Western Electric

V1 TELEPHONE REPEATER
A-C OPERATED

Instruction Bulletin No. 1053

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V1 TELEPHONE REPEATER A-C OPERATED

INTRODUCTION

General

The Western Electric a-c operated V1 Telephone Repeater and associated equipment fills a requirement for telephone companies where a small number of repeaters are to be used for toll lines. This equipment also fills requirements for railroads and pipe line companies for trunk line or dispatch purposes.

When used as a toll line or trunk repeater, it may be equipped for various kinds of signaling (20, 135, or 1000 cycles) and may be operated on the same circuit with a telegraph channel when the necessary composite set is used. It is provided with precision line balancing networks for use with uniform lines, or adjustable networks for use with lines having non-uniform impedance characteristics.

When used as a dispatch repeater, it is equipped with a by-pass for the 3½-cycle signals of the train dispatching equipment and is not arranged for operation with telegraph or on a phantom group basis. The dispatch repeater is limited to open wire use. Adjustable line-balancing networks are always furnished with dispatch repeaters because the impedance characteristics of the line change as the number of way station subsets connected to the line changes. An approximate balance is all that can be obtained under these conditions.

The equipment is provided in a steel cabinet or assembled on a framework for relay rack mounting. The items included in the cabinet or on the framework depend on the requirements of the particular installation. Descriptions of the V1 Telephone Repeater, the power supply unit, the line and line-balancing unit, the 2-wire terminating unit, the ringer units, and the signal battery and ringing supply unit are given later. The individual panels or units are assembled and wired together before shipment. A fully equipped cabinet weighs approximately 225 pounds, and the cabinet alone weighs about 75 pounds.

Power Consumption

The repeater power supply unit consumes a maximum of 25 watts when operated from a 105-125-volt 50-60-cycle source. The rectifier of the signal battery and ringing supply unit operates on a 105-125-volt 50-60-cycle source and consumes 60 watts. The 20-cycle static ringer generator of the same unit operates on 105-125-bolt 60-cycle source and consumes 60 watts at full load.

Testing Equipment

The following equipment will be found useful in conducting tests described in this bulletin. Any equivalent apparatus which may be available may be used.

1. Portable transmission measuring sets and 1000-cycle machine for measuring gain, or fixed pads, or a variable attenuator for use in making singing tests described under "Trouble Location," page 50.
2. Two 217D Plugs consisting of 600-ohm resistances for terminating amplifiers at the jacks.
3. One 528 Receiver equipped with a 241A Plug for monitoring.
4. Two P2AA Cords, 6 feet long, equipped with 241A Plug at each end. These are double-conductor test cords with twin plugs at each end.
5. Two S3F Cords equipped with 241A Plug at one end. These are 6-foot triple-conductor test cords equipped with a twin plug at one end and cord tips at the other.
6. One Weston model 697 ac-dc volt-ohm-milliammeter.

DESCRIPTION AND FUNCTIONS OF COMPONENT UNITS

V1 Telephone Repeater

A V1 Telephone Repeater consists of two voice amplifier units, including input and output jacks and monitoring features, as shown in Figure 1.

The voice amplifier circuit has a 600-ohm resistance bridged across the primary of the input transformer (IN) giving a nominal input impedance of 600 ohms. The impedance ratio of the input transformer is 300:357,000, and the secondary winding has five taps which provide gain adjustment in 4 db steps.

The output transformer (OUT) has four windings. Windings 7-8 and 1-2 are the usual plate and output windings, respectively; winding 9-10 is the feedback winding; and 3-4 is the monitoring winding. Because of the nature of the network connected across the feedback winding, the application of feedback through it produces an amplifier output impedance which approximates 600 ohms over the important voice-frequency range. The monitoring winding is a low impedance winding, and its output into a 600-

ohm termination is approximately 11 db below the output of the 1-2 winding similarly terminated.

A pentode vacuum tube is the amplifying element. Grid bias potential is obtained from the voltage drop in resistances (B) and (C) and the potentiometer, through which the total cathode current flows. The potentiometer serves as a supplementary gain control with a range of about 5.4 db. Since the cathode current flows through the potentiometer contact, a more posi-

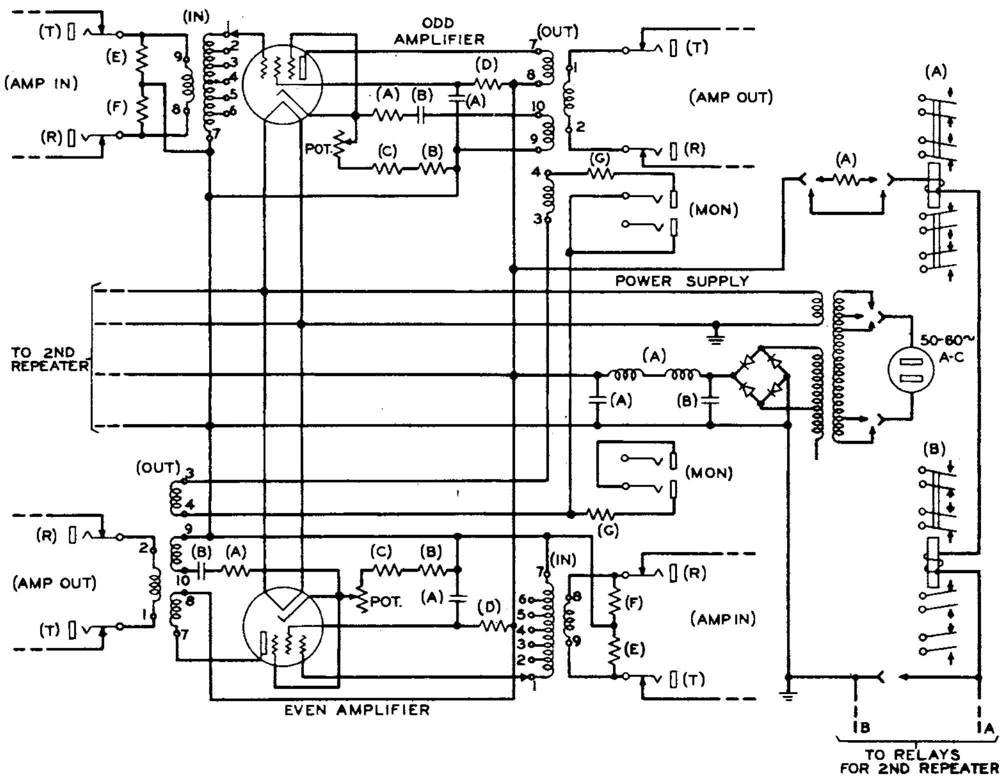


Figure 1—V1 Telephone Repeater and Power Supply.

tive contact is obtained than that of a gain control potentiometer operating in a "dry" circuit.

The amplifier employs negative feedback, which reduces gain fluctuations with changes in potentials applied to the vacuum tubes. The application of feedback also makes the output impedance of the amplifier substantially independent of the setting of the potentiometer. The feedback voltage is the resultant of the voltage induced in winding 9-10 of the output transformer plus the drop across resistance (A) and condenser (B) impressed across the a-c drop in resistances (B) and (C) and the used portion of the potentiometer. The amount of effective feedback, therefore, depends upon the setting of the potentiometer. The gain change resulting from a movement of the potentiometer contact arm is due to the combined effects of a change in feedback voltage and a change in the application of the vacuum tube resulting from the change in grid bias.

With the potentiometer resistance all in the circuit, the cathode current is a minimum and the gain is a minimum. With the potentiometer resistance all out of the circuit, the cathode current is a maximum and the gain is a maximum. Cathode current is measured as a voltage drop across resistance (B).

Jacks are provided on the voice amplifier units for picking up the input and output leads and for monitoring. Monitoring both directions of transmission is done at the odd amplifier (MON) jacks. The upper jack is used for a single double-conductor plug. With a twin plug, the receiver is connected to the sleeves and both jacks are used. A 1600-ohm resistance (G) is in the circuit between the monitoring jacks (MON) and the monitoring windings of the output transformers to allow the use of low or high impedance receivers with negligible loss to through transmission.

Power Supply Unit

The power supply unit provides 10 volt alternating current for the heaters of the vacuum tubes for one or two V1 Telephone Repeaters, and 130 volt direct current for plate supply to these vacuum tubes and for operation of the relays which, when released on power failure, cut out the repeaters.

The circuit is shown in Figure 1. It consists essentially of a power transformer, two selenium rectifier units connected in a bridge circuit and a filter consisting of condensers and retardation coil. The primary of the power transformer is connected to a 105-125-volt, 50-60-cycle supply. When power is furnished to two repeaters the heater, plate and ground leads of one amplifier are multipled with the corresponding leads of the other amplifiers and the windings of the four associated relays are connected in series between plate potential and ground. When only one repeater is connected two of the relay windings are replaced by a 5000-ohm resistance (A).

Line and Line-Balancing Unit

A line and line-balancing unit is furnished with every terminal repeater and two units with every intermediate repeater. That is, each line side of every side or phantom circuit requires a line and line-balancing unit. This is true also of a non-repeatered side or phantom circuit when part of the phantom group is repeatered or it is desired to arrange it for repeatered service later on. The unit is provided with the line repeating coils, line-balancing network, composite balancing equipment, equalizer equipment, filters, 20-cycle repeating coil equipment, signaling by-pass, and a repeater cut-out relay as required.

All of the functions of this equipment are shown in Figures 2 to 6 inclusive. For the sake of clarity the amplifiers, composite sets and signaling

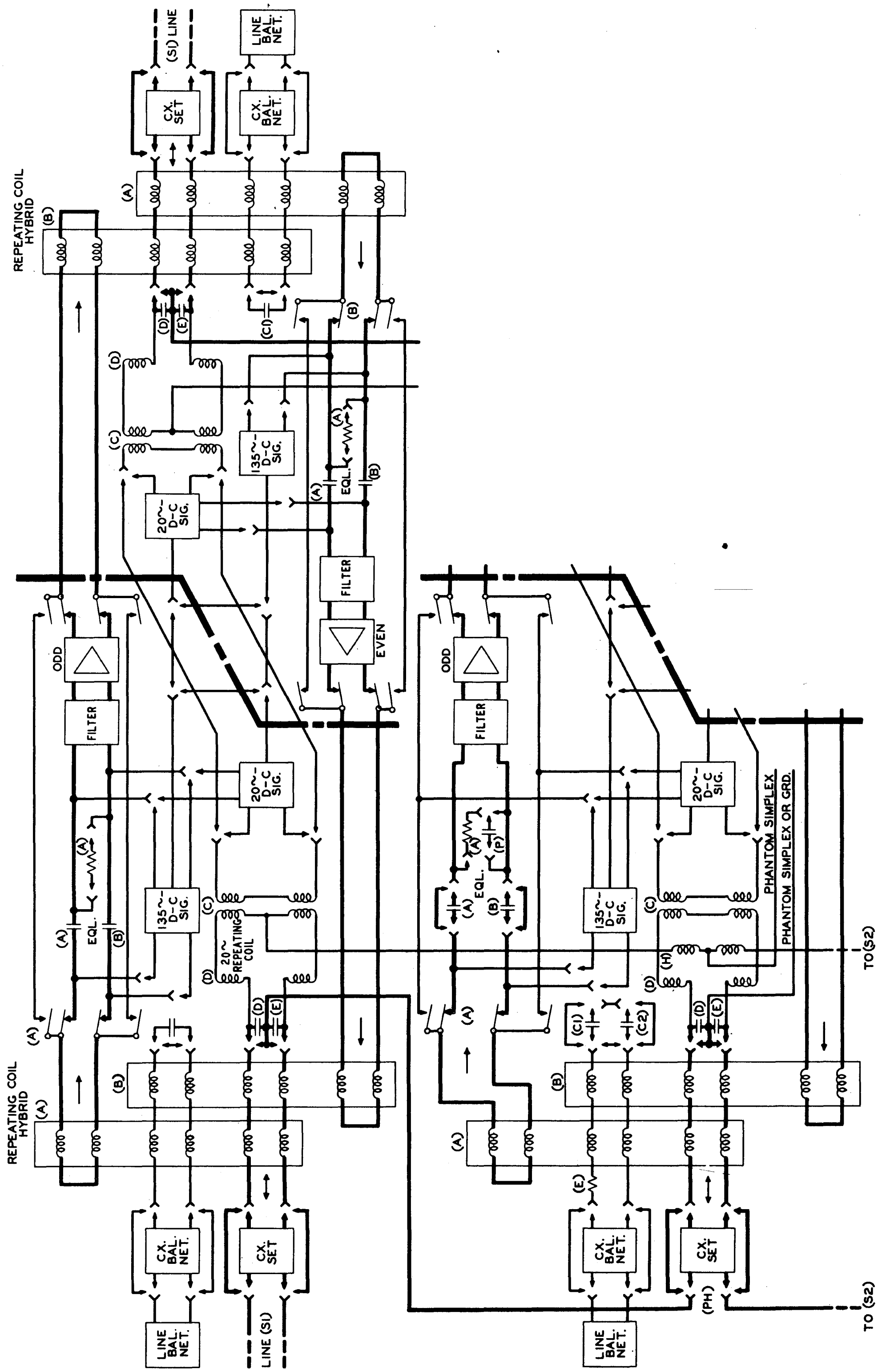


Figure 2—Intermediate Repeatered Phantom Group.

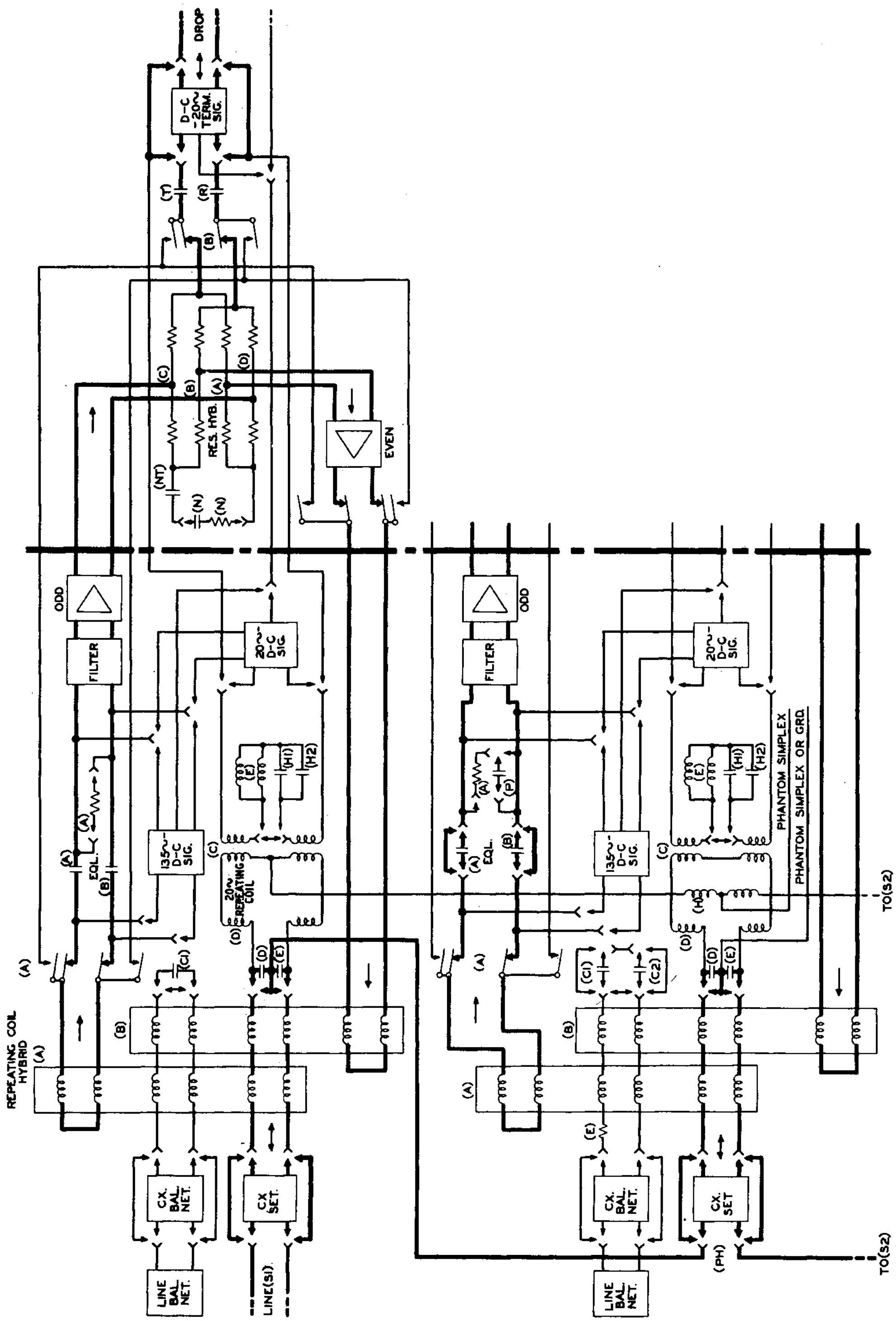


Figure 3—Terminal Repeatered Phantom Group.

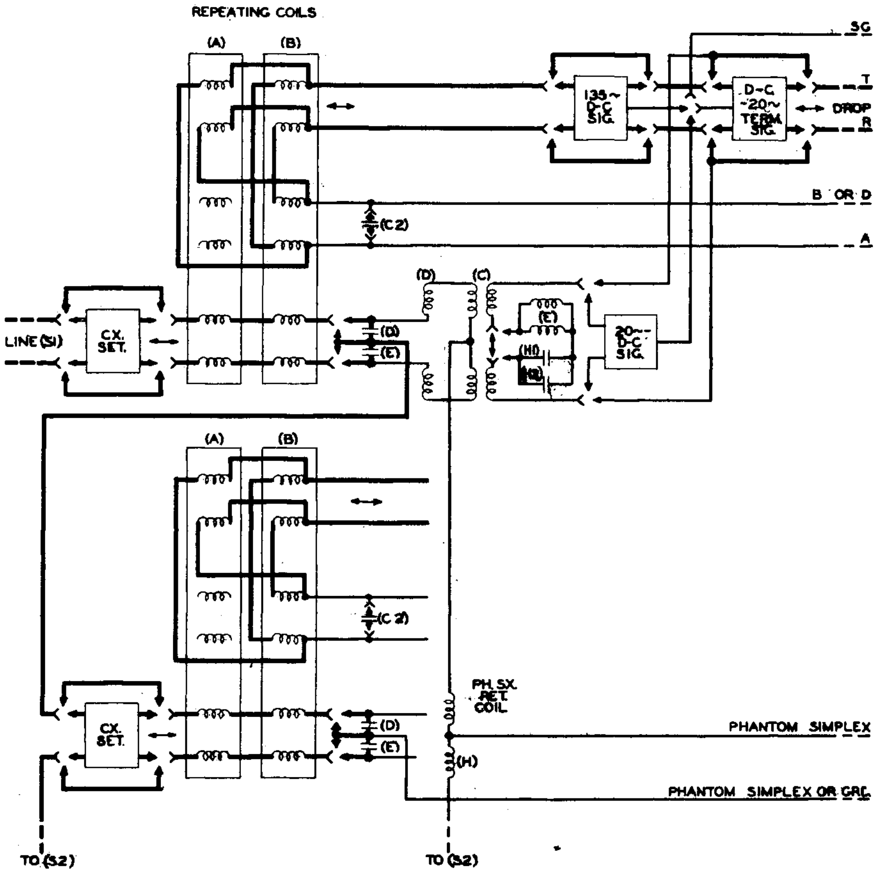


Figure 4—Terminal Non-Repeatered Phantom Group.

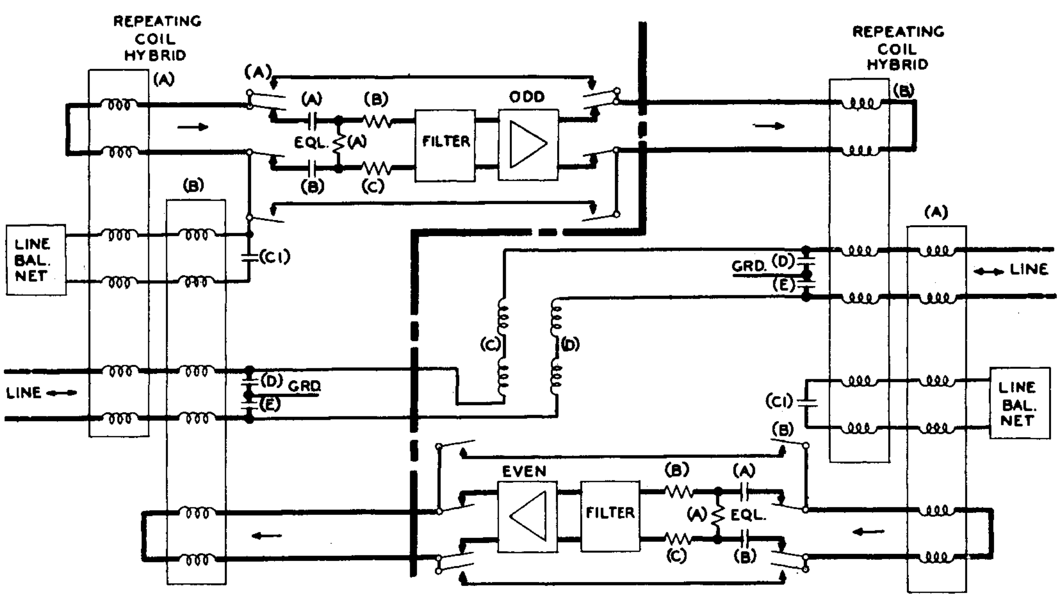


Figure 5—Railroad Dispatch Intermediate Repeater.

circuits are included in these figures although they are not part of the line and line-balancing units. Also, the windings of the repeater cut-out relays are shown with the power supply circuit in Figure 1, while the relay contacts are shown in Figures 2 to 6 inclusive. The heavy broken lines in these figures serve to indicate the equipment furnished on or associated with each line and line-balancing unit. Figures 2 to 4 inclusive illustrate complete phantom groups, but combinations of these are permissible by connecting any side circuit to any phantom circuit except for certain combinations such as 20-cycle signaling on phantom and cx. on sides. Also, phantom circuits need not be provided.

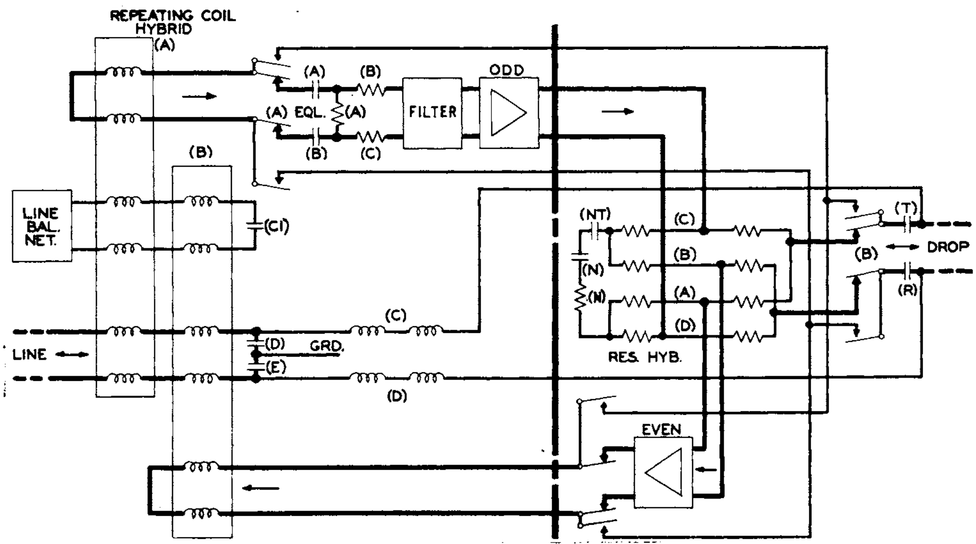


Figure 6—Railroad Dispatch Terminal Repeater.

The general arrangements of the repeaters and associated equipment for use at intermediate points are shown in Figure 2. On each side of the repeater are two separate and identical repeating coils, designated (A) and (B), which are interconnected in such a manner as to serve the combined function of a repeating coil of proper impedance ratio and of a hybrid coil. This combination, called "repeating coil hybrid," together with balancing networks, equalizer equipment and filters, form the line equipment.

Twenty-cycle equipment, when required, is connected in series with the line windings, as shown, and for this condition, the phantom is derived from the midpoint of two series condensers (D) and (E) bridged across the low frequency equipment.

When the repeater is used at the terminal of a 2-wire circuit as shown in Figure 3, the repeating coil hybrid toward the switchboard is replaced by a simple resistance network called "resistance hybrid" which is furnished as part of the 2-wire terminating unit described later. When a side or phantom circuit is to be terminated without the repeater as shown in Figure 4, the two repeating coils are interconnected to serve only the function of a repeating coil of the proper impedance ratio, and balancing networks, equalizer equipment, and filters are not used. A condenser is furnished between the A and B or D leads that are used in some instances for mid-point signaling.

Repeating Coil Hybrids

The repeating coils forming the repeating coil hybrids for 2-wire repeatered use are provided with more windings than the usual repeating coils and are so interconnected that phantom taps may be derived and equalizers, signaling, composite and balancing equipment may be connected between appropriate windings. The coils are low-inductance non-ring-through types and are furnished in a variety of ratios to match the various line impedances as follows:

Type of Circuit	*Rep. Coils (A) & (B)*	*Impedance Ratio*
Open Wire Side	173A	1:1
Open Wire Phantom	173D	0.6:1
16H44S	173A	1:1
16H25P	173D	0.6:1
16H172S	173C	2.30:1
16H63P	173A	1:1
19B88S	173C	2.30:1
19B50P	173B	1.69:1
19H88S	173B	1.69:1
19H50P	173A	1:1
19H172S	173C	2:30:1
19H63P	173A	1:1
19H174S	173C	2:30:1
19H106P	173B	1:69:1

Briefly, the functioning of the two coils is as follows: Current from the line flows through the line windings of both coils but because of the reversed poling of the network windings of one coil with respect to those of the other coil, the resulting voltage in the network is zero. Equal voltages are induced in the amplifier windings of each coil and the power is equally divided between amplifier input and output impedances, assuming these impedances to be equal. Also, current from the amplifier output induces equal voltages in the line and network windings (assuming that the line and network impedances are equal) but, due to the poling of the two network windings, the induced voltages cancel in the other amplifier input windings so that the resultant in this input circuit is zero, the power dividing equally between the line and network.

This arrangement requires that the windings of a given coil be mutually balanced to a high degree of precision but does not require a high degree of balance between separate coils since such balance is relatively unimportant from the standpoint of transmission from the line. Phantoms may be derived from these arrangements since the windings of each coil are noninductive to phantom currents. Here, again, the balance is confined to windings on the same coil except that the coils in the side circuits of a phantom group should have approximately the same d-c resistance. This is accomplished by using coils having the same group letter which is stamped on the coil in accordance with selective shop tests.

Equalization

The attenuation equalizers are associated with the line equipment connecting to the amplifier inputs. They consist of the (A), (B), and (P), condensers and (A) resistance shown in Figures 2 and 3 or the (A) and (B) condensers and (A), (B), and (C) resistances shown in Figures 5 and 6. The elements required for various conditions are shown in the following table:

TABLE OF EQUALIZER ELEMENTS

Type of Circuit	*Sig. Freq. Cycles*	*Composited (Cx)*	*(A & B) Cond.*	*(P) mf*	*(A) Ohms*	*(B & C) Ohms*
Open Wire Side	20	None	141QA	—	2000*	—
Open Wire Ph.	20	None	Short	Omit	Omit	—
Open Wire Side	135,1000	Cx	139QA	—	1000**	—
Open Wire Ph.	135,1000	None	139QA	Omit	1000**	—
Open Wire Side	135,1000	None	141QA	—	1000**	—
Open Wire Ph.	135	Cx	130QA	Omit	1000**	—
Open Wire Side	135,1000	None	141QA	—	1000**	—
Open Wire Ph.	1000	Cx	Short	Omit	Omit	—
Open Wire Side	135,1000	None	141QA	—	1000**	—
Open Wire Ph.	135,1000	None	141QA	Omit	1000**	—
Open Wire Side	20	None	141QA	—	2000*	—
Open Wire Ph.	135,1000	None	141QA	Omit	2000*	—
Open Wire Side	135,1000	None	141QA	—	1000**	—
Open Wire Ph.	20	None	139QA	Omit	1000**	—
16H44 Ca. Side	20	None	141QA	—	2000*	—
16H25 Ca. Ph.	20	None	Short	1.08	1000**	—
16H44 Ca. Side	135,1000	Cx	139QA	—	1000**	—
16H25 Ca. Ph.	135,1000	None	139QA	Omit	2000*	—
16H44 Ca. Side	135,1000	None	141QA	—	1000**	—
16H25 Ca. Ph.	135	Cx	139QA	Omit	1000**	—
16H44 Ca. Side	135,1000	None	141QA	—	1000**	—
16H25 Ca. Ph.	1000	Cx	Short	1.08	1000**	—
16H44 Ca. Side	135,1000	None	141QA	—	1000**	—
16H25 Ca. Ph.	135,1000	None	141QA	Omit	1000**	—
16H44 Ca. Side	20	None	141QA	—	2000*	—
16H25 Ca. Ph.	135,1000	None	141QA	Omit	2000*	—
16H44 Ca. Side	135,1000	None	141QA	—	1000**	—
16H25 Ca. Ph.	20	None	139QA	Omit	2000*	—
Other Ca. Side	Any	Any	175CA	—	Omit	—
Other Ca. Ph.	Any	Any	175CA	Omit	Omit	—
R.R. Dispatch	4.5	None	141QA	—	800	100**

Filters

Low-pass filters whose nominal impedance is 600 ohms are provided in the 4-wire branch of the line equipment associated with the amplifier

*When ordering separately specify 106A and value.
**When ordering separately specify 111B and value.

inputs. Three filters are provided which differ in their cut-off and are for use with various types of circuits as follows:

Type of Circuit	*Filter*	*Nominal Circuit Cut-Off W (10 db Point for 2 Repeater Sections)*
Open Wire Side With or Without 5 K.C. Carrier Line Filter Open Wire Phantom 16H44-25 Side or Phantom 16H88-50 Side or Phantom 19H88-50 Side or Phantom 19B88-50 Side or Phantom	128A	3500 cycles
Open Wire Side With 3 K.C. Carrier Line Filter 16H63 Phantom 19H63 Phantom	128C	2850 cycles
16H172 Side 19H172 Side 19H174-106 Side or Ph. R.R. Dispatch	128B	2450 cycles

Balancing Equipment

The gain at which a repeater can be operated is dependent upon the balance of the network against the line. Appreciable unbalance will cause the repeater to sing or oscillate when the gain is increased to the critical or so-called singing point. This point of gain is therefore used as a measure of the line and network balance.

Precision Networks

A standard precision network is available for each of the standard types of circuit on which repeaters are used, as follows:

Open Wire Circuit	*Network*	*Strap Terminals*	*See Fig.*
104 Mil Side, 6″ Non-Pole Pair	115T†	3 & 6	7
104 Mil Side, 8″ Non-Pole Pair	115T†	5 & 6	7
104 Mil Side, 12″ Non-Pole Pair	115T†	3 & 5	7
104 Mil Side, 12″ Pole Pair	115T†	None	7
104 Mil Side, 12″ Half Pole Pair	115T†	None	7
104 Mil Ph., 12″ Non-Pole Pair	115Y†	None	7
128 Mil Side, 6″ Non-Pole Pair	115U†	3 & 6	7
128 Mil Side, 8″ Non-Pole Pair	115U†	5 & 6	7
128 Mil Side, 12″ Non-Pole Pair	115U†	3 & 5	7
128 Mil Side, 12″ Pole Pair	115U†	None	7
128 Mil Side, 12″ Half Pole Pair	115U†	None	7
128 Mil Ph., 12″ Non-Pole Pair	115AA†	None	7
165 Mil Side, 6″ Non-Pole Pair	115W†	3 & 6	7
165 Mil Side, 8″ Non-Pole Pair	115W†	5 & 6	7

Open Wire Circuit	*Network*	*Strap Terminals*	*See Fig.*
165 Mil Side, 12″ Non-Pole Pair	115W†	3 & 5	7
165 Mil Side, 12″ Pole Pair	115W†	None	7
165 Mil Side, 12″ Half Pole Pair	115W†	None	7
165 Mil Ph., 12″ Non-Pole Pair	115AA†	5 & 6	7
114 Mil Side, 8″ Line Spacing	114A*	3-7	7 & 8
114 Mil Ph., 8″ Line Spacing	114B*	3-5	7 & 8
114 Mil Side, 10″ Line Spacing	114A*	5-7	7 & 8
114 Mil Ph., 10″ Line Spacing	114B*	4-6	7 & 8
114 Mil Side, 12″ Line Spacing	114A*	4-5 & 6-7	7 & 8
114 Mil Ph., 12″ Line Spacing	114B*	3-4 & 5-6	7 & 8
114 Mil Side, 14″-18″ Line Spacing	114A*	6-7	7 & 8
114 Mil Ph., 14″-18″ Line Spacing	114B*	4-6	7 & 8
114 Mil Side, 20″ Line Spacing	114A*	6-7	7 & 8
114 Mil Ph., 20″ Line Spacing	114B*	4-6	7 & 8
114 Mil Side, 22″ Line Spacing	114A*	4-6	7 & 8
114 Mil Ph., 22″ Line Spacing	114B*	4-6	7 & 8
114 Mil Side, 32″ Line Spacing	114A*	None	7 & 8
114 Mil Ph., 32″ Line Spacing	114B*	4-6	7 & 8

Entrance Cable	*Network*	*See Fig.*
13H31 Side normally used with 165 Mil O.W.	107A*	9
13H18 Ph. normally used with 165 Mil O.W.	107D*	9
16H31 Side normally used with 128 Mil O.W.	115AC	7
16H18 Ph. normally used with 128 Mil O.W.	115AE	7
19H31 Side normally used with 104 Mil O.W.	115AB	7
19H18 Ph. normally used with 104 Mil O.W.	115AD	7

Cable Circuit	*Network*	*See Fig.*
16H44 Side	104E*	9
16H25 Ph.	104F*	9
16H88 Side	115P	7
16H50 Ph.	115R	7
16H172 Side	104A*	9
16H63 Ph.	104C*	9
19B88 Side	115AF	7
19B50 Ph.	115AG	7
19H88 Side	115P	7
19H50 Ph.	115R	7
19H172 Side	104B*	9
19H63 Ph.	104D*	9
19H174 Side	104B*	9
10H106 Ph.	13T**	9

*These networks will not fit in the space provided for the 115 types on the line and line balancing unit. A separate line balancing unit is required.

**Since this network will not fit in the space provided for the other types, special provision will have to be made by the customer for its location outside the cabinet. The 22A Network (low frequency corrector) is necessary with it unless the repeater is inefficient at low frequencies for other reasons.

†See second paragraph, page 18.

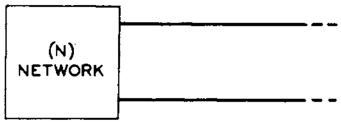


Fig. 7—Precision Network.

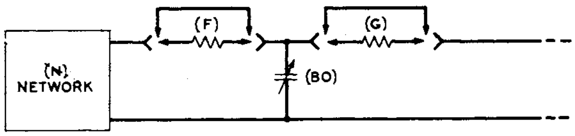


Fig. 8—Precision Network with "T" Section.

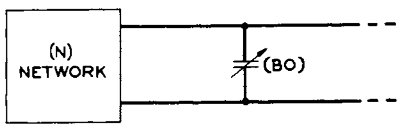


Fig. 9—Precision Network with Building-Out Condenser.

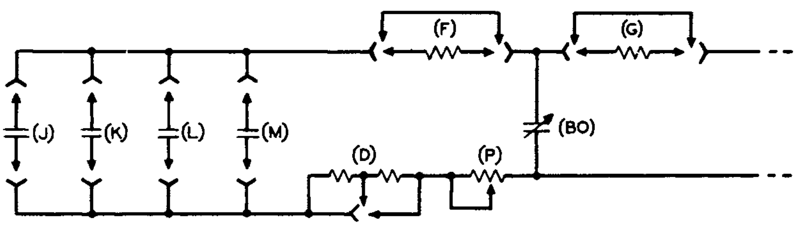


Fig. 10—Adjustable Network for Trunk Circuits.

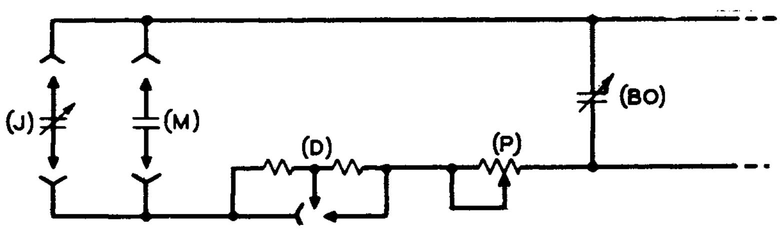


Fig. 11—Adjustable Network for Dispatch Circuits.

Adjustable Networks

An adjustable network may be used instead of a precision network under certain conditions. The adjustable network shown in Figure 11 is intended for dispatch circuits. The adjustable network shown in Figure 10 is for other circuits. It may be used to balance not only circuits for which precision networks are not available, but also to balance short open wire lines or longer lines where an extremely high balance is not possible due to irregularities in the line circuit.

On short circuits precision-type networks may not produce appreciably higher singing points than can be obtained with the adjustable-type networks; therefore the latter networks may be used on the shorter circuits if so desired. It should be noted, however, that these networks require more field adjustment than do the others. The table following indicates lengths of non-loaded open-wire circuits with which it is satisfactory to use adjustable networks. This table assumes a circuit with a repeater at one end only, and terminated in a subset at the distant end. For distances greater than these the coded network should be used. Also, for circuits having more than one repeater and of a grade suitable for switched business, the use of the precision networks will generally produce the best results unless large impedance irregularities are present, in which case the adjustable networks may produce higher singing points than the precision type, irrespective of the circuit.

Gauge (Mils)	*Spacing (Inches)*	*Maximum Length (Miles)*	
		Side	*Phantom*
165	12	580	640
128	12	340	420
114	12	290	350
104	12	240	290
165	8	430	
128	8	320	
104	8	220	

Building-Out Capacity with "T" Section

A building-out capacity, consisting of a 187-type multi-unit condenser is provided on the line and line balancing unit, when required, or provided within certain of the precision networks for balancing toll entrance cable or twisted pair adjacent to the repeater, and on loaded circuits for building out the network to correspond to the loading end section. When a considerable length of non-loaded cable or twisted pair is adjacent to the repeater,

Resistances			*Res. (Ohms)*	
(F)		*(G)*	*(F)*	*(G)*
	19W		10	10
	19Y		15	15
	19M		20	20
	19T		25	25
	19E		30	30
	19LR		34.5	34.5
	19B		40	40
	19ND		44	44
	19AM		50	50
18FH		18FH	56	56
	19L		60	60
	19KS		67	67
	19AK		70	70
18ED		18ED	75	75
	19JJ		80	80
	19LG		84	84
18Y		18Y	90	90
18AA		18AA	95	95
	19FG		100	100

a "T" section must be used instead of a simple bridged capacity. This consists of two resistances (F) and (G) with the condenser (BO) bridged from the common point to the other line lead, each resistance being equal to one-half the resistance of the non-loaded cable or twisted pair, and the capacity of the condenser being adjusted to equal that of the cable or twisted pair. The length of cable for which these resistances are needed depends on the grade of balance required, but ordinarily they should be used when the resistance of the cable exceeds 20 ohms. When not provided for in the design of the network, the code numbers of the various resistances used are given in the table on page 17. The resistances specified are installed and wired at the factory.

The 115T, 115U, 115W, 115Y, and 115AA Networks contain the building-out condenser. These networks are furnished with terminals 2 and 4 and terminals 3 and 4 strapped. When (F) and (G) resistances are required these straps are removed and replaced by 111A Resistances. These straps or resistances are in addition to the straps mentioned in the paragraph on Filters, page 13. The 111A Resistances are furnished in multiples of 5 ohms from 10 ohms to 100 ohms for this purpose.

Phantom Balancing Resistances

The (E) resistances shown in Figures 2 and 3 in the networks of the phantom circuits are for the purpose of balancing for the resistance of the line windings of the side circuit repeating coils. The resistance values required are as follows:

Rep. Coils in Sides	*(E) Res. in Phantom*
173A	18 Ohms
173B	37 Ohms
173C	54 Ohms

Composite (Cx) Balancing Network

Composite balancing networks are furnished, as required, on the line and line-balancing unit. They are used in the network leads as shown in Figures 2 and 3 to balance various types of composite sets which are standard arrangements. These composite balancing networks consist of retardation coils and condensers as shown in Figures 12, 13, 14 and 15.

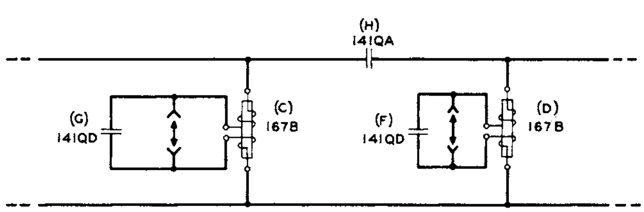


Fig. 12—Open Wire Terminal and Intermediate Cx Balancing Network.

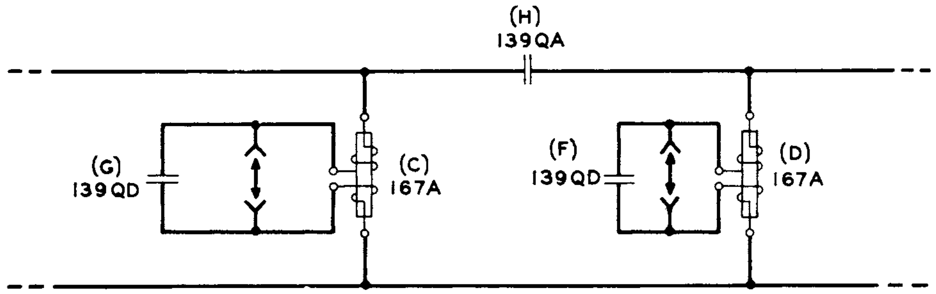


Fig. 13—Open Wire Terminal and Intermediate Phantom Cx Balancing Network.

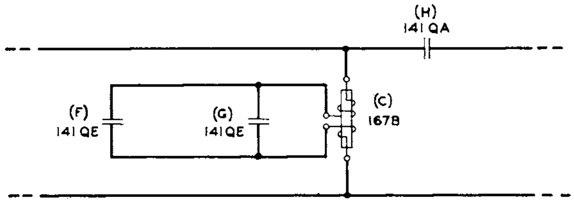


Fig. 14—Cable Terminal and Intermediate Cx Balancing Network.

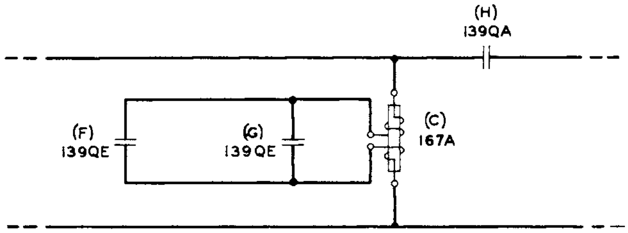


Fig. 15—Cable Terminal and Intermediate Phantom Cx Balancing Network.

For open wire circuits the (G) condenser will always be furnished but this will be short circuited by a strap when specified for terminal type composite set. The use of the various types is as follows:

	Open Wire	*Cable*
Sides Composited	Fig. 12	Fig. 14
Phantom Non-Composited	Fig. 13	Fig. 15
Sides Non-Composited	Omit	Omit
Phantom Composited	Fig. 12	Fig. 14

Balancing Condensers

A 157A Condenser consisting of two capacities (D) and (E) of 4.28-4.36-mf each is required on any side or phantom circuit having $3\frac{1}{2}$-cycle or 20-cycle signaling. On repeatered circuits a 2.14-2.18-mf condenser (C1) is required in each side or phantom circuit that is equipped with the 157A Condenser in order to have correct balance between the line and the network paths. A 4.28-4.36-mf condenser (C2) is required in a phantom circuit when the side circuits are equipped with 157A Condensers. This is in addition to the (C1) condenser if the phantom circuit also is equipped with a 157A Condenser.

$3\frac{1}{2}$-Cycle By-Pass

Signaling by-pass for the railroad dispatch repeater is obtained by connecting two 149E Retardation Coils in series with the line windings of the hybrid repeating coils as shown in Figures 5 and 6. These coils are furnished on the line and line-balancing unit associated with the odd amplifier when required.

20-Cycle Repeating Coil Circuit

The 20-cycle signaling systems are designed to take advantage of the repeating coil hybrid arrangements by bridging the 20-cycle branches across two capacities (D) and (E), which in turn are connected in series with the hybrid repeating coil line windings as shown in Figures 2, 3, and 4. This connection effectively inserts these condensers in series with the line impedance and the effects of the low-frequency bridging circuit upon voice-frequency transmission are much lower than arrangements which bridge the low-frequency branches directly across one of the transmission paths.

This method of connection affords a low-frequency channel which by the addition of a simple circuit is suitable for 20-cycle signaling. This circuit, called the 20-cycle repeating coil circuit, consists of a repeating coil (C) and a retardation coil (D). The use of the retardation coil modifies the impedance of the low-frequency channel in such a manner that the signaling range is materially increased without reducing the low-frequency singing margins. The 20-cycle repeating coil circuit is furnished, when required, on the line and line-balancing unit. It is used for 20-cycle by-pass as well as for 20-cycle relayed signaling. Figures 2, 3 and 4 show these circuit conditions and 135-cycle relayed signaling as well. To indicate the optional wiring required in each case the various conditions are shown separately in Figures 16 to 25 inclusive.

20-Cycle Ringing Ranges

Since lines have low loss at 20 cycles and since the ringing range depends to a large extent on the particular office circuit arrangements involved, it is not possible to make accurate predictions as to ringing ranges. However, the following table shows maximum ringing ranges which may be used as a guide for circuits equipped with either 172B, 196A, or 196F Relays in the line or cord circuits, and for repeating coil circuits employing 93 or 173 type repeating coils. These estimates are for $18\frac{1}{3}$ cycles and 97 volts, which are the normal lower limits of the 20-cycle generator. At $16\frac{2}{3}$ cycles the ranges are reduced in most cases. No data is available for spaces left blank in the table. The range is given in each case for one direction of ringing. Both directions should be taken from the table and the shortest range is controlling. Where an intermediate

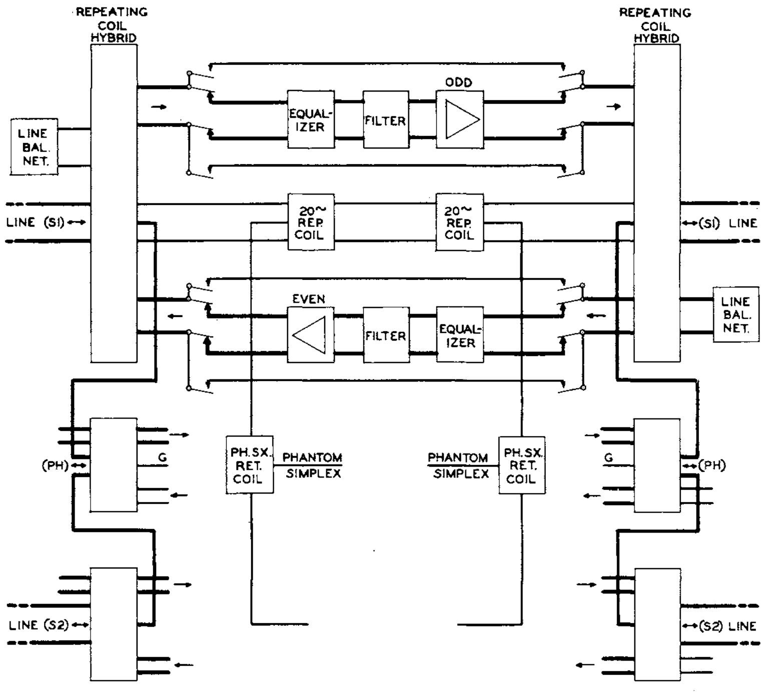


Fig. 16—Intermediate Repeated Phantom Group with 20-Cycle By-Pass.

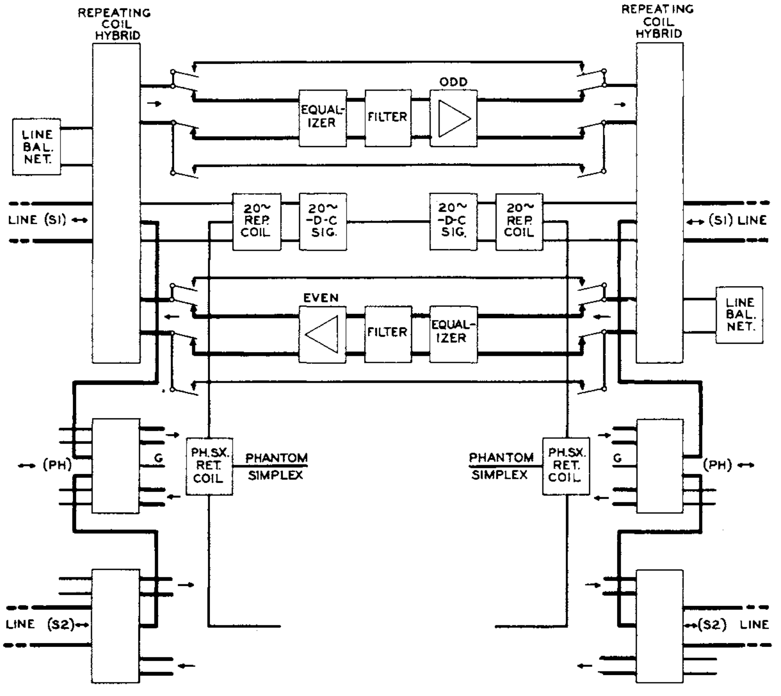


Fig. 17—Intermediate Repeated Phantom Group with 20-20-Cycle Relayed Ringing.

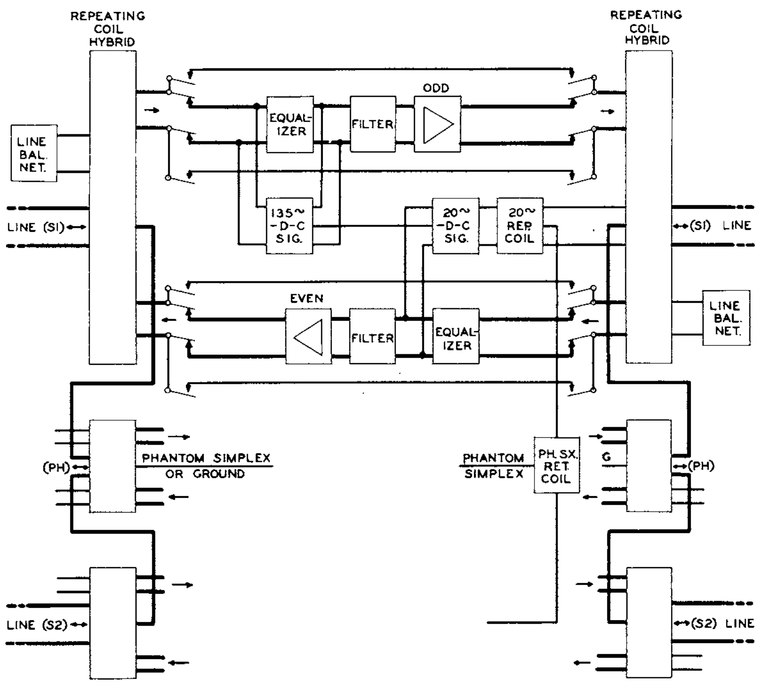


Fig. 18—Intermediate Repeated Phantom Group with 135-20-Cycle Relayed Ringing.

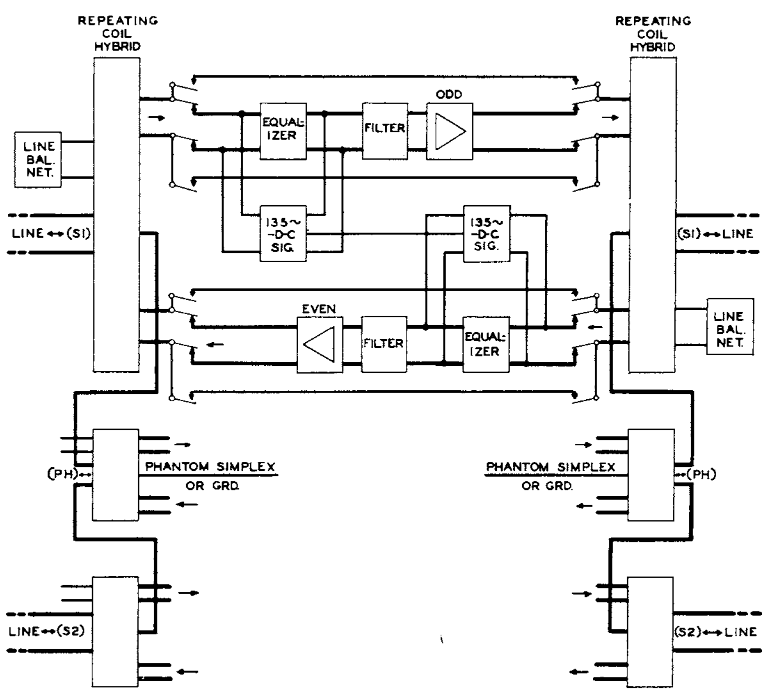


Fig. 19—Intermediate Repeated Phantom Group with 135-135-Cycle Relayed Ringing.

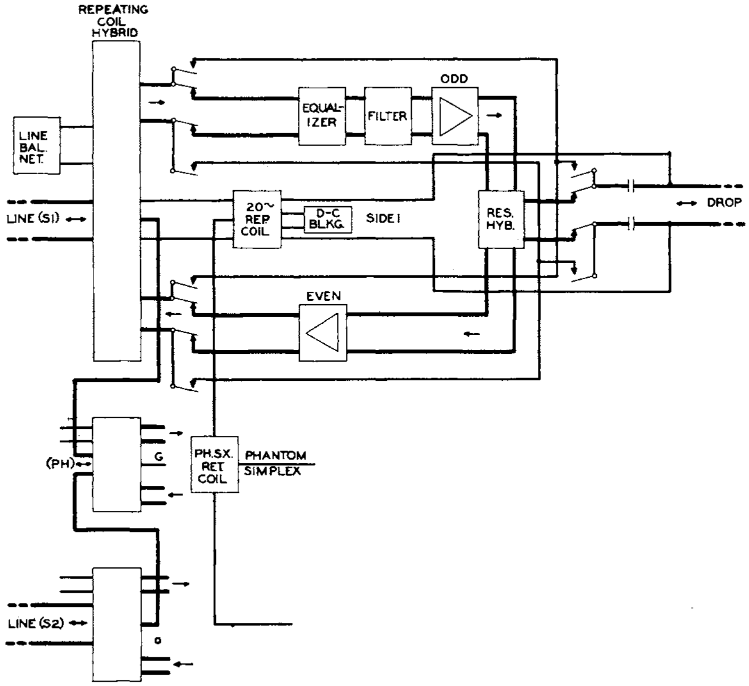


Fig. 20—Terminal Repeatered Phantom Group with 20-Cycle By-Pass.

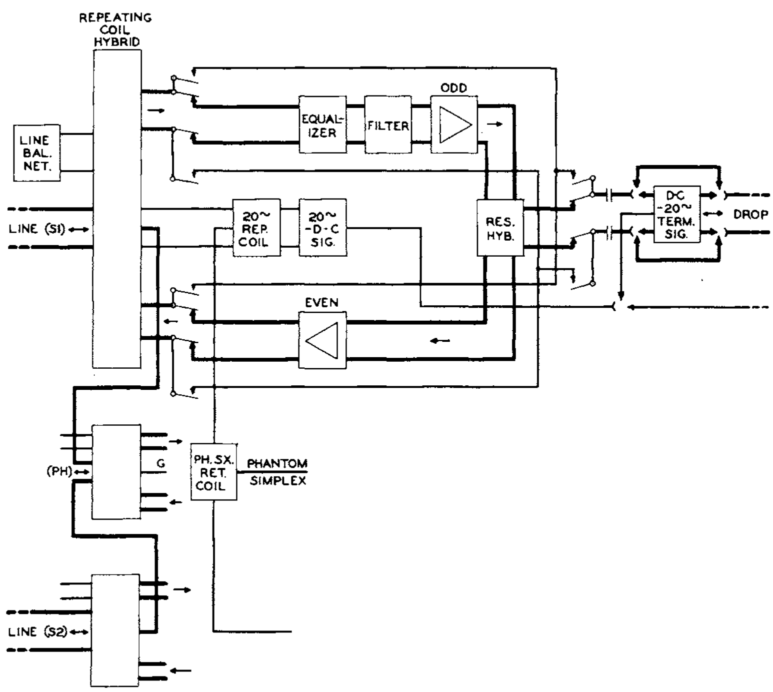


Fig. 21—Terminal Repeatered Phantom Group with 20-Cycle d-c Signaling or 20-20-Cycle Relayed Ringing.

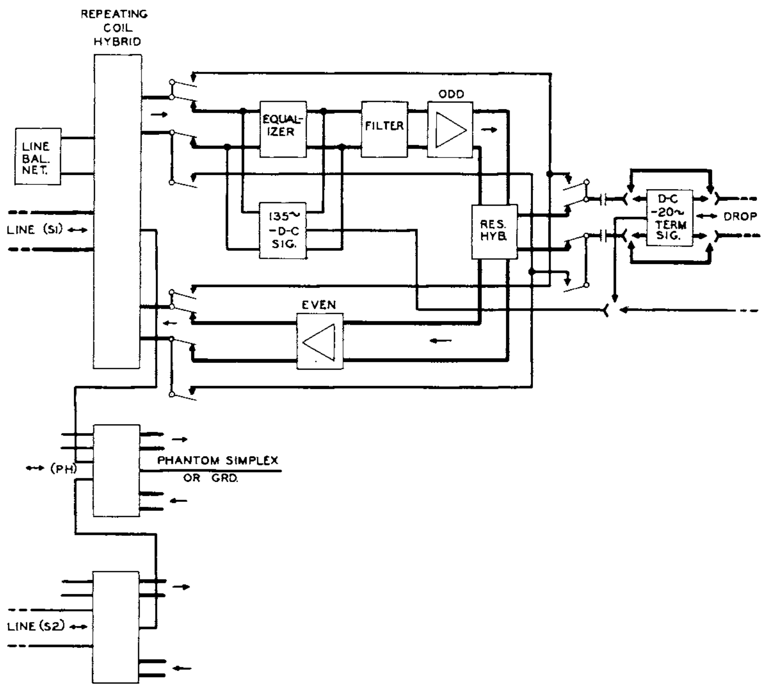


Fig. 22—Terminal Repeatered Phantom Group with 135-Cycle d-c Signaling or 135-20-Cycle Relayed Ringing.

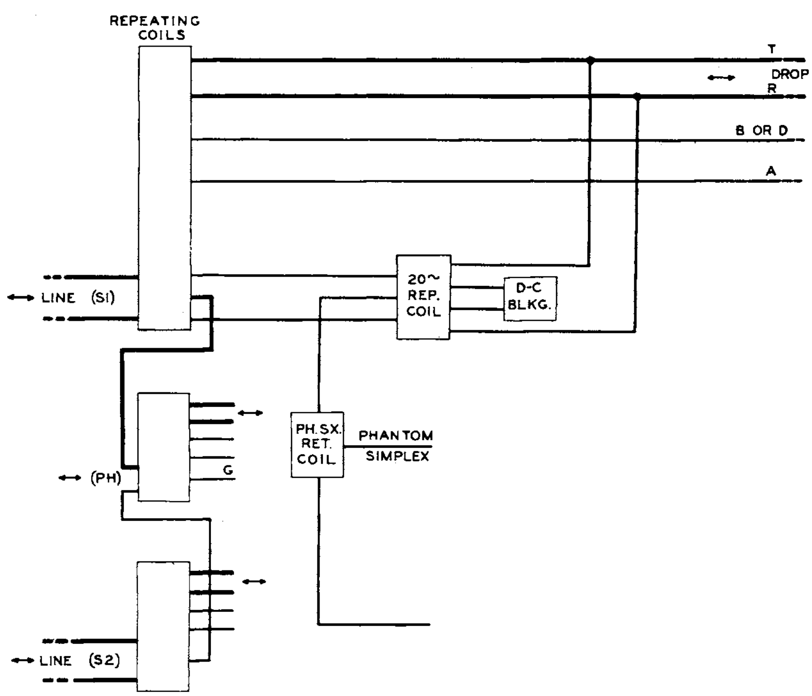


Fig. 23—Terminal Non-Repeatered Phantom Group with 20-Cycle By-Pass.

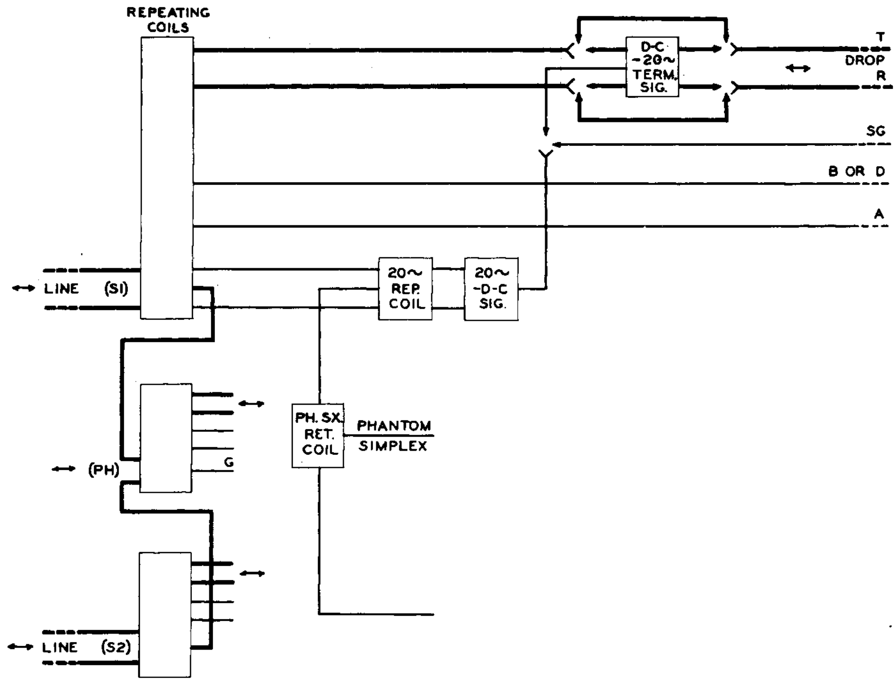


Fig. 24—Terminal Non-Repeatered Phantom Group with 20-Cycle d-c Signaling or 20-20-Cycle Relayed Ringing.

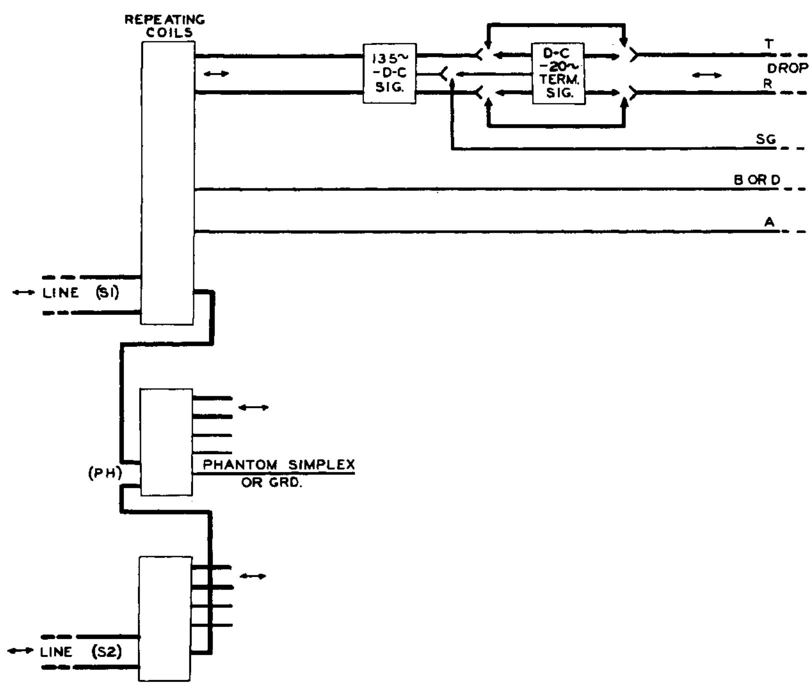


Fig. 25—Terminal Non-Repeatered Phantom Group with 135-Cycle d-c Signaling or 135-20-Cycle Relayed Ringing.

V1 Repeater is employed, consult the first half of the table. If the ringing range is given as less than the actual length of line section that it is desired to ring over, then it is not feasible to use 20-cycle by-pass with the V1 Repeater. Assume that 20-cycle relayed ringing (two 20-cycle d-c signaling circuits back-to-back) are employed at the intermediate repeater point and then consult the second half of the table for the section on each side of the repeater. If the ringing range is given as less than the actual length of a section between two offices, then it is not feasible to employ 20-cycle signaling on that section in the manner described in this bulletin.

Maximum 20-Cycle Ringing Ranges (Miles)

At Office	Circuit Condition	Line	20 Cycles Side	20 Cycles Ph.	16⅔ Cycles Side	16⅔ Cycles Ph.
(Send) (Int.) (Rec.)	Ringing through 93 Rep. Coil, through int. V1 Rep. by-pass, through 173 Rep. Coils to 20 cyc. DC.	Ca. O.W.	95 450	75	80	60
(Send) (Int.) (Rec.)	Ringing through 173 Rep. Coils, through int. V1 Rep. by-pass, through 173 Rep. Coils to 20 cyc. DC.	Ca. O.W.	105 450	80	100	70
(Send) (Int.) (Rec.)	Ringing through 93 Rep. Coil, through int. V1 Rep. by-pass, through 93 Rep. Coil to 172B Relay for No. 1 Toll Swbd.	Ca. O.W.	35 200	30	25	0
(Send) (Int.) (Rec.)	Ringing through 93 Rep. Coil, through int. V1 Rep. by-pass, through 93 Rep. Coil to 196A or F Rel. for No. 3 Type Toll Swbd.	Ca. O.W.	70 400	60	60	45
(Send) (Int.) (Rec.)	Ringing through 173 Rep. Coils, through int. V1 Rep. by-pass, through 93 Rep. Coil to 172B Relay for No. 1 Toll Swbd.	Ca. O.W.	50 200	40	40	20
(Send) (Int.) (Rec.)	Ringing through 173 Rep. Coils, through int. V1 Rep. by-pass, through 93 Rep. Coil to 196A or F Rel. for No. 3 Type Toll Swbd.	Ca. O.W.	100 400	85	90	70
(Send) (Int.) (Rec.)	Ringing through 93 Rep. Coil, through int. V1 Rep. by-pass, through 173 Rep. Coils to 172B Relay for No. 1 Toll Swbd.	Ca. O.W.	35 200	20	25	0
(Send) (Int.) (Rec.)	Ringing through 93 Rep. Coil, through int. V1 Rep. by-pass, through 173 Rep. Coils to 195A or F Rel. for No. 3 Type Toll Swbd.	Ca. O.W.	65 400	55	55	35
(Send) (Int.) (Rec.)	Ringing through 173 Rep. Coils, through int. V1 Rep. by-pass, through 173 Rep. Coils to 172B Relay for No. 1 Toll Swbd.	Ca. O.W.	45 200	30	35	0

At Office	Circuit Condition	Line	20 Cycles Side	20 Cycles Ph.	16⅔ Cycles Side	16⅔ Cycles Ph.
(Send) (Int.) (Rec.)	Ringing through 173 Rep. Coils, through int. V1 Rep. by-pass, through 173 Rep. Coils to 196A or F Rel. for No. 3 Type Toll Swbd.	Ca. O.W.	 400			
(Send) (Rec.)	Ringing through 93 Rep. Coil, through 173 Rep. Coils to 20 cyc. DC.	Ca. O.W.	100 700	110	90	100
(Send) (Rec.)	Ringing through 173 Rep. Coils, through 173 Rep. Coils to 20 cyc. DC.	Ca. O.W.	115 700	115	115	115
(Send) (Rec.)	Ringing through 93 Rep. Coil, through 93 Rep. Coil to 172B Relay for No. 1 Toll Swbd.	Ca. O.W.	50 300	55	30	35
(Send) (Rec.)	Ringing through 93 Rep. Coil, through 93 Rep. Coil to 196A or F Rel. for No. 3 Type Toll Swbd.	Ca. O.W.	80 600	95	70	90
(Send) (Rec.)	Ringing through 173 Rep. Coils, through 93 Rep. Coil to 172B Relay for No. 1 Toll Swbd.	Ca. O.W.	70 300	65	60	55
(Send) (Rec.)	Ringing through 173 Rep. Coils, through 93 Rep. Coil to 196A or F Rel. for No. 3 Type Toll Swbd.	Ca. O.W.	110 600	110	110	110
(Send) (Rec.)	Ringing through 93 Rep. Coil, through 173 Rep. Coils to 172B Relay for No. 1 Toll Swbd.	Ca. O.W.	50 300	55	30	35
(Send) (Rec.)	Ringing through 93 Rep. Coil, through 173 Rep. Coils to 196A or F Rel. for No. 3 Type Toll Swbd.	Ca. O.W.	80 600	95	70	90
(Send) (Rec.)	Ringing through 173 Rep. Coils, through 173 Rep. Coils to 172B Relay for No. 1 Toll Swbd.	Ca. O.W.	70 300	65	60	55
(Send) (Rec.)	Ringing through 173 Rep. Coils, through 173 Rep. Coils to 196A or F Rel. for No. 3 Type Toll Swbd.	Ca. O.W.	 600			

Relays for Repeater Cut-Out

Relays are employed to disconnect the repeater, filters and equalizers from the circuit and to establish continuity of voice transmission without the repeater whenever the power fails. Relays (A) and (B) are arranged to do this when they release. As shown in Figure 1, the plate supply is used to energize the windings of the relays. For an intermediate repeatered side or phantom circuit (see Figure 2) the contacts of the (A) relay are used to remove the odd amplifier and associated filter and equalizer from the circuit on power failure. The (A) relay is located on the line and line balancing unit associated with the odd amplifier. The contacts of relay (B) are similarly wired and this relay is mounted on the line and line-balancing unit associated with the even amplifier. For a terminal-repeatered side or phantom circuit (see Figure 3) the contacts of the (A) and (B) relays are used to remove both amplifiers, the filter, the equalizer, the resistance hybrid, and the compromise network when the power fails. Release of the relays connects the input leads, the output leads and the drop leads all together. The (A) relay is mounted on the line and line balancing unit, part of the contacts not being used. The (B) relay is mounted on the 2-wire terminating unit.

Phantom Simplex Retardation Coil Unit

When no 20-cycle channels are derived a phantom simplex for telegraph or dialing may be derived directly from the line windings of the phantom hybrid repeating coils as shown in Figures 18, 19, 22 and 25. When 20-cycle signaling is employed the phantom simplex is obtained by connecting a 149B Retardation Coil between the mid-points of the 20-cycle repeating coils of the side circuits. The simplex is then derived from the mid-point of the 149B Retardation Coil as shown in Figures 16, 17, 20, 21, 23 and 24. The retardation coil is located on the phantom simplex retardation coil unit which has a capacity of five coils. At intermediate points the simplex is by-passed by deriving the simplex in each direction as described above and connecting them together.

Line-Balancing Unit

The line-balancing unit is designed to mount two of any of the following type networks for line balancing: 104, 107, 114, as required. This unit supplements the line and line-balancing unit in cases where 115 Type Networks are not available for the line facilities involved.

Two-Wire Terminating Unit

The 2-wire terminating unit consists of a single line-terminating circuit, a repeater cut-out relay and, when required, a d-c blocking circuit.

The cut-out relay is provided on the two-wire terminating unit for the purpose of providing a transmission path without the repeater when the power fails. The function of this relay has been described in the third paragraph under 3½-Cycle By-Pass, page 20.

Line Terminating Circuit

The line-terminating circuit consists of a resistance hybrid, a compromise network and tip and ring condensers. On the drop side of the repeaters at circuit terminals a four-branch balanced lattice type resistance network called "resistance hybrid" is provided in place of the repeating coil hybrid, as shown in Figures 3 and 6. This resistance hybrid functions as a 2-wire—4-wire terminating set and terminates the amplifiers in the required 600-ohm 2-wire drop. The 1000-cycle loss through this arrangement is 10.7 db in each direction and it presents a 600-ohm impedance in the direction of the drop, the associated compromise network, the odd amplifier output, and the even amplifier input.

D-C Blocking Circuit

A d-c blocking circuit consisting of two condensers (H1) and (H2) and a retardation coil (E), as shown in Figures 3, 4, 20 and 23, is required for 20-cycle by-pass on terminal repeatered or non-repeatered circuits.

135-Cycle D-C Signaling Panel

The 135-cycle d-c signaling panel provides a circuit for use on terminal non-repeatered or terminal or intermediate V1 repeatered points. This circuit receives or sends 135-cycle signals on the line side and d-c signals on the drop side. When 20-cycle signals are required at the switchboard circuits the 135-cycle d-c signaling circuit is operated in tandem with a d-c 20-cycle terminal signaling circuit. When d-c signals are required at the switchboard circuits no other signaling circuit is required. These two conditions are shown in Figures 22 and 25. When both lines of an intermediate repeatered circuit are arranged for 135-cycle signaling, a 135-cycle d-c signaling circuit is associated with each line and their d-c branches are connected together as shown in Figure 19. When one line is arranged for 135-cycle signaling and the other for 20 the d-c branches of a 135-cycle d-c signaling circuit and of a 20-cycle d-c signaling circuit are connected together as shown in Figure 18.

20-Cycle D-C Signaling Panel

The 20-cycle d-c signaling panel is provided with one or two circuits for use on terminal non-repeatered or terminal or intermediate V1 repeatered points when 20-cycle by-pass is not feasible. This circuit receives or sends 20-cycle signals on the line side and d-c signals on the drop side. When 20-cycle signals are required at the switchboard circuits the 20-cycle d-c signaling circuit is operated in tandem with a d-c 20-cycle terminal signaling circuit. When d-c signals are required at the switchboard circuits no other signaling circuit is required. These two conditions are shown in Figures 21 and 24. When both lines of an intermediate repeatered circuit are arranged for 20-cycle signaling a 20-cycle d-c signaling circuit is associated with each line and their d-c branches are connected together as shown in Figure 17. The d-c leads of a 135-cycle d-c signaling circuit and of a 20-cycle d-c signaling circuit may be connected together, as shown in Figure 18, when one line employs 135 cycles and the other employs 20.

D-C 20-Cycle Terminal Signaling Panel

The d-c 20-cycle terminal signaling panel provides a circuit for use on terminal points where 20-cycle signals are required at the switchboard circuits and 20-cycle by-pass is not feasible. The transmission leads pass through this ringer but the d-c branch is connected to the corresponding d-c branch of a 135-cycle d-c or 20-cycle d-c signaling circuit associated with the line, as shown in Figures 21, 22, 24 and 25.

Battery and 20-Cycle Supply Unit

The battery and 20-cycle supply unit is used to supply power for operating ringer circuit relays and a 135-cycle interrupter and to supply 20-cycle signaling current when required. The power for the relays is obtained by means of a rectifier on the unit. The rectifier operates on 105-125-volt 50-60-cycle source. It is capable of supplying one 156B Interrupter and ten ringers or 20 ringers if no interrupter is used. A filter is used to improve the action of the 135-cycle interrupter and slow-acting ringer relays. 20-cycle supply is obtained by means of a static ringer generator on the unit. The generator operates on a 105-125-volt 60-cycle source. It is capable of supplying twenty 20-cycle ringers, assuming that rarely will two or more ringers operate simultaneously.

156B Interrupter (135-Cycle Supply)

A 135-cycle interrupter is used for supplying ringing current when required. The circuit consists essentially of a vibrator and a filter which serves to smooth out the wave shape of the output. In addition a filter may be provided for the 156B Interrupter to suppress radio frequency interference. The interrupter will supply 135-cycle current for ten 135-cycle d-c signaling circuits, assuming that only one will operate at a time except at infrequent intervals.

Transmission Performance and Testing Methods

Amplifier Gain Characteristics

The normal maximum 1000-cycle gain of each amplifier is 35 $\pm$2.0 db. These limits take into consideration manufacturing tolerances of the amplifier as well as tube variations and assume a variation of $\pm$5 volts in the a-c power supply. For a 10-volt change in the a-c voltage with a given tube the change in gain should not be more than about 0.5 db. A larger change in voltage results in a relatively larger gain change and also causes a reduction in the load carrying capacity of the amplifier. The main effect of an increase in the a-c supply voltage is a decrease in the life of the vacuum tubes caused by excessive current through the heaters.

A continuous range of gain adjustment of about 25.5 db is available by means of the five steps on the input transformer and the potentiometer. Taps on the input transformer provide gain steps of 4 db each. The range of the potentiometer is 5.4 $\pm$0.5 db.

Figure 26 gives the nominal gain frequency characteristic of the amplifier measured between 600-ohm resistances. The characteristic is approximately flat over the voice range being about 0.5 db below the 1000-cycle gain at 250 and at 4000 cycles.

The power carrying capacity of the amplifier is such that the output may be as high as +10 db transmission level.

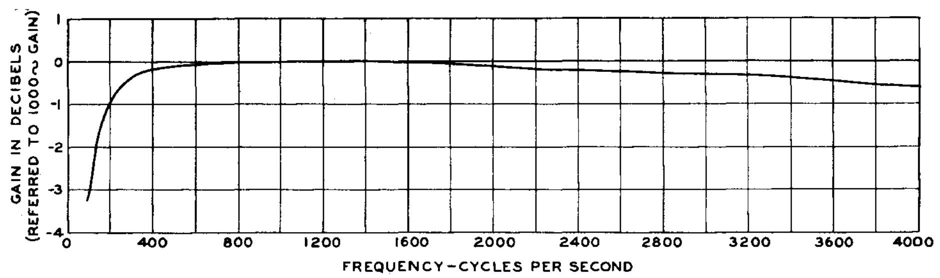


Figure 26—Typical Amplifier Gain—Frequency Characteristic.

Equalizer and Filter Characteristics

The type of equalizer used with this repeater depends upon the type of facility to which the repeater is connected as outlined in Section 2. In general, the loss-frequency characteristic of the equalizer is such as to compensate for the loss-frequency characteristic of a typical repeater section of the particular facility in use. At frequencies above 1000 cycles part of the compensation is obtained by the interaction effect of the filter working between the equalizer and amplifier impedances.

The type of filter used with this repeater also depends upon the type of facility to which the repeater is connected as outlined in Description and Functions of Component Units, pages 5 to 30 inclusive. The loss-frequency characteristics of these filters are such as to restrict the pass band of the repeater at the high frequency end as indicated on the repeater characteristic shown in Figure 27.

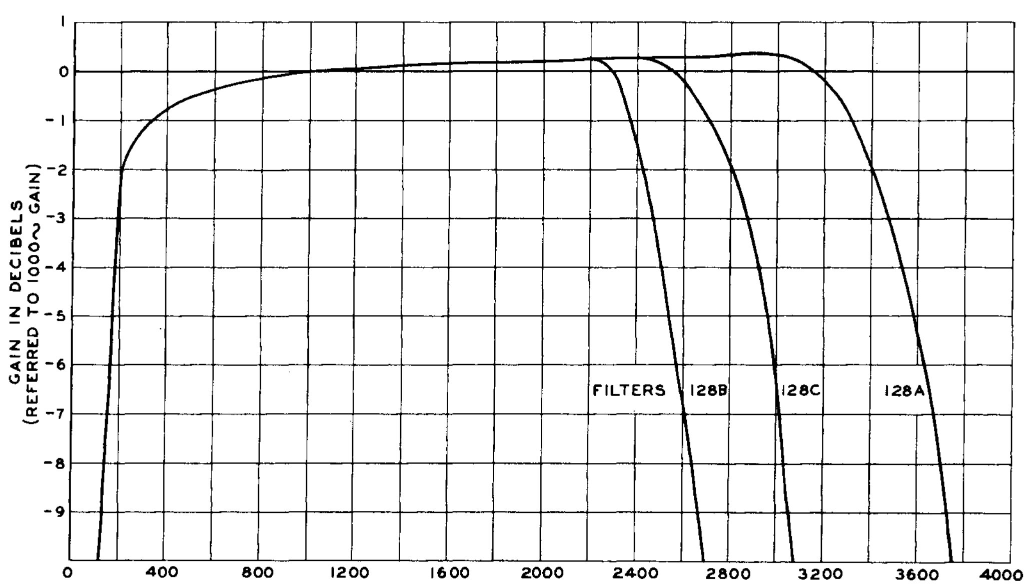


Figure 27—Typical Overall Gain—Frequency Characteristic as used on Open Wire Circuits.

Overall Repeater Characteristics

The overall insertion gain of the complete 2-wire repeater between line impedances will depend on the type of equalizer used. Assuming that the equalizer is one which introduces maximum loss, overall 1000-cycle insertion gains (amplifier gain less equipment loss—see paragraph on Determination of Singing Point Value, page 37) approximating those given below may be expected when the amplifier is adjusted for maximum gain.

Intermediate Trunk Repeater	22 db
Intermediate Dispatch Repeater	20 db
Terminal Trunk Repeater—Receiving	15 db
Terminal Dispatch Repeater—Receiving	13 db
Terminal Repeater—Transmitting	18 db

In most cases, however, it will not be possible to utilize all of the above gain, since the degree of balance between line and network is often the determining factor as outlined in the section on Balancing Equipment, page 14.

A typical overall transmission-frequency characteristic of the complete two-wire repeater is shown in Figure 27.

Gain Measuring Using Auxiliary Apparatus

Amplifier gains are usually measured on a transmission measuring set. In general, this apparatus consists of a sending source which delivers a known amount of a-c power (generally at 1,000 cycles) to the repeater; and a receiving device which is capable of measuring the power delivered to the repeater and power coming out of the repeater, or is capable of measuring the ratio of the output current, voltage, or power to the input current, voltage or power, respectively.

A portable transmission measuring set (9A or 12A) and a portable 1,000-cycle machine (KS-5472) may be used for this purpose. Auxiliary 600-ohm pads are required with these items when making repeater gain measurements. All of this equipment is described in Specification X-64282, which also gives instructions for use.

When a pad or attenuator having the characteristic impedance of the amplifier is connected between the input and output of an amplifier and phase relations are favorable, the amplifier will begin to sing when its gain just equals or slightly exceeds the loss of the pad. Making use of the above, the amplifier gain may be measured as follows:

1. Connect the attenuator between the AMP IN and AMP OUT jacks of the amplifier as shown in Figure 28. The line circuits are automatically disconnected from the amplifier when the plugs are inserted in the jacks.

2. When a variable attenuator is used, set the potentiometer of the amplifier being measured to the position where the gain is to be measured and decrease the loss of the attenuator until singing just begins.

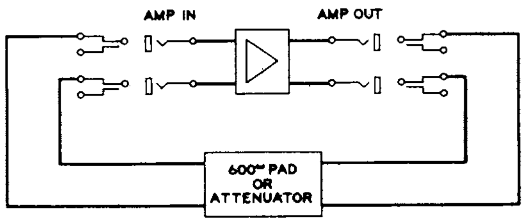


Figure 28—Singing Point Method of Measuring Gain.

3. This singing may be heard in the receiver connected to the monitoring jacks and usually consists of a single-frequency tone. The singing loss should then be determined for the other poling by turning over the connections to the AMP IN or AMP OUT jacks. In case singing is not heard with one of the polings, it is probable that the amplifier is singing at an inaudible frequency, and the other poling must be used.

4. The loss in the attenuator when the amplifier just begins to sing is equal to the amplifier gain at the frequency of singing. The loss for the poling which causes singing at the higher of the two attenuator settings should be taken as the amplifier gain. This will usually be somewhat less than the 1,000-cycle gain due to the shape of the amplifier gain-frequency characteristic as described later.

The procedure for measuring gain by means of fixed pads in the feedback circuit is the same as that described in the preceding paragraph except that the fixed pad makes it necessary to adjust the amplifier gain potentiometer until singing just begins. By trying fixed pads of different value, determine the pad value which results in a potentiometer setting nearest the desired one, when singing begins. Having determined the potentiometer setting which gives amplifier gain corresponding to the pad loss, it is then necessary to estimate by observing the position of the potentiometer shaft with reference to the desired position, what the actual gain is with the shaft in the desired position. The whole range of the potentiometer shaft corresponds to about 5.4 db. If audible singing is obtained with both polings, the lower of the two potentiometer settings should be taken as the one which gives amplifier gain corresponding to the pad loss.

When it is desired to adjust the amplifier gain to a given value, proceed as in the above paragraph except that the loss of the pad or attenuator is set to the nearest value corresponding to the desired gain. Then the gain of the amplifier is slowly increased until singing just begins. Reverse the connection between the attenuator and one pair of jacks and repeat the test. If audible singing occurs with both polings, take the lower of the two potentiometer settings as the correct one.

The principal limitations of all singing methods of measuring gain arise from the following factors:

1. All singing methods indicate the gain of the amplifier at the particular frequency at which singing occurs. Where the gain-frequency charac-

teristic of the amplifier is not flat the indicated gain will differ from the 1,000-cycle gain by at least the amount by which the gain of the amplifier at the singing frequency deviates from the 1,000-cycle gain.

2. In case the amplifier impedance at the singing frequency is not equal to the impedance of the pads used in the feedback circuit, an error is introduced in the gain measurement. In actual practice the errors so introduced are generally rather small. Another limitation that arises is that in most practical methods of measuring gains by the singing test, the loss of the feedback path can be varied only in finite steps and the size of these steps imposes a limitation on the ultimate accuracy which may be obtained by any such method.

In the following paragraphs a discussion of several singing methods of gain measurements will be given, with particular reference to their inherent limitations, advantages and disadvantages.

Singing Method Using Adjustable Attenuator

This method employs an adjustable 600-ohm attenuator of variable loss in the feedback path. The loss of these attenuators is generally variable in 0.5 db or 1.0 db steps. An example of such an attenuator is the 5A Attenuator, shown schematically in Figure 29.

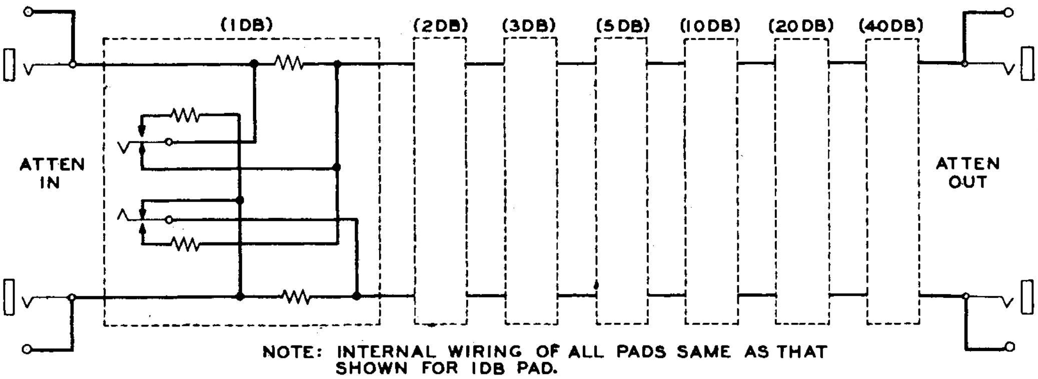
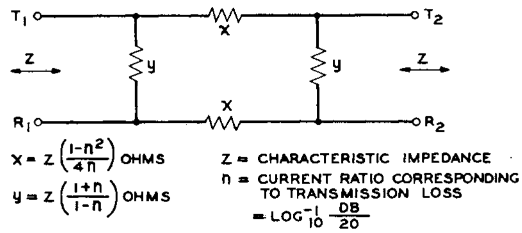


Figure 29—5A Attenuator.

Singing Method Using Fixed Pads

This method makes use of balanced-type 600-ohm pads of fixed loss in the feedback circuit, and the amplifier is made to sing by adjusting the amplifier gain, both polings being tested. In order to have available losses for the feedback circuit somewhat near the gain of the amplifier or working step it is desirable to provide a number of such pads arranged to be connected in tandem when required. A series of pads having losses of 1, 2, 4, 8, 16 and 32 db when used in tandem as required give 1.0 db steps from 0 to 63 db. The required resistances for such pads are shown in Figure 30. By making use of such a series of pads it should be possible to determine the amplifier gain to within about ±0.7 db at the singing frequency.

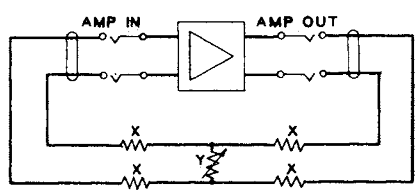


LOSS IN DECIBELS	X AND Y, FOR 600-OHM PADS	
	X IN OHMS	Y IN OHMS
1	34.7	10,420
2	69.8	5230
4	143.1	2656
8	317.0	1394
16	922.7	826
32	5970.3	630.9

Figure 30—Balanced π-Type Resistance Pads for Various Transmission Losses and Characteristic Impedances.

Singing Method Using Pad Having Adjustable Shunt Element

The construction of a pad whose loss is varied by varying the shunt element is shown in Figure 31. By using such a pad in the feedback circuit the gain of the amplifier may be measured while the potentiometer is left on



NORMAL LOSS IN DECIBELS	X IN OHMS
5	84
8	129
10	156
15	210
20	245
30	282

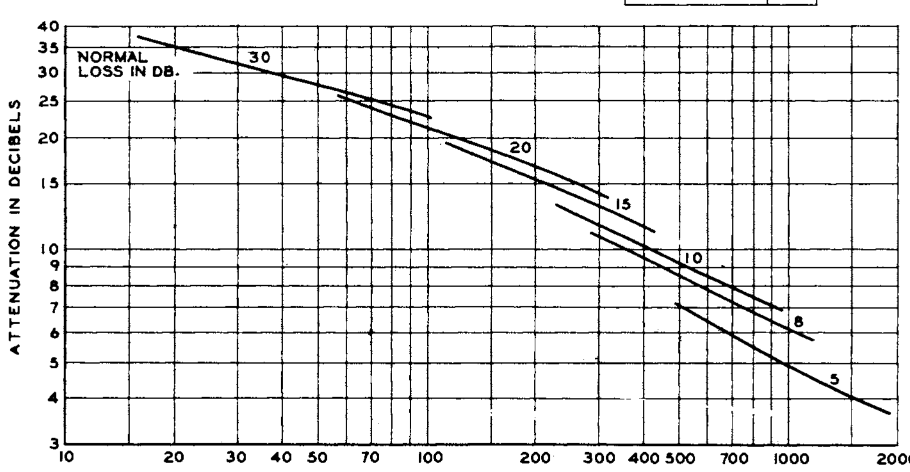


Figure 31—Simple Gain Test.

the working step. However, since the impedance of such a pad departs considerably from 600 ohms if the loss is varied much from the normal values, a normal value should be selected which is about equal to the normal amplifier gain.

This method suffers from any inaccuracies resulting from such improper pad impedances, but in general, if the proper selection of pad is made the errors resulting from this source should be small and accuracies of about ± 0.7 db should be obtained. A disadvantage of this method is that it requires a chart such as Figure 31 in order to determine the gain.

Measurement of Singing Points by "21 Tests"

A two-wire repeater forms a closed transmission path containing gains and losses. When the sum of all the gains just exceeds the sum of all the losses, and when favorable phase relations exist, continued oscillation, called singing, will take place. Use is made of this phenomenon in measuring the degree of balance between the line and network circuits. Such tests are called "21 tests."

To make a 21 test, the line and network circuits whose balance is to be measured are connected to one repeating coil hybrid of the repeater while a known loss (an attenuator consisting of a fixed or variable loss pad) is inserted between the AMP OUT jacks of one amplifier and the AMP IN

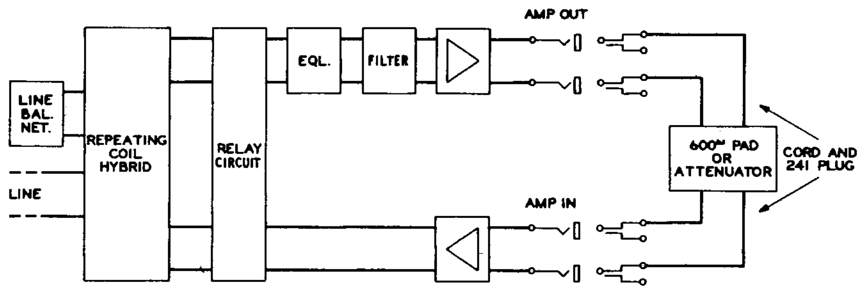


Figure 32—Connections for Measurement of Singing Points by "21 Tests" at Intermediate Repeaters or at the Line Side of Terminal Repeaters.

jacks of the other as shown in Figures 32 and 33. Adjustments are then made, either of the amplifier gains or of the known loss, until singing just begins. Knowing the amplifier gains and the inserted loss the balance existing at the other repeating coil hybrid may be determined, since the algebraic sum of the gains and losses must be zero when singing just begins. (Losses are considered positive quantities and gains negative quantities for the above summation). This test is a measure of the balance, or "singing point" between the line and network circuits at the singing frequency. The test is then repeated with the opposite poling, i.e., with the connections of the AMP IN or AMP OUT jacks turned over. The higher of the attenuator readings obtained with the two polings is taken as L_p in the singing point formula given below. When making tests as indicated in Figure 32, audible singing should be heard with both polings because of the low pass filter in the singing path. In circuits illustrated by Figure 33, however, audible singing may occur on one poling only, in which case, the attentuator setting with this poling must be used.

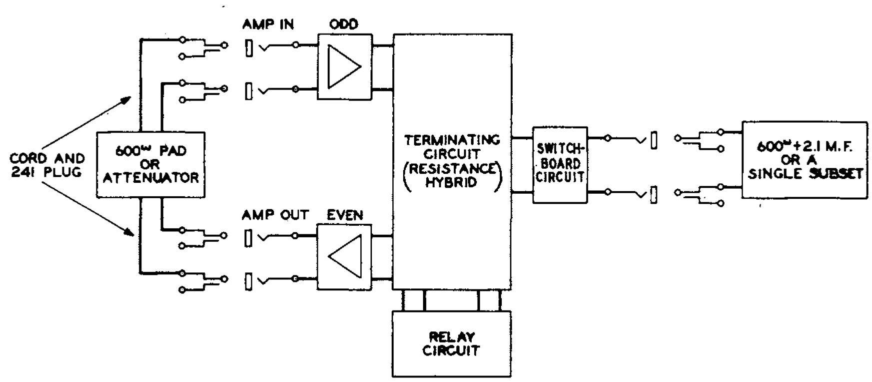


Figure 33—Connections for Measurement of Singing Points by "21 Tests" at Drop Side of Terminal Repeaters.

The result so obtained gives the balance at the singing frequency only. It is evident that the precision of the measurement is a function of the degree of accuracy with which the amplifier gains are known. Where measuring sets are available, the gains of the amplifiers at the singing frequency may be measured but where singing methods of gain-measuring are used the inherent inaccuracies of such methods are carried over into the 21 test results and the precision of the latter tests is modified accordingly.

Determination of Singing Point Value

The singing point as measured by the procedure described in the second paragraph under Measurement of Singing Points by "21 Tests," page 36, will then be

$$(g_1 + g_2) - L_e - L_p$$

where $(g_1 + g_2)$ equals the sum of the amplifier gains. L_p is the loss of the attenuator or fixed pad. L_e is the loss of the line equipment and includes the loss of the equalizer and filter. The following table gives values for L_e which as will be noted depend upon the line. A value of L_e for the two-wire terminating circuit is also given where it is desired to obtain the singing point between the compromise network and the switchboard connection. L_e as given here is the sum of the input and output equipment insertion losses at 1000 cycles. If the singing occurs at a frequency where L_e is materially different from the 1000-cycle value, e.g., above the cutoff frequency of the filter, an additional inaccuracy is introduced. It has been found, however, that with the poling which gives the higher value of L_p, the singing frequency is usually such that the value of L_e approximates the 1000-cycle value. The quantity L_e is of considerable use in laying out circuits since g_1 (the amplifier gain) $- L_e$ (the equipment loss) gives the insertion gain of the repeater and associated line equipment between line impedances in the g_1 direction of transmission.

1000-Cycle Equipment Insertion Loss
for use in Determining Singing Points

2-Wire Circuits

Cable Circuits

Type of Line	*Signaling Cycles*	*Insertion Loss—db* Input Equip-ment	*Insertion Loss—db* Output Equip-ment	L_e—db
16 or 19 H172S	All	4.7	3.6	8.3
16 or 19 H63P	All	4.7	4.0	8.7
16 or 19 H106P	All	4.4	4.0	8.4
16 or 19 H88S	All	4.4	3.6	8.0
16 or 19 H50P	All	4.6	4.0	8.6
19 B88S	All	4.5	3.6	8.1
19 B50P	All	4.7	4.0	8.7
16 H44S	20	5.5	3.8	9.3
16 H44S	135 or 1000	6.8	3.8	10.6
16 H25P	20 on Side and Phantom	6.8	4.0	10.8
16 H25P	20 on P; 135 or 1000 on S	5.6	4.0	9.6
16 H25P	20 on S; 135 or 1000 on P	5.6	3.9	9.5
16 H25P	135 or 1000 on S and P	6.9	3.8	10.7
Two-wire Terminating Ckt.	All	10.7	10.7	21.4

Open Wire Circuits—All Gauges and Spacings

Facility	*Cx and Carrier*	*Signaling Cycles*	*Insertion Loss—db* Input Equip-ment	*Insertion Loss—db* Output Equip-ment	L_e—db
S	None	20	5.5	3.6	9.1
S	None	135 or 1000	6.5	3.6	10.1
P	None	20 on S and P	4.0	3.9	7.9
P	None	20 on P; 135 or 1000 on S	6.8	3.9	10.7
P	None	135 or 1000 on P; 20 on S	5.5	3.9	9.4
P	None	135 or 1000 on S and P	6.8	3.9	10.7
S	Carrier	20	5.8	3.9	9.7
S	Carrier	135 or 1000	6.8	3.9	10.7
P	Carrier	20 on S and P	4.2	4.1	8.3
P	Carrier	20 on P; 135 or 1000 on S	7.0	4.1	11.1
P	Carrier	135 or 1000 on P; 20 on S	5.8	4.1	9.9
P	Carrier	135 or 1000 on S and P	7.0	4.1	11.1
S	Cx	All	6.5	3.8	10.3
P	Cx	All	6.8	4.0	10.8
S	Cx & Carrier	All	6.8	4.1	10.9
P	Cx & Carrier	All	7.0	4.2	11.2
Two-wire Term.		All	10.7	10.7	21.4
R.R. Dispatch	None	4.5	9.2	3.6	12.8

Note: These values include the losses of all equipment indicated, such as ringers, composite sets and carrier line filters.

INSTALLATION

Relay Rack Unit

The unit should be removed from the shipping frame and fastened to the relay rack by means of the 12—24 R.H.I.M. screws with which it was fastened to the shipping frame.

Cabinet-Mounted Unit

When the cabinet is used, it may be placed on the floor or on a shelf or mounted on wall brackets. One cabinet may be placed upon another, in which case it will be necessary to remove the handles, clinch rings, No. 18 screws, washers and nuts from the top of the lower cabinet and to make use of the clinch rings, etc., of the bottom of the upper cabinet for fastening the two cabinets together. When cabinets are set side by side, they should be placed on centers of at least 1 foot 10¼ inches, which will permit the doors to open 90 degrees.

Two knockouts are provided at the top of the cabinet and two at the bottom. Those at the top should be removed and the A2 Federal bushings—shipped loose—should be installed in their place. The line leads and ground lead should be brought through one of these and the power cord—also shipped loose—through the other. When the cabinet is supported by wall brackets any two knockouts may be used depending on whether the top or bottom is more suitable in each case. When one cabinet is placed upon another, the top one should contain the power supply panel serving the two repeaters in order that the power cord may be carried directly up out of the top cabinet. In this case the knockouts between the two should be removed and the A2 Federal bushings—furnished with the bottom cabinet —should be installed in their place. The line and ground leads should be brought through one of them, and crossed through the upper cabinet. The leads from the power supply unit of the upper cabinet to the equipment of the lower cabinet should be brought through the other.

The power cord, 15 feet long, is equipped with a non-polarized plug for insertion into a nearby outlet. If one-half inch conduit or BX cable is to be used the female plug should be connected to the power leads and the rest of the cord discarded.

It may be necessary, as outlined later, to make certain adjustments in the balancing networks at the time of installation. The apparatus and terminals on the rear of the line and line-balancing unit must be accessible for certain changes in connections necessary in making these adjustments. If the cabinet is to be mounted against a wall, temporary connections may be made with the cabinet located in such a manner as to allow access to the rear of the equipment. After the adjustments are completed, the cabinet may be moved to its permanent location. However, suitable arrangements should be made for access to the rear of the equipment when necessary for maintenance purposes.

When two repeaters are served by one power supply unit they should be located as closely together as possible in order to limit the length of wire and thereby reduce the possibility of noise induction into the grid circuit of the second repeater.

Battery and Signaling Supply

The 156B Interrupter and the battery and 20-cycle supply unit are mounted separate from the V1 Repeater assembly proper. When mounted in a cabinet the cabinet is installed as described above for the repeater cabinet. But when both battery supply and 20-cycle supply are required there will be two cords to pass through one hole in the cabinet. Since the A2 Federal bushing will not permit this it should be discarded and in its place a one-half-inch Chase nipple and a one-half-inch conduit lock nut or equivalent should be used. The power cords, 15 feet long, are attached to the equipment and are equipped on the other ends with non-polarized plugs for insertion into nearby outlets. If one-half-inch conduit or BX cable is to be used the entire cords should be discarded and wire run directly to the equipment.

Protection

The office protection used should include seven-ampere fuses, and 26/27 or 28/29 protector blocks. The blocks may be replaced by Western Union (Western Electric Co. D-48183—green stripe) office protector blocks.

To prevent damage from lightning, the following grounding arrangements are recommended when the repeater is used on exposed circuits;

(1) Where a low resistance ground, such as a city water supply system, is available the repeater and telephone line protector grounds should be connected to it. It is desirable and ordinarily will be found that the secondary side of the power circuit in the building is also connected to this ground.

(2) Where no such ground as a city water supply system is available the best practicable ground such as private water system, gas pipes, underground tank or other buried structures, or rod ground should be used as the common ground for the repeater, the telephone line protectors and the secondary power distribution circuit in the following manner:

(a) Provide a ground wire not smaller than No. 14 gauge between the power supply unit and ground.

(b) Provide a similar wire between the telephone line protectors and the ground used in (a) above.

(c) Bond ground used in (a) to the ground connection on the secondary side of the power circuit which supplies the building.

When the secondary neutral of the power line is grounded at the transformer pole rather than at the service entrance it will be desirable to request the power company to furnish a ground at the service entrance in the manner provided in Article 250 of the National Electric Code.

(d) On gas pipes, connection should be made to the line side of the meter.

Operating Adjustments

Before connecting power to the power supply unit, measure the power supply voltage and connect the proper transformer leads to the power receptacle on the unit as indicated by the following table. It should be noted that the leads to be connected also depend on whether one or two repeaters are to be served by one power supply unit.

Nominal Voltage of a-c Supply	*1 Repeater on Power Supply*	*2 Repeaters on Power Supply*
	Line Side Taps	*Line Side Taps*
110	Red and Blue	Red-White and Blue
115	Red and Blue-White	Red-White and Blue-White
120	Red and Green	Red-White and Green

Insert a 310A Vacuum Tube into the vacuum tube socket on each of the voice amplifiers, and connect power to the power supply unit. Allow at least one minute for the vacuum tubes to come up to the operating temperature.

The cathode current measured as voltage drop across resistance (B) in each voice amplifier with the potentiometer in the extreme clockwise direction should be between 450 and 800 millivolts direct current.

The voltage measured between terminals 1 and 6 of the vacuum tube socket in each voice amplifier should be 10 $\pm$0.6 volts alternating current.

If the above voltages are not within the limits specified, the performance of the power supply unit should be checked in accordance with the procedure outlined under "Trouble Location," page 50, and the wiring between the power supply unit and the voice amplifier should be checked.

With normal voltages on the amplifier, measure its gain by one of the methods described in the section on Trouble Location, pages 50 to 57 inclusive. If gain measuring apparatus is available, measure the gain from the AMP IN to the AMP OUT jacks at 1000 cycles with the potentiometer in the extreme clockwise position. For this test, the amplifier output should not exceed +10 dbm (10 db above one millivolt). With the adjustable lead connected to terminal 1 on the input transformer (IN) the gain should meet the requirement specified in the first paragraph under Amplifier Gain Characteristics, page 30. If the adjustable lead is connected to a terminal on the input transformer other than terminal 1, the gain should be 4 db per step less than that specified in the paragraph mentioned (see Figure 1). If gain is measured by one of the singing methods described under Transmission Performance and Testing Methods, pages 30 to 39 inclusive, allow

—2db additional margin in the requirement for inaccuracy in the method of measurement.

Working Gain of Repeater

The gain at which an amplifier in a repeater operates is called the working gain of that amplifier, and the loss of a repeatered circuit from one terminal to the other is known as the "overall net loss." The working gain setting depends on the line loss and the overall net loss and is also influenced by such factors as the load capacity of the vacuum tube output, noise, crosstalk, singing, and echo. The overall net loss is usually about 9 db under average conditions and should be approximately the same (within about ±1 db) in each direction.

For trunk repeaters connected to lines with uniform impedance characteristics, satisfactory operation will be obtained in the majority of cases: (1) if the line loss ahead of the repeater is not more than about 12 db at 1000 cycles for open wire circuits or about 18 db for cable circuits, and (2) if the transmission level at the output of the amplifier is not more than the level load carrying capacity of the amplifier. In general, it is advisable to operate the amplifier at a high output level but the level must not be high enough to cause overloading. In order that a preliminary working gain setting may be determined, the approximate line loss may be calculated by referring to the following table, which gives losses of various types of lines in db per mile.

Transmission Losses of Cable Circuits at 1000 Cycles and Average Temperature (55° F.)

	Loss per Mile—db	
Type of Circuit	*Side Ckt.*	*Phantom Ckt.*
16H172-63	0.16	0.16
19H172-63	0.27	0.28
19H174-106	0.28	0.22
16H88-50	0.19	0.16
19H88-50	0.35	0.30
19B88-50	0.28	0.23
16H44-25	0.25	0.21

Transmission Losses of Open Wire Circuits at 1000 Cycles and 68° F.

		Loss per Mile—db			
		Dry Weather		Wet Weather	
Spacing	*Gauge*	*Side Ckt.*	*Phantom Ckt.*	*Side Ckt.*	*Phantom Ckt.*
8-inch	165-mil	0.032		0.042	
8-inch	128-mil	0.050		0.060	
8-inch	104-mil	0.070		0.081	
12-inch	165-mil	0.030	0.025	0.038	0.035
12-inch	128-mil	0.046	0.038	0.054	0.049
12-inch	104-mil	0.066	0.054	0.075	0.066

Transmission Losses of Entrance Cable Used with Open Wire Circuits at 1000 Cycles and 55° F.

Type of Circuit	*Loss per Mile—db* Side Ckt.	Phantom Ckt.
13 Gauge Non-loaded	0.48	0.43
16 Gauge Non-loaded	0.72	0.62
19 Gauge Non-loaded	1.07	0.95
13H31-18	0.16	0.13
16H31-18	0.28	0.24
19H31-18	0.55	0.46

The method of determining the preliminary working gain setting depends somewhat on the type of repeater and its location in the circuit. Figure 34 shows an intermediate repeater located in a circuit between two non-repeatered terminals. Single lines are used for simplicity.

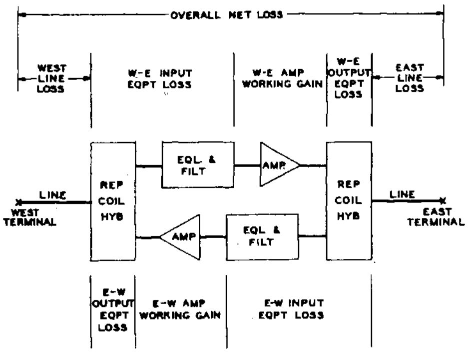


Figure 34—Intermediate Repeater—Gain and Loss Diagram.

To determine the preliminary working gain setting for the above intermediate repeater, proceed as follows:

1. Knowing the lengths of line and the loss per mile from the above table, determine the east and west line losses.
2. Add to the line losses the west-to-east input and output equipment insertion losses obtained from the table on page 38.
3. From this total, subtract 9 db, the overall circuit net loss, and the result will be the working gain of the west-to-east amplifier provided the transmission level at the output of the amplifier is not more than 19 db above the transmitting level at the west terminal.

4. Check this level, subtract from the gain obtained in (3) above the sum of the west line loss and the west-to-east input equipment loss. If the result is less than 10, the working gain previously obtained is satisfactory. If the result is more than 10, it will be necessary to reduce the working gain value until the result reaches 10. If this reduction becomes necessary, the overall net loss will be increased by a corresponding amount.
5. To obtain a corresponding working gain setting for the east-to-west amplifier proceed as above using east-to-west input and output equipment insertion losses in place of the corresponding west-to-east equipment insertion losses.
6. If it becomes necessary to increase the overall net loss in either direction because of the amplifier output level limitation, it is desirable to adjust the working gain of the other amplifier so that the overall net loss is the same in both directions.

When the intermediate repeater is located between two other repeater points, the working gain of the amplifiers should be adjusted to compensate for the line and equipment losses introduced between the output of the preceding amplifier and the input of the amplifier being adjusted. On long cable circuits containing a number of repeaters in tandem it is customary to allow a small margin between loss and amplifier gain so that the transmission level at each amplifier is approximately 0.5 db less than that at a preceding amplifier. This effectively tapers the transmission levels at the amplifier outputs, thereby improving echo and singing conditions at intermediate repeaters. This practice of tapering is not done on open wire circuits because with the lowered levels noise would be increased too much.

When the repeater is a terminal repeater, the methods of determining working gain are different for the two sides of the repeater. On the transmitting side, it is only necessary to compensate for equipment losses and raise the transmission level at the output of the amplifier to the desired value. It is considered good general practice to adjust the transmission level at the output of a terminal transmitting amplifier to about 7 db above the level at the input to the two-wire terminating set when transmitting into a cable circuit. The corresponding value for open wire circuits is 10 db. The level is higher for open wire circuits because noise conditions are usually worse than on cable circuits and it is desirable to have a high "signal to noise" ratio. The input equipment loss of the two wire terminating set from the table (page 37) is 10.7 db. The working gain of the transmitting amplifier, therefore, should be set normally at 17.7 db for cable circuits and 20.7 db. for open wire circuits.

On the receiving side of a terminal repeater, the working gain is calculated as indicated in the paragraphs on page 43 except that there is no line loss on the output of the repeater and the output equipment loss is that of the two-wire terminating circuit.

For trunk repeaters connected to lines with non-uniform impedance characteristics, the line loss may be approximated with the help of the values given in the loss table. Under these conditions, the preliminary working gain setting is not so important, since the final working gain will probably depend on the balance obtainable between the line and the adjustable network.

For dispatch repeaters a maximum preliminary working gain of 7 or 8 db more than the sum of the input and output equipment losses given in the table on page 37 is all that will be possible ordinarily, because of balance considerations.

When setting the amplifier gain, it is desirable to set the potentiometer as near as possible to the "high gain" end. When there are two possible combinations of input transformer tap and potentiometer setting to give the desired gain, always use the one with the higher-numbered (lower gain) transformer tap and higher gain potentiometer setting. This combination gives the most favorable output load carrying capacity of the vacuum tube.

Adjustment of Balancing Networks for Optimum Singing Point

After the preliminary working gain has been set, the balancing networks must be adjusted and the balance measured. The measurements are made by "21 tests" carried out in accordance with the methods described under Measurement of Singing Points by "21 Tests," pages 36 to 38, inclusive. In most cases the working gain settings of the amplifiers will provide sufficient gain for these tests. If necessary, however, the gain of one or both amplifiers may be increased. At the outset care should be taken to see that the strapping of the (C1), (D) and (E) condensers of the side circuit and the strapping of the (C1), (C2), (D) and (E) condensers of the phantom circuit and the value of the (E) resistance of the phantom circuit is in accordance with section on Description and Functions of Component Units, pages 5 to 30, inclusive.

Adjustment of Adjustable Network for Trunk Circuits

The nominal values of resistance and capacitance in the adjustable network (see Figure 10) for various types of line circuits are as follows:

Line	Spacing	*Resistance (ohms)* P+D	*Capacity (mf)* J+K+L+M
165 NL Side	12 inches	625	2.9
128 NL Side	12 inches	675	1.8
114 NL Side	12 inches	700	1.5
104 NL Side	12 inches	725	1.2
165 NL Phantom	12 inches	375	4.5
128 NL Phantom	12 inches	425	3.5
114 NL Phantom	12 inches	425	3.0
104 NL Phantom	12 inches	450	2.4
165 NL Side	8 inches	600	2.9
128 NL Side	8 inches	650	1.8
104 NL Side	8 inches	675	1.2

The desired setting of the adjustable network is that which will give the highest singing point test between it and the line circuit which it balances. The procedure for adjusting the east network is as follows:

(a) The line under test should be terminated at its distant end in a subset with the receiver off the hook, or, if there is a repeater at the distant end, the line should be terminated in the repeater in passive condition. This latter is accomplished by inserting 600-ohm plugs in the AMP OUT and AMP IN jacks on the far side of the distant repeater.

(b) Disconnect the west line equipment from the repeater by patching an attenuator, a fixed or variable loss pad between the AMP OUT and AMP IN jacks on that side.

(c) Adjust the capacity in the east bridged condenser (BO) to zero by disconnecting all units strapped to terminal A, except when a "T" section is required, in which case resistances (F) and (G) are used and condenser (BO) is set as outlined in the first paragraph on Building-Out Capacity and "T" Section, pages 17 and 18.

(d) Adjust the series capacity of the east network (the sum of J, K, L and M) to about 0.6 microfarad. M consists of a 141F Condenser which contains two units (0.25 and 0.5 mf) connected in parallel with J, K and L. Either or both of these units may be disconnected by breaking the straps connecting their terminals to L.

NOTE: The total connected capacity of multi-unit condensers is determined by adding the capacities of all units strapped to terminal A. The terminal arrangement and internal wiring are shown on Figure 35.

(e) Connect a telephone receiver to the monitoring jacks.

(f) Adjust the series resistance to the east network (the sum of P and D) to about 625 ohms, and find the singing point, using the methods described under Measurement of Singing Points by "21 Test," pages 36 to 38 inclusive.

(g) Increase P about 25 ohms and repeat (f). If the singing point has been increased, increase (P) until the setting for maximum singing point is found. If the singing point is decreased, decrease (P) until the maximum singing point is found.

(h) Leaving the network resistance at this setting, change the value of the series capacity, (J+K+L+M) to obtain maximum singing point using both polings.

(j) Readjust the resistance as above, leaving the condenser at the new value.

(k) Now with the potentiometers set just below the singing point make the bridged condenser (BO) about 0.01 mf. If this causes the repeater to sing with either poling, no other value need be tried, as zero is the best value. If, however, the singing gain is increased, increase the bridged condenser in steps of about 0.01 mf until no further improve-

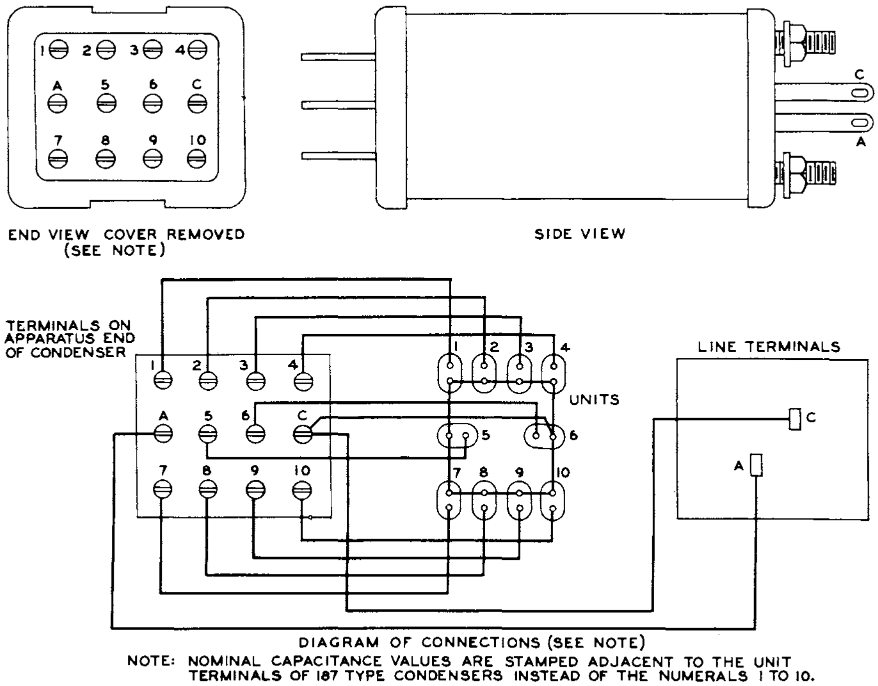


Figure 35—187-Type Multi-Unit Condenser.

ment is obtained. When a "T" section is used, condenser (BO) has been set per (C) above. In this case change the value of capacity in 0.01 mf steps on both sides of the original setting until the maximum singing point has been found. The actual value of the singing point which may be expected with this network depends mainly on the line impedance. If used with a uniform line, the singing point should be comparable with that obtained with a precision network. If the line is non-uniform, the singing point will depend on the type of irregularity and its distance from the repeater.

(l) Reconnect the west line equipment to the repeater by removing the plugs connecting the attentuator to the AMP IN and AMP OUT jacks.

To adjust the west network:

(m) Disconnect the east line equipment from the repeater by patching an attentuator, a fixed or variable loss pad between the AMP OUT and AMP IN jacks on that side. Terminate the west line at the distant end as described in paragraph (a).

(n) Proceed with adjustments as outlined in sections (c) to (k). If the west line is the same as the east line the initial values of resistances (D) and (P) and condensers (J), (K), (L), and (M) should be the same as the final values obtained for the east network.

(o) Connect the east line and network to the repeater.

(p) Set the two amplifier potentiometers to give the working gain of the repeater in each direction.

(q) Increase the settings of the two amplifier potentiometers until the repeater starts to sing. It should be possible to raise both potentiometers at least 3 db before singing starts.

Adjustment of Adjustable Network for Dispatch Circuits

The adjustment of this network may be made in a manner similar to that for trunk circuits described in the preceding paragraphs except that the series condensers in this network consist of the (J) and (M) condensers only. Before starting to make adjustments, however, about every third subset should be connected to the line in the listening condition for a distance of approximately 85 miles and the line should be terminated at the distant end in a subset with the receiver off the hook or a repeater in passive condition.

After obtaining a satisfactory adjustment, connect to the line at or near the repeater point a subset in the talking condition. If the repeater sings or if poor quality is obtained, lower the repeater gain in both directions until good quality is obtained. The setting of the amplifier potentiometers should be low enough so that both can be raised 2 or 3 db without causing singing.

When subsets are bridged across the line, particularly in the talking position, they cause a rather large impedance irregularity. Because of this, the balance cannot ordinarily be made sufficiently good to allow a repeater gain (amplifier gain less equipment loss) greater than 7 or 8 db in each direction. Larger gains than this may be obtained by inserting an "impedance corrector" between the line and the subset to increase the bridged impedance. This impedance corrector may be a resistance or an inequality ratio coil, with the high side in series with a condenser toward the line. With properly selected resistances, larger values being used near the repeater than at more distant points, the gain to be expected from the repeater is 11 to 12 db, if there is no large impedance irregularity near the repeater. An inequality ratio coil is desirable between the line and a branch circuit which is near the repeater.

The following table gives approximate values of resistances for various distances on each side of the repeater which have been found to give good results.

Distance from Repeater		
Line Loss	*Length No. 9 A.W.G.*	*Resistance*
0-2 db	0-35 miles	1000 ohms
2-4 db	35-70 miles	750 ohms
4-5 db	70-85 miles	500 ohms

The use of impedance correctors introduces a loss between subsets and the line. The following table shows this loss in db as compared with the efficiencies without correctors.

Resistance	Reduction in Subset Transmission: 295AK Listening	Talking	501A Listening	Talking
500 ohms	1	4	0	4.5
1000 ohms	2	7	0.5	7

If the repeater should sing at its working gain when no subsets are connected to the line, some arrangement must be made to avoid this extreme impedance condition. It is suggested that the operators at four or five stations on the side of the repeater away from the dispatcher be instructed to leave their subsets connected to the line in the listening condition whenever they are not being used for other purposes, thus insuring that one or two subsets are connected at all times. This will probably be necessary only in exceptional cases. Where the above procedure is impractical, a resistance may be substituted for the subsets by means of jack normals, 2500 ohms for the 295AK Set and 7500 ohms for the 501A Set.

Adjustment of 114A and 114B Networks

For 114-mil open wire circuits whose pin spacing is regular, the network adjustments given under Description and Functions of Component Units, pages 5 to 30, inclusive, will usually give the highest singing points. Adjust the network as indicated in the section on Precision Networks, pages 14 to 16 inclusive, and adjust the building-out capacitance (BO) as described in the paragraph on Open Wire Circuits, below.

Where the wire spacing differs from that shown in the table in Precision Networks, pages 16 and 17, or where the spacing changes throughout the circuit, some further adjustment of the network may be required to obtain the highest singing point. Make a preliminary adjustment of the network according to the table based upon the average pin spacing of the line, then adjust the building-out capacitance as described in the next paragraph. Then readjust the network to obtain the optimum singing point.

Adjustment of Building-Out Capacitance Associated with Precision Type Networks

Open Wire Circuits

The value of the building-out capacity (BO) should be adjusted to equal the capacity of the entrance cable or twisted pair. If the latter is not known, the building-out condenser should be adjusted to give the best balance as determined by the singing point tests previously described. When a "T" type building out section is required, the resistances are furnished as outlined in the paragraphs on Building-Out Capacity and "T" Section, pages 17 and 18.

Cable Circuits

For loaded cable circuits, the bare network is designed to balance the loaded cable with an end section of from 0.1 to 0.2 loading section, depending upon the particular type of network involved. Where the end section of the loaded cable is greater than the value for which the network is designed, the network must be built out to simulate the end section by connecting building-out capacitance across the network terminals. Where the loaded cable end section is less than that for which the network is designed, it is necessary to build out the line circuit by the addition of building-out capacitance in parallel with the line circuit. This adjustment is done by means of the 21 test, the building-out capacitance being varied until the optimum singing point is reached.

In the case of the 115AF and 115AG Networks, two resistances are provided to compensate for variations in impedance of the cable from an average cable. By means of a singing point test the proper strapping of these resistances may be determined.

When balancing precision networks against uniform lines, singing points of 25 db or more may be expected.

Compromise Network

At terminals of circuits, the impedances which may be connected to the circuit through the switchboard vary widely in value, depending upon the length and type of loop and switching trunk, type of subset, etc. Therefore, for terminal repeaters, it is not feasible to balance precisely such a widely varying set of impedances. Instead a compromise network consisting of 600 ohms in series with 2.1 mf is used. This network is not adjustable. A 21 test toward any connected drop circuit terminated in a sub-set with its receiver off the hook should give a minimum balance of about 6 db.

For circuits having only one repeater, assuming that the optimum balances have been obtained in each direction as described in preceding paragraphs, the working repeater gains assigned should be such that the gain of both amplifiers may be increased at least 3 db above the working gain settings before singing starts. If the circuit contains several repeaters in tandem, this margin should be increased by 1 or 2 db at each repeater. If the preliminary working gain setting of any amplifier is such that the above margins are not obtained, the setting should be reduced sufficiently to permit the above increases before singing starts. If the required margins are obtained without amplifier gain changes, the preliminary working gain setting becomes the final working gain setting and a record of the setting should be kept for future reference.

Trouble Location

The following paragraphs discuss certain types of troubles which may be encountered in a-c operated two-wire repeaters and associated equipment, and explain principles and methods which may be employed in locating and clearing such troubles. Since the possible causes of trouble are numerous and since the effects may be the result of a combination of contributing conditions, it is impracticable in the general case to follow a definite preconceived procedure in running down trouble. In many cases the methods used and the tests made must be adapted to meet the needs of a particular situation.

In any case, before undertaking extensive tests, it is advisable to insure that the trouble is not due (1) to some obvious defect of the equipment or its associated line circuits or (2) to the use of the equipment in a manner or for a purpose for which it was not designed.

It is important that the repeaters and associated equipment be properly protected from extraneous voltages such as those caused by lightning and induction from power lines. In order to avoid troubles arising from such sources, the protection practices set forth under Protection, pages 40 and 41, should be followed.

The tests enumerated below are designed to check the performance of the amplifiers and associated units and also to check the individual items of equipment comprising the units. These tests will make it possible to run down trouble conditions in an orderly manner with a minimum amount of soldering operations and with the minimum amount of auxiliary apparatus.

Identification of Trouble Producing Units

When improper performance is being obtained from the repeater, it is necessary to determine:

1. If operating conditions are normal.
2. In which unit the trouble, if any, is located.
3. The equipment item causing the trouble.

In many cases, the unit in trouble may be identified by the type of performance being obtained. If two repeaters fed from a common power unit both fail, or exhibit the same type of malperformance, it is logical to look for a common cause of trouble—in this case, the power supply unit. By the same reasoning, if only one repeater fails of a pair operating from a common power unit, the trouble most probably lies in the repeater or its associated line and line-balancing unit. Likewise, if both sides of a repeater fed singly from a power unit fail simultaneously a common source of trouble is indicated, e.g., the power unit or a common portion of the line and line-balancing unit.

Troubles in Power Supply Unit

The function of the power unit is to supply the proper potentials to the vacuum tubes in the repeater and to the relays in the line and line-balancing unit and two-wire terminating unit. Since proper potentials are essential to proper transmission performance, it is logical to check these potentials when improper transmission performance is being obtained. It is desirable to have available a double scale a-c voltmeter reading 0-15 volts and 0-150 volts, and also a d-c voltmeter reading up to 300 volts, the latter preferably having a resistance of 1000 ohms per volt. The ac-dc volt-ohm-milliammeter listed under Testing Equipment, page 5, combines the above meters in one instrument. The procedure for checking potentials is as follows:

1. Measure the a-c voltage applied to the primary of the 364D Transformer and see if the proper tap on the transformer is being used. The recommended taps are given in the table in paragraph on Operating Adjustments on pages 41 and 42.
2. If the applied a-c voltage is within ± 5 volts of the nominal voltage for the tap used, then the d-c voltage measured across the (A) condenser or between terminal 1 and terminal 12 of the power pack should be 140 volts ± 15 volts.
3. If the voltage measures slightly lower than the limits the selenium rectifier may have aged sufficiently to require additional applied voltage. Change the rectifier connection from the brown to the brown white lead.
4. If the voltage is still found to be too low, measure the voltage across the terminals of the (A) retard coil. If this latter voltage is greater than 5 volts, an abnormal load on the rectifier is indicated. Such an abnormal load could be caused by:
   - (a) Dielectric breakdown or leakage of the (A) condenser in the power supply unit.
   - (b) A ground on the (A) resistance in the power supply unit.
   - (c) Dielectric breakdown of the (A) condensers in the amplifiers associated with the power supply unit.
   - (d) Faulty vacuum tube in the amplifiers.
   - (e) Ground on the (D) resistance of the amplifiers.
5. Check whether all the switching relays of the line and line-balancing units associated with the power pack are operated. The failure of one or more to be operated indicates a ground trouble in the relay circuit.
6. As a further check on the power supply the following voltages should be checked with the a-c voltmeter.

Voltages and Limits Measured on the 364D Transformer Under Normal Load Conditions

One Repeater on Power Supply Panel

Primary Taps Used	*Measured Supply Voltage*	*Voltage Measured Across Orange and Orange-White Leads*	*Voltage Measured Across Green-White and Brown Leads*
Red & Blue	110 ± 5V	10 ± 0.6	137 ± 10
Red & Blue-White	115 ± 5V		
Red & Green	120 ± 5V		

Two Repeaters on Power Supply Panel

Primary Taps Used	*Measured Supply Voltage*	*Voltage Measured Across Orange and Orange-White Leads*	*Voltage Measured Across Green-White and Brown Leads*
Red-White & Blue	110 ± 5V	10 ± 0.6	137 ± 10
Red-White & Blue-White	115 ± 5V		
Red-White & Green	120 ± 5V		

Since the power supply unit is wired directly to the amplifier units and the switching relays of the line and line-balancing unit, the individual units cannot be isolated without disconnecting wires. However, by removing the tubes from all the amplifiers associated with a power supply unit and removing the D-3 lead [which comes from the (A) condenser of the power supply unit] from terminal 1 of the power supply unit it can be determined whether or not the power supply unit is operating satisfactorily. Proceed as follows:

(a) Remove all vacuum tubes from their sockets. This removes the load from the heater winding of the 364D Transformer.

(b) Remove D-3 lead from terminal 1 of the power supply unit. This removes all the plate load and the switching relay circuit.

(c) Connect a 3500-ohm test resistance across the (A) condenser of the power supply unit to simulate the total plate and relay circuit load.

(d) Connect a 7.8-ohm test resistance across terminals 15 and 16 of the power supply unit to simulate the heater load of four vacuum tubes.

(e) Measure the line voltage and check the connections to the line side of the 364D Transformer. The transformer taps should be connected as specified for "Two Repeaters on Power Supply Unit" in item (6) on page 52.

(f) Measure the voltage across the (A) condenser of the power supply unit. This should be 132 ± 10 volts d-c.

(g) Measure the voltage across terminals 15 and 16 and also across terminals 13 and 14 of the power supply unit. This should be 10 ± 0.6 volts a-c.

(h) If these limits are met the power supply unit is operating satisfactorily. Restore the power supply unit to normal by removing the 7.8-ohm and 3500-ohm resistances and reconnecting the D-3 lead to terminal 1.

Troubles in the Amplifier Units

In the following paragraphs there are enumerated certain tests which should be helpful in locating any troubles which may occur in the amplifier units. At the outset it may be well to state that little trouble should be experienced in these units provided proper protective measures have been carried out. It is of primary importance that the protective measures specified in the paragraphs on Protection, pages 40 and 41, be rigidly adhered to in order to avoid subjecting the repeaters and associated equipment to extraneous voltages such as those caused by lightning and power-line induction.

However, if trouble is experienced in transmission through the repeater the gain of the amplifiers should be checked. If transmission measuring equipment is available, the measured gain should check the working gain of the amplifier determined at the time of installation within 0.5 db. If gain is measured by a singing method, a 1 db variation is allowable. If the gain of the amplifier fails to meet the above requirements the most likely cause is vacuum tube failure. It is advisable, therefore, to have available a spare vacuum tube known to be good and known to be representative of the average vacuum tube as regards gain and filament activity. One of the simplest ways of locating a defective tube is by substituting a tube known to be good. When this is done and the resulting change in gain is more than 1.0 db, the indications are that the original tube was defective.

In case it is desired to make a filament activity test on the tube in service, this can be done by noting the change in voltage across the 100-ohm (B) resistance of the amplifier when the power transformer tap is varied from the blue to the blue-white wires and the blue-white to the green wire. It is preferable that the tests should be made only after the tube has been burning continuously for 5 minutes or more. The maximum tolerable change in voltage is shown on the following table:

	Limiting Change in Voltage in Per Cent	
Line Voltage	*Change from Blue to Blue-white*	*Change from Blue-white to Green*
105-110 110-115	15%	—
115-120 120-125	—	15%

With the potentiometer in the extreme clockwise direction the voltage across the 100-ohm (B) resistance should be between 450 and 800 millivolts.

If no vacuum tube trouble exists, the wiring and apparatus should be checked by methods specified in the last three paragraphs on page 57.

Troubles in the Line and Line Balancing Unit and Two-Wire Terminating Unit

If overall transmission performance is not normal and no trouble is found in the power unit or amplifier units, the equipment on the line and line-balancing units and two-wire terminating unit should be checked.

Instructions for checking the operation of the switching relays are given in the section on Troubles in Power Supply Unit, on pages 51 to 53 inclusive. However, the contacts should also be checked and readjustments made, if necessary, in accordance with the section on Relays, on pages 58 to 60 inclusive.

If transmission measuring equipment is available the line equipment may be checked by measuring the input and output equipment losses and the transhybrid loss. Since these equipment losses are measured between 600-ohm resistances they are not the same as the equipment insertion losses given in the paragraph on Determination of Singing Point Value, on pages 37 and 38.

For these tests, dummy plugs should be inserted in the AMP IN and AMP OUT jacks, power should be connected to the unit, the balancing network on the line and line-balancing unit should be disconnected and terminals 3A and 4A of this unit should be terminated in 600 ± 1 ohm.

For measuring the three kinds of losses, test connections should be made as indicated below. The terminal numbers refer to numbers on the terminal blocks with which the units are equipped.

		Transmission Measuring Set Connected		*600 ± 1 Ohm Connected*
Eqpt. Loss Measured	*Unit*	*From Terminals*	*To Terminals*	*Across Terminals*
Input	Line & Line Bal.	1A-2A (See Note)	9A-10A	5A-6A
	Two-Wire Term.	3-4	7-8	1-2
Output	Line & Line Bal.	5A-6A	1A-2A (See Note)	9A-10A
	Two-Wire Term.	1-2	3-4	7-8
Trans-hybrid	Line & Line Bal.	5A-6A	9A-10A	1A-2A (See Note)
	Two-Wire Term.	1-2	7-8	3-4

Note: When checking line equipment used on phantom circuits, terminals 1A and 2A on each side circuit line and line-balancing unit should be connected together to form one of these terminals.

Since the line equipment used with a repeater depends upon the type of circuit to which the repeater is connected, the following table gives 1000-cycle loss requirements for various combinations of line equipment specified for various types of line circuits.

		1000-Cycle Equipment Loss—DB				
	Type of Signaling	*Input*		*Output*		*Trans-hybrid*
Type of Circuit	*Values in Cycles*	*Max.*	*Min.*	*Max.*	*Min.*	*Min.*
Open Wire Side (1) Without Telegraph Composite Sets or Carrier Line Filters (2) With 5 KC Carrier Line Filters	20 135 or 1000	4.7 5.7	6.2 7.2	3.1 3.1	4.1 4.1	55.0 55.0
Open Wire Side With Telegraph Composite Sets and 5 KC Carrier Line Filters	135 or 1000	5.5	7.0	3.1	4.1	55.0
Open Wire Side With 3 KC Carrier Line Filters	20 135 or 1000	4.7 5.7	6.2 7.2	3.1 3.1	4.1 4.1	55.0 55.0
Open Wire Side With Telegraph Composite Sets and 3 KC Carrier Line Filters	135 or 1000	5.5	7.0	3.1	4.1	55.0
Railroad Dispatch Circuits	3-½	8.1	9.6	3.1	4.1	55.0

Type of Circuit	Type of Signaling Values in Cycles	1000-Cycle Equipment Loss—DB Input Max.	Input Min.	Output Max.	Output Min.	Trans-hybrid Min.
Open Wire Phantom Without Composite Sets on Sides or Phantom	20 Sides and Ph.	3.3	4.7	3.4	4.4	50.0
	20 Phantom 135 or 1000 Sides	6.2	7.6	3.4	4.4	50.0
	20 Sides 135 or 1000 Phantom	4.9	6.3	3.4	4.4	50.0
	135 or 1000 Sides and Phantom	6.2	7.6	3.4	4.4	50.0
Open Wire Phantom With Telegraph Composite Sets On Side Circuits	135 or 1000	6.2	7.6	3.5	4.5	50.0
Open Wire Phantom With Telegraph Composite Sets On Phantom	135 or 1000	3.5	4.9	3.5	4.9	50.0
16 or 19 Ga. H-172-63 Cable-Side	All	5.8	7.2	4.1	5.1	55.0
16 or 19 Ga. H-172-63 Cable-Phantom	20 Sides and Ph.	4.3	5.7	3.4	4.4	50.0
	20 Phantom 135 or 1000 Sides	4.3	5.7	3.4	4.4	50.0
	20 Sides 135 or 1000 Phantom	4.1	5.5	3.4	4.4	50.0
	135 or 1000 Sides and Phantom	4.1	5.5	3.4	4.4	50.0
19 Ga. H-174-106 Cable-Side	All	5.8	7.2	4.1	5.1	55.0
19 Ga. H-174-106 Cable-Phantom	20 Sides and Ph.	5.4	6.8	3.8	4.8	50.0
	20 Phantom 135 or 1000 Sides	5.4	6.8	3.8	4.8	50.0
	20 Sides 135 or 1000 Phantom	5.2	6.6	3.8	4.8	50.0
	135 or 1000 Sides and Phantom	5.2	6.6	3.8	4.8	50.0
19 Ga. B-88-50 Cable-Side	All	5.2	6.7	4.1	5.1	55.0
19 Ga. B-88-50 Cable-Phantom	20 Sides and Ph.	4.9	6.3	3.7	4.7	50.0
	20 Phantom 135 or 1000 Sides	4.9	6.3	3.7	4.7	50.0
	20 Sides 135 or 1000 Phantom	4.7	6.1	3.7	4.7	50.0
	135 or 1000 Sides and Phantom	4.7	6.1	3.7	4.7	50.0
19 Ga. H-88-50 Cable-Side	All	4.5	6.0	3.5	4.5	55.0
19 Ga. H-88-50 Cable-Phantom	20 Sides and Ph.	4.0	5.4	3.3	4.3	50.0
	20 Phantom 135 or 1000 Sides	4.0	5.4	3.3	4.3	50.0
	20 Sides 135 or 1000 Phantom	3.8	5.2	3.3	4.3	50.0
	135 or 1000 Sides and Phantom	3.8	5.2	3.3	4.3	50.0
16 Ga. H-44-25 Cable-Side Without Telegraph Composite Sets	20	4.7	6.2	3.1	4.1	55.0
	135 or 1000	5.7	7.2	3.1	4.1	55.0
16 Ga. H-44-25 Cable-Side With Telegraph Composite Sets	135 or 1000	5.5	7.0	3.1	4.1	55.0

Type of Circuit	Type of Signaling Values in Cycles	1000-Cycle Equipment Loss—DB Input Max.	Input Min.	Output Max.	Output Min.	Trans-hybrid Min.
16 Ga. H-44-25 Cable-Phantom Without Composite Sets On Sides or Phantom	20 Sides and Ph.	6.3	7.8	3.4	4.4	50.0
	20 Phantom 135 or 1000 Sides	4.9	6.4	3.4	4.4	50.0
	20 Sides 135 or 1000 Phantom	4.9	6.4	3.4	4.4	50.0
	135 or 1000 Sides and Phantom	6.2	7.6	3.4	4.4	50.0
16 Ga. H-44-25 Cable-Phantom With Telegraph Composite Sets on Side Circuits	135 or 1000	4.9	6.4	3.4	4.4	50.0
16 Ga. H-44-25 Cable-Phantom With Telegraph Composite Set on Phantom	135 or 1000	6.3	7.8	3.4	4.4	50.0
Two-Wire Terminating Circuit	Without Signaling by-pass	10.3	11.1	10.3	11.1	60.0
Two-Wire Terminating Circuit	With Signaling by-pass	10.3	11.1	10.3	11.1	52.0

If transmission measuring equipment is not available, the wiring and apparatus on the line and line-balancing unit and two-wire terminating unit associated with the repeater in trouble should be checked by methods outlined in the three following paragraphs.

D-c tests may be used to check continuity of wiring. Care should be taken, however, that the d-c current passed through any coil should be limited preferably to a few mils so as not to cause permanent damage to the coil. For continuity testing the ohmmeter scale of the Weston volt-ohm-milliammeter listed under Testing Equipment, on page 5, is an excellent instrument.

Resistances suspected of being in trouble may be checked with this ohmmeter. This instrument may also be used to check whether a coil winding is open.

A check for a broken-down condenser may be made with a telephone receiver in series with a flashlight cell. Be sure that no d-c path exists across the condenser in question or if so remove the condenser from the circuit. Connect the receiver and battery successively across the terminals of the condenser in question. On this test the good condenser will cause a click in the receiver when contact is first made but almost inaudible subsequent clicks when repeated contacts are made. A defective condenser will cause a uniform intensity of click each time contact is made.

Apparatus Requirements and Adjusting Procedures

Vacuum Tubes

If no tube testing equipment is available, tubes known to be in good condition may be substituted every six months or whenever tube trouble is suspected. A tube needs replacing when substitution of a new tube in the socket gives marked improvement in operation. See the second and third paragraphs under Troubles in the Amplifier Units, on pages 53 and 54.

Jacks

In case a jack fails to operate satisfactorily it should be replaced.

Relays

U- and Y-Type Relays used in this equipment should have armature travel in accordance with the following table:

Relay	*Desig.*	*Arm. Trvl.*	*Unit*
U293	(A)	0.047-inch	d-c—20-Cycle Terminal Signaling
U349	(R)	0.047-inch	d-c—20-Cycle Terminal Signaling
U1063	(A & B)	0.041-inch	Line and L.-Bal. and 2-W. Terminal
U1065	(R)	0.053-inch	20-Cycle—d-c Signaling
Y107	(GR)	0.047-inch	20-Cycle—d-c and 135-Cycle—d-c Signaling
Y187	(GR)	0.047-inch	20-Cycle—d-c and 135-Cycle—d-c Signaling
Y200	(R)	0.047-inch	20-Cycle—d-c and 135-Cycle—d-c Signaling

Use the proper 132-Type Gauge applied between the armature stop pins and the core or between the armature and core when no stop pins are provided, or in the case of Y-Type Relays between the embossed surface of the armature and the core. When using the gauge the long axis should be in a horizontal position. The tolerance should be +0.003-inch. To check the armature travel adjustment, attempt to insert a gauge 0.003-inch larger than the specified armature travel gauge in the armature gap. If the gauge enters it should enter with a tight fit.

The following table gives the location of stud gaps of the U- and Y-Type Relays used in this equipment. Spring number one is at the left facing the front, not counting buffer springs, which do not have contacts.

Relay	*Desig.*	*Stud Gap T Located Between Springs*	*Stud Gap S Located Between Springs*
U293	(A)	2 & 3 top 1 & 2 bottom	
U349	(R)	2 & 3 top 2 & 3 bottom	
U1063	(A & B)	5 & 6 top 5 & 6 bottom	1 & 2 top 1 & 2 bottom
U1065	(R)	3 & 4 top 1 & 2 bottom	
Y107	(GR)	1 & 2 top 2 & 3 bottom	1 & buffer spring top 1 & 2 bottom
Y187	(GR)	2 & 3 top 1 & 2 bottom	1 & 2 top 1 & buffer spring bottom
Y200	(R)	2 & 3 top 2 & 3 bottom	

With the relay unoperated there should be a clearance between the stud and the spring (stud gap T in table) of 0.006-inch minimum. This requirement is met if there is a clearance between the spring and the stud with the No. 133A Gauge inserted between the armature and the end of the stud which rests against the armature. With the relay unoperated there should be a slight clearance between the spring studs and the spring (stud gap S in table).

The separation between each pair of contacts normally open or between each pair of contacts that are opened when the relay is electrically operated should be 0.005-inch minimum. On normally closed contacts the requirement is met if the contacts break when the relay is electrically energized against a 0.004-inch 132-Type Gauge inserted between the armature and core.

Except for the latter test, before testing or readjusting the relays, disconnect the a-c power from the power supply unit. A 131A Gauge (consisting of a nest of 132-Type Gauges), 133A Gauge (stud gap), 265B Contact Burnisher, 474A Tool (3/16-inch by 1/4-inch hexagon closed end offset wrench), 505A Tool (spring adjuster for 0.013-inch springs), 506A Tool (spring adjuster for 0.018-inch and 0.023-inch springs), 507A Tool (spring adjuster for 0.030-inch springs), KS-6320 Orange Stick, a small screwdriver and a pair of long nose pliers will be found useful.

196F Relays

The 196F Relay (IR) of the 20-cycle—d-c signaling panel should have an unoperated armature air gap (marked A in Figure 36) of 0.006 inch minimum, 0.009 inch maximum. This is the gap between the core of the upper coil and the armature measured at the nearest point when the back contact (or stop) screw is touching the armature. To adjust for the unoperated armature air-gap proceed as follows: Loosen the lock nut on the back contact (or stop) screw with the No. 220 Tool (socket wrench) and turn this screw in a counter-clockwise direction with the KS-6854 Screw-

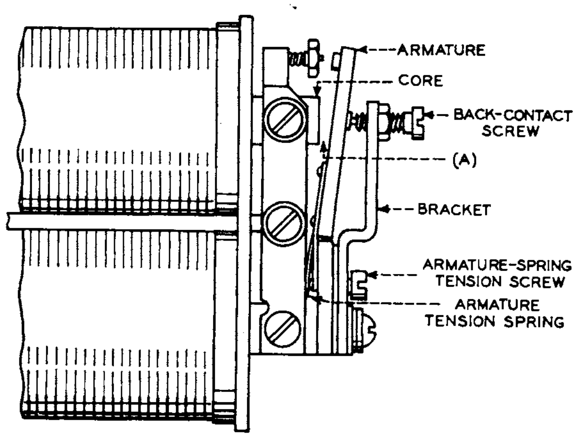


Figure 36—196F Relay—Partial Side View

driver until the 0.008 inch blade of the No. 74D Gauge can be inserted between the armature and the core of the upper coil at the nearest point. Then while holding the gauge against the core of the upper coil turn the back contact (or stop) screw in a clockwise direction until the armature just touches the gauge. If necessary turn the front contact (or stop) screw in a clockwise direction using the No. 388A Tool (wrench). Tighten the lock nut securely and remove the gauge.

There should be an armature travel of 0.003 inch minimum and 0.005 inch maximum. This is the separation between the back contact (or stop) screw and the armature when the front contact (or stop) screw is touching the armature. To adjust for the armature travel proceed as follows: Turn the front contact (or stop) screw in a clockwise direction with the No. 388A Tool (wrench) until the 0.004 inch blade of the No. 74D Gauge can be inserted between the armature and the back contact (or stop) screw. Then while holding the gauge against the back contact (or stop) screw turn the front contact (or stop) screw in a counter-clockwise direction until the front contact (or stop) screw just touches the armature and the armature touches the gauge. Remove the gauge. The tension of the armature against the back contact screw should be adjusted to approximately 5 grams measured at the top of the armature. This should give a good adjustment for proper sensitivity and protection against false signals. A No. 220 Tool (socket wrench) (3/16-inch hexagon socket), a No. 338A Tool (wrench), (3/16-inch and 1/4-inch hexagon open-end offset), a KS-6854 Screwdriver, a No. 74D Gauge (thickness gauge nest), a No. 70F Gauge (10-0-10 gram gauge) and a pair of long nose pliers will be found useful.

B56 Relays

The B56 Relay (RC) of the 135-cycle—d-c signaling panel should have an armature travel of 0.030 inch, a contact separation of at least 0.005 inch, and should make reliable contact pressure when the battery supply unit is functioning. A No. 74D Gauge (thickness gauge nest), a No. 259 and a No. 300 Tool (spring adjusters), a small screwdriver and a pair of long nose pliers will be found useful.

218B Relays

The 218B Relay (IR) of the 135-cycle—d-c signaling panel should be adjusted as follows:

Contact Spring Adjustment—Figure 37 (C)

With the relay in the adjusted position,—i.e., with the contact adjusted to the position indicated in the paragraph on Contact Separation, Figure 37 (B) on page 63—the front contact spring should rest firmly against the lug on the stop spring. This should be considered as having been met if, with pressure applied at the top of contact spring there is a perceptible movement (approximately 0.005 inch) of the top of the spring before the spring breaks from the lug on the stop spring.

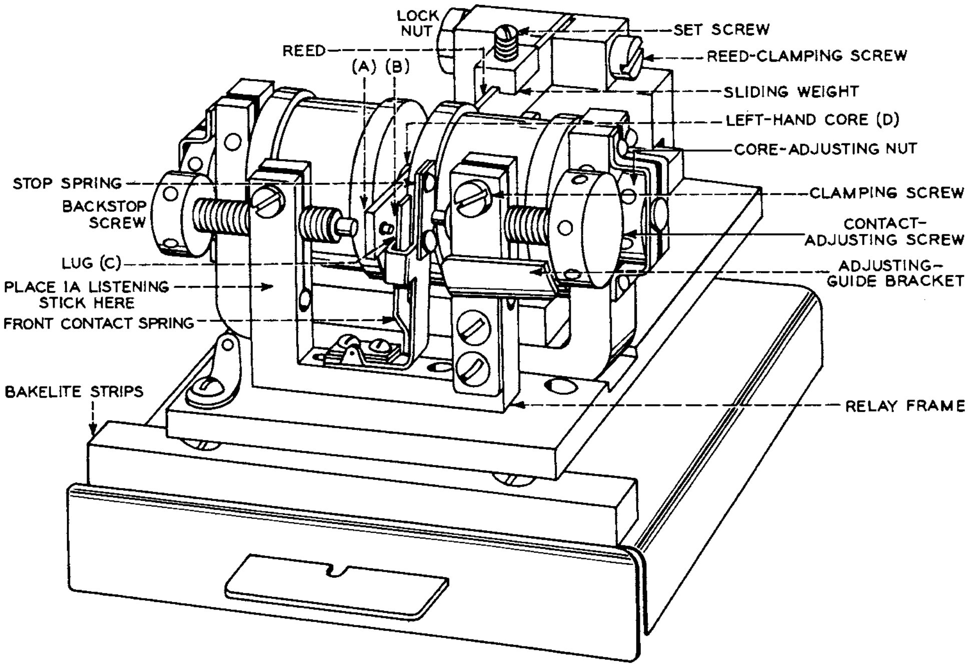


Figure 37—218B Relay—Front View

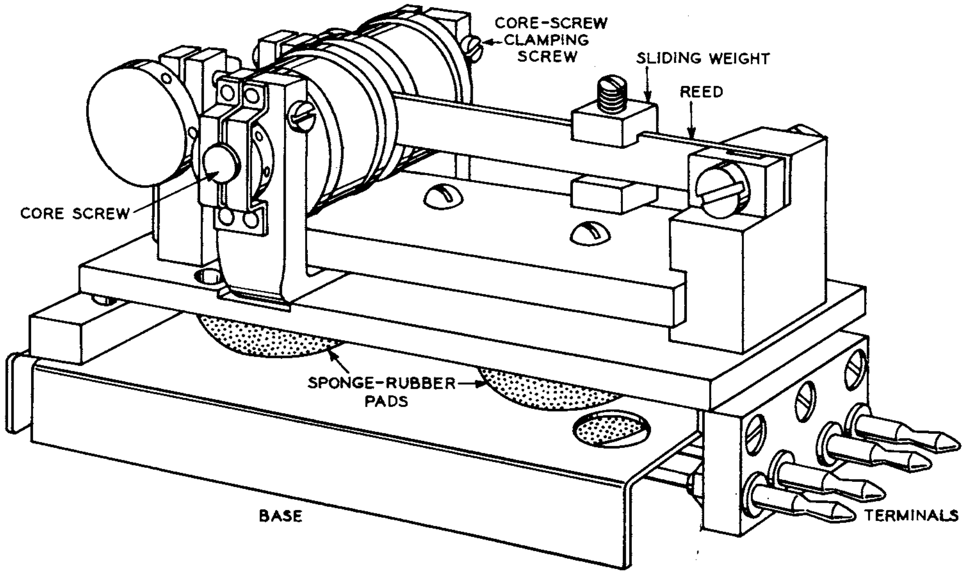


Figure 38—218B Relay—Side View

To correct the position of the contact spring against the lug (seldom required), loosen the contact clamping screw with the 3-inch cabinet screwdriver, back off the contact adjusting screw with the No. 340 Tool (adjusting key) and adjust the spring as required using the No. 363 Tool (spring adjuster). Apply the tool slightly above the crook in the spring and give it a slight twist towards or away from the lug on which it rests.

Core Air-Gap Adjustment—Figure 37 (D)

(a) The air-gap between the reed and each core should be: Minimum 0.014 inch, maximum 0.020 inch.

Measure with the 91A and 91B Gauges.

(b) The air-gap between the reed and each core should be approximately equal. Gauge by eye.

To adjust the core air-gaps, loosen the core and back stop clamping screws with the 3-inch cabinet screwdriver just enough to permit turning the core adjusting nut and back stop screws with the No. 340 Tool (adjusting key) and back off the cores as far as possible. Turn in the contact adjusting screw with the No. 340 Tool (adjusting key) until the contact just makes with the reed. Then back off the contact adjusting screw until the contact just breaks. Turn in the back stop screw with the No. 340 Tool (adjusting key) until the contact just makes, then back off the back stop screw until the contact just breaks. When this contact closes it will operate the B type relay. In order to gauge the closing or opening of the contacts the contact adjusting screw should be turned very slowly.

Insert the No. 91A Gauge between the reed and the right-hand core and turn this core in with the No. 340 Tool (adjusting key) until the gauge touches both the core and the reed. Then back off the core slightly until the gauge can be withdrawn and inserted freely. This establishes the right-hand air-gap. Securely tighten the clamping screw for the right-hand core.

Insert the same gauge between the reed and the left-hand core and turn this core in with the No. 340 Tool (adjusting key), at the same time holding the reed against the stop screw, until the gauge touches both the core and the reed. Then back off the core slightly until the gauge can be withdrawn and inserted freely. This establishes the left-hand air-gap. Securely tighten the clamping screw. Readjust the contact separation and back stop gap and if necessary reset the sliding weight.

Back Stop Gap Adjustment—Figure 37 (A)

The gap between the reed and back stop screw should be approximately 0.004 inch. Gauge by eye.

To make these adjustments, adjust the relays in a spare circuit if available or in the circuit in which it is used, when removed from service. With the relay connected in this manner, adjust as follows:

Loosen the clamping screws for the back stop and contact screws with the 3-inch cabinet screwdriver just enough to permit turning the stop and contact screws with the No. 340 Tool (adjusting key). Turn the front contact screw in until the contacts just make, as indicated by the operation of the apparatus associated with the relay in the circuit. Then slowly turn this screw back just enough to open the contacts.

Exercise care not to turn the front contact screw back too far, since the contact separation adjustment is made from the position of the contact screw as left after making the back stop gap adjustment.

Turn the back stop screw in until it just touches the reed and causes the reed to come in contact with the front contact, as indicated by the operation of the apparatus associated with the relay in the circuit. Now turn back the back stop screw $\frac{1}{4}$ of a turn, leaving a separation of approximately 0.004 inch between the reed and the screw. Tighten the back stop clamping screw securely.

Contact Separation Adjustment—Figure 37 (B)

The separation between the contact on the reed and the contact on the spring should be at least four divisions on the head of the contact adjusting screw. The contact separation should be considered satisfactory if the contacts do not make before the front contact screw has been turned in four full divisions of the head of the screw. If the separation is checked in this manner and is found satisfactory the screw should be turned back four divisions from the point where the front contact breaks contact with the reed.

With the front contact screw in the position in which it was left in the last paragraph on Back Stop Gap Adjustment, turn it back 4 divisions on the milled head as measured by the adjusting guide bracket.

If it has not been necessary to adjust the back stop gap, adjust for the contact separation as follows: Loosen the front contact clamping screw with the 3-inch cabinet screwdriver just enough to permit turning the contact screw with the No. 340 Tool (adjusting key). Turn the contact screw in until the contacts just make, as indicated by the operation of the apparatus associated with the relay in the circuit. Turn the contact screw back slowly until the contacts just open as indicated by the operation of the apparatus associated with the relay in the circuit. Then turn the screw back 4 divisions of the milled head as measured by the adjusting guide bracket.

Clamping and Set Screws Adjustment

The clamping screws and the set screw should be just tight enough to hold the contact and back stop screws, the reed, the cores and the sliding weight in their adjusted positions. Gauge by feel.

To tighten the clamping screws, use the 3-inch cabinet screwdriver.

To tighten the set screw use the KS-6854 Screwdriver.

Operation

The operation of the relay should be checked by observing the operation of the circuit in which it is used when 135-cycle current is being received over the line.

With the above mechanical adjustment the relay should operate properly in its circuit if the sliding weight is located properly and the sponge rubber pads are in good condition.

A mark is placed on the reed for the approximate setting of the sliding weight on new relays as the final factory adjustment and may be used as a reference line in case the readjustment of the sliding weight is necessary. On relays not marked in this manner the approximate setting of the sliding weight on the reed may be obtained as follows:

Operate the relay electrically under circuit conditions and loosen the set screw on the sliding weight with the KS-6854 Screwdriver so that the weight will chatter. Then change the position of the sliding weight until the noise made by the chattering weight reaches a maximum as determined by means of the 1A Listening Stick. Hold the end of the listening stick against the frame of the relay as shown in Figure 37 while the ear is applied to the diaphragm of the listening stick.

If it is not possible to adjust the relay in this manner, change the core air-gap slightly. It is desirable that the gaps on either side of the reed be as near equal as practicable. However, it may be necessary to vary this slightly.

If a listening stick is not provided, insert the relay in the connecting block of the circuit which represents the most severe service condition, or the connecting block of the circuit in which it is used, with the circuit removed from service. With the sliding weight set on the scribe marks on the reed (if provided), observe the operation of the relay by means of the operation of the associated apparatus in the circuit when 135-cycle current is being received over the line.

If the relay fails to function satisfactorily as indicated by the operation of associated apparatus in the circuit check the contact separation and adjust if necessary. Loosen the set screw on the sliding weight with the KS-6854 Screwdriver and move the weight slightly in either direction. Again observe the operation of the relay. If the operation of the relay is more nearly satisfactory as indicated by the operation of associated apparatus in the circuit, it indicates that the weight was moved in the proper direction. Repeat this operation until the relay operates satisfactorily, shifting the weight by smaller amounts as the relay becomes more sensitive.

After each adjustment of the sliding weight, check the contact separation and adjust. Tighten the set screw on the sliding weight after each adjustment sufficiently to prevent the weight from shifting. Care must be exercised in tightening the set screw, in order not to bend the reed. By the above method of adjusting, it is possible to tune the reed to 135 cycles and thus obtain maximum sensitivity of the relay. When the relay is exactly tuned to the signaling frequency (135 cycles) the current required to operate the relay is of a minimum value.

149BN Relays

The 149BN Relay of the 135-cycle interrupter should have an armature travel of 0.025 inch minimum and 0.030 inch maximum, contact follow of approximately 0.005 inch, contact separation of 0.005 inch and sufficient tension (15 to 25 grams) in spring 1 to insure reliable contact and sufficient tension in spring 2 to hold the armature against the adjusting screw. A No. 74D Gauge (thickness gauge nest), a No. 70D Gauge (50-0-50 gram gauge), a No. 50B and a No. 259 Tool (spring adjusters), a small screwdriver and a pair of long nose pliers will be found useful.

Vibrator

The vibrator of the 135-cycle interrupter should be adjusted as follows:

Air-Gap

(a) Figure 39 (B) and (D)—The reed should not strike either magnet core when the interrupter is operating on the maximum voltage.

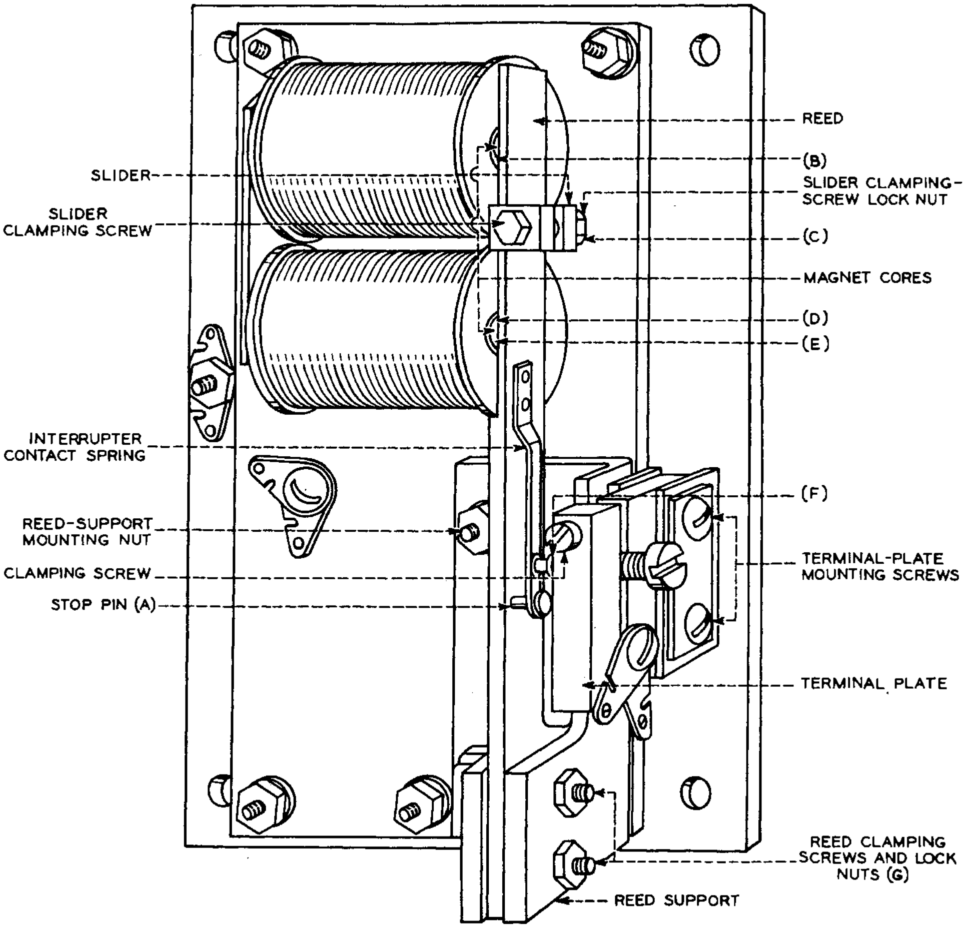


Figure 39—Vibrator—Partial Front View

(b) Figure 39 (E)—The air-gap between the magnet core nearer the supported end of the reed and the reed should be a minimum of 0.060 inch. Measure with the 91C Gauge.

If the reed touches either magnet core while it is operating, or if the air-gap between the magnet core nearer the supported end of the reed is not satisfactory, check the voltage and if it is not at maximum, regulate it for this test by adding the required dry cells.

Loosen the reed support mounting nuts with the No. 277 Tool (wrench) or the No. 43 Tool (wrench) and shift the reed support until the specified gauge can be placed easily between the reed and the magnet core nearer the supported end of the reed. Then securely tighten the mounting nuts.

If the reed touches either magnet core when the interrupter is operating on the maximum voltage, loosen the reed support mounting nuts and increase the air-gap as required. Then securely tighten the nuts.

Interrupter Contact Spring Tension Adjustment—Figure 39 (F)

When the reed is held in such a position that the contacts are open, the pressure of the interrupter contact spring against the head of the stop pin [Figure 39 (A)] measured at the contact should be:

Test —Minimum 15 grams, maximum 35 grams

Readjust—Minimum 20 grams, maximum 30 grams

Use the No. 70D Gauge.

If the tension of the contact spring is insufficient, increase it slightly by adjusting the offset portion of the spring close to the base with the No. 363 Tool (spring adjuster). Give the adjuster a slight twist in the direction which will increase the pressure of the spring against the stop pin [Figure 39 (A)]. If the tension is too great, decrease it by twisting the spring adjuster in the opposite direction. Take care in making this adjustment not to kink the spring, as this may cause it to bind on the stop pin.

Interrupter Contact Spring Location—Figure 39 (A)

The interrupter contact spring should not bind on the stop pin. Gauge by eye and by feel.

If the contact spring binds on the stop pin, adjust the spring at the bend nearer the stop pin using the No. 363 Tool (spring adjuster).

Contact Adjustment—Figure 39 (F)

The contacts of the interrupter should be adjusted so that there will be minimum sparking at the contacts and the reed should vibrate with a smooth, even motion on any battery or rectified d-c supply voltage from 20 to 28 volts.

Tightness of Clamping Screws and Lock Nuts—Figure 39 (C) and (G)

The clamping screws and lock nuts should be just tight enough to maintain their adjusted position. Gauge by feel.

Tighten the clamping screws with the 3-inch cabinet screwdriver, the reed lock nuts and reed support mounting nuts with the No. 43 or 277 Tool (wrench) and the slider clamping screw lock nut with the No. 220 Tool (wrench).

Start

The interrupter should start on minimum voltage.

To determine whether or not the interrupter will start on the specified minimum battery voltage, decrease the voltage of the battery or rectified d-c supply to that required by means of counter emf cells and not by the use of a potentiometer. Observe the operation of the interrupter.

If the interrupter does not start on the minimum specified voltage, decrease the air-gap toward the minimum limit as outlined in 3, 4 and 5 above.

Frequency of Output Current

When the output of the interrupter is compared with a standard 135-cycle source, the number of beats indicating the difference in frequency should be:

Test —Less than 3 beats per second (135 ± 3 cycles)

Readjust—Less than 3 beats per 10 seconds (135 ± 1/3 cycle)

Standard tone is that obtained from a 135-cycle generator, a No. 12A Tuning Fork or from an interrupter which has been checked and is known to supply a tone within the limits of the frequency specified.

If the generator tone is used for checking the interrupter, check the frequency of the generator used as a source of standard tone immediately before making an adjustment by the means provided at the office where the generator is located and, if this frequency is found to differ from 135 cycles by more than 1/2 cycle, readjust the speed of the generator.

Wherever possible, make adjustments while the battery is on discharge.

To obtain the minimum and maximum voltages for testing and re-adjusting the interrupter, No. 6 dry cells may be used to decrease or increase the voltage supplied to the interrupter by the office battery.

Exercise care to avoid grounding the interrupter reed or its associated parts when adjusting an interrupter, as this will blow the circuit fuse. Where the wiring of the interrupter circuit is such that battery is supplied to the reed through the contact of a relay, this relay should be temporarily blocked non-operated while using the tools on the interrupter. This is particularly important when other interrupters in the working equipment are connected to the same fuse.

Disconnect the output leads from terminals 5 and 6 and connect ground to terminal 7 of the terminal strip on the 135-cycle interrupter panel. Connect a receiver to terminals 5 and 6. If the 12A Tuning Fork is used for checking the frequency, set it into vibration with the fingers, or by striking it lightly against a soft object. Do not set the fork into violent vibration, for this will introduce harmonics which will interfere with the test. Hold the base of the vibrating fork against the case of the receiver and by means of a 0-200-ohm potentiometer in the output leads of the interrupter, regulate the volume of the tone from the interrupter under test to about the same volume as that supplied by the vibrating tuning fork. Beats will be heard unless the two frequencies are exactly equal. The number of beats per second is equal to the difference in the frequencies of the interrupter tone and the vibrating tuning fork tone. If more than three beats per second are obtained, adjust the interrupter as outlined in the next paragraph. If a generator tone is used this should be connected to the receiver as well as the output of the interrupter.

Loosen the slider on the reed with the No. 220 Tool (wrench) and move it so as to decrease the number of beats to a minimum. It may not be possible to eliminate the beats entirely, in which case reduce them to less than three beats per ten seconds. Moving the slider toward the contacts increases the frequency and moving it away from the contacts decreases the frequency.

Since the adjustment of the contacts may change the frequency adjustments slightly, recheck the frequency after this adjustment has been made. Violent vibration of the reed indicates an unsatisfactory adjustment which, even if the proper frequency is obtained, will not remain constant for any length of time. A smooth even motion of the reed should be obtained.

An interrupter may be tested without being removed from service, but this is not as satisfactory since outgoing rings, if they occur during the period of test, will cause a variation in the frequency and output.

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