L4 CARRIER
OVERALL SYSTEM
DESCRIPTION
LINE REPEATERS

CONTENTS PAGE

1. GENERAL

1.01 Repeaters for the L4 carrier system are of five types which can be divided into two groups according to location: line repeaters and main station repeaters. Main station repeaters are described in Section 359-200-102.

1.02 This section is reissued to add information for later equipment, to correct errors, to delete references to the 20.448-MHz line pilot which is manufacture discontinued, and to expand the explanations. Due to the extensive revision, arrows are not used to indicate changes.

1.03 ***Main stations,*** located approximately 150 miles apart, include receiving and transmitting repeaters which are powered from low-voltage dc sources. These stations contain high-voltage dc sources which furnish power to the line repeaters over the center conductor of each coaxial line.

1.04 Line repeaters are of three types: basic, regulating, and equalizing.

(a) A ***basic*** repeater (Fig. 1) is the simplest and most numerous repeater and provides a fixed gain with a frequency characteristic which matches the loss of 2 miles of coaxial line.

(b) A ***regulating*** repeater (Fig. 2) performs the basic repeater function and provides automatic gain regulation to compensate for changes in line loss due to cable temperature variations.

(c) An ***equalizing*** repeater performs the regulating repeater functions and provides gain equalization across the L4 band by means of six stepped or manually adjusted networks.

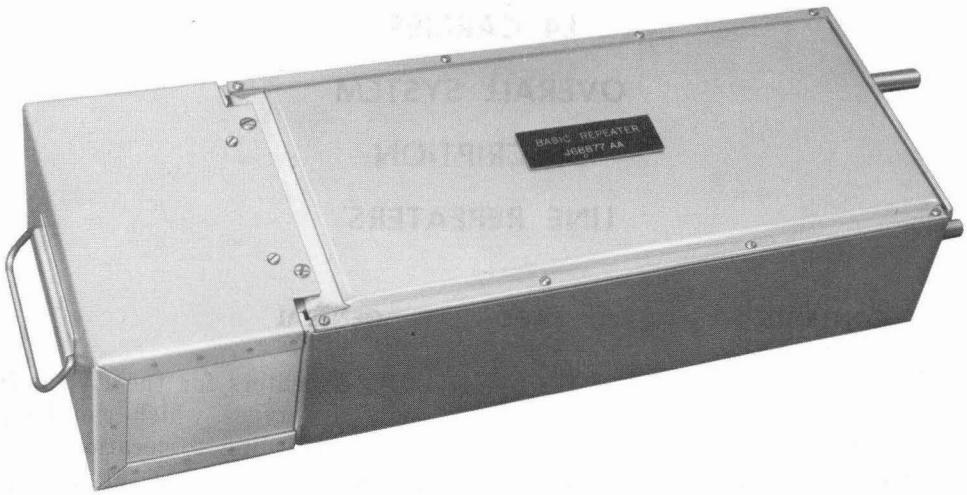

Fig. 1—Basic Repeater

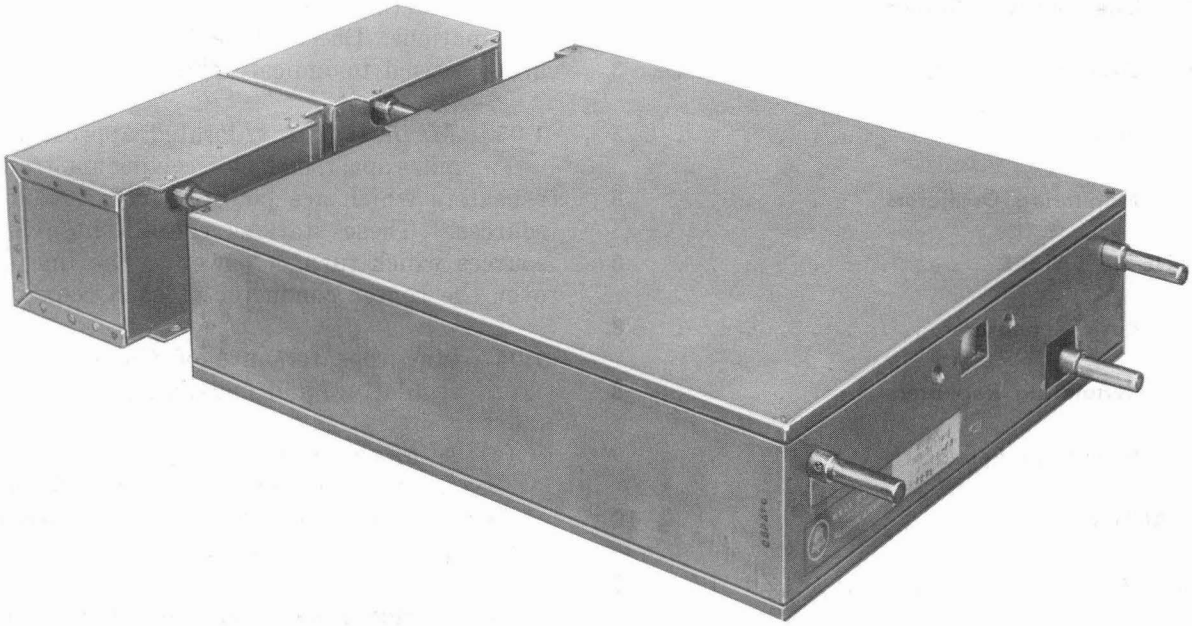

Fig. 2—Regulating Repeater

1.05 A ***monitoring oscillator*** is associated with each repeater. Monitoring oscillators associated with a group of adjacent repeaters in a line can be turned on from either main station, and the signals can be measured or displayed on a spectrum analyzer.

2. SYSTEM LAYOUT

2.01 This part explains some terms pertaining to the L4 system. Other terms are explained where introduced in this section.

A. General

2.02 An ***L4 system*** includes coaxial cable, line repeaters, main station repeaters, and line connecting, line switching, and power equipment. In addition, the L4 system includes a remote control system that permits measuring gain deviations, control of equalizer test oscillators, adjustment of stepped equalizers, and control of monitoring oscillator signals.

2.03 An ***L4 cable*** contains up to twenty-two 0.375-inch disc-insulated coaxial lines. One standby line is provided in each direction of transmission for protection of the regular lines. In addition, the cable contains insulated pairs which are used for voice order wires, to carry dc power to monitoring oscillators, and for other uses. The cable is pressurized with dry air and is laid underground or buried at a depth of approximately 4 feet. The cable path is marked by wooden yellow-topped poles approximately 10 feet tall. Poles are spaced so that, from any pole, the next one is visible. Wherever the cable passes under a road, a pole with a warning sign indicating buried cable is located at each side of the road.

2.04 A ***coaxial line*** provides one direction of transmission and includes repeaters at 2-mile spacing. A high-voltage direct current is applied to the center conductor of each line to power the line repeaters. This high-voltage power is fed from dc-dc converters located in the main stations.

B. Repeaters

2.05 The L4 repeaters provide the amplification, regulation, and equalization necessary to maintain the overall transmission objectives of the system.

2.06 Transmission in an L4 system is based on a compact, fixed-gain ***basic*** repeater which amplifies the broadband signal and has the signal-handling and modulation performance required for high-quality transmission. Because of the number and location of line repeaters, reliability is a most important consideration.

C. Line Repeater Stations

2.07 Line repeater stations are small, unattended, underground structures located approximately 2 miles apart with space for enough basic, regulating, or equalizer repeaters to serve all the lines in a cable. Basic and regulating repeater stations are entered by removing a ground-level manhole cover. Equalizing repeater stations may have a small above-ground storage building which is over the entrance to the underground room.

2.08 Several factors contribute to the relative simplicity of the line repeater stations. The overall plan of regulation and equalization and the use of the monitoring oscillators allow most of the maintenance, except for the physical replacement of units, to be performed from the main stations.

2.09 At each line repeater station, the repeater equipment is mounted in pressurized apparatus cases (Fig. 3). At a basic repeater station, one apparatus case contains four basic repeaters and the associated monitoring oscillator assembly (Fig. 4).

D. Repeater Functions

2.10 Transmission deviations in an L4 system are corrected at the line and main station repeater locations. In general, one-half of the required correction is made at each end of the line section in which the deviation occurs. This method of ***post***-deviation and ***pre***deviation gain corrections reduces system noise by halving the maximum signal level deviations which would exist if the total correction were made at one end of the line section.

2.11 The following paragraphs provide a brief description of the repeaters used in the L4 system.

2.12 A transmitting and a receiving main station repeater together provide ***gain*** to compensate for 2 miles of coaxial line, with each repeater providing approximately one-half the gain. Each line repeater provides gain to compensate for 2 miles of line; 1 mile of line preceding the repeater and 1 mile of line following the repeater. Thus, each repeater compensates for one-half the loss in the adjacent line section(s).

2.13 Terrain and other factors do not always permit the location of line repeater stations at the nominal 2-mile spacing. Line building-out (LBO) networks are used in each of the line and main station repeaters to electrically build out short lengths of coaxial line to the nominal 2-mile length

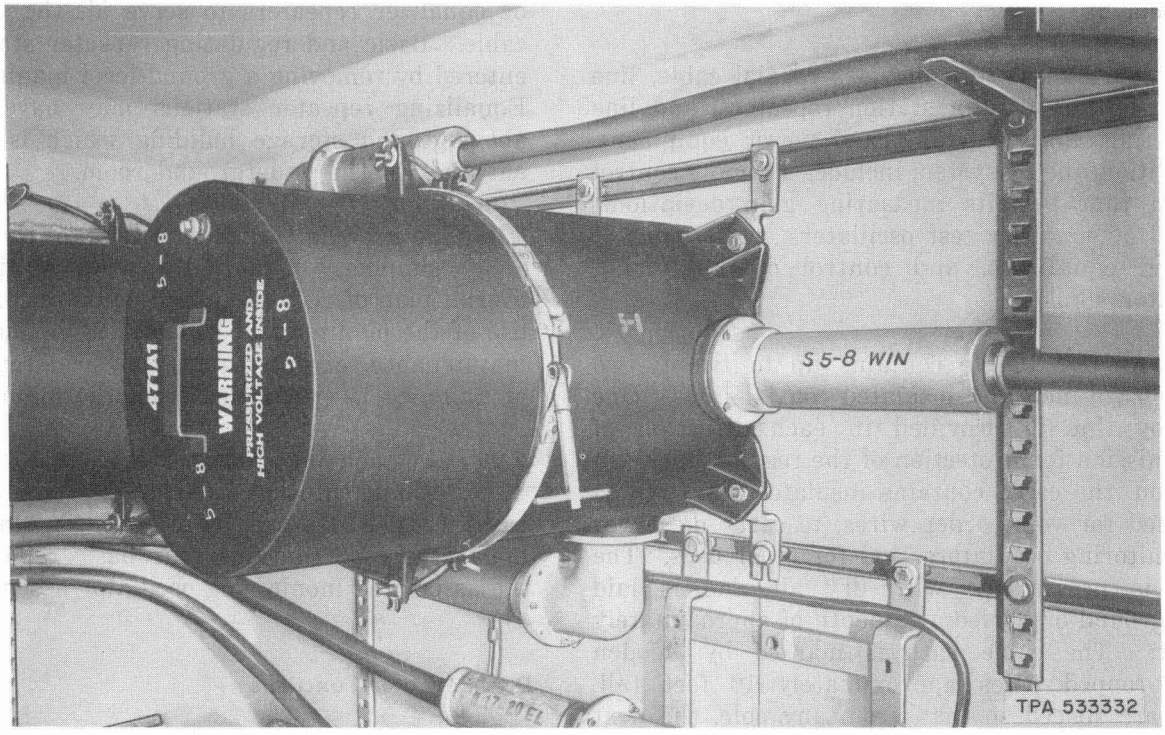

Fig. 3—L4 Basic Repeater Apparatus Case

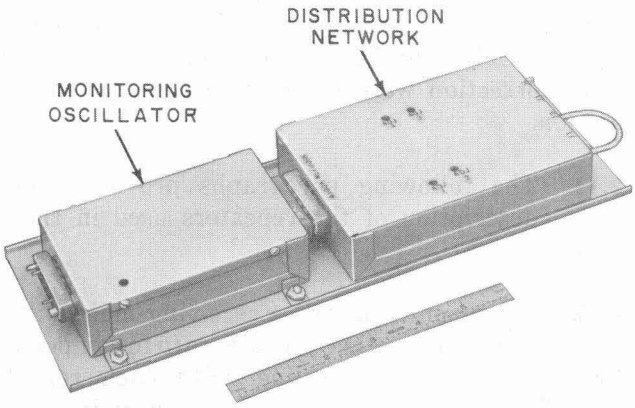

Fig. 4—L4 Monitoring Oscillator Assembly

between repeaters. These LBO networks are available to simulate up to 1 mile of coaxial line in 0.1-mile steps.

2.14 ***Regulation*** refers to automatic, continuous gain corrections controlled by resistance changes in a thermistor or by the level of the received 11.648-MHz line pilot.

2.15 The gains of all L4 repeaters, except basic repeaters, provide regulation as follows:

(a) Transmitting main repeaters provide ***preregulation*** which compensates for line loss deviations due to ground-temperature changes. This regulation compensates for one-half the anticipated gain deviation to the adjacent regulating repeater and is controlled by an adjustable resistor.

(b) Regulating line repeaters provide ***post-regulation*** under control of the level of the received 11.648-MHz line pilot and ***preregulation*** based on the effects of ground temperature on a thermistor buried outside the line repeater station.

(c) Receiving main repeaters provide ***post-regulation*** under control of the level of the received 11.648-MHz line pilot.

2.16 Main station and regulating repeaters include a ***fixed*** deviation equalizer. These equalizers compensate for gain deviations caused by a number of basic repeaters having a total gain which does not exactly match the loss-frequency characteristic of a line section.

2.17 Two adjustable static equalizers, designated A and B, are provided at the main stations to permit gain corrections across the L4 band. An A equalizer has six networks and a B equalizer has ten networks. These networks provide bump-shaped gain changes at various frequencies as indicated in Fig. 5.

E. Power

2.18 The L4 system includes three types of solid-state dc-dc converters: the coaxial line supply converters, main station equipment converters, and monitoring oscillator converters. These converters are located in the main station and obtain power for operation from standard 24-volt office battery. A monitoring oscillator converter is provided at an equalizing repeater location.

2.19 All repeaters between main stations are powered by direct current from the L4 line power bay J86858 (Fig. 6). A constant current of 520 milliamperes is supplied to the center conductor of each coaxial line. Voltage drop in a line is 2.9 volts per mile at 520 milliamperes. The line repeaters are arranged for series connection with a voltage drop of 28.6 volts at a basic repeater, 65.6 volts at a regulating repeater, and 116 volts at an equalizing repeater with a manual A equalizer or 152 volts at an equalizing repeater with a stepped A equalizer.

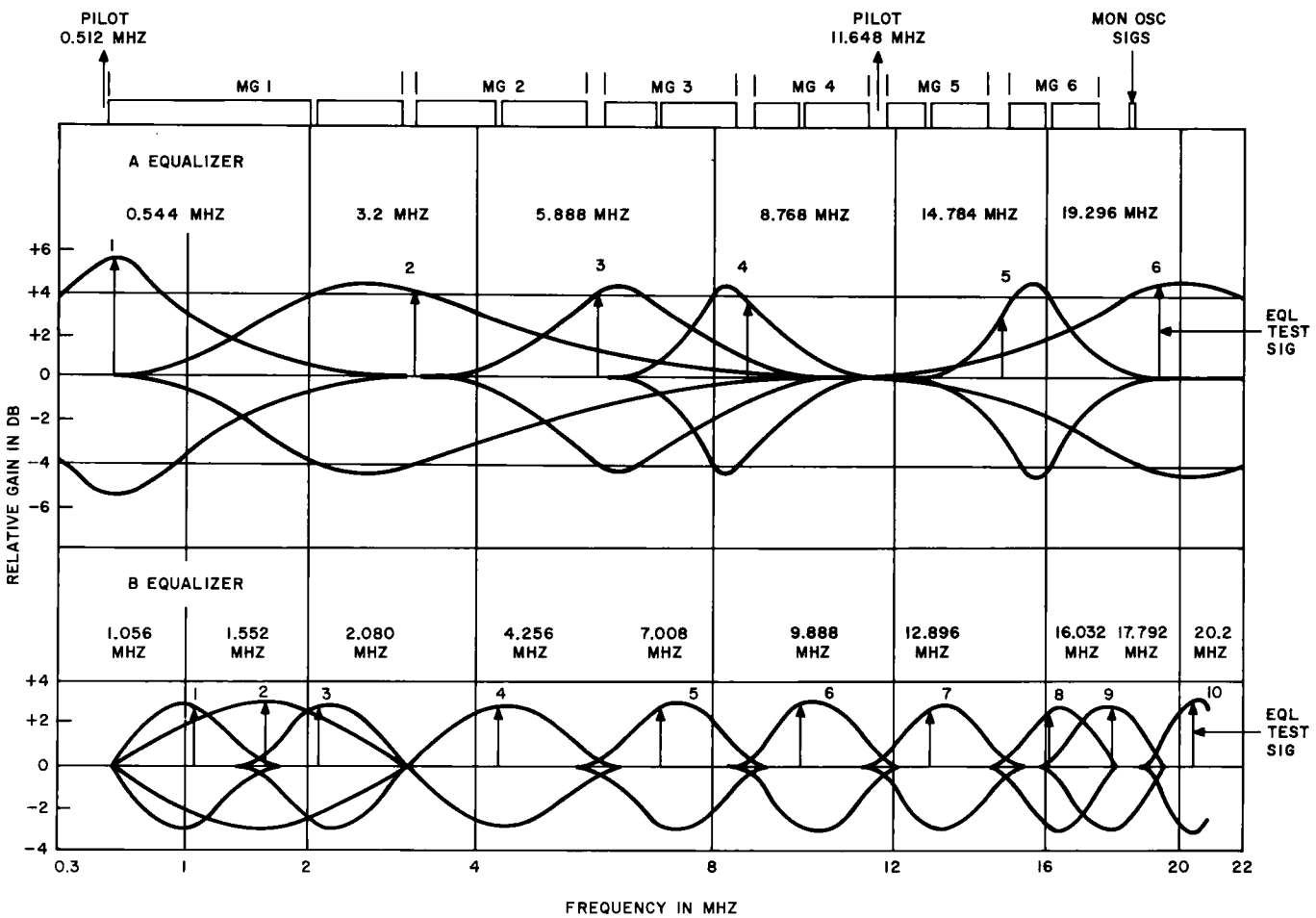

Fig. 5—Gain-Frequency Characteristics of A and B Equalizers

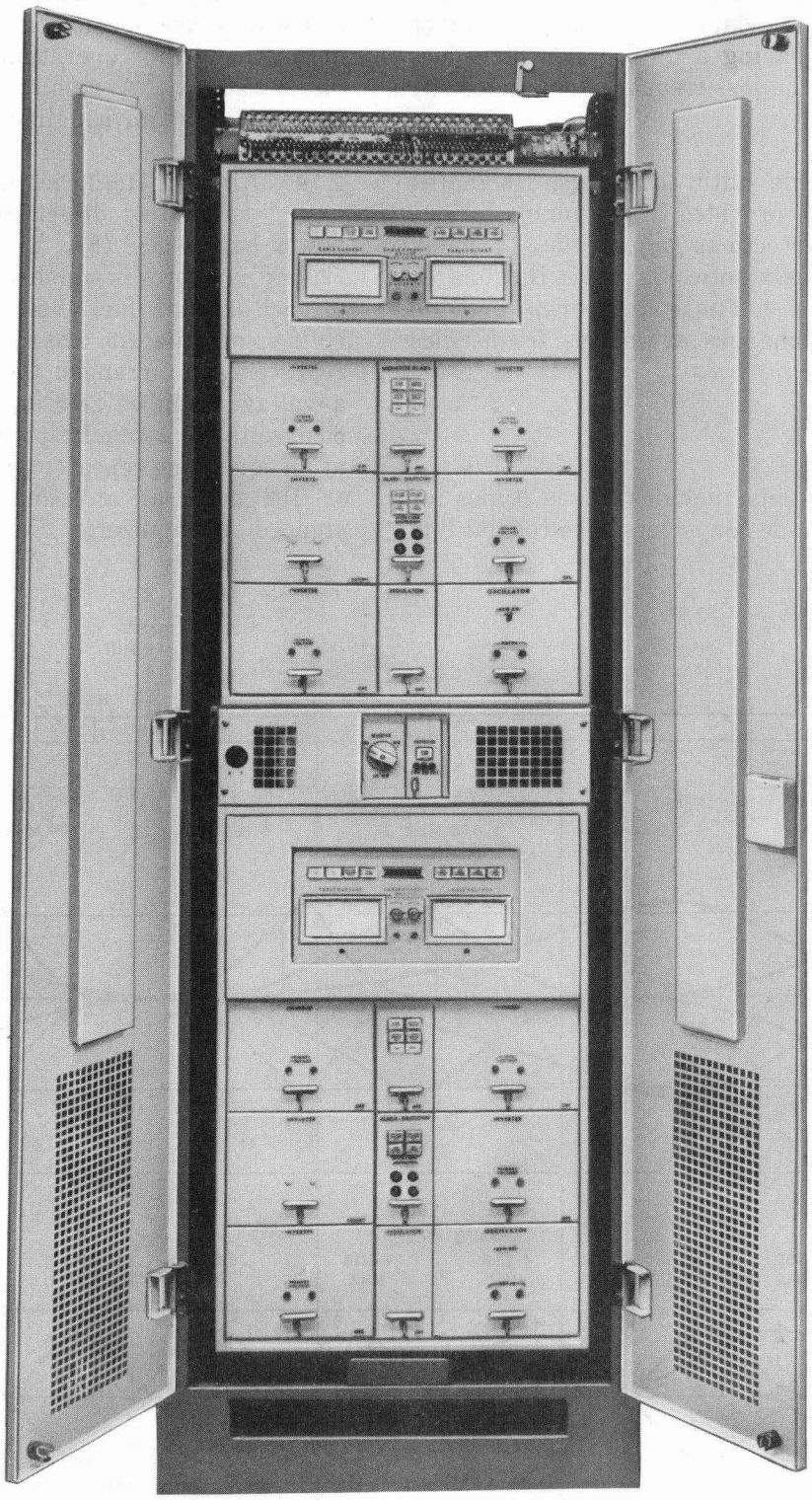

Fig. 6—L4 Line Power Bay

2.20 Figure 7 illustrates in simplified form a typical power section with a power source at each main station. One such circuit is required for each pair of lines. Line current is connected to the center conductor of each coaxial line through a power separation filter (PSF). Transmission and power currents make common use of these center conductors. The transmission and power currents are separated by a PSF in a line repeater and are passed to the respective portions of the repeater and recombined at the output. This process occurs at each repeater.

2.21 For a main section less than 75 miles in length, power for the line repeaters in a pair of lines is supplied from one main station with a grounded connection between the power separation filters at the other main station.

2.22 Since dc ground currents can cause corrosion (electrolysis) of metals as they leave or enter the earth, the power loop is completed through a return coaxial line. Thus, the power supplies are operated in pairs, just as the receive and transmit coaxial lines are operated in pairs for the high-frequency transmission.

2.23 If the power loop is grounded at only one point, no ground current will flow. However, if a ground fault were to develop, the current could change in some parts of the circuit. To prevent this from happening, a normally open-circuited ground protector is located between the two ungrounded supplies. If all supplies of the loop deliver ***equal*** voltages, the ground protector voltage is zero and nothing happens. However, if the potential at this point changes drastically as in the case of a ground fault or supply shutdown, the ground protection breaks down and the circuit closes, thus providing a second ground in the loop. In this way, the original loop is essentially split into two loops, with the power supply and transmission returning to normal in one line and shutting down in the other.

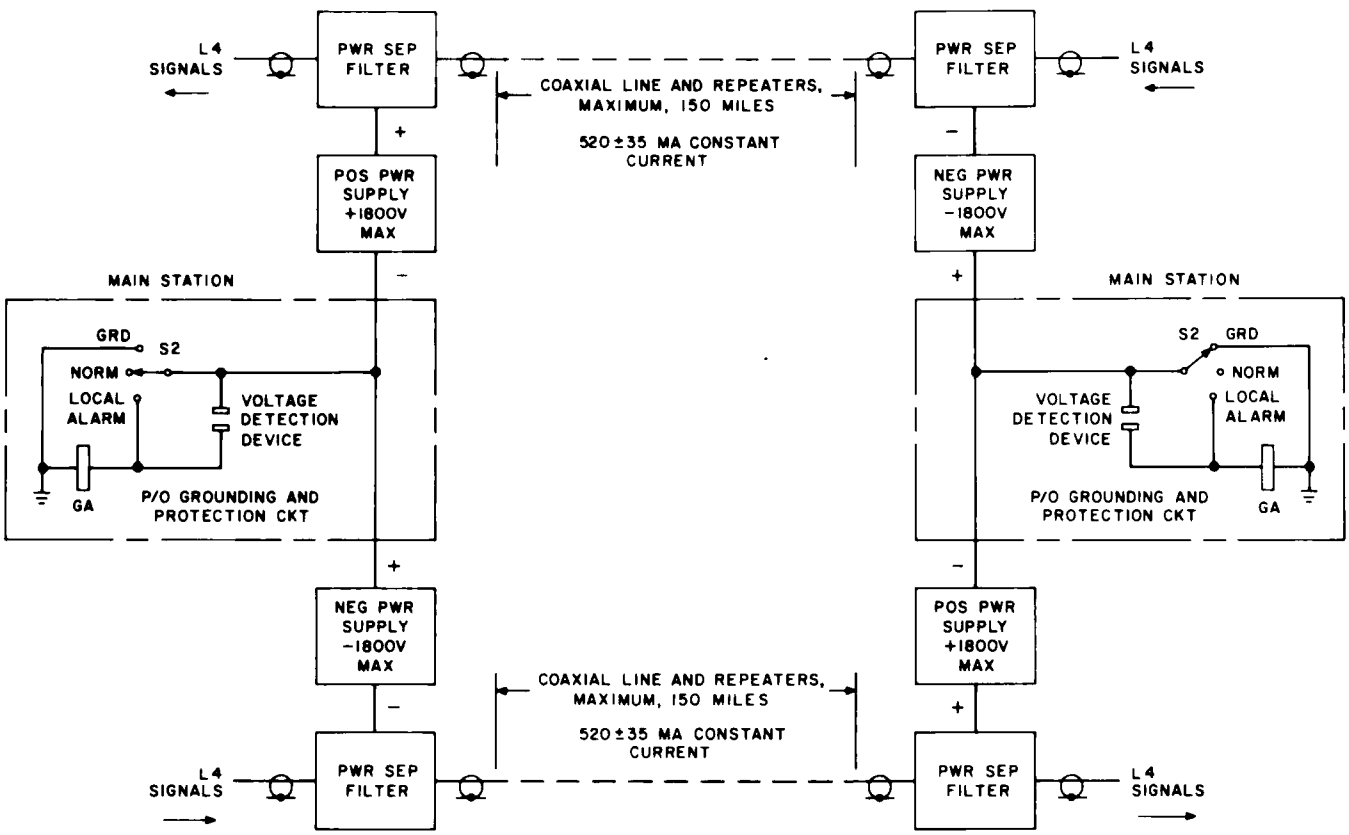

Fig. 7—L4 Line Power Arrangement

2.24 Part of the grounding and protection circuit is shown in simplified form in Fig. 7. If system balance is disturbed because of a line or component fault, high voltage will appear on the unaffected line at the ungrounded end. A predetermined voltage increase at the grounding and protection circuit will operate a voltage detection device, grounding the midpoint between the power supplies, and will restore power to the normal line of the power section. Operation of the protection circuit energizes a lamp and an office alarm.

F. Monitoring Oscillators

2.25 Since the line repeaters are numerous and relatively inaccessible, monitoring oscillators are provided to evaluate the performance of the individual repeaters and to aid in trouble locating.

2.26 A monitoring oscillator assembly (Fig. 4) consists of two coded units: a 66-type oscillator and a distribution network. Both units are secured to a fixture for mounting in the apparatus case.

2.27 The distribution network contains a circuit for splitting and distributing the oscillator output to four coaxial jacks located on the front of the unit. Four level adjustment controls, one for each of the four outputs, are accessible through holes in the housing. A coaxial patch cord and a 51A pad are used to connect an oscillator signal to each L4 line through the parallel input jack of each repeater in the apparatus case.

2.28 Monitoring oscillators are powered, in groups, from the main stations and equalizing repeater stations in response to commands from a control center. A main section may contain up to six groups. A group may contain up to 21 monitoring oscillators operating at different frequencies. The received signals can be observed on a spectrum analyzer in the main station or can be measured individually using test equipment. Monitoring oscillator signals are applied to four lines at a time, two lines in each direction.

3. LINE REPEATERS

A. Basic Repeater

3.01 A ***basic repeater*** J68877AA provides fixed gain with a frequency characteristic (Fig. 8) matching the loss of 2 miles of coaxial line at 55°F. Each basic repeater includes an LBO network which simulates a given length of coaxial line. The basic repeater is a plug-in unit which utilizes the apparatus case for environmental protection, heat dissipation, and access to the coaxial line. Four basic repeaters and a monitoring oscillator assembly are mounted in one 471A1 apparatus case (Fig. 9).

3.02 The basic repeater (SD-50668) consists of an input amplifier, an output amplifier, a network which incorporates the power separation filters and an avalanche diode, and an LBO network.

- If line building-out for a single section of line is necessary, the LBO networks are selected to provide approximately one-half the required buildout in the repeaters at each end of the line section.

- If buildout is necessary in two adjacent line sections, one-half the buildout required for each line section is provided at the middle repeater. The other half of the required buildout for each section is provided in the repeater at the other end of that section.

3.03 Two coaxial plugs on the rear of the repeater provide input and output connections. These plugs mate with coaxial jacks recessed behind the baseplate of the repeater apparatus case. Parallel input and output jacks are used for testing. The monitoring oscillator signal is connected via a 51A pad to the parallel input jack.

B. Regulating Repeater

3.04 A ***regulating repeater*** J68877AB provides continuous gain correction to compensate for changes in line loss due to temperature changes. This correction is applied in two parts: ***post-regulation,*** which is controlled by the level of the received 11.648-MHz pilot, and ***preregulation,*** which is controlled by ground temperature effects on a buried thermistor. The total regulation control range is 12 dB at 20 MHz, ±6 dB from a nominal value.

3.05 The fixed gain of a basic repeater compensates for the loss of 2 miles of line at 55°F. Line loss increases with higher temperature and decreases with lower temperature. Therefore, at intervals not exceeding five basic repeaters (12 miles of line), a regulating repeater is provided. This

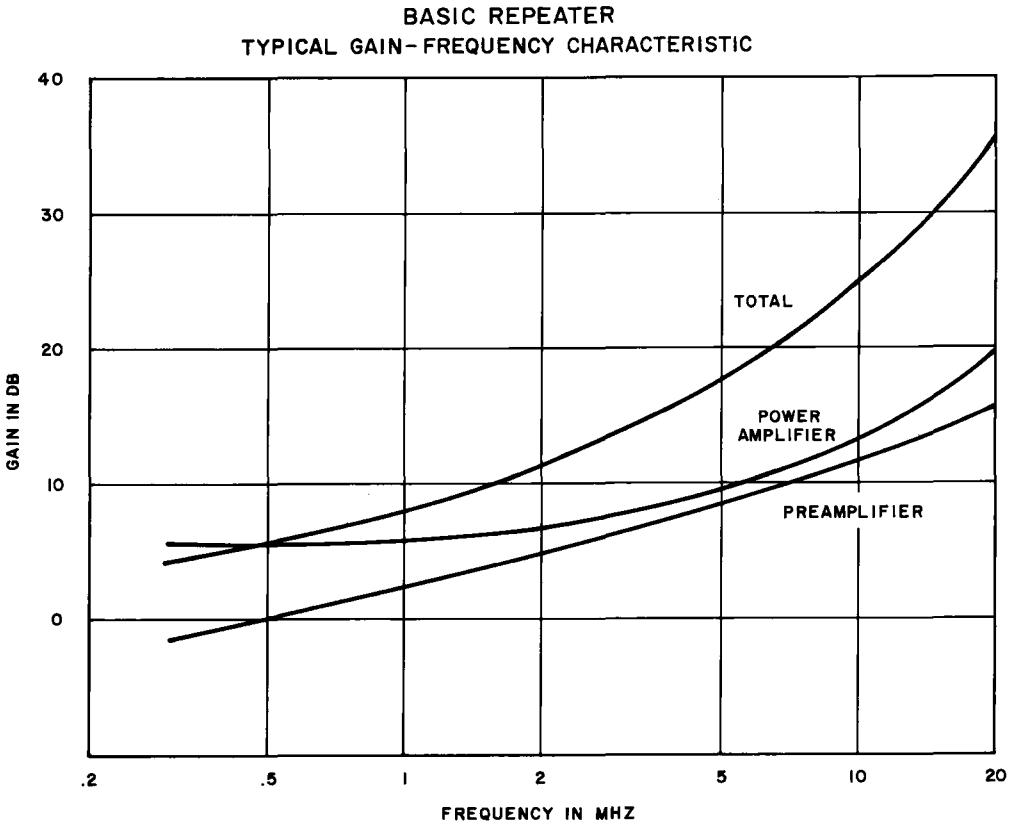

Fig. 8—L4 Basic Repeater—Typical Gain-Frequency Characteristic

repeater includes two amplifiers, each of which is regulated. The regulation is controlled by two variable factors: the ***received level*** of the 11.648-MHz pilot and the ***ground temperature*** at cable depth a short distance outside the repeater station. Each of these factors controls one of the amplifiers in the regulating repeater.

3.06 The regulating repeater (SD-50669) consists of an input amplifier, a pilot-controlled post-regulating unit, a cable temperature-controlled pregulating unit, a cable temperature-controlled preregulating unit, a power separation filter network, and two noninterchangeable LBO networks.

3.07 Four coaxial jacks are mounted on the front of the repeater. These jacks provide input and output connections for the two LBO networks. Three coaxial plugs are mounted on the rear of the repeater. Two of the plugs provide repeater input and output connections to the line and the third provides access to the buried thermistor.

3.08 The regulating repeater also includes a fixed equalizer which compensates for slight deviations between the actual gain of the line repeaters in a regulating section and the expected loss of the section at 55°F. This deviation equalizer is supplied in different codes, one for each allowable number of basic repeaters between the regulating repeaters.

3.09 Two regulating repeaters and a monitoring oscillator assembly are mounted in one 471B1 apparatus case. Only two of the oscillator outputs are used to serve the two regulating repeaters in the apparatus case.

C. Equalizing Repeater

3.10 An ***equalizing repeater*** J68877AC, plus manual A equalizer J68877EJ or stepped A equalizer J68877AD, performs the regulating repeater function and contains an adjustable A equalizer with six networks for correcting gain deviations across the L4 band. The regulating and equalizing portions of the repeater are physically separate. One equalizing repeater with stepped A equalizer occupies a 471C1 and a 471D1 apparatus case. An equalizing repeater with manual A equalizer can be mounted

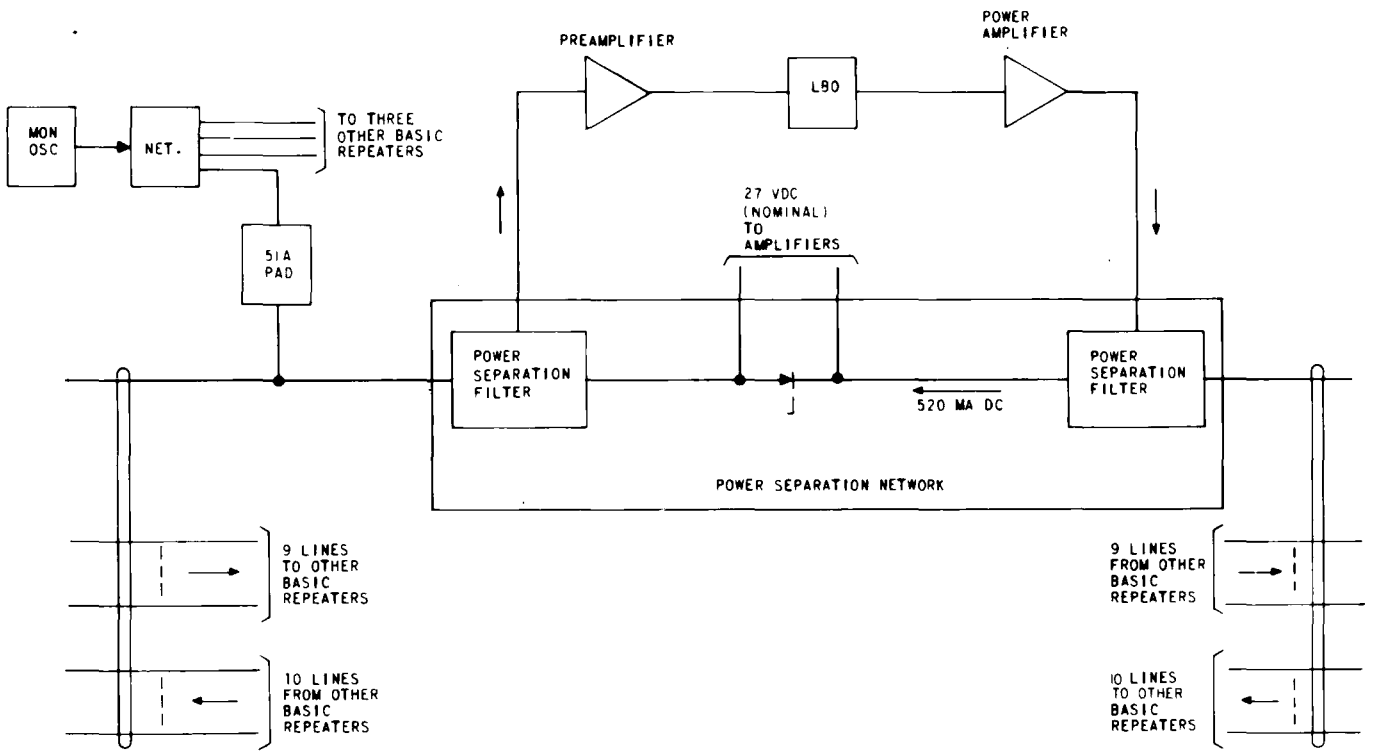

Fig. 9—L4 Basic Repeater Arrangement

in one apparatus case. A monitoring oscillator assembly is provided for each equalizing repeater.

3.11 Equalizing repeaters (SD-50670) are required at intervals not greater than 54 miles along the route. An exception is made in sideleg routes which may be as long as 75 miles without equalizing repeaters.

4. MAINTENANCE

A. General

4.01 Equipment in the L4 system is designed to require minimum maintenance at the line repeater stations. Underground installation of the coaxial cable and line repeaters results in reduced temperature change and increased protection from accidental damage. The coaxial cable and the line repeater apparatus cases are pressurized with dry air to exclude moisture.

4.02 Most routine maintenance is performed at the main stations. Initial isolation of trouble at the unattended locations is by means of alarms and the use of monitoring oscillator signals and test equipment at the main stations.

B. Order Wires

4.03 Loaded pairs, included in the cable, are used for several 4-wire order wires. Voice-frequency repeaters for the order wires are provided in the main stations.

4.04 Four voice order wires are used for L4 system maintenance. These order wires are designated cableman order circuit (COC), local order circuit (LOC), L4 order circuit (L4OC), and express order circuit (XOC). The COC and LOC appear at the main stations and at each line repeater station (Fig. 10).

4.05 The COC is provided for use during cable trouble and is on two pairs in the outer layer of cable so it will be available for use until splicing is completed. This order wire may also be used for communication at line repeater stations. The LOC is provided primarily for use from line repeater stations during maintenance at these

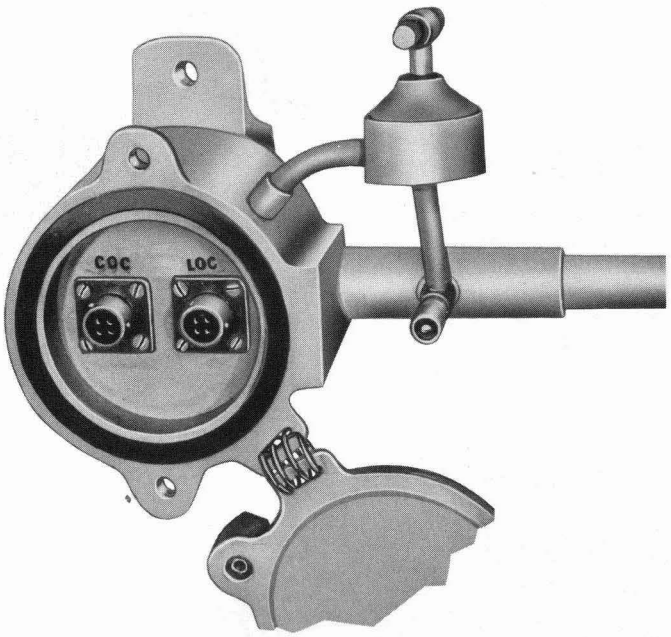

Fig. 10—Order Wire Appearances at L4 Line Repeater Station

locations. This order wire is on two pairs in the outer bundles of pairs. If necessary, this order wire may also be used during cable splicing.

4.06 A 100-type communication set (Fig. 11) is used for communication at line repeater stations and cable-splicing locations. The communication set is a solid-state, battery-operated, portable unit using 2600-Hz outgoing signaling. The communication set does not contain a ringer and remote locations page to get an answer. A 4-conductor plug is used for connection to order wire jacks at line repeater stations; cable clips are used at cable-splicing locations.

C. Main Station

4.07 An L4 main station will include some or all of the following equipment for use in maintenance:

(a) ***Transmission measuring equipment*** such as Wandel-Goltermann AT444 for measurements in the L4 band.

(b) ***Frequency measuring equipment.***

(c) ***Spectrum analyzer.***

(d) ***Pilot meters*** in each line bay to indicate continuously the levels of the received line pilots.

(e) ***Remote control system*** to permit centralized measurements of gain deviations and to provide facilities for in-service adjustment of stepped equalizer networks at remote locations. The remote control system also permits turning on the monitoring oscillators in groups so that the received signals may be observed for locating troubles.

(f) An ***L4 line repeater test set J68906B*** or ***J68906C*** used for three principal functions, as follows:

(1) Acceptance tests of L4 line repeater equipment units received from the manufacturer

(2) Preparation tests of repeater equipment units prior to installation at a specific line repeater station

(3) Confirmation tests to determine that suspected equipment units removed from service are defective.

D. Line Repeater Station

4.08 Two units have been developed for use at the L4 line repeater stations: a pilot-measuring test set and a pilot hit detector.

4.09 A ***pilot-measuring test set*** is used at line repeater stations to measure the gain of a repeater at the 11.648-MHz line pilot, to check for the presence of line current, and to serve as a bypass for the line current when replacing a defective repeater.

4.10 A ***pilot hit detector*** is used to indicate short interruptions of transmission on L4 lines. When the 11.648-MHz pilot drops 6 dB for 50 microseconds, a hit is indicated. A hit of this magnitude may cause automatic line switching.

4.11 In order to indicate and isolate hits, the hit detector is connected to a line at a line repeater station. The hit detector and battery pack are placed in the spaces above and below the monitoring oscillator assembly in a repeater apparatus case.

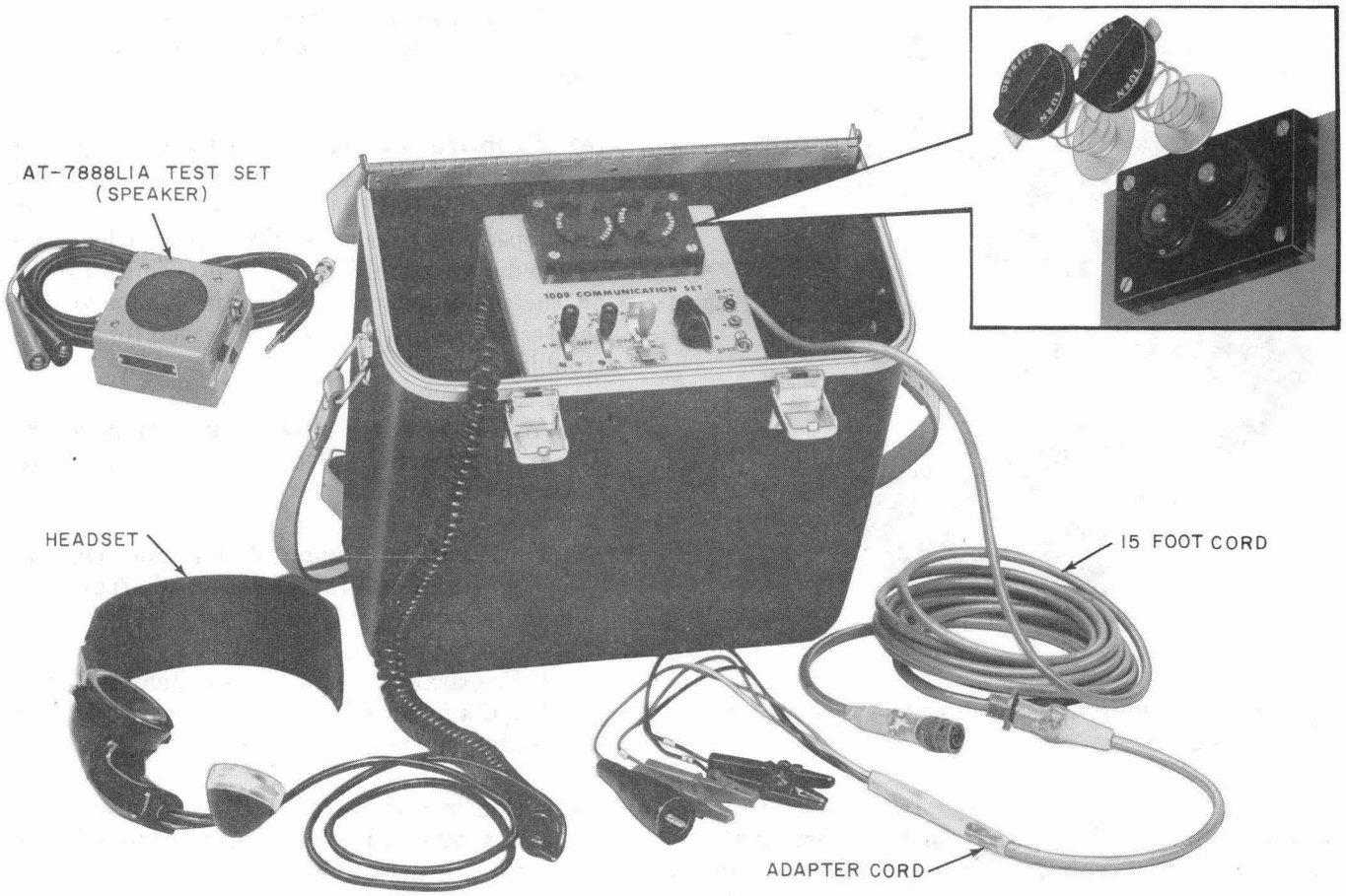

Fig. 11—100B Communication Set

4.12 The hit detector may be operated in two modes, local and remote.

(a) In ***local*** operation, observations are made at the line repeaters and hits are indicated by a lamp on the hit detector. For hits occurring frequently, this mode permits the source of hits to be located quickly. The hit detector is moved from one repeater station to another until the source of hits is isolated.

(b) In ***remote*** operation, the hit detector is connected to an L4 line at a repeater station and hits are indicated on the monitoring oscillator signals display in a main station. For hits occurring infrequently, this mode permits unattended operation for up to 7 days, depending on the life of the batteries.

In ***both*** modes of operation, the hit detector must be reset after each hit. Resetting is performed from a main station by turning off the group of monitoring oscillators and then turning the group on again.

4.13 If, as a result of indications at a main station, additional checks on the line appear to be needed, the line may be taken out of service by switching to the standby line. If trouble is indicated at a line repeater, personnel may be dispatched to the repeater site to verify the faulty repeater. The faulty repeater is replaced by a duplicate repeater which has previously been checked out on the L4 line repeater test set at the main station. Removal and replacement of repeaters from a powered line are accomplished with the aid of the portable pilot-measuring test set as a patching tool or a line power patch tool. With the new repeater in place, the pilot-measuring test set is again used to verify correct operation.

4.14 Access is provided to the 4-wire COC and LOC order wires to permit verifying proper operation with main station personnel before leaving

the site. The faulty repeater is returned to the main station for a check on the repeater test set. This check is to ensure that the repeater is defective and to isolate the defective portions prior to shipment of the repeater to a repair center.

4.15 In the interest of safety, the line equipment has been designed so that any unit containing high voltages will have its exterior grounded from two or more independent connections. In the case of plug-in units, a feature inherent in the design of the coaxial connectors is that the ground connection (outer shell) is always made solidly before the center connection and is broken after the center connection is interrupted. The outer shell connection is the more reliable of the two, thereby ensuring that internal faults cannot cause dangerous voltages to appear on the metal chassis.

E. Apparatus Cases

4.16 An apparatus case (Fig. 3) is cylindrical and is approximately 15 inches in diameter, 26 inches in length, and weighs approximately 150 pounds unequipped. The base is cast iron and the cover is of welded steel construction. The seal between the base and cover is maintained by an O-ring and a V-band clamp. Bolts are provided on the base to hold the cover and base together, to facilitate placement of the V-band clamp, and for safety in the event of V-band failure while the case is under pressure.

4.17 Under normal operating conditions, the cable and the apparatus cases are at a pressure of 9-1/2 pounds per square inch with dry air supplied from main stations and equalizing repeater stations. An apparatus case is provided with an air-pressure valve arrangement; therefore, an opened apparatus case can be isolated from the cable air supply. The air in the case must be released before removing the cover for maintenance work. After closing, the case is recharged to normal cable air pressure from a cylinder on the line maintenance truck. The air-pressure valve is then reopened to return to normal conditions.

F. Line Truck

4.18 A specially equipped truck is used for trips to the line repeater stations. This truck has the following features:

(a) Two-way radio mounted in the cab for communication with main stations and other line trucks.

(b) Spare parts bins and large storage compartments on both sides of the body.

(c) 110-volt ac generator mounted on the rolling shelf at the rear to provide power for lights, blower, and pump.

(d) Blower to ventilate underground structure at basic and regulating repeater stations.

(e) Pump to remove water from underground room. A sump is located below the entrance to the underground room.

(f) Cylinder of gas for repressurizing apparatus cases. At equalizing stations, a cylinder is located in the above-ground room.

(g) Rack for carrying one of the yellow-topped poles used to mark cable location.

(h) Davit with blocks and line for lowering and raising gas cylinder and other heavy items. At basic and regulating stations, the truck can be parked above the entrance to a station.