2nd Flr

A3

E1 TELEPHONE REPEATER SD-95465-01

COMMON SYSTEMS

(J98611A)

CONTENTS

FIGURES

*Indicates attached figure.

1. GENERAL

1.01 This section is reissued to make a general revision of the text, therefore the arrows ordinarily used to indicate changes have been omitted.

1.02 The E1 telephone repeater is a voice-frequency repeater developed for use in exchange areas where only moderate transmission gains (up to 8 or 10 db) are required. These figures represent average gains over the whole voice-frequency range of approximately 300 to 3500 cycles. The gains are not the same at all frequencies but are high at some and low at others. This is explained in Part 2, CIRCUIT FEATURES.

1.03 This repeater is designed for exchange plants and will find extensive use in trunks and special service lines such as long subscriber lines, off-premises PBX extensions, etc. It is a 2-way repeater, requiring only one amplifier and associated equipment for transmission in both directions. The equalizer and filter functions are performed by the vacuum tube amplifier and gain adjusting network circuits, in addition to their other functions. The d-c supervision and pulsing signals, as well as the ringing signals, are transmitted directly through the repeater.

1.04 Putting the E1 repeater into service is a simple process, requiring only two cross-connections and a relatively simple testing procedure.

1.05 This section covers general information and is provided for educational purposes. Detailed procedures for connecting, adjusting, testing, and maintenance are covered in other sections. A reference list of operational sections and selected circuit and equipment drawings is included in Part 5.

Applications

1.06 Among the services in which the E1 repeater is expected to find extensive application are the following:

(a) Exchange special services
Foreign exchange lines
Off-premises PBX extensions
PBX tie trunks
Special service lines
(b) Long tandem trunks
(c) Long toll connecting trunks
(d) Tributary trunks
(e) Centralized intercept operator trunks
(f) Centralized information operator trunks.

1.07 There are three general types of repeater application as follows: (see Fig. 1)

(1) Intermediate repeaters inserted between two loaded or two non-loaded cable facilities.

(2) Terminal repeaters at the end of loaded or non-loaded cable facilities.

(3) Intermediate repeaters between loaded and non-loaded cable facilities.

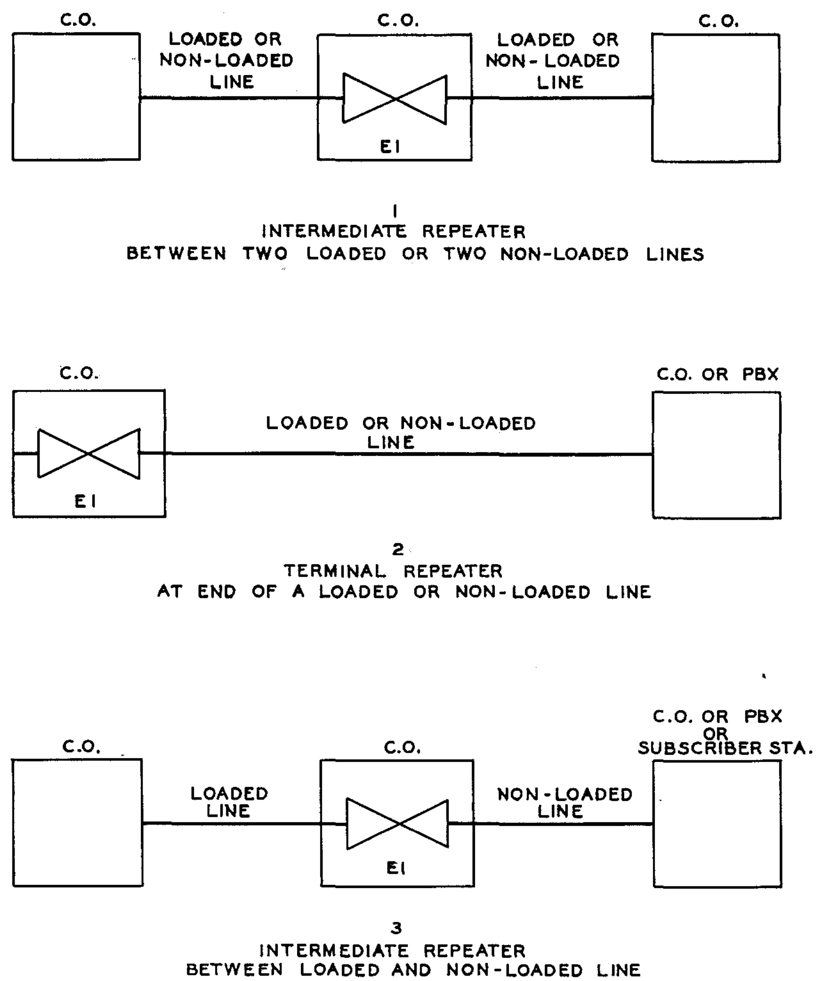


FIG. 1 - DIAGRAMS ILLUSTRATING GENERAL TYPES OF E1 REPEATER APPLICATIONS

2. CIRCUIT FEATURES

(A) General

2.01 The outstanding principle embodied in the E1 repeater is known as negative impedance. However, this description does not go into the negative impedance theory. Instead, the operation of the repeater is described on the basis of energy transfer and deals with simple voltage and current relationships without using mathematics.

2.02 A feedback amplifier is employed, in which the input and output are in a common circuit. With this arrangement the weak speech input signals are applied between the cathode and ground, and plate current flows through both the output and input circuits.

2.03 Figs. 2A and 2B, with the accompanying brief description, illustrate the basic difference between the type of amplifier used in the E1 repeater and the previous types. In these figures, for simplicity, basic connections are used and such details as heater connections, resistors, capacitors, etc. have been omitted.

2.04 Fig. 2A is a simple schematic illustrating a conventional grounded cathode amplifier. Here the input voltage (E) across the secondary winding of the input transformer makes the grid potential vary with the changes in input voltage. The plate to cathode current, and any variation in it, is restricted to the output circuit.

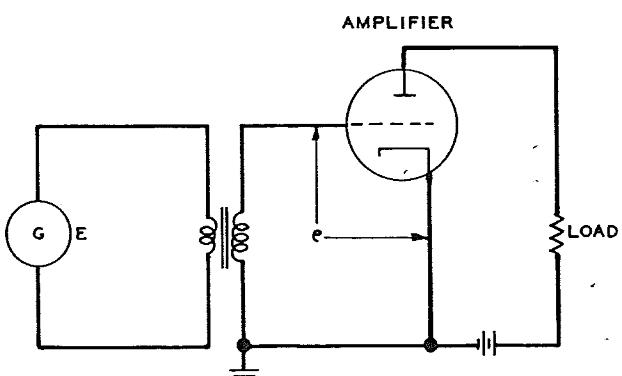


FIG. 2A - GROUNDED CATHODE AMPLIFIER CKT.

2.05 Fig. 2B is a simple schematic illustrating a grounded grid amplifier arrangement which, with some modification, is used in the E1 repeater design. In this case, the input voltage (E) across the secondary winding of the input transformer makes the cathode potential vary with changes in input signal. The secondary winding is part of the input circuit and also part of the plate to cathode (or output) circuit. With this arrangement, plate to cathode current flows through both the output and input circuits, and plate to cathode current changes are used to return an induced voltage to the primary side of the input transformer.

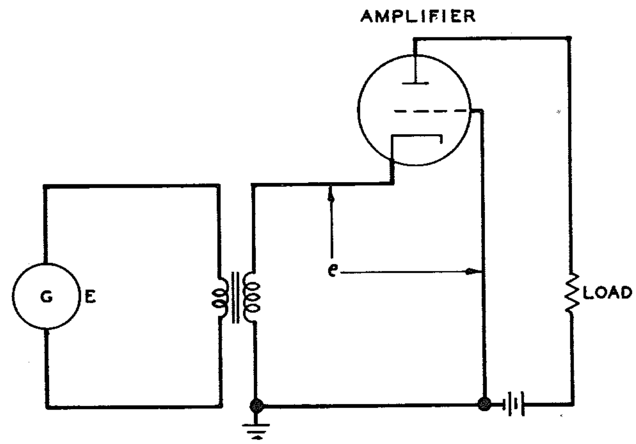


FIG. 2B - GROUNDED GRID AMPLIFIER CKT.

2.06 The modification mentioned in Par. 2.05 consists of coupling the grid through a capacitor to a gain adjusting network (both not shown). This arrangement makes it possible to phase the voltage returned to the primary side of the input transformer so that it will aid the line current, and also to control the amount of added current as required at different voice frequencies. This feature is explained in (D) and (E) of this part.

(B) Association of Repeater with Trunk or Line

2.07 There are three principal equipment elements in the E1 repeater.

(1) An input transformer.

(2) A vacuum tube amplifier unit.

(3) A gain adjusting network.

2.08 Fig. 3 shows these elements of the repeater and how they are associated with a trunk or line by means of the input transformer. The two primary windings of the transformer are cross-connected in series with the trunk. These windings have low resistance and inductance, and therefore cause only a small loss in the d-c and low frequency signals used in supervision, pulsing, and ringing.

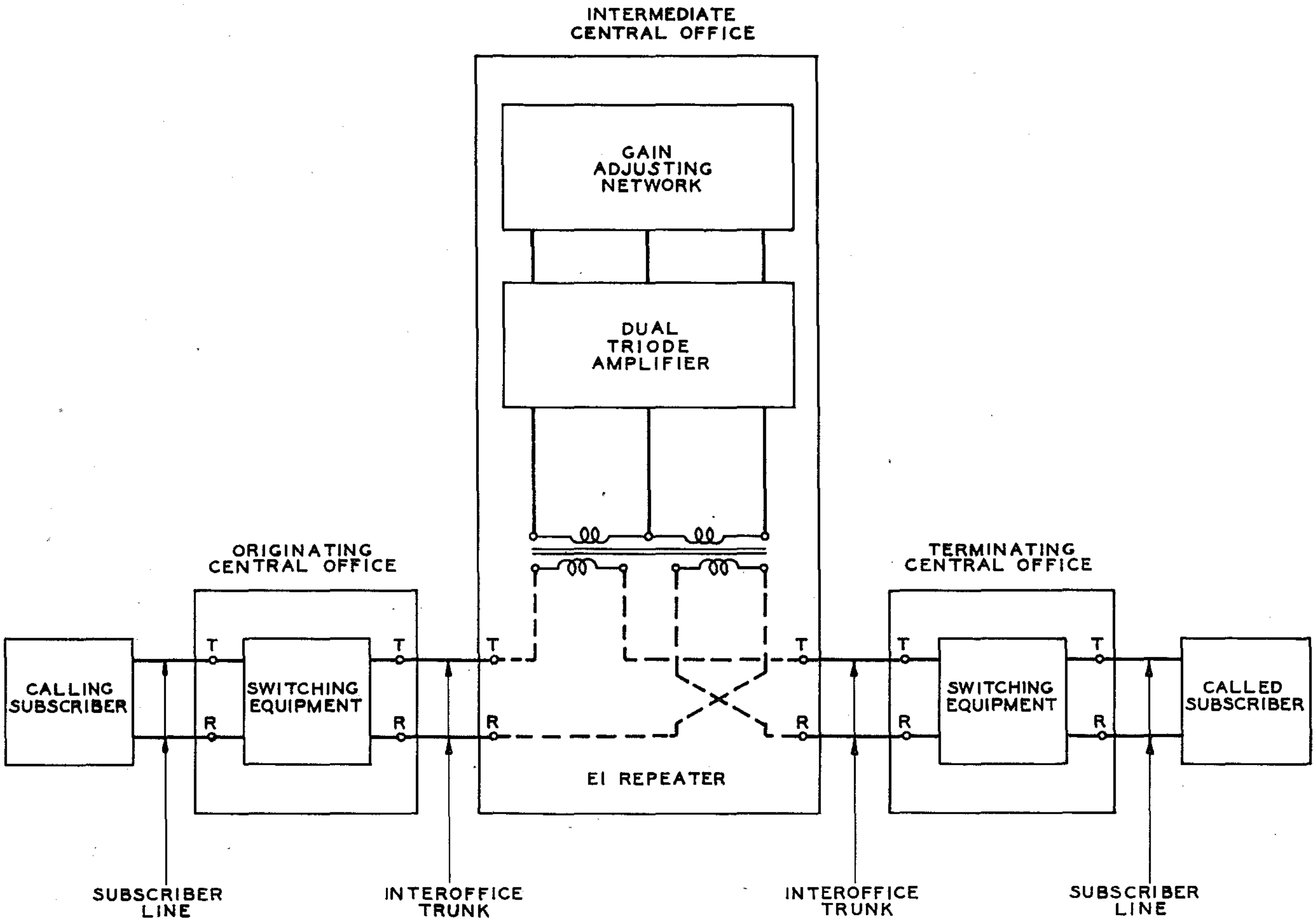


FIG.3 - TYPICAL APPLICATION OF INTERMEDIATE REPEATER

(C) Circuit Considerations

2.09 If trunks or lines were purely resistive, the level of all frequencies transmitted over them would be attenuated (lowered) by the same amount. However, this is not the case since all trunks and lines have reactance (capacitive and inductive) as well as pure resistance, which makes the amount of attenuation (loss) vary over the voice-frequency band. If the loss at different frequencies for any given trunk or line is plotted on graph paper and a curve is drawn through the plotted points, the curve will have a definite shape for that trunk or line. This is termed the loss-frequency characteristic of the given trunk or line.

2.10 The E1 repeater partially compensates for these loss variations by providing relatively high gain where the line loss is high and correspondingly low gain where the line loss is low. This varying or "shaping" of the gain is accomplished by using suitable combinations of resistances and reactances in the gain adjusting network.

2.11 An ideal arrangement would be to adjust the repeater to reduce the line loss to the same value for all frequencies. Practically, this can only be partially accomplished because the loss-frequency characteristic of a line or trunk changes its shape whenever it is connected to other circuits. For example, on one call the trunk might be connected between two short subscriber lines while on the next call it might be connected between a short subscriber line and a long tandem trunk. The loss-frequency characteristic for the first case would be considerably different from that in the second case. It is therefore impossible to reduce the line loss to the same value for all frequencies on all the different types of telephone connections that are encountered in an exchange area plant.

2.12 Therefore, the gain of the repeater is shaped in accordance with the loss-frequency characteristic of the trunk or line to which it is permanently wired. Although the gain-frequency characteristic is shaped, the gains at the different frequencies are set low enough to provide sufficient margin against repeater singing. If the gains were not properly adjusted, singing might occur on some telephone connection where the particular connecting circuits used lowered the loss at some critical frequency where the repeater was set for a high gain.

2.13 Charts have been prepared, and are included in the A300 series, which show what straps to install on the gain adjusting network to obtain specified gains for the more commonly used types of cable facilities. Choice of strapping shown on these charts is based on the following considerations:

(a) Type of cable facilities involved, that is, the gauge and loading.

(b) Type of repeater application (see Fig. 1).

(c) Length of the end sections.

The basic strapping shown on the charts is determined by (a) and (b) above, and the supplemental strapping by (c). The supplemental strapping is required whenever loaded cable facilities are involved. (Basic and supplemental strapping are defined in Pars. 4.18 and 4.19.)

2.14 When intermediate repeaters are used with loaded cable pairs, they are inserted between two consecutive loading points. The lengths of trunk from each of these loading points to the repeater are referred to as end sections. The two end sections are given in tenths of the standard distance used between loading points of the particular cable pair in question.

2.15 In practice, some sections will be greater or less than the standard distance. For example, in a transmission line with standard loading intervals of 6000 feet, the repeater may be inserted between loading points separated by a distance considerably in excess of 6000 feet.

2.16 The end sections are given in tenths of the standard distance between loading points, and not in tenths of the actual distance. Therefore in some cases the end sections may add up to more than ten tenths. For example, if the repeater is located 4800 feet from one loading point and 2400 feet from the other, the end sections are respectively 0.8 and 0.4 of the standard loading section of 6000 feet, which adds up to twelve tenths. Where unequal end sections of this kind are encountered, a chart is used which translates them to an equivalent or compromise end section for the purpose of using the network strapping charts.

2.17 Terminal repeaters on loaded facilities and intermediate repeaters between loaded and non-loaded facilities have one end section.

2.18 Where the more commonly used types of plant facilities are involved and the required gains are within the limits determined by the nature of the line facilities (shown on curves in Section AB22.151), relatively simple instructions for strapping the gain adjusting network are provided.

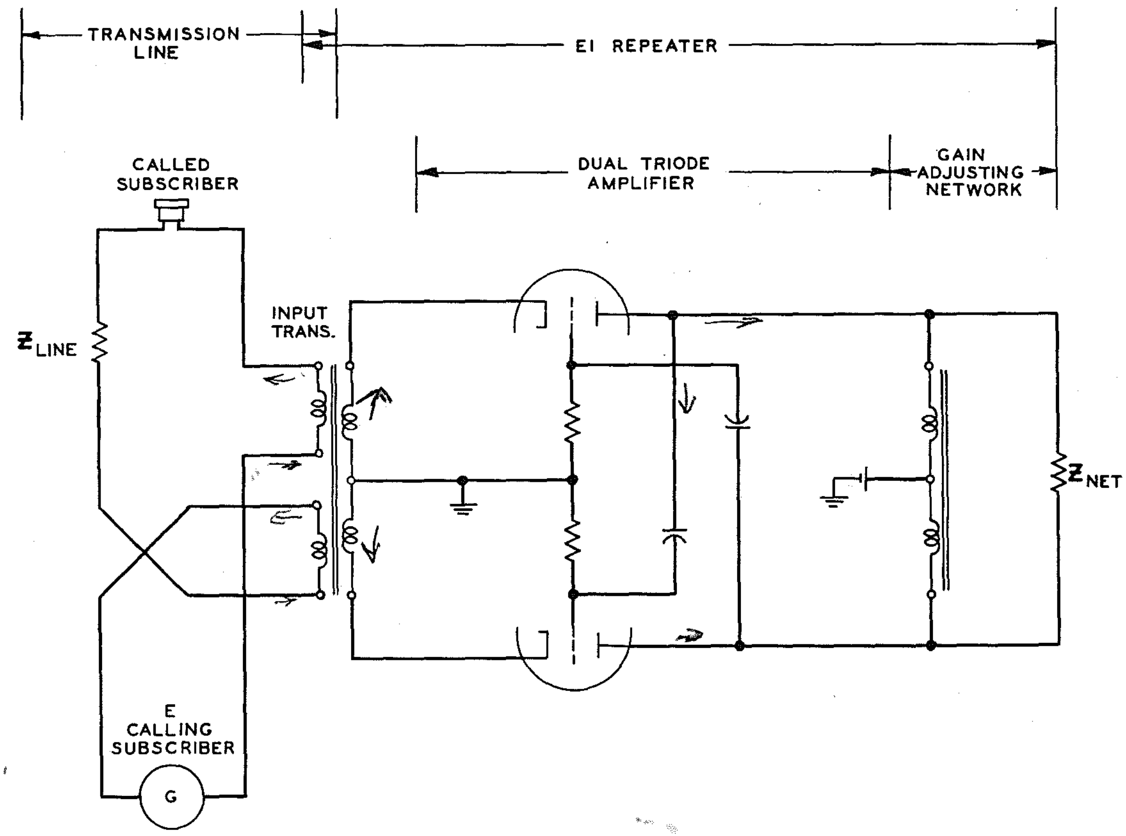
2.19 In some areas the terminals to be strapped will be listed in the layout or assignment information. In other areas the service order will refer to a series of charts from which the proper strapping is determined. In both of these cases little testing and adjusting is ordinarily required.

2.20 However, there are some cases where a mixture of types of plant facilities are involved or where the gains required are high with respect to the limits determined by the nature of the line facilities. In such cases individual testing and "tailoring" of the gain adjusting networks may be necessary.

2.21 Samples of the charts and general procedures for strapping and testing the gain adjusting network are covered in Part 4, SERVICE AND MAINTENANCE FEATURES.

(D) Circuit Operation - General

2.22 Fig. 4 is a simplified schematic showing some of the major elements of the repeater. In this figure, the impedance of the transmission line is shown for convenience as a lumped impedance Z_{LINE}. (The transmission line includes all the apparatus and wiring through which the speech current must pass in traveling from the calling subscriber transmitter to the called subscriber receiver.)



Z LINE = LUMPED IMPEDANCE OF TRANSMISSION LINE AS SEEN FROM REPEATER
E = A-C VOICE FREQUENCY VOLTAGE

FIG. 4 - SIMPLIFIED SCHEMATIC

2.23 During the static condition, that is, before a signal voltage is applied to the cathodes, a steady current of about 5 milliamperes (0.005 amperes) flows through each triode in the repeater unit. The path of this current through each of the triodes is from the plate battery, through the winding of the retardation coil to the plate, then to the cathode, and finally through the secondary winding of the input transformer back to the plate battery. This current flows through the various pieces of apparatus in the same way that current flows through relay windings and other apparatus in any direct current circuit.

2.24 When the calling subscriber talks, he converts the d-c talking battery fed from the central office to an a-c voice-frequency voltage designated E. The resulting current flows all along the connecting circuits forming the transmission line from speaker to listener, and since the primary winding of the repeater input transformer is in series with the line, an alternating voltage is induced in the secondary winding of the transformer which is applied to the cathodes of each of the triode sections.

2.25 When the signal voltage is applied to the cathodes, the currents through both triode circuits change in magnitude from their static value under control of the gain adjusting network. These changing currents flow through the secondary windings of the input transformer and in turn induce voltages in the primary windings of the transformer.

2.26 These induced voltages appearing in the primary windings are of greater magnitude and of opposite polarity to the original signal voltage drops across these windings. Therefore, they are series aiding with the voltage generated by the subscriber. This series aiding effect increases the current in the line and is the means by which this repeater provides gain. This entire operation is explained more fully in (E), Circuit Operation - Detailed.

The gain provided by the El repeater is equal in both directions on the transmission line. It covers the range of frequencies from about 300 cycles to about 3500 cycles, the upper limit depending on the cut-off frequency of the line facilities.

(E) Circuit Operation - Detailed

General

2.27 The preceding material has described the operation of the repeater in general terms. The operation will now be described in detail, and related to the actual apparatus elements.

2.28 Fig. 5A, attached, shows all of the major elements of the repeater in schematic form. Certain resistors and capacitors which are used for miscellaneous purposes, such as to prevent parasitic oscillations in the grid and plate circuits, etc., have been omitted to simplify the description of the major functions of the repeater. These secondary features will be discussed later.

2.29 The twin triode vacuum tube operates in the circuit as a class A-1 push-pull amplifier. Push-pull means, simply, that the two triode elements are connected so that as the plate current in one triode is increasing the plate current in the other is decreasing. Therefore, the voltages applied by one triode to its associated section of the output coil are oppositely phased to the voltages applied by the other triode to its section of the coil. It follows that the voltages are additive and the combined effects of the two elements are obtained. The push-pull arrangement also eliminates distortion of the output voltage.

2.30 Class A-1 as applied in the El repeater means that the grid is always negative with respect to the cathode with normal input signal levels. This is important because if the grid were allowed to become positive with respect to the cathode, current would flow from the grid to the cathode and the plate output voltage would not be an exact replica of the speech voltage wave.

2.31 The cathodes are connected to the secondary windings of the input transformer. This puts the cathode in both the input and output circuits, and the amplified signal voltage returned to the transmission line is so phased that it aids the subscriber generated voltage. How this phasing occurs is described in the following discussion.

Static Condition

2.32 When the batteries are connected to the heaters and the plate, current flows in each of the two identical triodes. The path of the current is from the plate battery through the retardation coil to the plate; then to the cathode through the secondary winding of the input transformer; and then back to the plate battery, thus completing the circuit.

2.33 The cathodes of both triodes are equally positive by the amount of the voltage drops across their associated secondary windings of the input transformer, i.e., the voltage drop from (e) to (f) is equal to the voltage drop from (g) to (f). This establishes the difference in potential (or bias) of the cathode with respect to the grid, which is at ground potential.

2.34 As a result of the equal static currents there are equal voltage drops between points (h) and (i) and (j) and (i) of the retardation coil. Therefore, points (h) and (j) are at the same potential and equally less positive than the plate battery by the amount of the voltage drops.

Dynamic Condition

2.35 Up to this point the circuit is in a static condition. We shall now see what happens when speech occurs, or in other words, when a signal is applied and the circuit enters the dynamic (or operating) condition.

2.36 When speech occurs at the calling subscriber's transmitter, an alternating current flows through the line and causes voltage drops across the input windings of the transformer.

2.37 To appreciate what happens we will consider instantaneous values of voltage and current. True, the input signal voltage is changing as the subscriber speaks, both in relative amplitude and frequency, but if we start by considering the voltage and current relationships at a particular instant, it will be easier to visualize what happens during a full cycle of input signal. Fig. 5A shows such a relationship for a given instant.

2.38 The following symbols are used in Fig. 5A to show the relationships, both as to polarity and magnitude, of the voltages in the circuit during the static and dynamic conditions.

(a) The circles show the polarities of the cathodes and the plates with respect to ground during the static condition.

(b) The squares show the polarities of the subscriber generated voltage, the resulting voltage drops throughout the transmission line, and the induced voltage applied to the repeater.

(c) The hexagons show the polarities of the cathodes with respect to ground as a result of the applied signal before any current change in the triodes.

(d) The triangles show the polarities of the cathodes and grids with respect to ground due to the changes in current caused by the applied signal.

(e) The diamonds show the polarities of the amplified signal induced into the transmission line and the resulting new voltage drops throughout the line.

2.39 Although the action is actually instantaneous (as previously mentioned), these symbols are used to simplify the explanation by describing the action as though it occurred in a definite time sequence (a), (b), (c), (d), (e).

2.40 The relative heaviness of the plus and minus signs gives a rough picture of the magnitudes of the voltages at each step.

2.41 The polarities of the voltage drops during the static condition, as shown in the circles, have been previously discussed under <u>Static Condition</u>.

2.42 For the instant (or fraction of a signal cycle) assumed, the squares in Fig. 5A show that the voltage drops, due to the signal, across the input windings of the transformer are such that point (b) is positive with respect to point (a) and point (d) is positive with respect to point (c). The effect of these voltage drops on the current flow in the line is the same as though the primary windings were disconnected and batteries of the same value as the voltage drops were substituted for them with the terminals connected with the polarities shown in the squares, that is, in either case the current would be reduced to the same value. Thus, to simplify the discussion, voltage drops can be replaced with opposing batteries of like values which are 180 degrees out of phase with the subscriber generated voltage (E in Fig. 5), and the same amount of current will flow in the line.

2.43 Now if a second battery of the same voltage were placed in series with the first battery but opposing it, that is, in phase with the subscriber's generated voltage, the effect would be the same as though the voltage drop were nullified and there would be an increase of current in the line. Further, if the second battery were of greater voltage than the first battery, there would naturally be a still greater increase in the current in the line.

2.44 The El repeater in effect does the same job that the aiding (or in phase) batteries would accomplish, that is, it induces amplified voltage in the primary windings of the input transformer (as shown in the diamonds) which is 180 degrees <u>out of phase with the voltage drop</u> but <u>in phase with the subscriber generated voltage.</u>

2.45 As shown by the signs in the diamonds, it is only across the windings of the input transformer that the reversal takes place; this happens here because the voltage drop is replaced by an aiding amplified voltage induced from the repeater.

2.46 Fig. 5A shows that the voltage induced in the secondary windings of the input transformer associated with triode No. 1 is opposite in polarity to the bias (or voltage) between the cathode and grid due to the static current; conversely, the voltage induced in the secondary winding associated with triode No. 2 is of the same polarity as that of the bias between the cathode and grid due to the static current. Since there is close relationship between the two triodes in performing their functions in the operation of the repeater, we will describe them together.

<u>OPERATION OF TRIODE NO. 1 AND TRIODE NO. 2</u>

<u>TRIODE NO. 1</u>

(1) Signal voltage induced between points (e) and (f), shown in the squares, is <u>opposite</u> in polarity to the bias between the cathode and grid due to the static current.

<u>TRIODE NO. 2</u>

(1') Signal voltage induced between points (f) and (g), shown in the squares, is <u>of the same</u> polarity as the bias between the cathode and grid due to the static current.

TRIODE NO. 1

(2) This induced voltage is equivalent to a battery in series with the cathode and opposing the bias. Therefore, the cathode becomes less positive with respect to the grid, as shown by the light positive sign in the hexagon. In other words, the potential difference between the cathode and grid has been reduced.

(3) The reduction of the potential difference permits more current to flow than was flowing during the static condition.

(4) The increased current flow results in an increased voltage drop between points (e) and (f). This voltage drop is equivalent to a battery with the positive terminal connected to (e). This battery is greater in magnitude but of the same polarity as the potential due to the voltage drop created by the static current.

(5) The result of this increased voltage drop is to move the cathode in the positive direction, thus partially nullifying the swing created by the input signal voltage which had been induced across the secondary winding. This causes less current to flow than if the full swing of the input signal voltage had been maintained on the cathode. In other words, the cathode does not change its potential with respect to the grid by the full amount of the input signal and the current is only slightly greater than the static value.

(6) However, at the same instant the grid is made positive and causes a further increase in current, as is explained in (7), (8), and (9).

(7) At the instant that event (3') took place and less current flowed in the circuit of triode No. 2, the voltage drop across points (i) and (j) of the retardation coil of triode No.2 decreased because of this smaller current flow.

(8) Therefore, point (j) became more positive with respect to the plate battery than it was under the static condition.

(9) The increase in potential of point (j) causes the charge on capacitor (k) to increase. The charging current causes a voltage drop across resistor (m) with the result that the grid becomes positive with respect to ground. The net result is that both the cathode and the grid are more positive than they were in the static condition, as shown by the signs in the triangles, and the current in triode No. 1 is much greater than the value in step (5).

TRIODE NO. 2

(2') This induced voltage is equivalent to a battery in series with the cathode and aiding the bias. Therefore, the cathode becomes more positive with respect to the grid, as shown by the heavy positive sign in the hexagon. In other words, the potential difference between the cathode and grid has been increased.

(3') The increase of potential difference permits less current to flow than was flowing during the static condition.

(4') The decreased current flow results in a decreased voltage drop between points (g) and (f). This voltage drop is equivalent to a battery with the positive terminal connected to (g). This battery is smaller in magnitude but of the same polarity as the potential due to the voltage drop created by the static current.

(5') The result of this decreased voltage drop is to move the cathode in the less positive direction, thus partially nullifying the swing created by the input signal voltage which had been induced across the secondary winding. This causes more current to flow than if the full swing of the input signal voltage had been maintained on the cathode. In other words, the cathode does not change its potential with respect to the grid by the full amount of the input signal and the current is only slightly less than the static value.

(6') However, at the same instant the grid is made negative and causes a further decrease in current as explained in (7'), (8'), and (9').

(7') At the instant that event (3) took place and more current flowed in the circuit of triode No. 1, the voltage drop across points (h) and (i) of the retardation coil of triode No.1 increased because of this greater current flow.

(8') Therefore, point (h) became less positive with respect to the plate battery than it was under the static condition.

(9') The decrease in potential of point (h) causes the charge on capacitor (ℓ) to decrease. The discharging current causes a voltage drop across resistor (n) with the result that the grid becomes negative with respect to ground. The net result is that both the cathode and the grid are less positive than they were in the static condition, as shown by the signs in the triangles, and the current in triode No. 2 is much less than the value in step (5').

TRIODE NO. 1

(10) Because of this increased current, the voltage change across points (e) and (f) is greater in magnitude and opposite in direction to the original input signal.

(11) The increased current which caused step (10) also induces a voltage across points (a) and (b), as shown in the diamonds, which is greater in magnitude and opposite in polarity to the original voltage drop.

TRIODE NO. 2

(10') Because of this decreased current, the voltage change across points (g) and (f) is greater in magnitude and opposite in direction to the original input signal.

(11') The decreased current which caused step (10') also induces a voltage across points (c) and (d), as shown in the diamonds, which is greater in magnitude and opposite in polarity to the original voltage drop.

2.47 The magnitude and the phase of the voltage returned to the transmission line by the repeater depends upon the potential changes at points (h) and (j), as explained in steps (9) and (9'). The potentials at points (h) and (j) in turn depend upon the elements (resistors, capacitors, and coils) strapped in the gain adjusting network, which, as has been previously explained, were selected to obtain the desired gain-frequency characteristic of the repeater.

2.48 The above step-by-step description assumed an instant in the cycle of input signal voltage when the current in triode No. 1 was increasing, while that in triode No. 2 was decreasing. Conversely, it can be demonstrated that, during an instant in the other half of the cycle, the current in triode No. 1 would be decreasing and that in triode No. 2 would be increasing.

2.49 While speech is occurring, the currents through the triodes and the secondary windings of the input transformer are constantly changing in magnitude, thus inducing voltages in the primary windings. When the currents are equal in each half of the secondary windings, there is no induced voltage in the primary windings. On the other hand, a decreasing current in one half of the secondary winding and an increasing current in the other half induce equal voltages in the same direction in each half of the primary winding. This is characteristic of all push-pull amplifier operation.

2.50 Thus, with the push-pull and feedback design, the full cycle of subscriber input signal voltage is amplified and returned in such a direction as to increase the current in the transmission line.

2.51 Fig. 5B, attached, shows graphically the potentials with respect to ground of the cathodes and grids during the static condition and the progressive changes in the potentials of these elements for the instant of input voltage assumed for Fig. 5A. The potentials are represented by blocks, and the lengths of the blocks indicate the relative magnitudes of the potentials.

2.52 The chart shows that during the static condition (I and I') both cathodes are positive and both grids are at ground potential. The lengths (a and a') represent the difference in potential (or bias) between the cathodes and grids.

2.53 At the instant the input signal is applied and before any change in current occurs in the triodes, the cathodes change in potential as shown in steps II and II'. The cathodes move in opposite directions since the input voltages across the secondary windings of the input transformer are opposite in phase; and new potential differences are established between the respective cathodes and grids, namely, the potential difference decreases to (b) in triode No. 1 and increases to (b') in triode No. 2.

2.54 Because of these new potential differences, the current increases in triode No. 1 and decreases in triode No. 2. The new current values cause the cathodes to move in opposite directions again; but this time the cathodes move toward their static condition values as shown in steps III and III'. This condition occurs if, as previously discussed, the effects of the coupling capacitors are not taken into account. At steps III and III' the current flowing in the triodes and the potential differences, c and c', between the cathodes and grids are only slightly different from their respective static condition values.

2.55 However, as previously explained, when the effects of the coupling capacitors are taken into account the grids move from ground potential. In triode No.1, the grid moves in the same direction as the cathode, thus increasing the current; while in triode No. 2 the grid moves in the direction opposite to the cathode thus decreasing the current. (The distance that the grids move away from ground potential is related to the gain desired at a particular frequency.) Because of these new current values brought about by the grid changes, the potentials of the cathodes are again changed. These combined effects (the voltages fed back to the grid by the coupling capacitors and the new current values) on the potentials of the grids and cathodes are shown in steps IV and IV'.

2.56 Of course, the potentials of these elements actually change instantaneously from steps I and I' to steps IV and IV'. The net result, then, of the applied input signal is that the current increases in triode No. 1 and decreases in triode No. 2, and these changing currents return induced voltages to the primary side of the input transformer which are in series aiding with the subscriber generated voltage.

(F) Supplementary Circuit Features

2.57 Fig. 6, attached, includes the elements in the repeater which are used for miscellaneous purposes as follows.

2.58 The capacitors C3 and C4, in addition to their major function of providing an a-c path for the voltages fed back to the grid and blocking the d-c plate voltage, combine with resistors R5 and R6 to provide increasing attenuation to frequencies below 100 cycles.

2.59 The capacitors C1 and C2 by-pass frequencies above 3000 cycles around resistors R5 and R6 to ground. These capacitors also combine with resistors R3 and R4 to provide increasing attenuation at high frequencies (above 50,000 cycles).

2.60 The attenuation and by-passing of these frequencies (which are outside of the voice-frequency range) insure that voltages within these frequency ranges are not fed back to the grid for amplification. The filtering action of these elements is in addition to the filtering action within the gain adjusting network, with the result that those frequencies within the voice band (300 to 3500 cycles) receive the desired amplification.

2.61 Resistors R5 and R6 also provide the ground return path for the grids.

2.62 Resistors R1 and R2 limit any grid current which tends to flow at very high speech levels.

2.63 Resistors R1 and R2 also prevent parasitic oscillations in the grid circuits, and resistors R7 and R8 perform the same function in the plate circuits. Such parasitic oscillations are the result of inherent characteristics of an amplifier. The frequencies at which they occur are far removed from the voice-frequency range for which the amplifier is designed, and if they were not suppressed they would impair the quality of speech.

2.64 The input transformer secondary winding consists of two sections, one section being wound on top of the other. Since the two sections must be electrically balanced, the outer winding, being further from the core, has more wire and therefore greater resistance than the inner section. The R9 and R10 resistors are used to balance this unequal d-c resistance of the two sections, and also to build out the biasing resistance in each cathode circuit to the required 350 ohms.

3. EQUIPMENT ELEMENTS

(A) General

3.01 The "package" nature of the E1 repeater simplifies engineering, installation and maintenance. The unit is so small in size that two repeaters are mounted on a single 1-3/4" by 19" mounting plate. Fig. 7 shows the front and rear view of such an assembly.

3.02 There are no external jacks, coils, or networks associated with the repeater such as are found in the conventional repeaters. The only external connections are the battery supply leads and the leads to the trunk or line it serves.

3.03 There are three principal elements in the repeater:

(1) An input transformer (647C).

(2) A vacuum tube amplifier unit.

(3) A gain adjusting network (426A).

3.04 Fig. 6 shows the elements of one repeater in schematic form, and the following paragraphs describe the major apparatus assemblies.

(B) Input Transformer

3.05 The input transformer is coded 647C and consists of two primary windings and a center-tapped secondary winding. These windings are electrically balanced for precise energy transfer and provide a voltage coupling ratio of 1 to 3 from trunk or line to amplifier. This ratio permits obtaining the maximum power output from the particular triodes used.

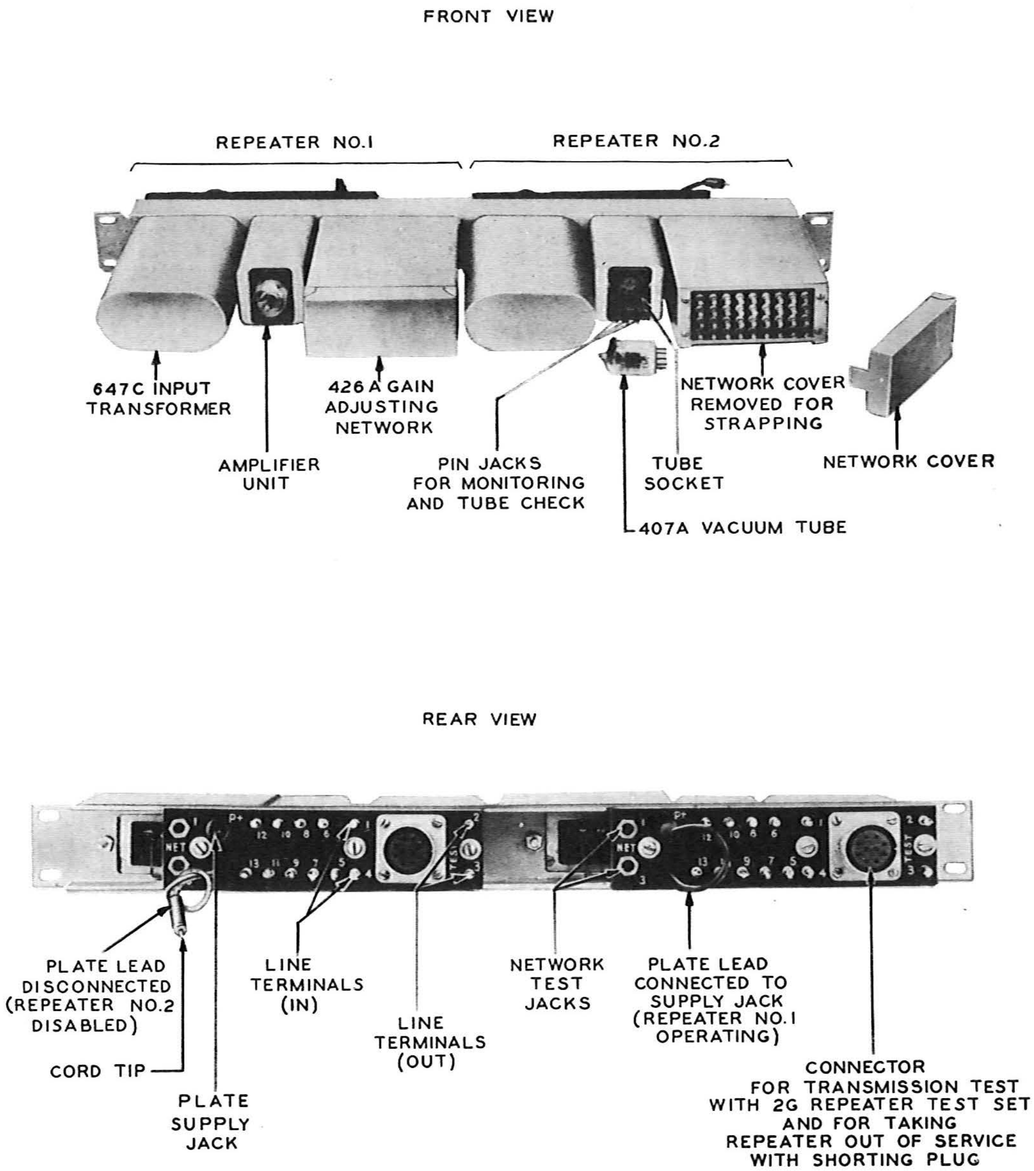


FIG. 7 - FRONT AND REAR VIEWS OF E1 REPEATER

3.06 The primary windings are connected to terminals 1, 2, 3, and 4 on the rear of the unit (see Fig. 6). These terminals are cables to a distributing frame where they can be cross-connected to trunks or lines. They are also connected to the amphenol connector socket on the rear of the unit, which is used as a convenient outlet for transmission testing with the No.2G repeater test set.

3.07 The secondary windings are internally connected to the amplifier.

3.08 The transformer is assembled in an aluminum case and is electromagnetically and electrostatically shielded to keep interference from adjacent equipment at a minimum.

(C) Amplifier Unit

3.09 The amplifier unit is enclosed in a small metal case which is mounted between the input transformer and the gain adjusting network, as shown in Fig. 7.

3.10 The vacuum tube is located on the front side of the assembly to permit easy replacement. The tube is a No. 407A miniature twin triode arranged with its circuit components to operate on a Class A-1 push-pull basis. Power for the plates is obtained from the +130-volt connection at the center tap of the retardation coil located in the gain adjusting network unit. The return path for this battery is via the ground at the center tap of the input transformer secondary.

3.11 The functions of the remaining amplifier elements have already been described in (D) of Part 2.

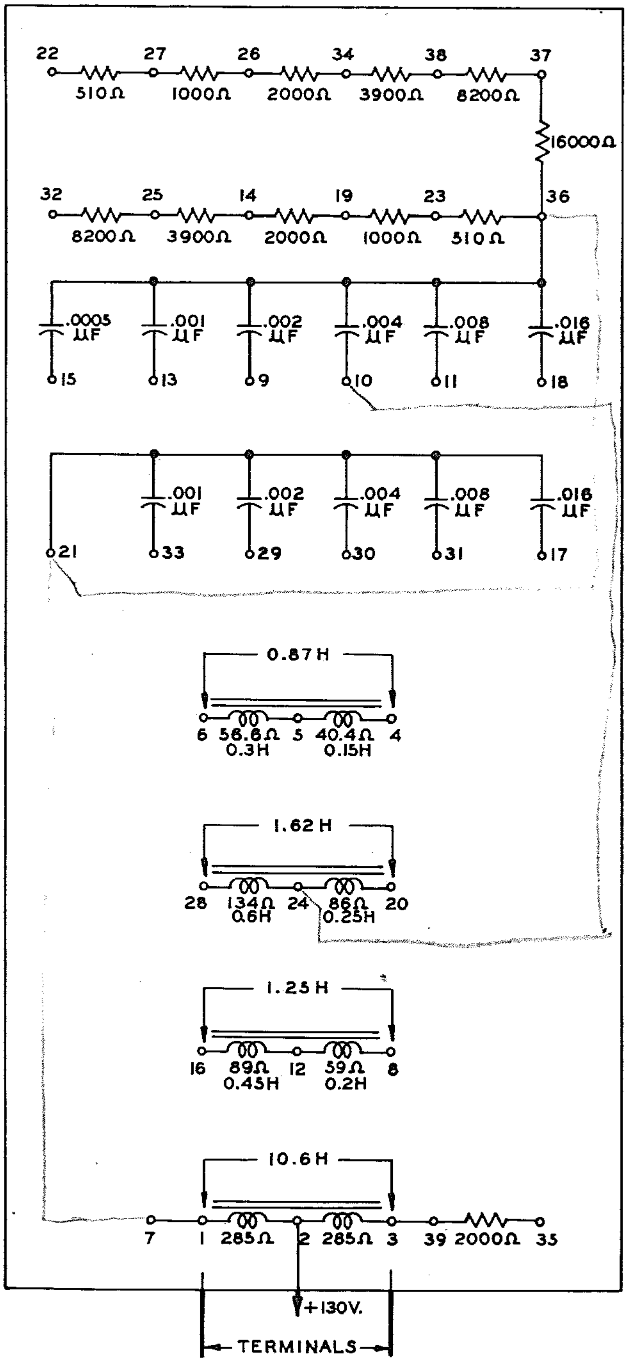


FIG. 8 - 426A GAIN ADJUSTING NETWORK ELEMENTS

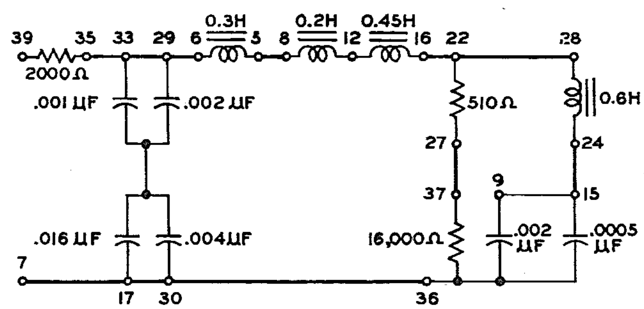
(D) Gain Adjusting Network

3.12 The gain adjusting network is coded 426A. It consists of 27 impedance elements (see Fig. 8) as follows:

12 resistors
11 capacitors
3 tapped inductances
1 plate retardation coil.

These elements are internally wired to 36 strapping terminals numbered 4 to 39 which are located (under cover) on the front side of the network as shown in Fig. 7. By choice of interconnections, the various elements can be combined to give different amounts of gain.

3.13 Fig. 9A shows schematically the strapping used to obtain a gain of 3 db for a typical trunk. Fig. 9B is a line drawing of the front view of the terminal strip showing this strapping in place.



BASIC STRAPPING: 5-8, 9-15-24, 16-22-28, 27-37
END SECTION: 6-29-33-35, 7-17-30-36
H175 LOADED 19DNB CABLE
6.5 db GAIN - 0.3 END SECTION, (CHART 16X)
HEAVY LINES ARE STRAPS

FIG. 9A - SCHEMATIC-SAMPLE NETWORK STRAPPING

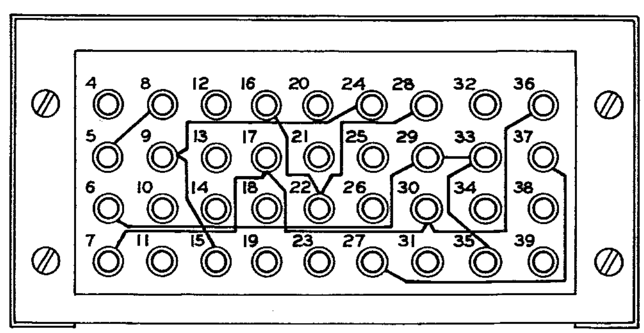


FIG. 9B - FRONT VIEW OF 426A NETWORK TERMINAL STRIP WITH SAMPLE STRAPPING

3.14 The amplifier unit is connected to the gain adjusting network by fixed wiring as follows:

(a) Terminals 1 and 3, located on the rear of the network unit, are used to connect the plates of the amplifier unit to the terminals of the plate battery supply retardation coil. These terminals are also internally wired to terminals 7 and 39 to which the variable strapping field is connected.

(b) Terminal 2, also located on the rear of the network unit, is used to connect the center tap of the retardation coil to the plate battery supply through the pin jack P+.

(E) Power Supply

3.15 Power for the vacuum tube heaters can be supplied from either 24- or 48-volt central office battery. The current drain per repeater is 100 milliamperes for 24-volt battery operation and 50 milliamperes for 48-volt battery operation. Plate power supply requires 130-volt plate supply, and the current drain is about 10.6 milliamperes per repeater.

3.16 The operating voltage for the heaters is approximately 20 volts for 24-volt central offices and 40 volts for 48-volt offices. Resistors R11, R12, R13,and R14, which are mounted on the rear of the repeater, provide graded values of resistance that can be strapped in various combinations to adjust the central office voltage to obtain the required heater voltages.

3.17 The cord tip and the pin jack shown in the +130-volt lead associated with the gain adjusting network (see Figs. 6 and 7) are provided as a safety measure for removing the plate voltage from the repeater while adjusting the network, and also for disabling the repeater to prevent oscillation during trouble conditions. They are located on the rear of the repeater mounting plate.

(F) Testing Equipment

3.18 Pin jacks for tube tests and monitoring, designated C1, P-, and C2, are located on the front of the repeater mounting plate directly below the tube socket as shown in Fig. 7 (see also Fig. 6, attached). They are for voltmeter connections to check the cathode voltages, which are a measure of plate activity. These jacks are used also for connecting a high impedance headset (about 75,000 ohms) for monitoring speech.

3.19 Four one-ohm resistors, R15, R16, R17, and R18, are connected in series with the tip and ring conductors as shown in Fig. 6. The repeater test set is bridged across these resistors to measure gain. Both sides of each resistor are connected to terminals on the amphenol test socket, designated TEST, which is located on the rear of the repeater mounting plate (see Fig. 7).

3.20 This test socket serves two purposes. It can be used to connect the No. 2G repeater test set to the repeater for lining up and measuring transmission gain without disconnecting the repeater from the trunk or line. It can also be used to remove the repeater from service by inserting a plug which short-circuits the two primary windings of the input transformer.

3.21 The network test jacks NET 1 and NET 3 are located on the rear of the repeater mounting plate (see Fig. 7) and are connected to network terminals 1 and 3 as shown in Fig. 6, attached. These jacks are used to connect the duplicate network of the No. 2G test set to the amplifier for the purpose of checking the effectiveness of the strapping specified. The method of doing this is described in Part 4, SERVICE AND MAINTENANCE FEATURES. The jacks are also used for tracing trouble.

4. SERVICE AND MAINTENANCE FEATURES

(A) General

4.01 E1 repeaters will be located in local central office buildings, and therefore will be under the service care of the local maintenance personnel.

4.02 The procedure for putting the repeaters into service is simple and there should be little, if any, maintenance required once they are properly adjusted. All tests and adjustments are made at the repeater itself. The test operations required at the distant office are simple, and consist of items such as originating calls to the repeatered office or putting terminations on trunks as requested by the test man.

4.03 Layout or assignment information is provided for the plant force on each job, which covers the instructions for putting the repeaters into service. These instructions include the trunk or line terminations to be applied, the strapping to be installed in the gain adjusting network, and the testing procedure to be followed.

(B) Network Strapping

4.04 The gain, or the return loss, applicable to each trunk or line is determined by the group responsible for layout and assignment information. The strapping of the gain adjusting network to obtain this gain is also determined by this group. The information for strapping the network may be transmitted to the plant force in different ways in different cases.

4.05 In some cases the layout or assignment information will merely list the terminals to be strapped. In other cases, charts, supplemented in some instances by additional information, will be used to indicate the strapping directions. These charts which are included in the A300 series are of three types as follows:

(a) A master chart, or key sheet, which is used to locate the charts which show network strapping for the various applications of the El repeater.

(b) X charts, which show the network strapping for repeaters associated with loaded cable facilities.

(c) A Y chart, which shows the network strapping for repeaters associated with non-loaded cable facilities.

(C) Master Chart

4.06 As shown in Fig. 10, attached, the commonly used cable facilities are listed in coordinate form, that is, across the top of the chart and also down the left-hand side. At the intersection of a vertical column designated by a given cable facility with a horizontal row designated by the same or another given facility, is found the number (1X, 1Y, 16X, etc.) of the particular chart which shows the network strapping for a repeater associated with these particular cable facilities.

4.07 The following are a few examples showing how the master chart is used.

(a) To find the chart which shows the strapping for an intermediate repeater inserted between two loaded cables, for example, a B88 loaded 19 CNB cable and an H175 loaded 19 DNB cable, we locate the horizontal row whose designation includes the B88 19 CNB cable and the vertical column designated H175 19 DNB. At their intersection we find 16X which is the number of the required chart.

(b) To find the chart which shows the strapping for an intermediate repeater located between a loaded cable, for example, a B88 19 CNB, and a non-loaded cable we locate the intersection of the horizontal row whose designation includes the B88 19 CNB with the vertical column designated Non-Loaded and find 1XY. This combination indicates that part of the strapping information on chart 1X is used as shown and that part is modified by information shown in the layout or assignment information.

(c) To find the particular chart which shows the strapping for a terminal repeater at the end of a non-loaded line, we follow the horizontal row designated Terminal Repeater to its intersection with the vertical column designated Non-Loaded and find 1Y. This is the number of the chart which shows the strapping.

4.08 The master chart is included in the A300 series for general reference purposes only.

4.09 As a matter of interest, the codes used on the master chart and the network strapping charts indicate the make-up of the cable circuits. For example, in the code H175 19 DNB:

H indicates that the loading distance of one section is 6000 feet, 175 is the inductance in millihenries and 19 is the wire gauge.

D is the issue number of the design drawing covering the physical construction of the cable.

N indicates that the dielectric strength of insulation withstands a 700-volt breakdown test, with a capacity of 0.066 microfarads per mile.

B is the original identification for the 19 gauge cable which was used before numbers were used for gauges. It is still maintained for record purposes.

4.10 Where a listing covers several types of cables such as B88 loaded 19 CNB, 22 or 24 DSM, it indicates that the three types of cable are treated alike from a strapping standpoint.

(D) X Charts

4.11 The X charts cover the network strapping for all of the types of loaded cable facilities commonly encountered in the exchange plant. These charts have been prepared from data involving desired gain, types of facilities, and other circuit considerations. Wherever possible, these charts are used for selecting the network arrangement.

4.12 In cases where these charts are used to transmit network strapping information, the layout or assignment information refers to a particular place on the particular chart where the terminals to be strapped are listed.

4.13 In some cases, the layout or assignment information will refer to the charts for part of the strapping information and will also list in detail certain modifications to fit a particular application of a repeater.

4.14 Strapping information for the following general combinations of cable facilities is covered in the X charts:

(a) Complete network strapping for terminal repeaters associated with loaded cable facilities.

(b) Complete network strapping for intermediate repeaters inserted between loaded cable facilities.

(c) Partial network strapping for intermediate repeaters inserted between loaded and non-loaded cable facilities. (The remainder of the strapping is given in detail in the layout and assignment information.)

4.15 Figs. 11 and 12, attached, show portions of two charts, 1X and 16X, the former for a B88 loaded 19 CNB, 22, or 24 DSM cable and the latter for H175 loaded 19 DNB cable facilities. Referring to these figures, column 1, designated Normal Gain, applies to (a) and (b) above, while column 2 applies to (c).

4.16 For repeater applications falling in classifications (a) and (b), the layout or assignment information will usually specify the number of the X chart, the Nominal Gain in decibels (column 1), and the equivalent end section for network strapping purposes. Opposite the Nominal Gain, under the headings Basic Strapping and Supplemental Strapping, are shown the terminals to be strapped.

4.17 Fig. 9A (Par. 3.13) shows schematically the strapping of the network for an intermediate repeater inserted between two H175 loaded 19 DNB cable circuits with an equivalent end section of 0.3 and a gain of 6.5 db.

4.18 <u>Basic strapping</u> covers all of the trunk (or line) and its loading up to and including the loading nearest the repeater.

4.19 <u>Supplemental strapping</u> for the end sections covers a variable trunk length from the first loading point to the repeater location. A 0.3 section is the smallest section covered in the charts. In certain cases where the end section is less than 0.3, it may be desirable to bridge a capacitor (referred to as a building-out capacitor) across the tip and ring conductors to build out the total end section capacitance to a different value to obtain increased gain. The layout or assignment information will specify these additional capacitors when they are required.

4.20 In all cases, both the basic and supplemental strapping shown on the X charts must be installed to complete the network circuit.

4.21 For repeater installations falling in class (c), Par. 4.14 (where a repeater is inserted between loaded and non-loaded cable facilities), the number of the X chart, the return loss in db (column 2) and the end section will be specified.

4.22 The supplemental strapping is made as shown on the chart. However, the basic strapping applies only to the loaded cable and it must be modified (as mentioned in example (b) under Master Charts, Par. 4.07), as specified in the layout and assignment information, to provide for the resistance of the non-loaded cable circuit.

<u>(E) Y Chart</u>

4.23 The Y chart covers the network strapping for terminal repeaters associated with non-loaded cable facilities and for intermediate repeaters inserted between non-loaded cable facilities.

4.24 In this chart (see Fig. 13, attached) the loop resistances of the cables are shown in column 1, and the corresponding terminals to be strapped in columns 2 and 3.

4.25 For intermediate repeaters inserted between non-loaded cable facilities, the layout or assignment information specifies the chart designation and the type and resistance of each of the cables. The terminals to be strapped are shown in columns 2 and 3. In all cases of this type, both sets of strapping must be installed to complete the network circuit.

4.26 The following two examples illustrate the use of this chart for intermediate repeaters.

(a) Assume both cables to be type 19 CNB and that the resistance of one cable is 230 ohms and that of the other 360 ohms. In this case the strapping in column 2 opposite the resistance range of 225 to 350 ohms and the strapping in column 3 opposite the resistance range of 351 to 480 ohms would be used (both under cable type 19 CNB).

(b) Assume one cable to be type 19 CNB with a resistance of 360 ohms and the other type 22 BSA with a resistance of 690 ohms. In this case the strapping in column 2 opposite the resistance range of 350 to 480 ohms under cable type 19 CNB, and the strapping in column 3 opposite the resistance range 671 and up, under cable type 22 BSA, would be used.

4.27 For terminal repeaters the chart designation, the type of cable, and the resistance of the cable loop are specified. The terminals to be strapped are shown in column 2 under the type of cable and opposite the range of resistance values which include the specified resistance. The strapping shown in column 3 is not used on terminal repeaters and therefore terminals 35 and 36 must be strapped to complete the network circuit.

(F) Uses of X and Y Charts

4.28 The X and Y charts, in addition to their use to transmit predetermined network strapping arrangements, will also be of advantage where it is necessary to adjust the strapping for various reasons such as insufficient gain, singing, etc. In such cases the layout and assignment group can transmit information over the telephone for making network changes by referring to the charts; for example, by specifying the strapping opposite a lower gain or a different end section strapping. This method is of course more efficient than transmitting in detail a large number of different sets of terminals to be strapped.

(G) Putting Repeaters Into Service

General

4.29 The following discussion gives a general picture of the procedures which are followed in putting a repeater into service. There are two testing procedures, one of which is relatively simple and does not require the repeater test set, while the other is more extensive and makes use of the test set. The procedure to be used is specified in the layout or assignment information.

4.30 The following description is for general information only. The detailed procedures for both methods are covered in the A300 series.

4.31 Because of the presence of 130-volt potential, care must be exercised when working on the repeater.

Simplified Procedure (Without Repeater Test Set)

4.32 In general, where the network strapping is taken from the charts included in the A300 series, the repeater can be put into service without gain measurement or adjustment of the network, and therefore the simplified test procedure is used.

This procedure is usually followed where:

(a) The most commonly encountered types of loaded cable facilities are used, the trunks or lines are uniform, and the same general type of loading is used throughout.

(b) Experience with other identical circuits has shown the network strapping to be satisfactory. For example, this method can be used to put repeaters into service on a group of trunks having the same cable facilities if one or two of the first applications have been checked by the procedure using the repeater test set.

4.33 Test Equipment: With the simplified procedure the following equipment is required for putting the repeaters into service. This equipment is also used for general and trouble maintenance.

(a) A vacuum tube voltmeter RCA Volt Ohmyst Jr., or a Weston Analyzer (20,000 ohms per volt), or an equivalent high impedance voltmeter.

(b) A high impedance (75,000 ohms) headset.

(c) Miscellaneous items, such as test resistors, cords, and plugs for connecting the instruments, etc.

4.34 Procedure: The following steps are involved in putting the repeater into service:

(a) The repeater is cross-connected to the assigned trunk or line (heat coils are removed at distant end).

The pair of terminals at the connecting block for the trunk or line extending in one direction may be designated 1 and 4 or merely IN. The pair of terminals for the trunk or line extending in the other direction may be designated 2 and 3 or merely OUT. The repeater is symmetrical in that either pair of terminals may be connected to the trunk or line in either direction.

(b) Power is connected to the repeater.

(c) D-c voltages are measured.

These measurements are made between each of the two cathodes and ground, with the gain adjusting network short-circuited.

(d) +130-volt battery is disconnected from P+ jack.

(e) The network is strapped.

(f) +130-volt battery is connected to P+ jack.

(g) The stability check is made.

The purpose of this check is to make sure that there is a margin between the maximum gain provided by the repeater and its singing point. The network impedance has been calculated to provide a margin of about ten per cent. To check this margin, the high impedance headset is bridged across the secondary winding of the input transformer. The impedance of the headset is such that, on the average, it reduces the calculated ten per cent margin to five per cent. Thus if the actual margin is less than five per cent, singing occurs when the monitoring set is connected.

For terminal repeaters the check for stability is made with a 100-ohm resistance across the tip and ring conductors at the office where the repeater is located, in place of the trunk or line equipment, and with the far end of the trunk or line open, unless some other termination is specified in the layout or assignment information.

For intermediate repeaters the stability check is made with the trunks or lines open at the far ends, unless some other termination is specified.

If the repeater sings when the monitoring headset is connected, the test man reports the condition to the group responsible for layout or assignment information, who generally specify a changed strapping for a slightly lower gain, or change the value of the capacitor in the end section strapping.

(h) On terminal repeaters connection is made to the assigned trunk or line relay equipment at the repeatered office; on intermediate repeaters the connection is made at the distant office (heat coils in place).

(i) A test call is made.

A routine test call is made on the trunk or line, employing the signaling means and associated circuits which the line will normally use. The call is terminated at a subscriber station in the distant office.

The test man monitors the repeater during the test call to make sure that:

(1) The correct number is reached.

(2) The talking connection sounds satisfactory.

(3) Repeater singing does not occur.

4.35 If the preceding tests have met the requirements, the line or trunk can be turned over for service.

Procedure Using the Repeater Test Set

4.36 This procedure is usually followed where:

(a) A large percentage of mixed facilities is used. This is usually the case with special service lines.

(b) One or both of the end sections fall outside the limits of the 0.3 to 1.2 end sections shown on the charts.

(c) Trouble has been experienced on a repeater tested with the simplified test procedure.

(d) A large group of trunks is involved and it is desired to confirm the network strapping before all repeaters are placed into service.

(e) Certain central office equipment, such as a long line circuit, is connected between the repeater and the trunk.

(f) The group responsible for layout or assignment information desire a measurement of the actual insertion gain.

4.37 Test Equipment: With the test set method the following equipment is required in addition to that required for the simplified method:

(a) The 2G repeater test set.

(b) An oscillator of the Hewlett-Packard 200 series or a 19C oscillator, or equivalent.

(c) A No. 2A or 2B noise measuring set with a monitoring receiver or a No. 400C Hewlett-Packard vacuum tube voltmeter equipped with a No. 509 type headphone or any other high impedance receiver.

(d) Plugs and cords for connecting the oscillator and noise measuring set to the repeater test set.

4.38 The 2G repeater test set (shown in Fig. 14) provides a duplicate network which can be substituted for the repeater network. Network adjustments involve setting up a trial network and making minor changes, if necessary, until gain measurements and stability tests indicate that a satisfactory network has been obtained.

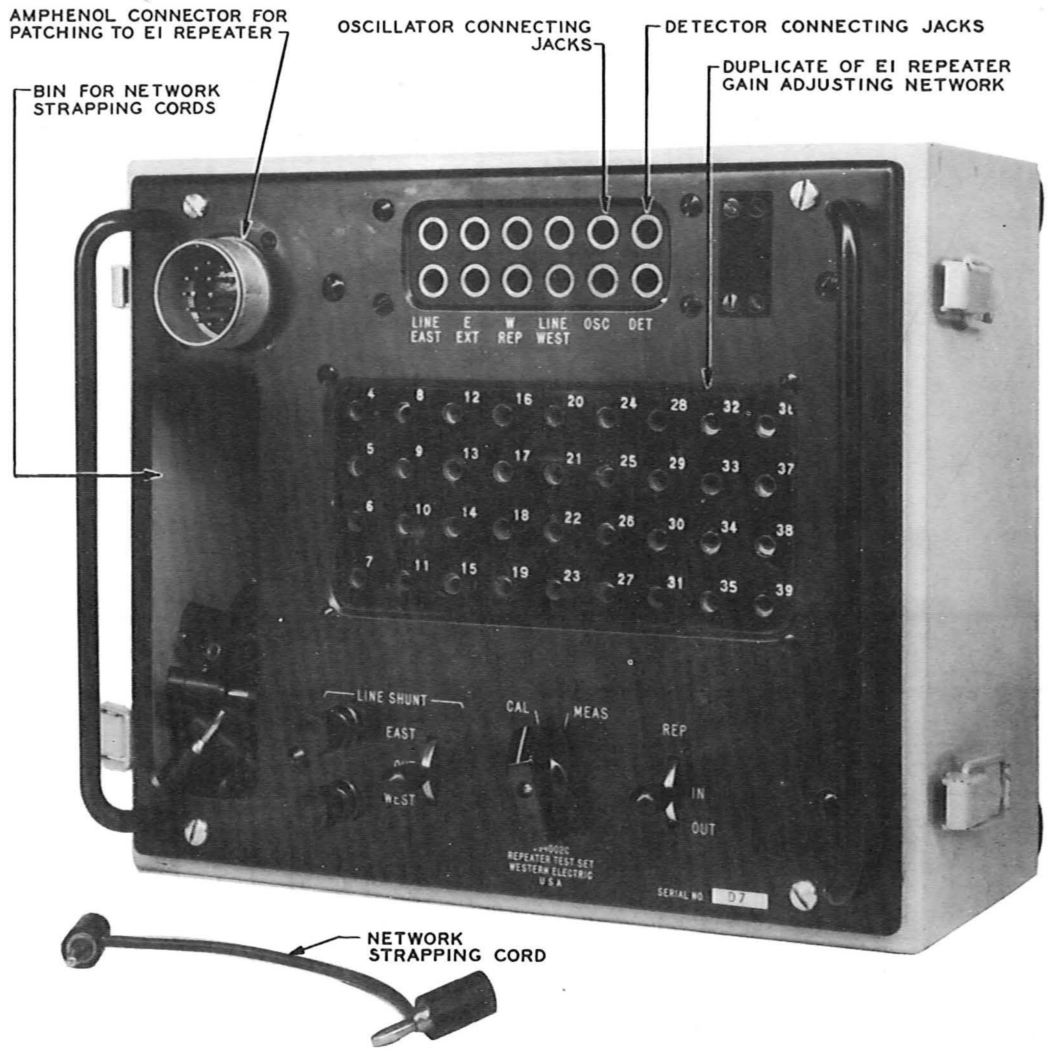


FIG. 14 - NO. 2G REPEATER TEST SET

4.39 The test set also provides means for making transmission measurements of the actual gain of the repeater when it is inserted in a working trunk or line. For this purpose the oscillator and noise measuring set (or vacuum tube voltmeter) are used.

4.40 The Hewlett-Packard oscillator is preferable to the 19C oscillator because it provides much higher output levels. Test readings made at high levels are less apt to be affected by noise.

4.41 Procedure: The test set method of putting the repeater into service includes the following steps:

Steps (a) to (d) are the same as for the simplified procedure (Par. 4.34).

(e) The test set is connected to the repeater.

The 2G test set is connected as shown in Fig. 15. The trial network on the face of the test set (or the repeater network) is strapped in accordance with instructions in the layout or assignment information.

(The following description assumes that the test set network is to be strapped before strapping the repeater network. The general procedure is much the same when the repeater network is strapped initially.)

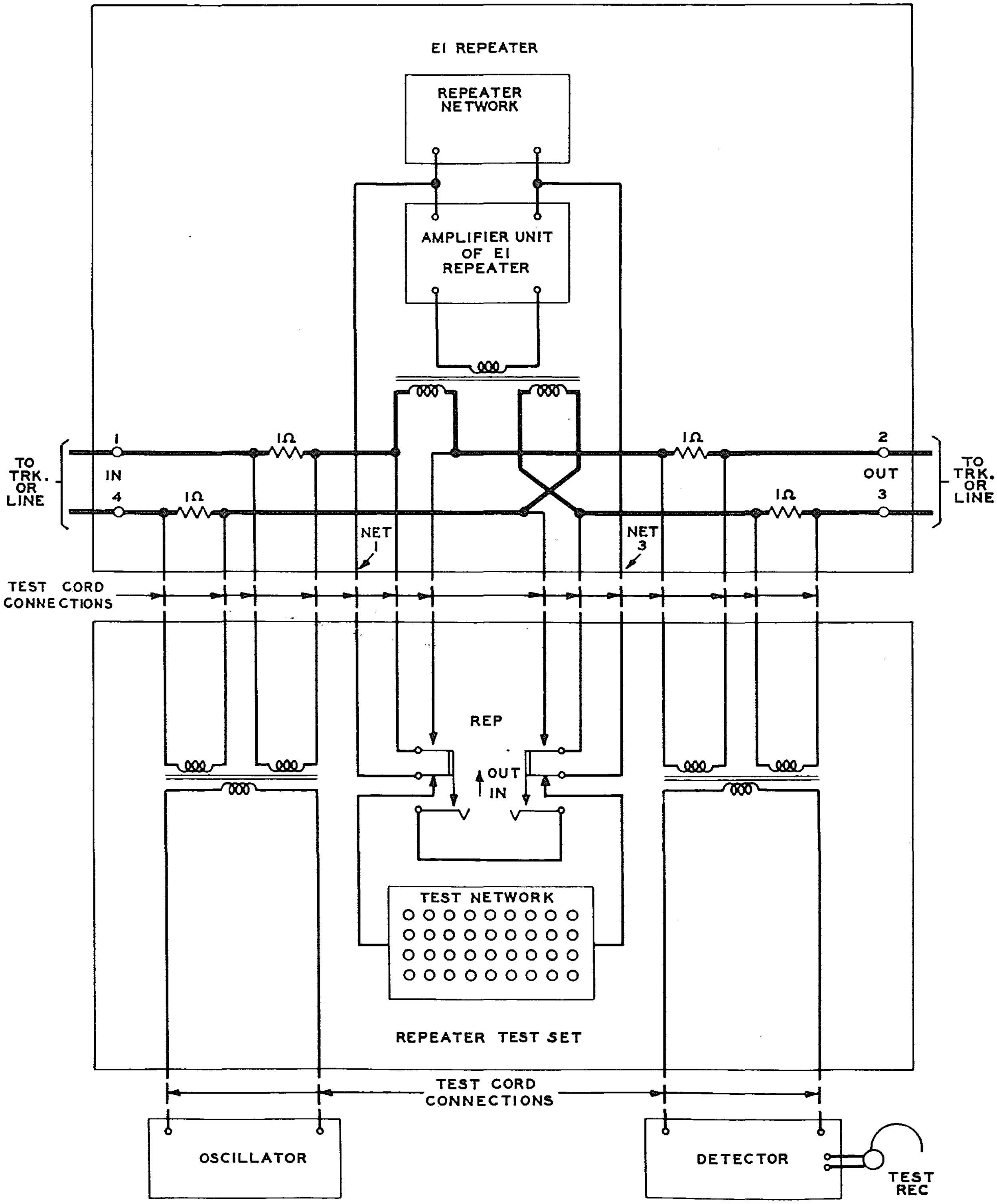


FIG. 15 - NO. 2G REPEATER TEST SET CONNECTED TO EI REPEATER

(f) +130-volt battery is connected to P+ jack.

(g) The stability check is made.

The stability check is made with the trunk or line terminations as described in step (g) under Simplified Procedure. The test connections and details of the test are covered in the A300 series.

The stability of the repeater is checked by two tests. The first is to listen for singing with the monitoring receiver connected to the noise measuring set or the vacuum tube voltmeter. The oscillator is not connected to the repeater test set while monitoring so that any tone heard will be coming from the repeater.

If the repeater does not sing, the second test is made in which the oscillator is connected and its control slowly rotated over the range of frequencies from 100 to 6000 cycles. The test man checks that the gain of the repeater does not exceed 20 db at any frequency. This measurement of gain is made to determine whether there is sufficient margin against singing.

If singing occurs or the gain exceeds 20 db, the layout or assignment group is notified. They specify another network strapping and the stability test is repeated.

(h) Gain is measured.

A regular or simulated talking connection is set up for this test in order to permit gain measurements of the repeater with actual terminations and other conditions which occur during a normal service connection. If a regular talking connection is set up, connection is made to the assigned trunk or line relay equipment (heat coils in place) at this time. If a simulated talking connection is set up (which might be necessary if the assigned trunk is one to an intercept or information operator) connection is not made until step (j), and spare trunk relay equipment is used. In either case, regular or simulated, the trunk or line is terminated at each end in a subset with the receiver off the switchhook. However, if room noise interferes with the test a 900-ohm resistor can be bridged across the tip and ring at each end, in which case the receivers are replaced on the switchhooks.

As previously stated, repeater gains vary with frequency. The values of gain, especially those measured on a loaded trunk, when plotted against frequency appear as a series of peaks and valleys which vary in magnitude at different frequencies. However, for loaded facilities or combinations of loaded and non-loaded facilities, the gain is taken as the average of the maximum gain (gain peak) and the minimum gain (gain valley) nearest to and preferably on opposite sides of 1400 cycles.

In making this measurement the frequency control of the oscillator is slowly rotated from about 900 to about 1900 cycles. The highest gain reading and the lowest gain reading nearest to 1400 cycles are recorded.

For non-loaded facilities the frequency control is rotated from 500 cycles to 3500 cycles and gain readings are taken and recorded at each 500 point, that is, 500, 1000, etc. The gain is taken as the average of these readings.

(i) The repeater network is strapped.

Following the above measurements the regular repeater network is strapped in the repeater in place of the test set trial network and the gain measurements are made again. If these measurements verify those made with the trial network, the equipment is ready for a test call.

(j) A connection is made to the assigned trunk or line relay equipment if the gain measurement was made over a simulated connection. (Heat coils in place.)

(k) A test call is made.

The test call is made with the same setup as is used for gain measurement. While the test call is being made, the repeater is monitored to make sure that:

(1) The right number is reached.

(2) The parties at both ends appear to have a satisfactory talking connection.

(3) Repeater singing does not occur.

If no singing or other trouble occurs, the trunk or line can be turned over for service.

Routine Maintenance Tests

4.42 Routine maintenance of the repeater is rather simple. The input transformer and the gain adjusting network require none. The amplifier requires only visual inspection of the vacuum tube and occasional measurement of cathode voltages.

4.43 Test calls or other tests which are normally made on trunks and telephone circuits as a routine procedure can also be made on the lines or trunks to which repeaters are applied.

4.44 Detailed procedures for making routine tests are covered in the A200 series.

Trouble Maintenance

4.45 Detailed procedures for taking the repeater out of service and for tracing troubles will be covered in the A300 series.

4.46 Because of the simplicity of the repeater, there should be few trouble conditions encountered in it, other than vacuum tube or power failures. Many of the trouble conditions will be due to irregularity in the trunk or line with which it is associated. Ordinarily, improper operation on a repeatered trunk or line will be indicated by either poor transmission or singing.

4.47 The repeater design is such that d-c continuity of the line or trunk is maintained, and therefore regular testing procedures can be followed in locating troubles such as shorts, opens, grounds, and low frequency signaling faults.

4.48 For ordinary trouble maintenance, the repeater should not be disabled but should be operating with its normal connection to the line or trunk. This simplifies the locating of most repeater troubles.

4.49 In cases of poor transmission, that is, where subscribers have difficulty in hearing each other, the usual cause is that the repeater has failed internally and as a result is giving inadequate transmission gain, or possibly a loss. This may occur without affecting the d-c continuity of the line or impairing signaling and supervision. The most likely causes of such trouble are vacuum tube failures and power supply failures. These can be easily checked and corrected.

4.50 A singing condition in the repeater is usually indicated by an audible tone on the circuit. Singing may be continuous on the line, idle or occupied, or it may occur only during certain stages such as when pulsing or ringing signals are transmitted, or when some particular type of connection is made. Singing may be caused by a change in assignment of the line or trunk, trouble in the line or trunk, or trouble in the repeater

4.51 Trouble in the repeater is the least likely cause of singing. The first check in case of singing should be to determine whether the line or trunk has been changed since the repeater was connected. Even an apparently minor change, such as substituting one pair for another in the same cable, may cause the trouble because of a loading irregularity in the new pair.

4.52 The next check should generally be to determine whether a trouble condition exists on the line or trunk. This should be done by using regular central office test board procedures for locating trouble conditions. A short or open circuit, or a bridged connection of a monitoring or test device at any point on the line where such conditions do not normally exist when the line is in use, may cause the repeater to sing.

4.53 If the preceding checks show that no irregularity exists in the line or trunk, the repeater should be checked.

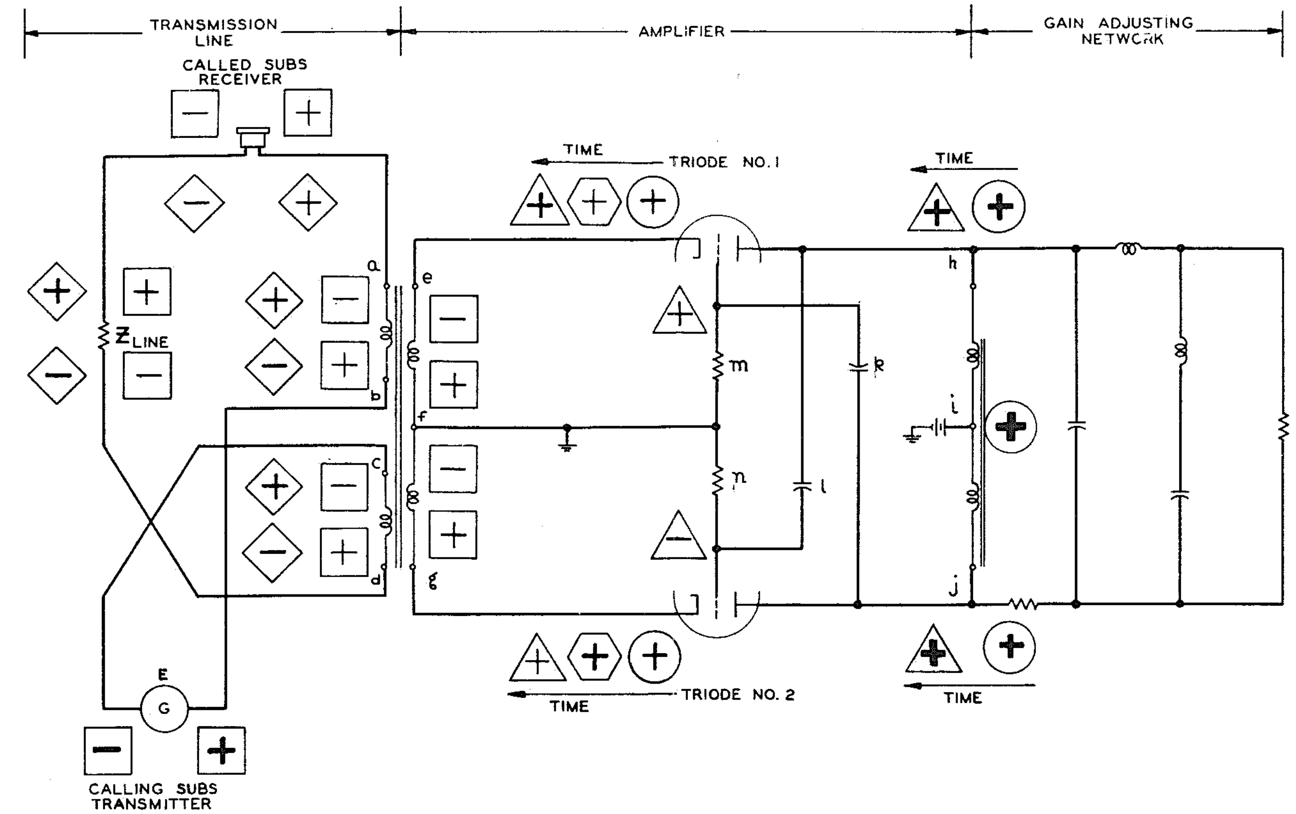
4.54 Procedures for checking the repeater may include monitoring, measurement of heater, plate and cathode voltages, and detailed inspection of the wiring of the repeater. Where the repeater test set is available, a gain check may also be required.

5. REFERENCE LIST OF BSP'S, CD'S, SD'S, AND ED'S

Section A204.486	Tests and Inspection
Section A304.486	Standard Strapping for Gain Adjusting Network
Section A304.487	Putting Repeater into Service
Section A304.488	Analysis of Trouble and Taking Repeater Out of Service
Section A702.604	Description of No. 2G Repeater Test Set
Section AA636.419	Performance Requirements
Circuit Description CD-95134-01	- 2G Repeater Test Set
Circuit Description CD-95465-01	- E1 Repeater
Schematic Drawing SD-95465-01	- E1 Repeater
Equipment Drawing ED-92200-01	- E1 Repeater Equipment Arrangements

Bell Telephone Laboratories, Inc.

6 Attachments -
Figs. 5A and 5B, 6, 10, 11, 12, and 13.

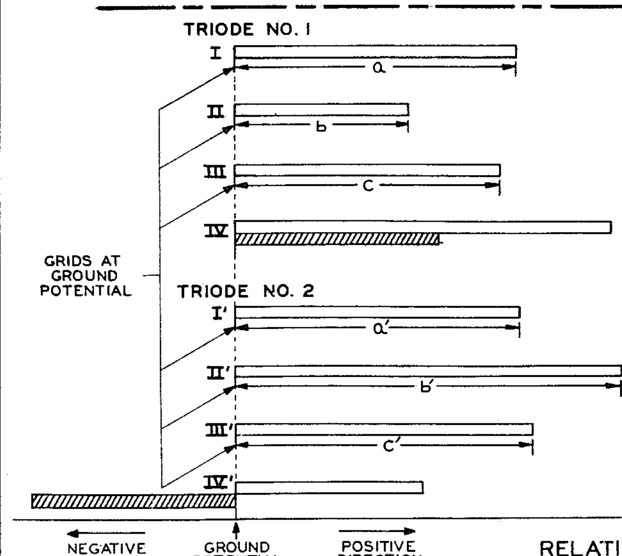


RELATIVE HEAVINESS OF PLUS AND MINUS SIGNS INDICATES RELATIVE MAGNITUDES OF VOLTAGES AT EACH STEP

- (circle) POLARITIES–STATIC CONDITION
- (square) POLARITIES–SIGNAL APPLIED
- (hexagon) POLARITIES OF CATHODES AS RESULT OF SIGNAL
- (triangle) POLARITIES OF CATHODES AND GRIDS DUE TO CURRENT CHANGES IN TRIODES
- (diamond) POLARITIES OF AMPLIFIED VOLTAGES

E = A-C VOICE FREQUENCY VOLTAGE

FIG. 5A
OPERATIONAL SCHEMATIC



NOTES:

I AND I'	POTENTIALS DURING STATIC CONDITION.
II AND II'	POTENTIALS AT TIME INPUT SIGNAL IS APPLIED BUT BEFORE THE CURRENTS IN THE TRIODES CHANGE.
III AND III'	POTENTIALS AFTER THE CURRENTS IN THE TRIODES CHANGE–WITHOUT THE EFFECT OF THE FEEDBACK CAPACITORS.
IV AND IV'	POTENTIALS AFTER THE CURRENTS IN THE TRIODES CHANGE–WITH THE EFFECT OF THE FEEDBACK CAPACITORS.

LEGEND:

- CATHODE
- GRID

FIG. 5B
RELATIVE CATHODE AND GRID POTENTIALS

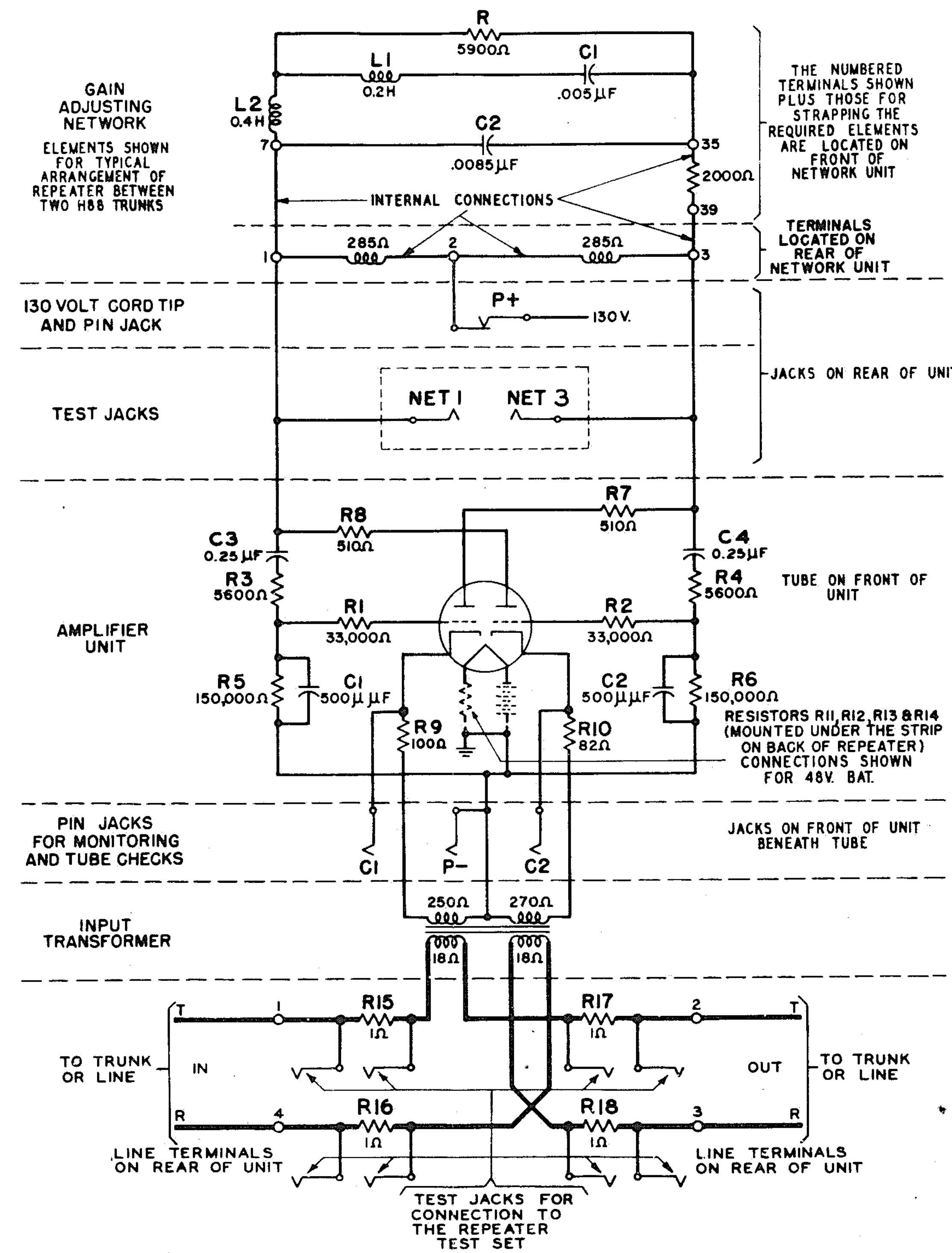


FIG. 6
SCHEMATIC
SHOWING ELEMENTS
OF E1 REPEATER

MASTER CHART

FOR USE IN SELECTING NETWORK STRAPPING CHART

Facility On One Side of Repeater → / Facility On Other Side of Repeater ↓		Non-Loadedø	B88		D88		H88		M88	B135		D135		H135		B175	D175	H175
			19 CNB 22 24 DSM	19 DNB 24 CSM*	19 CNB 22 24 DSM	19 DNB 24 CSM*	19 CNB 22 24 DSM	19 DNB 24 CSM*	19 DNB	19 CNB 22	19 DNB	19 CNB 22	19 DNB	19 CNB 22	19 DNB	19 DNB	19 DNB	19 DNB
None (Terminal Rptr)		1Y	1X	2X	3X	4X	5X	6X	7X	8X	9X	10X	11X	12X	13X	14X	15X	16X
Non-Loadedø		1Y	1XY	2XY	3XY	4XY	5XY	6XY	7XY	8XY	9XY	10XY	11XY	12XY	13XY	14XY	15XY	16XY
B88	19 CNB 22 24 DSM	1XY	1X	1X	3X	4X	5X	6X	7X	8X	9X	10X	11X	12X	13X	14X	15X	16X
	19 DNB 24 CSM*	2XY	1X	2X	3X	4X	5X	6X	7X	8X	9X	10X	11X	12X	13X	14X	15X	16X
D88	19 CNB 22 24 DSM	3XY	3X	3X	3X	3X	5X	6X	7X	8X	3X	10X	11X	12X	13X	14X	15X	16X
	19 DNB 24 CSM*	4XY	4X	4X	3X	4X	5X	6X	7X	8X	9X	10X	11X	12X	13X	14X	15X	16X
H88	19 CNB 22 24 DSM	5XY	5X	5X	5X	5X	5X	5X	7X	5X	5X	10X	5X	12X	13X	5X	15X	16X
	19 DNB 24 CSM*	6XY	6X	6X	6X	6X	5X	6X	7X	6X	6X	10X	11X	12X	13X	6X	15X	16X
M88	19 DNB	7XY	7X	7X	7X	7X	7X	7X	7X	7X	7X	7X	7X	12X	13X	7X	7X	16X
B135	19 CNB 22	8XY	8X	8X	8X	8X	5X	6X	7X	8X	8X	10X	11X	12X	13X	14X	15X	16X
	19 DNB	9XY	9X	9X	3X	9X	5X	6X	7X	8X	9X	10X	11X	12X	13X	14X	15X	16X
D135	19 CNB 22	10XY	10X	10X	10X	10X	10X	10X	7X	10X	10X	10X	10X	12X	13X	10X	15X	16X
	19 DNB	11XY	11X	11X	11X	11X	5X	11X	7X	11X	11X	10X	11X	12X	13X	11X	15X	16X
H135	19 CNB 22	12XY	12X	12X	12X	12X	12X	12X	12X	12X	12X	12X	12X	12X	12X	12X	12X	16X
	19 DNB	13XY	13X	13X	13X	13X	13X	13X	13X	13X	13X	13X	13X	12X	13X	13X	13X	16X
B175	19 DNB	14XY	14X	14X	14X	14X	5X	6X	7X	14X	14X	10X	11X	12X	13X	14X	15X	16X
D175	19 DNB	15XY	15X	15X	15X	15X	15X	15X	7X	15X	15X	15X	15X	12X	13X	15X	15X	16X
H175	19 DNB	16XY	16X	16X	16X	16X	16X	16X	16X	16X	16X	16X	16X	16X	16X	16X	16X	16X

* 24 CSM and 24 ASM are identical for network determination. Assume 24 DSM unless the 24 gauge is known to be 24 CSM or 24 ASM.

ø XY preceded by a number means that the X chart of that number is used with a modification which is to be designated in the layout or assignment information.

FIG. 10
MASTER CHART

CHART 1X

FOR B88 LOADED 19 CNB, 22, 24 DSM CABLE

1	2	3	4			
			Supplemental Strapping			
Nominal Gain DB	Return Loss DB	Basic Strapping	Sect.	Terminal Numbers	Sect.	Terminal Numbers
1.5	6	(4-8-20-25) (5-10-15-24) (7-14-21-36)	.3	(12-29-30-35)	.8	(12-29-30-31-33-35)
			.4	(12-29-30-33-35)	.9	(12-17-35)
			.5	(12-31-33-35)	1.0	(12-17-29-35)
			.6	(12-29-31-33-35)	1.1	(12-17-30-35)
			.7	(12-30-31-33-35)	1.2	(12-17-29-30-35)
2.0	9	(4-9-13) (5-20-25) (7-21-36) (14-19)	.3	(24-30-35)	.8	(15-24-29-31-35)
			.4	(15-24-30-33-35)	.9	(24-30-31-35)
			.5	(15-24-29-30-35)	1.0	(24-30-31-33-35)
			.6	(24-31-35)	1.1	(15-24-29-30-31-35)
			.7	(24-31-33-35)	1.2	(15-24-29-30-31-33-35)
2.5	11	(6-8-25-28) (7-21-36) (9-12-15-24) (19-23)	.3	(5-29-33-35)	.8	(5-31-35)
			.4	(5-30-35)	.9	(5-31-33-35)
			.5	(5-30-33-35)	1.0	(5-29-31-35)
			.6	(5-29-30-35)	1.1	(5-29-31-33-35)
			.7	(5-29-30-33-35)	1.2	(5-30-31-35)
3.0	14	(4-8-24-32) (7-21-25-36) (9-12)	.3	(6-15-28-29-35)	.8	(6-15-28-29-30-35)
			.4	(6-15-28-29-33-35)	.9	(6-15-28-29-30-33-35)
			.5	(6-28-30-35)	1.0	(6-28-31-35)
			.6	(6-28-30-33-35)	1.1	(6-28-31-33-35)
			.7	(6-15-28-30-33-35)	1.2	(6-15-28-31-33-35)
3.5	16	(4-8-32) (5-20) (7-21-36) (9-12) (23-25)	.3	(15-24-29-35)	.8	(15-24-29-30-35)
			.4	(15-24-29-33-35)	.9	(15-24-29-30-33-35)
			.5	(24-30-35)	1.0	(24-31-35)
			.6	(24-30-33-35)	1.1	(24-31-33-35)
			.7	(15-24-30-33-35)	1.2	(15-24-31-33-35)
4.0	20	(7-19-21-36) (14-25) (16-20-32) (24-29)	.3	(9-12-35)	.8	(10-12-13-15-35)
			.4	(9-12-13-35)	.9	(9-10-12-15-35)
			.5	(9-12-13-15-35)	1.0	(9-10-12-13-35)
			.6	(10-12-35)	1.1	(9-10-12-13-15-35)
			.7	(10-12-13-35)	1.2	(11-12-15-35)

FIG. 11
PORTION OF CHART IX

CHART 16X (CONTINUED)

1	2	3	4			
			Supplemental Strapping			
Nominal Gain DB	Return Loss DB	Basic Strapping	Sect.	Terminal Numbers	Sect.	Terminal Numbers
6.5	-	(5-8) (9-15-24) (16-22-28) (27-37)	.3	(6-29-33-35) (7-17-30-36)	.8	(6-30-31-35) (7-17-36)
			.4	(6-29-30-35) (7-31-36)	.9	(6-29-30-31-33-35) (7-17-36)
			.5	(6-29-30-35) (7-17-36)	1.0	(6-31-33-35) (7-21-36)
			.6	(6-31-35) (7-17-36)	1.1	~~(6-29-31-35)~~ 6-31-33-35, see add. (7-21-36)
			.7	(6-29-30-35) (7-21-36)	1.2	(6-29-31-35) (7-21-36)
7.0	-	(5-12) (6-29-33) (7-31-36) (16-26-28) (34-37)	.3	(9-20-35)	.8	(9-10-20-35)
			.4	(9-13-20-35)	.9	(9-10-15-20-35)
			.5	(10-20-35)	1.0	(9-10-13-15-20-35)
			.6	(10-15-20-35)	1.1	(11-15-20-35)
			.7	(10-13-20-35)	1.2	(11-13-20-35)
7.5	-	(4-20-22) (6-9) (26-27) (34-37)	.3	(7-31-36) (28-29-33-35)	.8	(7-17-36) (28-31-33-35)
			.4	(7-29-31-36) (28-30-35)	.9	(7-17-33-36) (28-29-31-35)
			.5	(7-21-36) (15-28-29-33-35)	1.0	(7-21-36) (28-29-30-33-35)
			.6	(7-17-36) (28-29-30-35)	1.1	(7-17-36) (28-29-30-31-33-35)
			.7	(7-17-36) (28-29-30-33-35)	1.2	(7-21-36) (15-28-31-35)
8.0	-	(4-8-22) (6-9) (12-20) (34-37)	.3	(7-30-31-36) (28-29-33-35)	.8	(7-17-33-36) (28-29-31-35)
			.4	(7-17-36) (28-30-35)	.9	~~(7-21-36)~~ ~~(28-29-30-33-35)~~ see add.
			.5	(7-17-36) (28-30-33-35)	1.0	(7-17-36) ~~(28-29-30-31-33-35)~~ see add.
			.6	(7-17-36) (28-29-30-33-35)	1.1	(7-21-36) ~~(15-28-31-35)~~ see add.
			.7	(7-17-31-36) (28-29-30-33-35)	1.2	(7-21-36) ~~(15-31-33-35)~~ see add.

FIG. 12
PORTION OF CHART 16X

CHART 1Y

FOR 19 CNB OR 19 DNB CABLE		
1	2	3
	Strapping	
Resistance Ohms	Terminal Numbers	Terminal Numbers
225 to 350	(7-9-11-18-22) (26-36)	(17-19-29-31-35) (21-36)
351 to 480	(7-9-11-18-26) (34-36)	(14-17-29-31-35) (19-21-36)
481 to 650	(7-9-11-18-22) (26-27) (34-36)	(14-17-29-31-35) (19-23) (21-36)
651 to 800	(7-9-11-18-27) (34-36)	(14-17-29-31-35) (21-23-36)
801 and Up	(7-9-11-18-22) (34-36)	(14-17-29-31-35) (21-36)

FOR 24 CSM OR 24 DSM CABLE		
1	2	3
	Strapping	
Resistance Ohms	Terminal Numbers	Terminal Numbers
400 to 460	(7-22) (9-18-26-27) (34-36)	(14-17-29-35 (19-21-23)
461 to 580	(7-22) (9-18-27) (34-36)	(14-17-29-35) (21-23)
581 to 700	(7-22) (9-18-27-34) (36-38)	(14-21-23) (17-25-29-35)
701 to 840	(7-22) (9-18-27) (26-34) (36-38)	(14-19) (21-23) (17-25-29-35)
841 to 1200	(7-22) (9-18-26-27) (36-38)	(17-25-29-35) (19-21-23)
1201 and Up	(7-22) (9-18-27) (36-38)	(17-25-29-35) (21-23)

FOR 22 BSA OR 22 CSA CABLE		
1	2	3
	Strapping	
Resistance Ohms	Terminal Numbers	Terminal Numbers
330 to 430	(7-22) (11-18-26-27) (34-36)	(14-17-31-35) (19-21-23)
431 to 550	(7-22) (11-18-27) (34-36)	(14-17-31-35) (21-23)
551 to 670	(7-22) (11-18-27-34) (36-38)	(14-21-23) (17-25-31-35)
671 and Up	(7-22) (11-18-27) (26-34) (36-38)	(14-19) (21-23) (17-25-31-35)

FOR 26 AST OR 26 BST CABLE		
1	2	3
	Strapping	
Resistance Ohms	Terminal Numbers	Terminal Numbers
550 to 650	(7-22) see ~~(9-10-27-34)~~ (36-38) add.	(14-21-23) (25-29-31-35)
651 to 920	(7-22) ~~(9-10-27)~~ see (26-34) add. (36-38)	(14-19) (21-23) (25-29-31-35)
921 to 1100	(7-22) see ~~(9-10-26-27)~~ (36-38) add.	(19-21-23) (25-29-31-35)
~~1101 to 11~~30 see add.	(7-22) (9-10-13-27) (36-38)	(21-23) ~~(25-29-31-~~35) see add.
1301 and Up	(7-22) (9-10-13-27-38) (36-37)	(21-23-25) ~~(29-31-32-35)~~ see add

FIG. 13
CHART 1Y