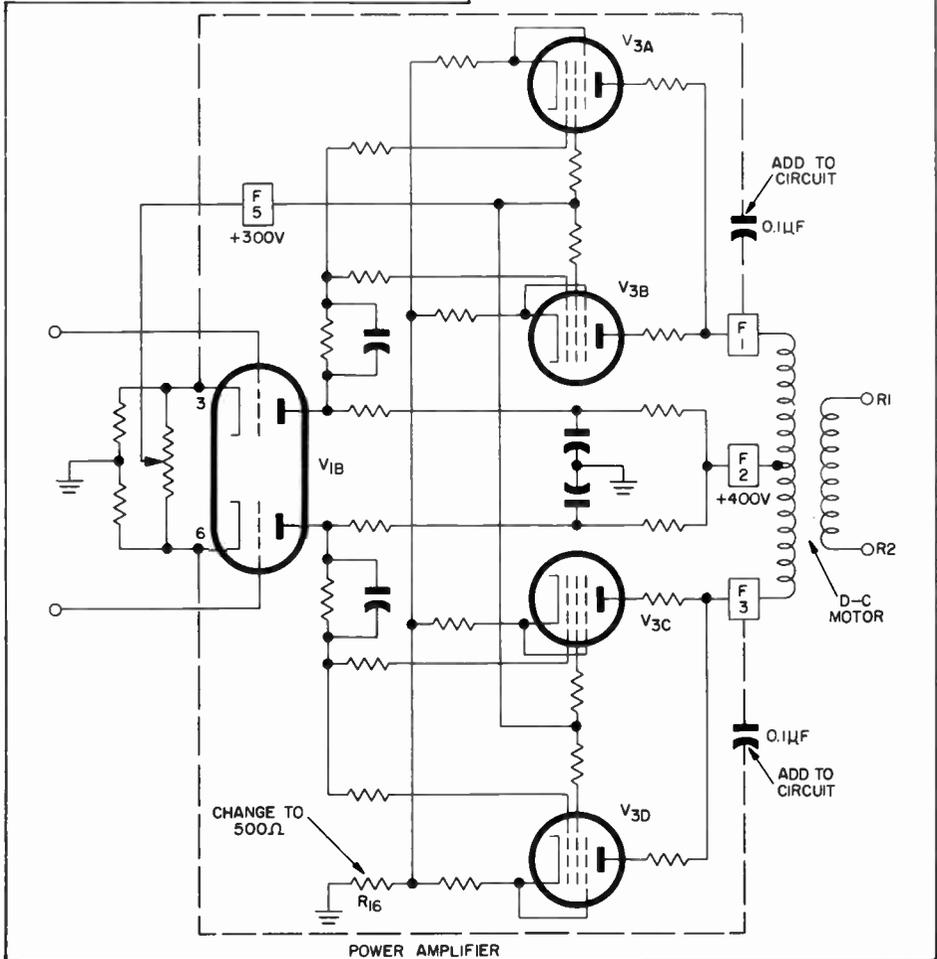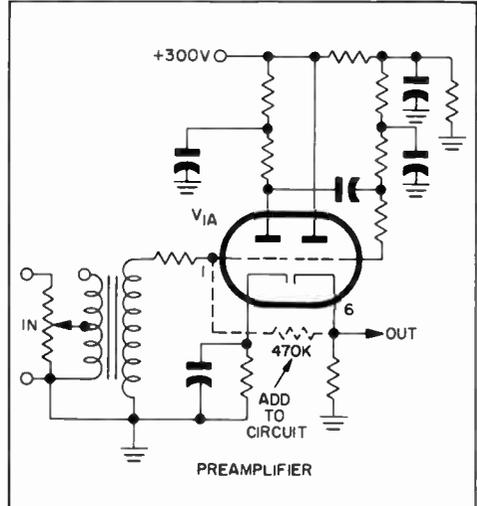

PREAMPLIFIER

POWER AMPLIFIER

Figure 1. Schematic Diagram of Preamplifier and Power Amplifier Sections of Amplifier M1A2

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value is given by $E = L\ di/dt$, where L is the inductance in henrys, and di/dt is the rate of change of the current with respect to time in amperes per second.)

As a corrective measure, a degenerative feedback circuit is added to the amplifier so that part of the output is fed back to the cathodes of V1B by means of two $0.1\text{-}\mu f$ capacitors. This circuit prevents the final stages from being overdriven, thereby eliminating the high transient voltages in the output. The percentage of feedback chosen is such that approximately 70 volts of a-c signal remain in the output; this causes a "dither" action in the servo which makes it highly responsive to an error signal. Good servo response could not be obtained at slow fuze rates with less than 70 volts with the servo as designed.

Preventing the final stages from being overdriven gives the amplifier a considerable increase in over-all sensitivity since, in the original condition, a d-c signal could not be fully effective in unbalancing the average d-c output current because of the high a-c content. As a result, the correct setting for the GAIN control is now found to be near

the low end of the potentiometer element. To correct this, negative feedback is introduced in the preamplifier by means of a 470K resistor, thus reducing the effective gain of the preamplifier. This procedure acts to bring the correct setting of the GAIN potentiometer near the center of the resistance element.*

To make the necessary changes, refer to figure 1 and proceed as follows:
1. Replace common cathode resistor R16 with a 500-ohm, 25-watt, wire-wound resistor.
2. Connect a $0.1\text{-}\mu f.$, 600-volt capacitor between F1 on the terminal strip and pin No. 3 of V1B. Connect a $0.1\text{-}\mu f.$, 600-volt capacitor between F3 on the terminal strip and pin No. 6 of V1B.
3. Connect a 470K, 1-watt resistor between pin No. 6 and pin No. 1 of V1A.

*During modification work on several M1A2 Amplifiers, three different types of GAIN potentiometers were found—a 10K potentiometer, a 500K potentiometer, and a 500K potentiometer loaded with a 10K fixed resistor. The amplifier and lagmeter circuits will function properly only when the 500K potentiometer alone is used, since the input circuit (from the synchro control transformer) is excessively loaded with either of the other potentiometers.


"What's Your Answer?"

This month's problem is submitted by Philco Field Engineer Leland N. Van Allen, one of our more prolific contributors.

A battery of unspecified voltage is connected in a circuit with a fixed resistor, R_1 (value unknown), and a variable resistor, R_2. When adjusted to a value of 8 ohms, R_2 dissipates a certain amount of power; when adjusted to a value of 98 ohms, it dissipates the same amount of power.

What is the value of R_1?

R_1 (Solution next issue . . .)
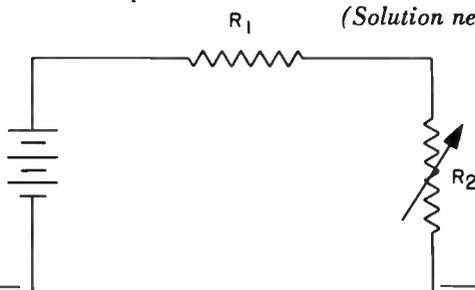
RADIO MONITOR SYSTEM

by Norman S. Lavigne

Philco Field Engineer

Constructional details of the effective radio monitor system in use at the 760th AC&W Squadron.

THE SYSTEM DESCRIBED in this article was designed to monitor all VHF and UHF radio channels at the 760th AC&W Squadron. Since the monitor is installed in the operations room, it is necessary that a method of quieting be incorporated so as to prevent feedback during local transmissions. Another re-


Figure 1.   Front-Panel View of Radio Monitor System, Showing Speaker, Indicators, and Controls

quirement is for background noise levels to be very low in order to avoid confusion or interference with· other operations activities. The use of a carrier-operated system would require extra lines from the receiver building, modification of receivers, and would complicate receiver patching; therefore, it was decided to use an audio system for actuating visual channel indicators. Audio from each receiver was readily available at the wall frame in the message center, and vacuum-tube mixing was utilized to provide for complete isolation between lines.

GENERAL DESCRIPTION

(The system shown in figure 1 is designed for 10-channel operation; however, any number of channels may be added by increasing the current capabilities of the power supply.)
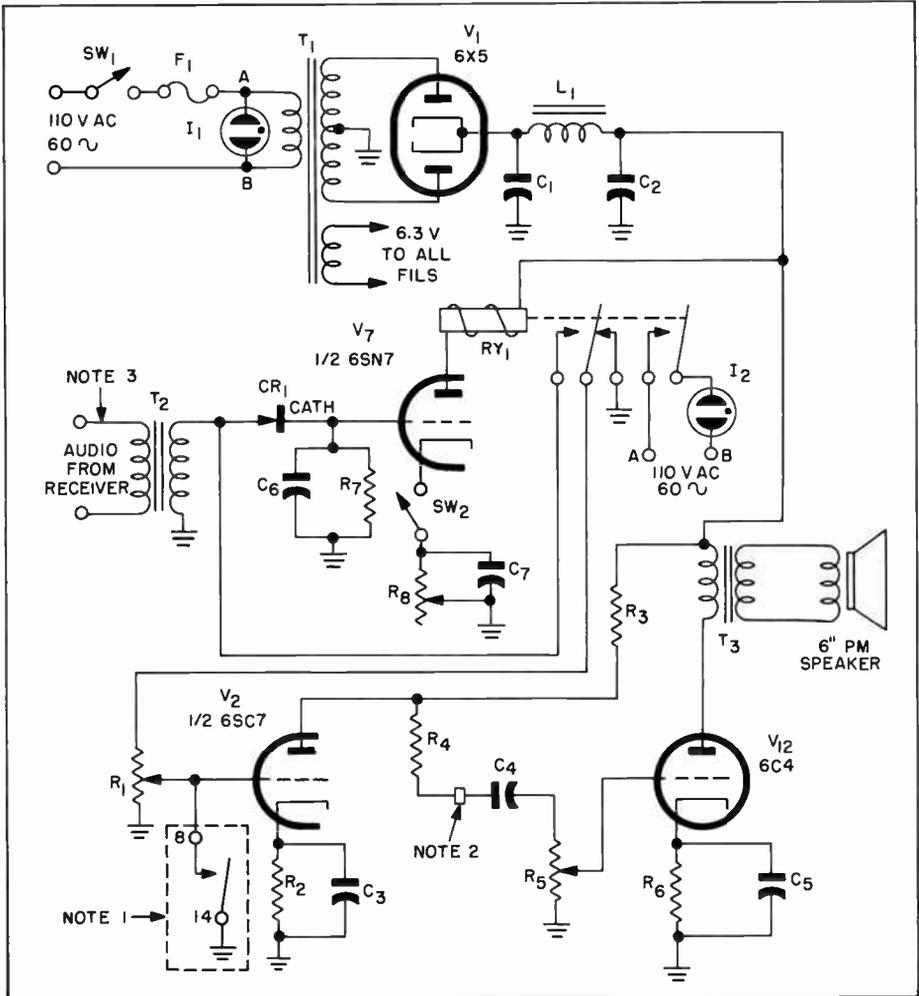
Figure 2. Schematic Diagram of Common Power Supply, Common Audio Amplifier, and Mixer and Relay Stages for Single-Channel Operation. Notes: (1) Contacts in K-1 through K-15 Transmit-Receive Relays in Frame TA-171/GT. Reference T.O. 16-30FPS3-23, Figure 7-10, Page 68. (2) Common Tie-Point for Each Mixer Output. (3) Audio From Each Receiver Taken From Wall Frame on 20-Pair Cable. Same Cable Is Used for Relay Leads Referred to in Note 1

As shown in the photograph, the monitor uses a single speaker, individual channel indicator sensitivity controls, individual indicator release switches, individual channel volume controls, and a master volume control. The channel indicators are $\frac{1}{4}$-watt neon lamps, housed in 1-inch (dia.) pilot lamp assemblies. Each indicator lens is white and has its channel number lettered in black. Since most aircraft calls are very short, the indicator circuits are designed so that each channel lamp remains lighted following a call, until it is released manually. This feature eliminates any possibility of missing a channel identification.

The schematic diagram of figure 2 shows the common power supply (V_1), and the common audio amplifier (V_{12}) with its associated speaker. Since all channels are identical, the schematic is drawn to show the mixer stage (V_2) and the relay stage (V_7) for a single
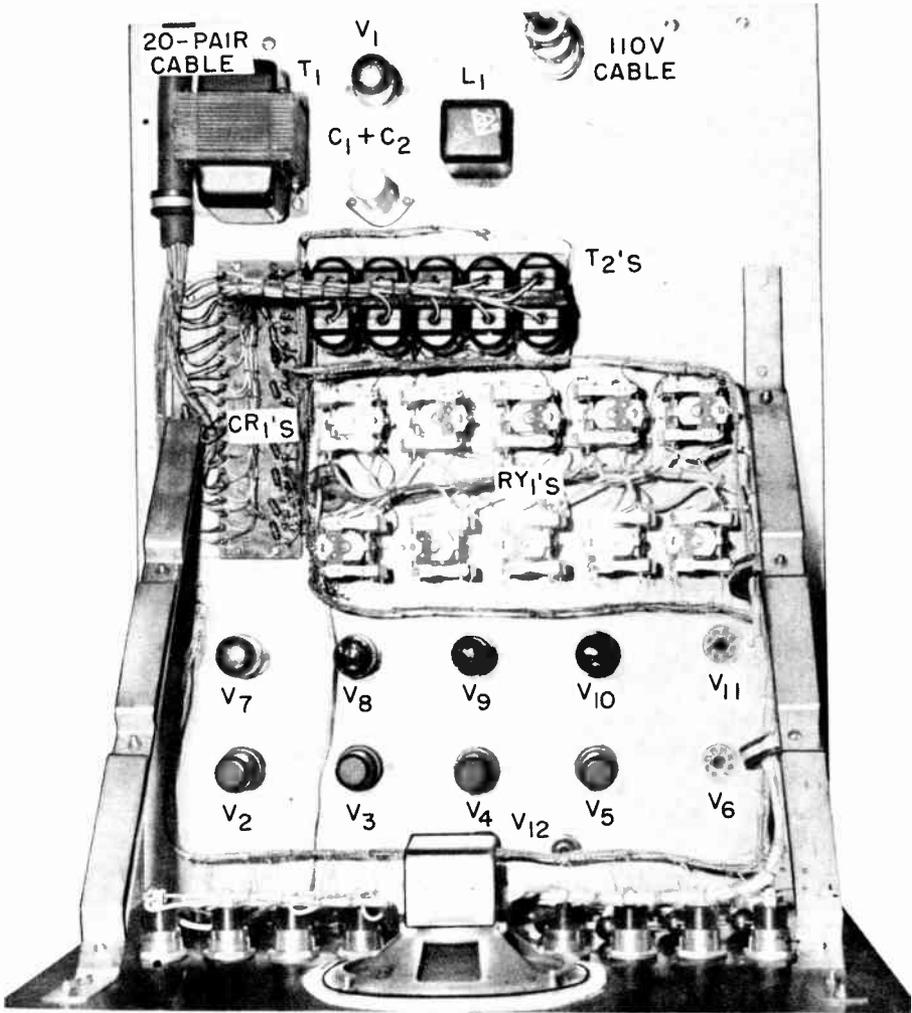

Figure 3. Top View Of Radio Monitor Chassis, Showing Disposition of Components

audio channel. Through the use of dual triodes, each mixer and relay tube will handle two channels. Thus, in the 10-channel system under discussion, five 6SN7's and five 6SC7's are used in addition to the single 6X5 and 6C4 tubes.

THEORY OF OPERATION

Audio from the receivers is picked up at the wall frame in the message center and run into the operations room to the monitor through a 20-pair cable. This cable connects to the master console (obsolete AN/FPS-3 "A" scope cabinet) by means of a cable plug. Inside the console, another short section of a 20-pair cable runs to a terminal strip on the monitor chassis, as illustrated in figure 3. From the terminal strip, each receiver pair connects to the primary of its individual isolation transformer. Line-to-headset telephone transformers are adapted for this purpose by reversing the windings to obtain a voltage step-up. One side of each secondary is grounded, and the high side is tied directly to the input of the relay tube circuit and also to the input of the mixer stage through one set of relay contacts.

The audio voltage at the input to the relay stage is rectified by CR_1. During signal conditions, current flow is such that a positive voltage is developed on the grid side of C_6, opposing the cathode bias developed by R_8 and C_7, and permitting the tube to conduct more heavily. Sensitivity control R_8 is adjusted initially so that relay RY_1 remains de-energized under no-signal conditions. When a signal is received, the increased conduction of the tube energizes the relay. In the energized condition, one set of relay contacts applies 110 volts to the channel indicator lamp, and the other set of contacts applies the audio

signal to the mixer tube input. Volume for the particular channel is controlled by channel volume control R_1. Circuit components are such that the resting current will hold the relay closed once it has been energized, so that it remains closed after the audio signal ceases. Thus, the channel indicator lamp remains on until it has been observed and released by the operator, by means of indicator release switch SW_2, which opens the cathode circuit of the relay tube. In the de-energized position of the relay, the mixer input lead is grounded through the relay contacts; this prevents unwanted a-c pickup by the wiring, eliminating all background noise when no signal is received.

In order to eliminate feedback and provide complete quieting of the channel during local transmissions, the grid of the mixer tube is grounded through the transmit-receive relays in the Telephone Relay Rack Frame TA-171/GT. This relay operates each time the controller keys the transmitter, and one set of contacts (pins 8 and 14) makes to positive battery, which is ground. The transmit-receive relay leads appear at the wall frame for convenience, so that one wire for each channel can be taken into the monitor console through the same 20-pair cable used for the audio.

Plate mixing is used for the audio, and the output from each stage is connected (through its individual R_4 resistor) to the input of the common audio amplifier at the point indicated on the schematic diagram. R_5 serves as a master volume control for the over-all system.

Specifications for all components used in the construction of the radio monitor system are given in TABLES 1 and 2.

TABLE 1. MATERIALS REQUIRED FOR FABRICATION OF COMMON POWER SUPPLY AND AMPLIFIER UNITS

Quantity	DESCRIPTION	Symbol
1	S-P-S-T toggle switch	SW_1
1	Fuse, 2 amp., with holder	F_1
1	NE 45 neon lamp	I_1
1	Power transformer, primary 110v 60 cycle; secondary 250-0-250v at 150 ma. d.c.; 6.3v at 6 amp.	T_1
1	6X5GT tube	V_1
1	Electrolytic capacitor, 20-20 μf., 400v d.c.	$C_1\ C_2$
1	Choke coil, 8 hy., 100 ma.	L_1
1	Octal tube socket	
1	Pilot lamp assembly, red lens 1" dia.	
1	Capacitor, .005 μf., 600v d.c.	C_4
1	Electrolytic capacitor, 10 μf., 25v d.c.	C_5
1	Potentiometer, 470K	R_5
1	Resistor, 1000 ohms, 2 watts	R_6
1	6C4 tube	V_{12}
1	Transformer, plate-to-voice coil	T_3
1	Speaker, 6 inch, PM	
1	Tube socket, miniature, 7 contact	

## TABLE 2. MATERIALS REQUIRED FOR FABRICATION OF MIXER AND RELAY STAGES

Quantity (2 Chan.)	DESCRIPTION	Symbol
2	S-P-S-T toggle switch	SW_2
2	NE 45 neon lamp	I_2
2	Pilot lamp assembly, white lens 1" dia.	
2	C505 line-to-headset transformer (reversed windings); 600-ohm line-to-grid transformer if necessary to purchase	T_2
1	Electrolytic capacitor, 10 μf., 25v d.c.	C_3
2	Capacitor, 1.0 μf., 200v d.c.	C_6
2	Capacitor, .47 μf., 200 v d.c.	C_7
2	Potentiometer, 2 megohms	R_1
1	Resistor, 2000 ohms, 1 watt	R_2
2	Resistor, 220K, ½ watt	R_3
2	Resistor, 1 megohm, ½ watt	R_4
2	Resistor, 39K, ½ watt	R_7
2	Potentiometer, 10K, 2 watts	R_8
2	Potter & Brumfield Relay, LM 11, d.p.d.t., 10,000-ohm coil	RY_1
2	1N69 germanium diode	CR_1
1	6SC7 tube	V_2
1	6SN7	V_7
2	Octal tube socket	
	Miscellaneous terminal strips and hardware, depending on the number of channels desired	

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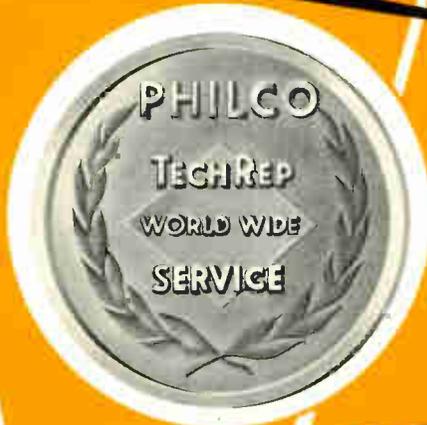
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