Order

GEI-33857

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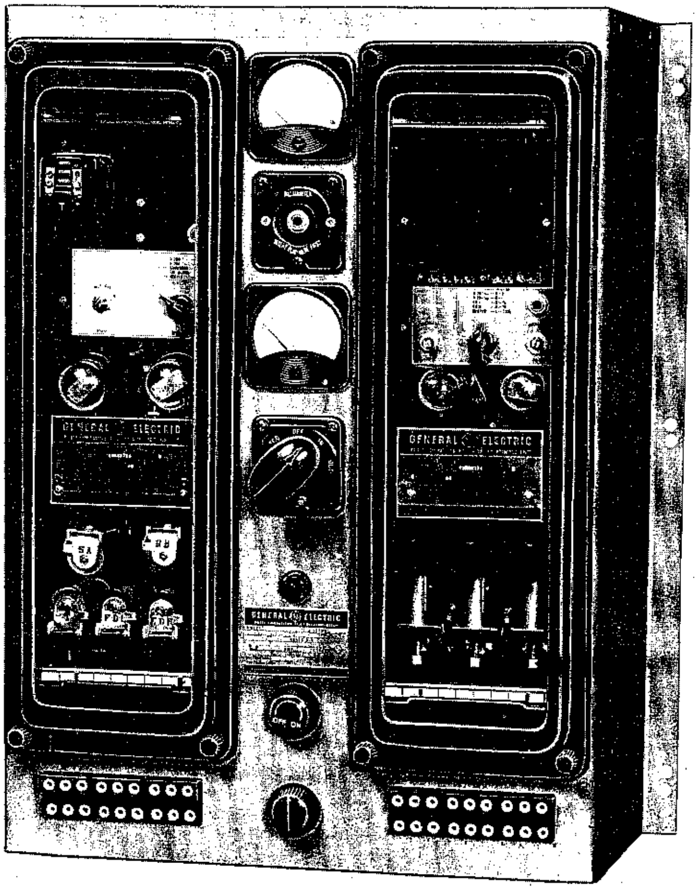
INSTRUCTIONS

Switchgear

PHASE-COMPARISON CARRIER-PILOT RELAYS



Types EDD12A
and EDD12B

GENERAL ELECTRIC

A

CONTENTS

Cover (8012009)

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

PHASE-COMPARISON CARRIER-PILOT RELAY
TYPE EDD

INTRODUCTION (SECTION A)

The Type EDD relay is a phase comparison relay designed primarily to provide instantaneous differential protection for transmission lines.

A_1 APPLICATION

These relays are protective devices used to close trip circuits whenever a predetermined value of internal fault current is reached on transmission lines with up to 35 decibels attenuation to the carrier current.

Protection is provided for two-ended transmission lines, with or without tapped loads, providing the conditions described in SECTIONS H_1 and H_2 are met.

In some cases this relay may be used for three-ended lines. The Type EDD relay has two fault detectors to compensate for the possible two-to-one ratio of fault current magnitude between the ends of a three-ended line. The necessity of setting the phase-overcurrent units above full-load current, plus the two-to-one ratio mentioned previously, raises the minimum tripping level.

Applications requiring zero-sequence excitations for ground faults on three-ended lines need special consideration.

Provisions are incorporated in the phase-comparison relay for its use with directional-comparison relays. This application is for medium and longer length lines, where distance-type relays may be used to advantage for phase relaying; while, because of mutual induction with parallel lines, the phase-comparison relay will be selected for ground faults.

As an auxiliary service the phase-comparison relay may be used for telemetering or supervisory control.

A_2 RATINGS

A_3 RELAY

The ratings of the phase-comparison relay are given in Table I.

A_4 TARGET-SEAL-IN ELEMENT

The 2-ampere tap has a d-c resistance of 0.13 ohms and a 60 cycle impedance of 0.53 ohms, while the 0.2 ampere tap has a 7 ohm d-c resistance and a 52 ohm 60 cycle impedance. The tap setting used on the seal-in element is determined by the current drawn by the trip coil.

TABLE I

PHASE COMPARISON RELAY RATINGS	
Current circuits, continuously,	5A, 60 cycles
Phase current circuits, 1 sec.	200A, 60 cycles
Phase current circuits, max. RMS phase-to-phase	500A, 60 cycles
Ground current circuit, 1 sec.	200A, 60 cycles
Ground current circuit, max. RMS	300 X tap setting
D-c control circuit, continuously	129 (or 258) V.
D-c control circuit, max. (See Section F)	140 (or 280) V.

The 0.2 ampere tap is for use with trip coils that operate on currents ranging from 0.2 to 2.0 amperes at the minimum control voltage. If this tap is used with trip coils requiring more than 2 amperes, there is a possibility that the 7 ohm resistance will reduce the current to so low a value that the breaker will not be tripped.

The 2 ampere tap should be used with trip coils that take 2 amperes or more at minimum control voltage, provided the tripping current does not exceed 30 amperes at the maximum control voltage. If the tripping current exceeds 30 amperes, an auxiliary relay should be used. The connections should be such that the tripping current does not pass through the contacts or coil of the target-seal-in element.

TABLE II

SEAL-IN ELEMENT RATING		
FUNCTION	AMPERES, AC OR DC	
	2-Amp Tap (0.13 Ohm)	0.2 Amp Tap (7 Ohm)
Tripping Duty	30	5
Carry Continuously	4	0.8

A_5 CONTACTS

The current-closing rating of the contacts is 30 amperes for voltages not exceeding 250 volts. After tripping occurs, the tripping circuit must be opened by an auxiliary switch on the circuit breaker or by other automatic means as the relay contacts are sealed closed when tripping current is flowing.

A_6 A-C TEST SOURCE

The 15 second rating of the a-c test source is 3.5 amperes for two-ended lines, and 6.5 amperes for three-ended lines.

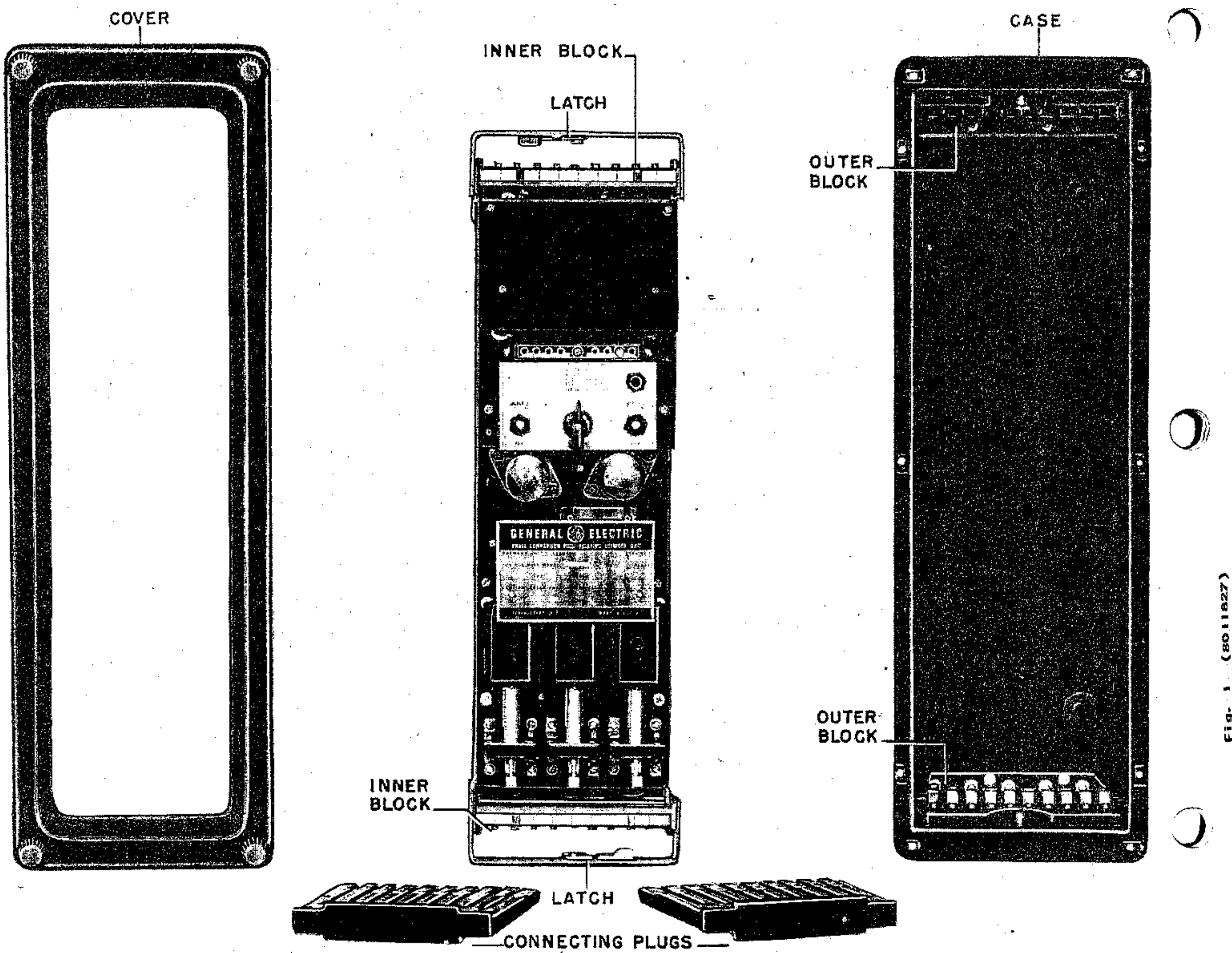


Fig. 1 The Network Unit Of The Type EDD Relay Disassembled

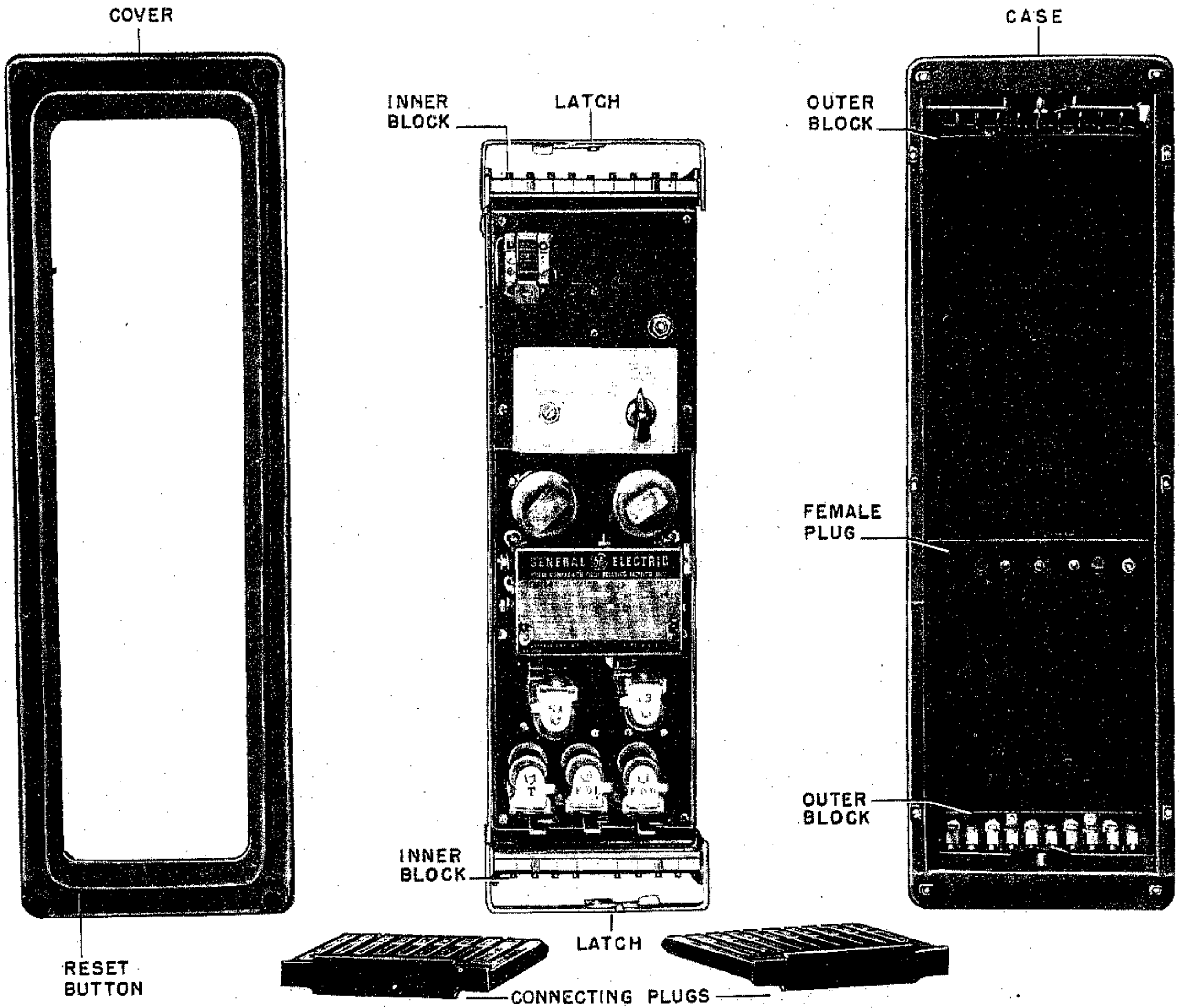


Fig. 2 The Tripping Unit Of The Type EDD Relay Disassembled

Fig. 1 (8011827)
Fig. 2 (8011828)

A7 BURDENS

The relay burdens are given in Table III.

TABLE III

FAULT		CT BURDEN-OHMS	
Phase Fault Any CT		Z 0.15 $\angle 42$	R+j X 0.11+j 0.1
GROUND FAULTS (Burden of highest phase)	Tap (Mult. by)	Z	R+j X
	2.0	0.23 $\angle 18$	0.22+j 0.07
	0.67	0.33 $\angle 36$	0.26+j 0.20
	0.47	0.40 $\angle 44$	0.29+j 0.28
	0.33	0.52 $\angle 50$	0.33+j 0.40
	0.23	0.74 $\angle 58$	0.38+j 0.63
	0.17	1.18 $\angle 66$	0.47+j 1.08

A8 LOADS IMPOSED BY RELAY

The continuous load imposed by the relay on the d-c source (129 or 259 volts) is 0.8 amperes.

NOTE: This 0.8 ampere does not include the current drawn by the associated carrier-current equipment.

During tests and adjustments, the load imposed on the a-c test source is 3.5 amperes for two ended lines, and 6.5 amperes for three-ended lines at 115 volts, 60 cycles.

A9 RELAY RANGES

The settings of the relay, except for zero-sequence excitation, are continuously adjustable in their ranges. Zero-sequence excitation is set by taps. The setting is the tap marking times the pick-up of the relay for phase-to-phase faults.

TABLE IV

TYPE OF FAULT	CURRENT TRANSFORMER SECONDARY AMPERES FOR TRIPPING			
	2-ended lines		3-ended lines	
	Normal	Min.	Normal	Min.
3 Phase	8	5.3	16	10
Phase-to-phase	3	2	6	4
Phase-to-ground*	6	4	12	8
Phase-to-ground with zero seq. excitation **	0.5-2.0	0.33	Refer to the General Electric Company	
MAX. LOAD	5	3.3	5	3.3

* This phase-to-ground current in the network unit contains no effect of the zero-sequence-component.

**C-T secondary amperes, with single-end feed and no grounding transformer on same side of relay as the fault.

To obtain correct operation of the Type EDD relay on three phase faults, the ratio between the phase-fault detectors and FD-H pickup must be kept at 4 to 3.

The phase-shifter settings are adjustable from 0 to 24 degrees. The extreme counterclockwise position of the phase-shifter rheostat is the 0 degree setting.

If settings beyond those given in Table IV are required, refer to the General Electric Company.

RECEIVING, HANDLING AND STORAGE (SECTION B)

These relays, when not included as a part of a control panel, will be shipped in cartons designed to protect them against damage. Immediately upon receipt of a relay, examine it for any damage sustained in transit. If injury or damage resulting from rough handling is evident, file a damage claim at once with the transportation company and promptly notify the nearest General Electric Apparatus Sales Office.

Reasonable care should be exercised in unpacking the relay in order that none of the parts are injured or the adjustments disturbed.

If the relays are not to be installed immediately, they should be stored in their original cartons in a place that is free from moisture, dust and metallic chips. Foreign matter collected on the outside of the case may find its way inside when the cover is removed and cause trouble in the operation of the relay.

DESCRIPTION (SECTION C)

The relay consists of a network unit, tripping unit, two test switches (RTS and CTS), d-c test equipment, and a-c test equipment. The network unit, Fig. 1, contains, in an L2 case, a negative-phase-sequence network, three phase-overcurrent relays, a voltage amplifier, and fault detectors, low (L) and high (H). The tripping unit, Fig. 2, contains, in a special L2 case of 23 studs, a power amplifier, RC phase shifter, and five telephone-relay elements. The d-c test equipment, Fig. 3 is composed of a telephone jack mounted with associated parts. The a-c test equipment, Fig. 3, consists of two tapped resistors, a tap switch, rheostat, relay test switch, and voltmeter.

C1 RELAY TYPES

The Type EDD12A relay, Fig. 3, is arranged for panel mounting.

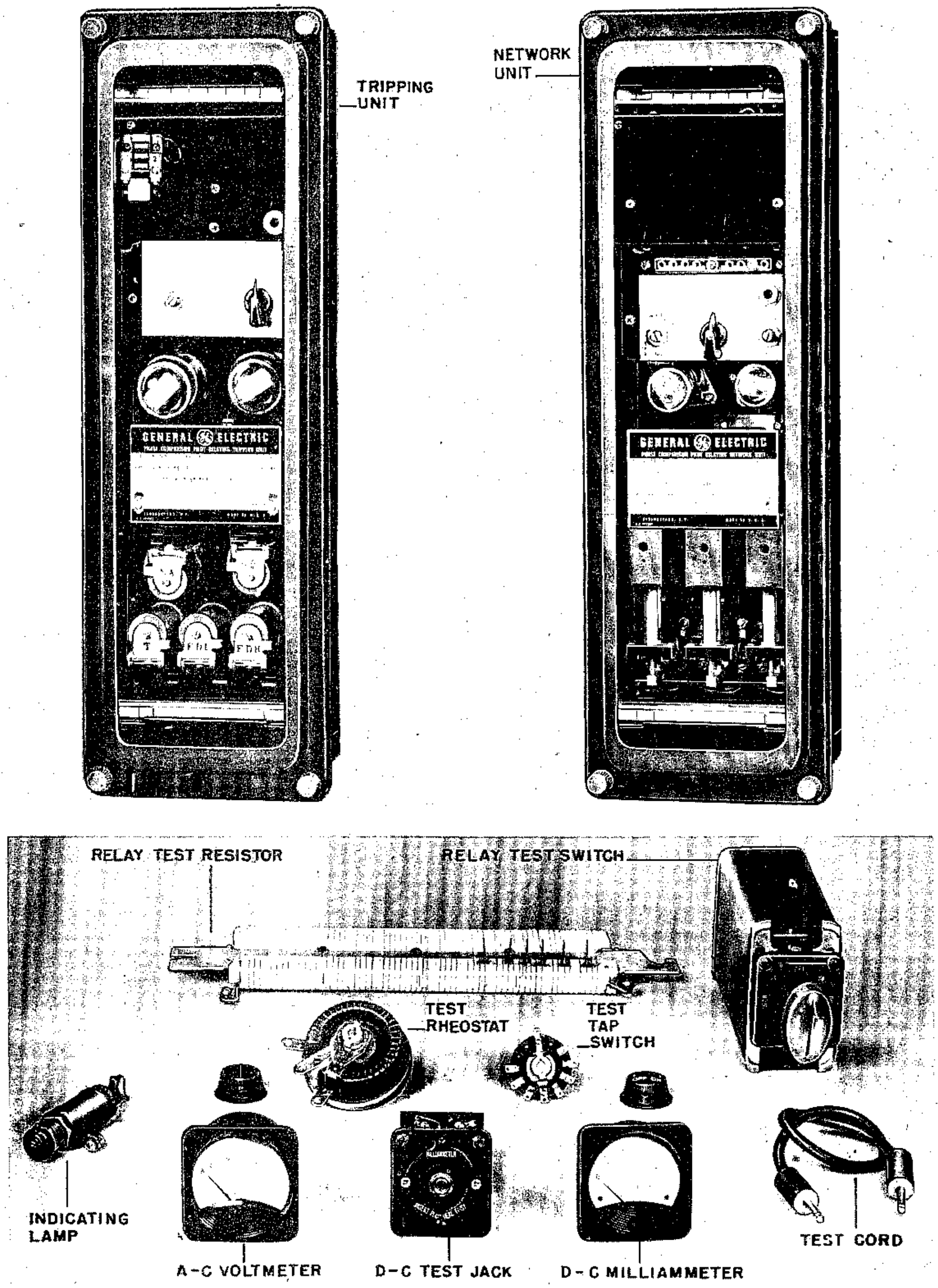


Fig. 3 (8012030)

Fig. 3 EDD Equipment For Panel Mounting

The Type EDD12B relay is similar to the Type EDD12A relay, except it is assembled in a subpanel for mounting in a carrier-current transmitter-receiver cabinet as shown on the cover.

C2 CASE

The L2 case is suitable for either surface or semiflush panel mounting, and an assortment of hardware is provided for either mounting. The cover attaches to the case and also carries the reset mechanism when one is required. Each cover screw has provision for a sealing wire.

The case has studs or screw connections at both ends for the external connections. The electrical connections between the relay units and the case studs are made through spring backed contact fingers mounted in stationary molded inner and outer blocks between which nests a removable connecting plug which completes the circuits. The outer blocks, attached to the case, have the studs for the external connections, and the inner blocks have the terminals for the internal connections.

The relay-unit mechanisms are mounted in a steel framework called the cradle and is a complete unit with all leads being terminated at the inner block. This cradle is held firmly in the case with a latch at the top and the bottom and by a guide pin at the back of the case. The case and cradle are so constructed that the relay cannot be inserted in the case upside down. The connecting plug, besides making the electrical connections between the respective blocks of the cradle and case, also locks the latch in place. The cover, which is fastened to the case by thumbscrews, holds the connecting plug in place.

To draw out the relay unit, the cover is first removed, and the plug drawn out. Shorting bars are provided in the case to short the current transformer circuits. The latches are then released, and the relay unit can be easily drawn out. To replace the relay unit, the reverse order is followed.

A separate testing plug can be inserted in place of the connecting plug to test the relay in place on the panel either from its own source of current and voltage, or from other sources. Or, the relay unit can be drawn out and replaced by another which has been tested in the laboratory.

C3 SEAL-IN ELEMENT

The seal-in element, Fig. 25, has its coil in séries and its contacts in parallel with the trip telephone-relay element contacts. When the main trip contacts close, the seal-in element picks up and seals in. When the seal-in element picks up, it raises a target into view which latches up and remains exposed until released by pressing a button beneath the lower left corner of the tripping unit.

INSTALLATION (SECTION D)

D1 LOCATION

The location should be clean and dry, free from dust and excessive vibration, and well lighted to facilitate inspection and testing.

D2 MOUNTING

The relay should be mounted on a vertical surface. The outline and panel diagrams are shown in Figs. 30, 31, and 32 for panel mounting, and Fig. 33 for cabinet mounting.

D3 CONNECTIONS

The internal connection diagrams for the various relay types are shown in Figs. 4, 5, and 6. An elementary wiring diagram is shown in Figs.16 to 21, inclusive. The external panel connections are shown in Fig. 7.

One of the mounting studs or screws should be permanently grounded by a conductor not less than No. 12 B & S gage copper wire or its equivalent.

The d-c supply consists of two sources which are arbitrarily designated "carrier d-c" and "switchgear d-c". These two circuits are kept separate in order to minimize the amount of equipment connected through the trip-circuit fuses, and to maintain correct polarity on the electronic circuits while accommodating the polarity of existing trip circuits.

The signal-alarm circuit should be fused separately from the "carrier d-c" supply, as one of the functions of this circuit is to detect the loss of the "carrier d-c" supply.

The a-c voltages, which supply currents for the a-c test equipment, must be in phase with each other at the two ends of the line with one side grounded as indicated in the elementary diagram, Fig. 17.

The CT circuits must be connected to the relay with phase sequence 1-2-3 as shown in Fig. 10, and phase 1 must be the same conductor at both ends of the line.

INSTALLATION TEST AND ADJUSTMENTS (SECTION E)

The following has been put in an abbreviated form to facilitate its use. For a detailed explanation of the relay operation, see PRINCIPLES OF OPERATION (SECTION G).

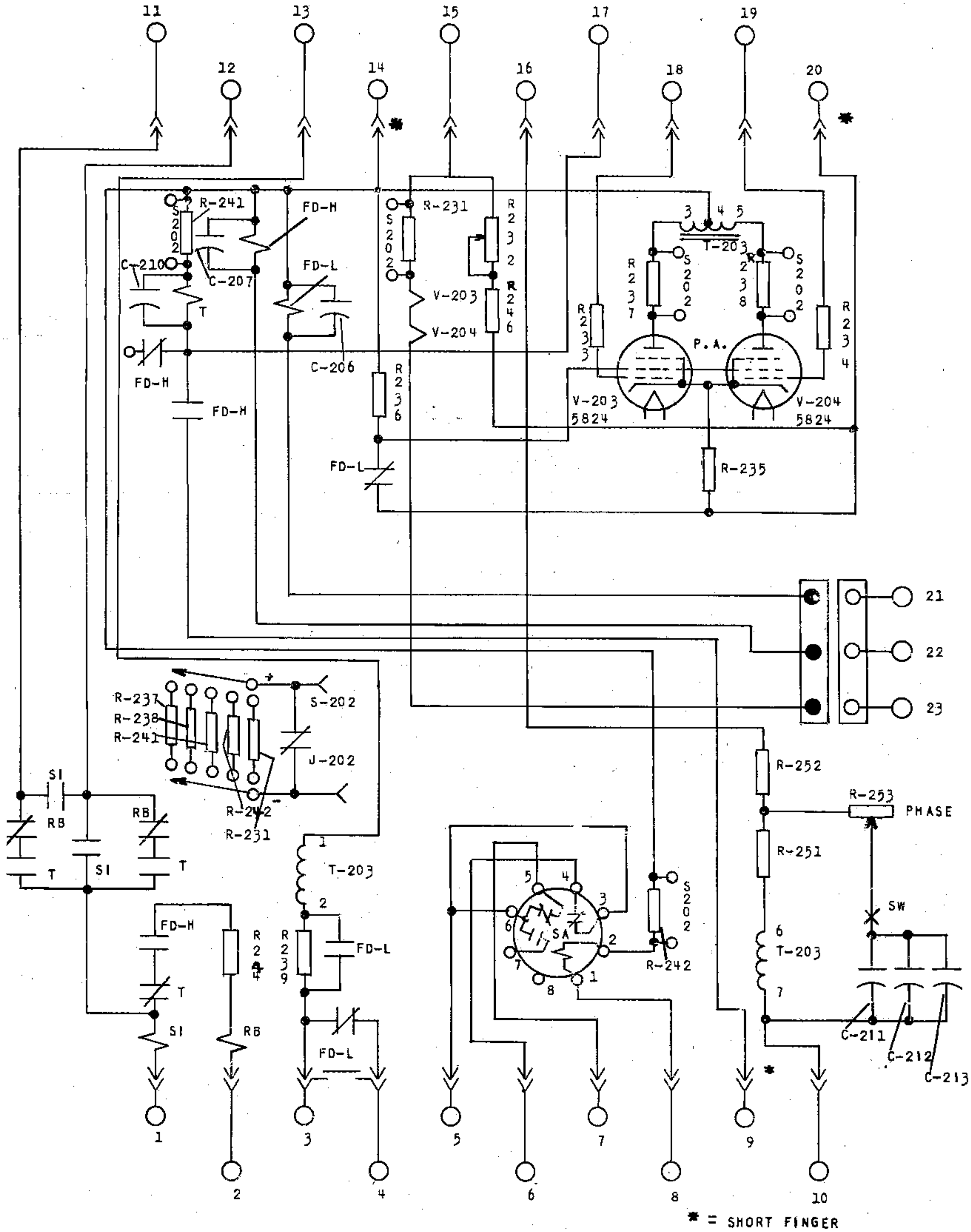


Fig. 4 Internal Connections For The Type EDD Relay (Tripping Unit)

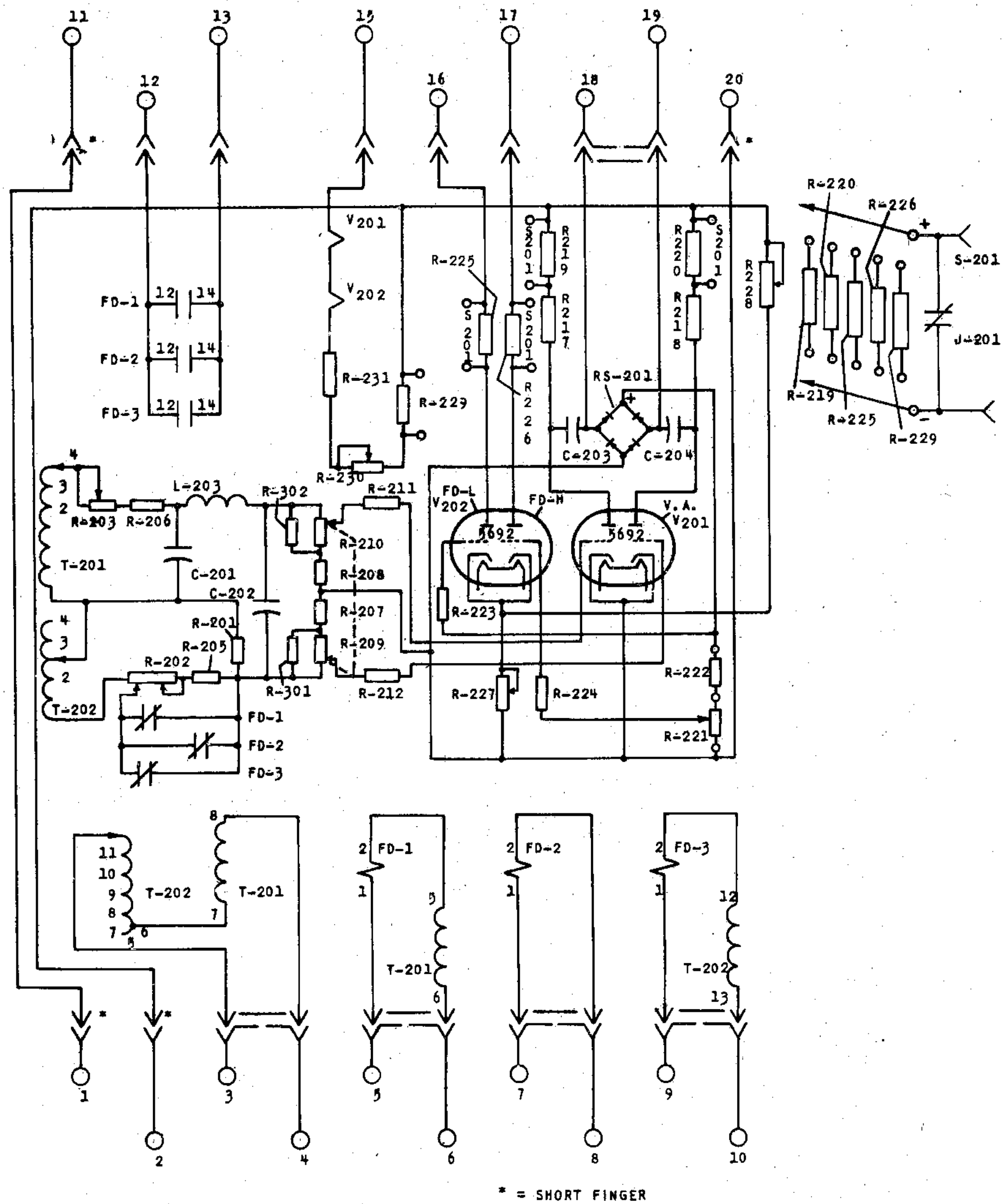


Fig. 5 Internal Connections For The Type EDD Relay (Network Unit)

NOTE: Tests are for 2-ended lines using normal settings given in Table IV.

1. Make all tests on the transmitter-receiver unit insofar as possible.

2. Perform the following tests, SECTIONS E_1 to E_{12}, to insure correct connections and to adjust the equipment for a specific installation.

3. When final adjustments have been made on both transmitter-receivers, perform tests, SECTIONS E_{13} to E_{23}.

4. Perform tests, SECTIONS E_{24} to E_{28} if desired, or if there is reason to suspect that factory settings have been changed.

NOTE: Disconnect the trip wires from terminals 11T and 12T of the tripping unit.

E_1 D-C POLARITY (CHECK)

1. Cabinet mounting terminals K14 (+) and K3 (-).

2. Panel mounting - tripping unit studs 14T (+) and 20T (-).

E_2 TARGET TAP (SET)

TRIP COIL CURRENT (MIN. CONTROL VOLTAGE)	TAP SETTING
0.2 to 2 amp.	0.2
2 to 30 amp.	2

CAUTION: Tighten a screw in the desired tap before removing the screw from the other tap. Spare screws may be obtained from the left-hand stationary contact.

E_3 TRIP CIRCUIT (CHECK)

1. Turn RTS (Relay Test Switch) to "NOR" position. For cabinet mounted equipment, momentarily jumper terminals J7 and J9, then J7 and J10. Battery voltage should appear across terminals J8 and J9, then J8 and J10, respectively. (Breaker should trip, if trip coil is connected to J9 or J10.) For panel mounted relay, jumper terminals 1T and 11T, then 1T and 12T on the tripping unit. Voltage should appear across 11T and 20T, then 12T and 20T.

2. Manually operate the tripping relay, marked T, and observe the same results.

E_4 ALARM CIRCUIT (CHECK)

1. Remove carrier fuses, then see that contacts of the signal alarm element (SA) ring the proper alarm. Replace carrier fuses.

2. If desired, disconnect alarm leads at the relay for remainder of installation tests.

E_5 TEST SOURCE CURRENT (SET)

E_6 Type EDD12A Relay

1. Place external ammeter in series with a-c test source.

2. With the relay test switch turned to the "IN" position, hold the voltmeter at 100 volts by means of the tap switch and the rheostat while selecting the proper turn of R-204 on the untapped section to obtain 3.4 to 3.5 amperes*.

3. Turn the relay test switch to the "OUT" position. Holding the voltmeter at 100 volts by means of the tap switch and the rheostat, adjust the current from 2.3 to 2.4 amperes** by selecting the proper turn of R-204.

4. Return the test switch to "OFF" position.

*6.4 to 6.5 when used for three-ended lines.
**2.4 to 2.5 when used for three-ended lines.

E_7 Type EDD12B Relay

The a-c network unit in this relay has been preadjusted at the factory to draw the same current as the Type EDD12A relay when the voltmeter is set at 100 volts by means of the tap switch and rheostat as outlined for the Type EDD12A relay.

The factory adjustment is for two-ended lines with normal relay settings.

E_8 PHASE-FAULT DETECTOR (SET)

1. Turn relay test switch to "OFF" position at both ends of the line.

2. Insert drawout test plug, connected as shown in Fig. 8, in the bottom of the network unit.

3. Apply current between terminals 5 and 9 on relay side of test plug. All three fault detectors should be dropped out at 5.7 amperes and picked up at 6.3 amperes. (Increasing from zero.)

4. Adjustment may be made by turning the knurled armature A shown in Fig. 24.

5. If any contact adjustment seems advisable, it should be made in accordance with SECTION J_3.

6. Return test switches to "NORMAL" position.

E_9 CT CONNECTIONS (CHECK)

1. This check requires line current. If the line is not in service, or if the load current is too small, it is sometimes possible to apply a three-phase short circuit at one end of the line and then build up a machine at the other end to full load current.

2. THE SUM OF THE CT SECONDARY CURRENTS MUST ADD UP TO ZERO. This may be checked by placing an ammeter in series with each phase

Fig. 5 (K-6556430)

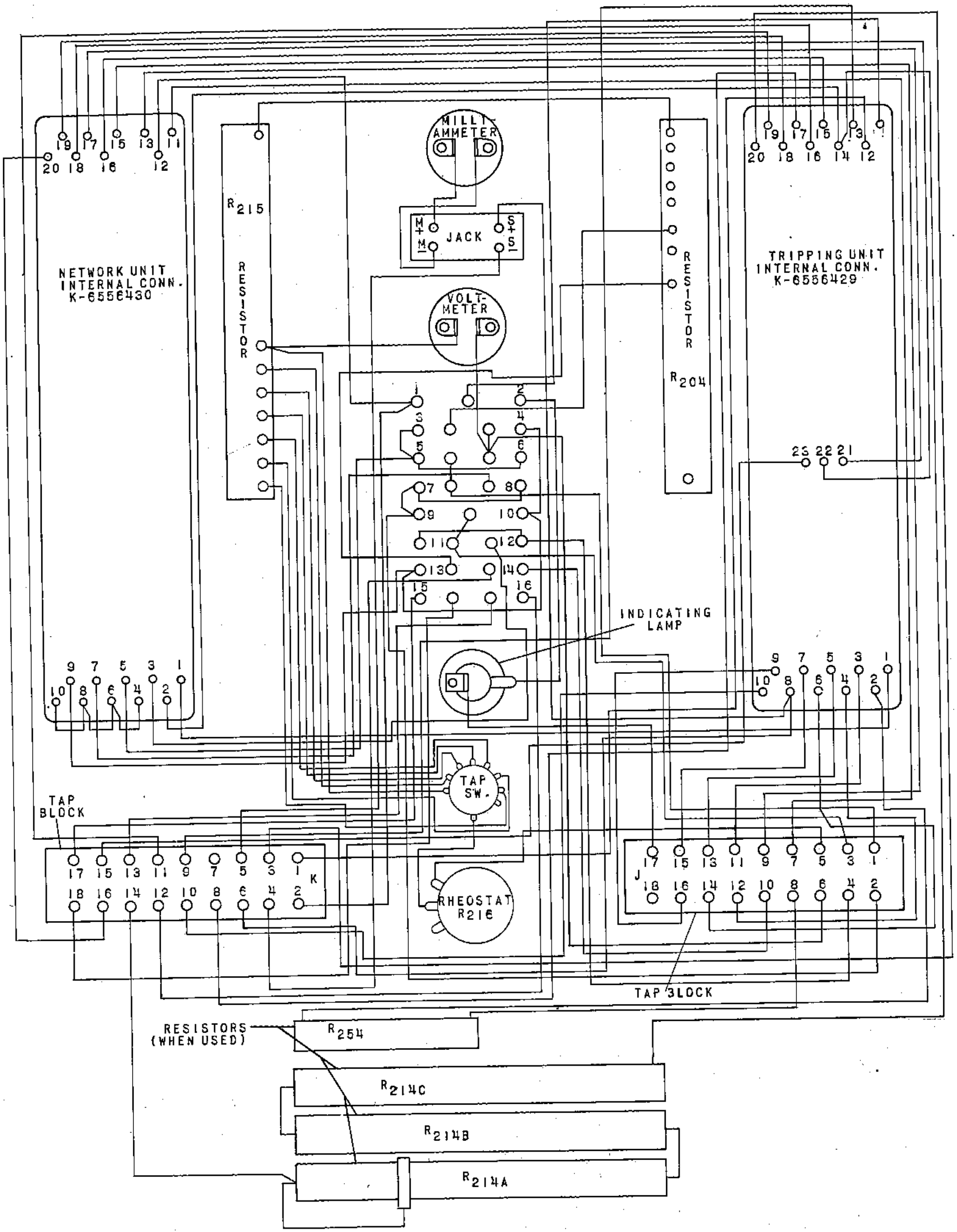


Fig. 6 Internal Connections for the Type EDD Relay (Sub Panel) (Back View)

Fig. 6 (P-6229824)

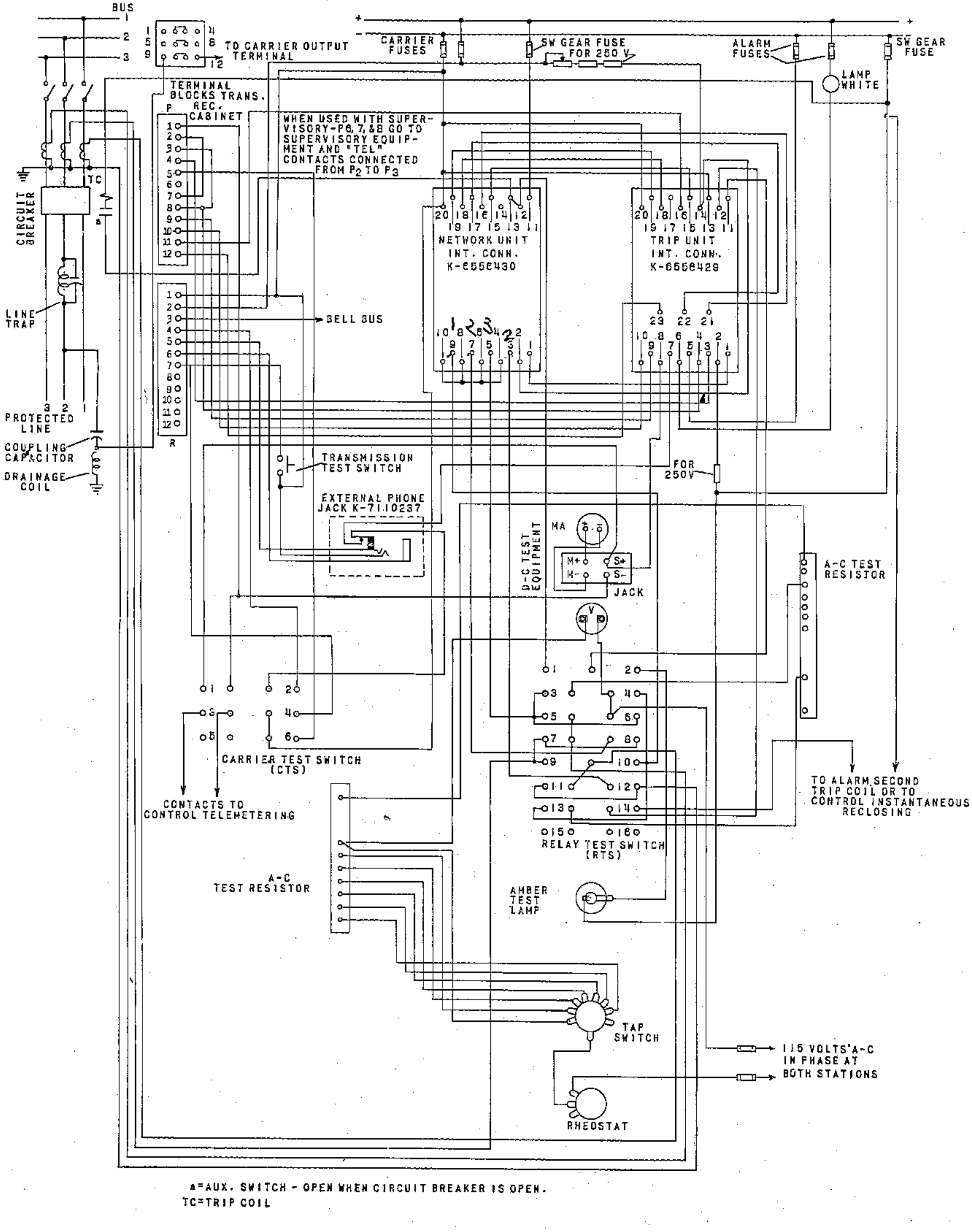


Fig. 7 External Connections for the Type EDD Relay (Panel Mounted)

Fig. 7 (P-6229828)

Fig. 6 (P-6229824)

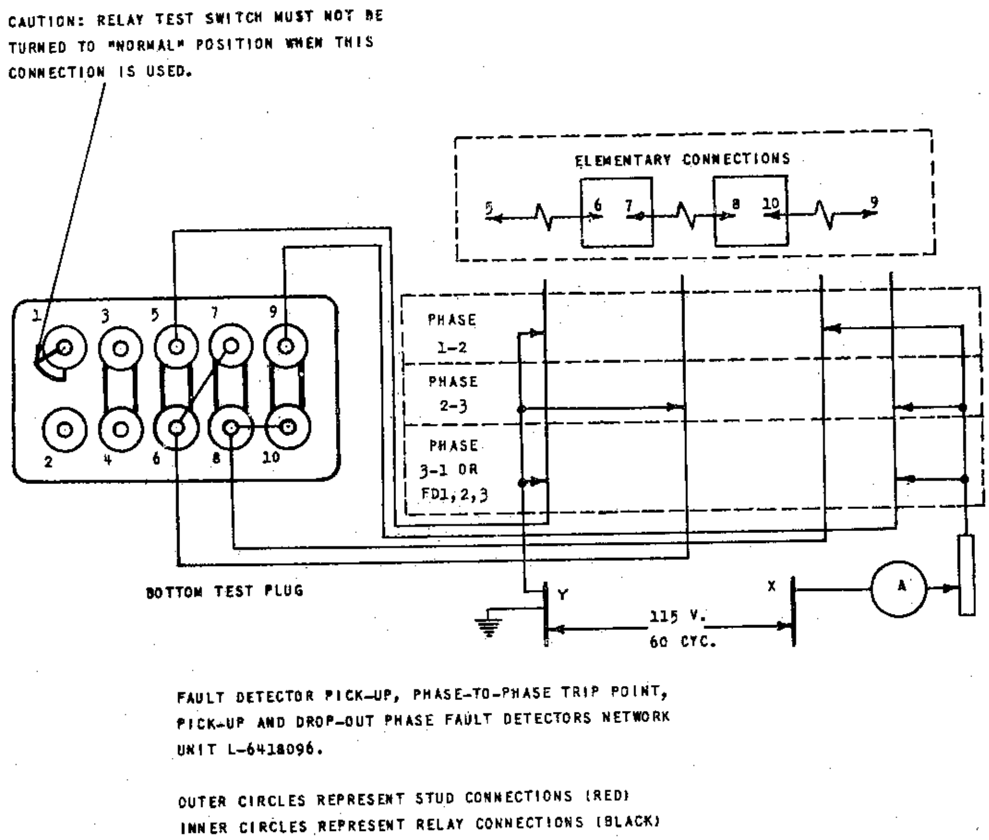


Fig. 8 Drawout Test Plug Connections For Phase-To-Phase Pickup Check

Fig. 8 (K-6556528) Sh. 2

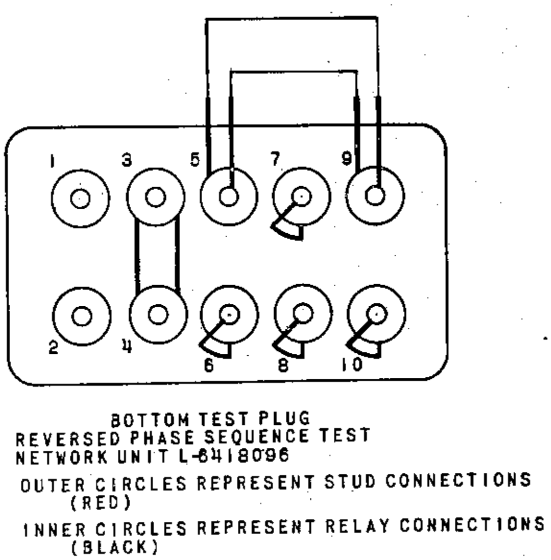


Fig. 9 Drawout Test Plug Connections For Reverse Phase Sequence Test

Fig. 9 (K-6556528) Sh. 5

and noting their equality, then in the neutral and observing no current. The ammeter may be connected from line side to relay side of a drawout test plug which may then be inserted in the bottom of the network unit. The three phases are terminals 5, 7, and 9, and the neutral is terminal 3. All terminals must be connected from line side to relay side.

3. The current must have the phase sequence shown by Fig. 10. Apply an a-c voltmeter of 1000 ohms per volt across the tripping unit terminals 3T and 20T, or cabinet terminals K3 and J11. The correct phase sequence, with sufficient current applied to pick up FD-L on incorrect sequence, should give a voltage reading of less than 15 volts, and will not pick up FD-L. Incorrect phase sequence will give a reading from 270 to 330 volts. Check the results by applying reverse phase-sequence currents by means of a drawout test plug, connected as shown in Fig. 9, inserted in the bottom of the network unit. If connections are not correct, correct them at network unit terminals 3N, 5N, 7N, and 9N for panel mounted relays, or terminals J1, J2, J3, and J4 in cabinet mounted equipment.

E_{10} HEATER ADJUSTMENTS, NETWORK UNIT (SET)

1. Plug the test cord into the milliammeter jack and into the network unit jack. Turn selector switch in the unit to "HEATER".

2. Remove the coverplate from R-230, then move slider of R-230 to give 552 to 562 milliamperes with 129 (or 258) volts on the battery. With 250 volt equipment, adjust the external cage type resistor 214A to give 128-130 volts across stud 14T and stud 20T of the tripping unit. Make these two adjustments alternately until both current and voltage are correct.

E_{11} HEATER ADJUSTMENTS, TRIPPING UNIT (SET)

1. Plug the test cord into the milliammeter jack and into the tripping unit jack. Turn the selector switch in the tripping unit to "HEATER" and adjust the slider on R-232 until the current reads 1/2 of the value read on the network unit heater. This value should be from 276 to 281 milliamperes. It may be necessary to repeat the adjustment under SECTION E_{10} and then SECTION E_{11} to obtain the correct values of heater current in both the network unit and tripping unit.

E_{12} POWER AMPLIFIER PLATE CURRENT (CHECK)

1. Plug the test cord into the milliammeter and tripping unit. Turn the selector switch to V-203. No signal current should be supplied to the network unit.

2. The milliammeter should read 35 to 50 milliamperes when FD-L is picked up by hand at 129 volts d-c bus potential.

3. Repeat for V-204 and record both readings for future comparison.

E_{13} SIGNAL ALARM AND COMPARER PLATE CURRENT (SET)

1. Close grounding switch on carrier transmitter.
2. Adjust battery voltage within 2% of normal.
3. Set carrier test switch to "RECEIVE" and relay test switch to "OFF" position.
4. Plug test cord into milliammeter and tripping unit and set selector switch to "SIGNAL ALARM". The following adjustments are made on the Transmitter-Receiver:
5. Set S10 to its left-hand position.
6. Adjust R47 fully counterclockwise.
7. Adjust R38 until signal alarm current is just below 0.5 milliampere.
8. Set S10 to right-hand position.
9. Turn R47 fully clockwise and then adjust counterclockwise until a point is found where signal-alarm current just begins to drop.
10. Then adjust R38 for between 5-6 milliamperes in comparer as read at relay unit in trip condition. Be sure R47 is set so that signal alarm current drops to less than 0.5 milliampere on receipt of continuous carrier.
11. Open grounding switch on carrier transmitter.

E_{14} SIGNAL ALARM CURRENT (CHECK)

1. Turn local carrier test switch to "SEND" and relay test switch to "OFF".

2. Plug test cord into milliammeter and tripping unit and set selector switch to "SIGNAL ALARM".

3. Milliammeter reading should be 0.5 milliampere, or less.

4. Turn local carrier test switch to "RECEIVE" and have remote carrier test switch set on "SEND".

5. Milliammeter should read 0.5 milliampere, or less.

E_{15} RESERVE SIGNAL (SET)

1. Have both relay test switches in the "OFF" or "NORMAL" position.

2. Have remote carrier test switch turned to "SEND".

3. Perform the following operations on the transmitter-receiver unit: Depress button S-11 (or turn local carrier test switch to "TEST") and adjust R29 to give a current of 1 to 3 milliamperes, measured at the signal alarm current jack (J4). Record the current reading and resistor setting for future comparison.

4. Note that this setting should be made only when transmission conditions are normal. Current will increase as transmission efficiency is decreased by sleet, etc.

E_{16} PHASE SHIFTER (SET)

NOTE: For lines of length up to 50 miles the phase shifter may be set at 0 degrees (extreme counterclockwise rotation).

1. Determine degrees of lag of carrier-current signal due to the time of propagation from one line end to the other. The approximate lag per 100 miles of open line is 12 degrees.

2. Turn both relay test switches to "IN".

3. Turn phase shifter to 0 degree phase shift (extreme counterclockwise position).

4. Use calibrated phase shifter to supply a signal of about 125 V. a-c between P9 and P10, after first blocking the "a" contacts of FD-H open.

5. Adjust the shop calibrated phase shifter for minimum comparer plate current.

6. From the point found in 5, turn the shop phase shifter, in a lagging direction, the number of degrees calculated in 1.

7. Adjust phase shifter of tripping unit for minimum comparer tube plate current. Lock phase shifter control in place by means of the locking nut.

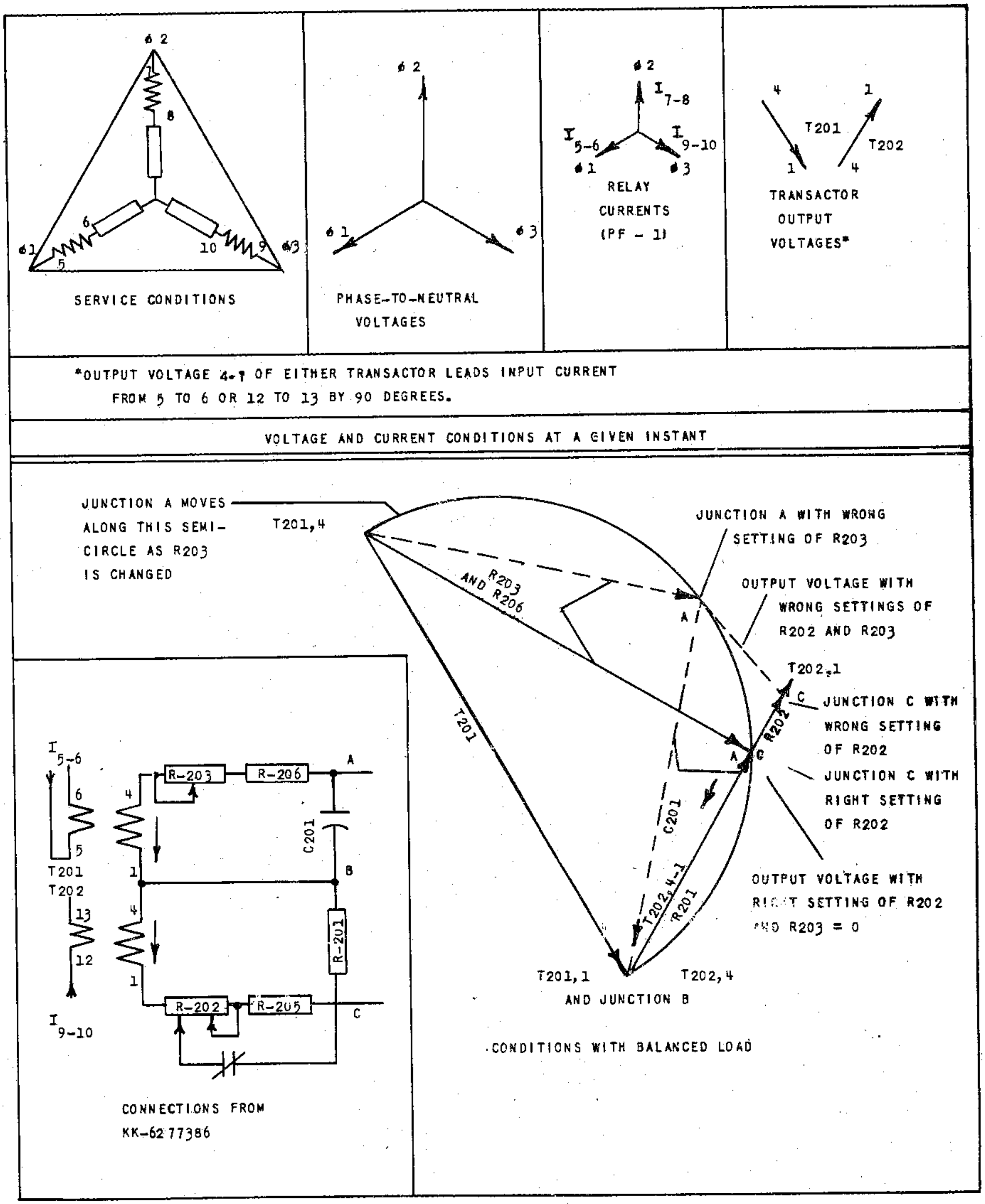
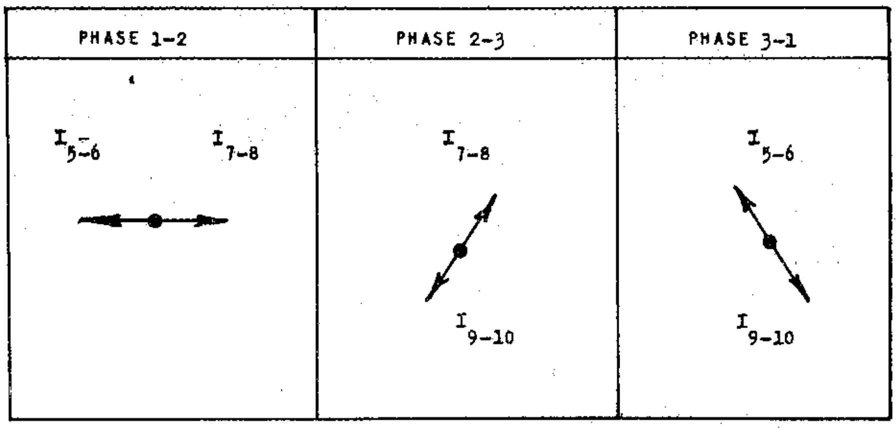
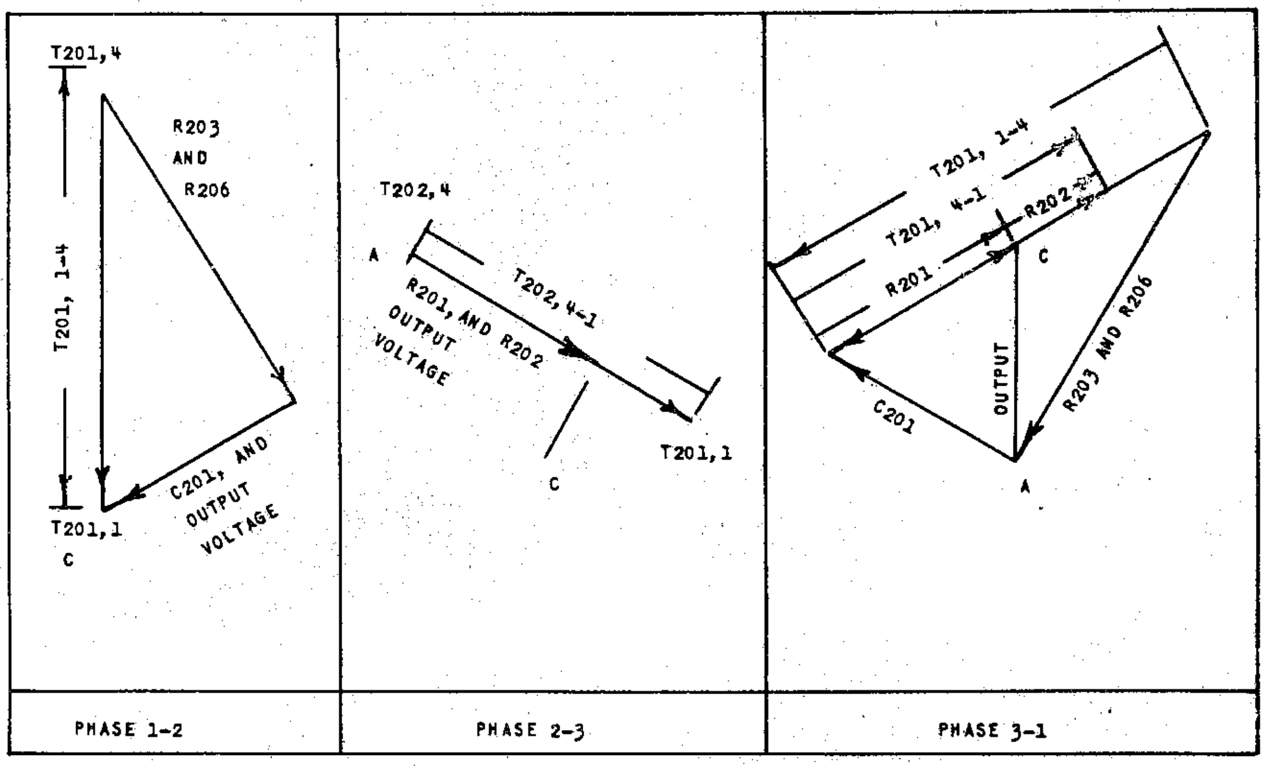


Fig. 10 Vector Relations In Negative-Sequence Network For Balanced Loads

Fig. 10 (K-6204059) Sh. 1



CURRENTS FOR PHASE-TO-PHASE FAULTS, ASSUMING LINE R = 1/2 OF LINE Z SO THAT I LAGS LINE-TO-NEUTRAL VOLTAGE BY 60°.



OUTPUT VOLTAGES FOR PHASE-TO-PHASE FAULTS, RESULTING FROM THE LINE CURRENTS SHOWN ABOVE.

Fig. 11 Vector Relations In Negative-Sequence Network For Phase-To-Phase Fault

Fig. 10 (K-6204059) Sh. 1

Fig. 11 (K-6204059) Sh. 2

E_{17} PHASING OF TEST SOURCES (CHECK)

1. If a cathode ray oscilloscope is available, connect its vertical input between the ground and line terminal of the transmitter receiver.

2. Turn relay test switches at both ends of the line to "IN". Oscilloscope should indicate approximately 0 degree phase displacement between the local and remote signals.

3. Turn relay test switch at one end of line to "OUT", other end to "IN". Oscilloscope should indicate approximately 180 degrees displacement.

4. If oscilloscope patterns are considerably different from 0 to 180 degrees, the voltages at the two ends are from different phases. In this case, substitute either of the other two phases of the a-c test source at one end of the line at terminals M5 and M6. Repeat phasing tests.

5. If oscilloscope is not available, plug the test cord into the milliammeter and tripping unit, and turn switch to "COMPARER".

6. Milliammeter should read approximately 6 milliamperes with the relay test switches in like positions, or 0 to 0.5 milliamperes when the switches are in opposite positions.

7. If the difference between the two readings is less than 4 milliamperes, the test voltages at the two ends are from different phases. In this case, proceed as indicated in 4 above.

E_{18} COMPARER PLATE CURRENT (CHECK)

1. Record the comparer plate current with the relay test switches at the two ends of the line in the same position ("IN" or "OUT") (Approximately 6 ma. See SECTION E16).

2. Repeat with the switches in opposite positions (0 to 0.5 ma.).

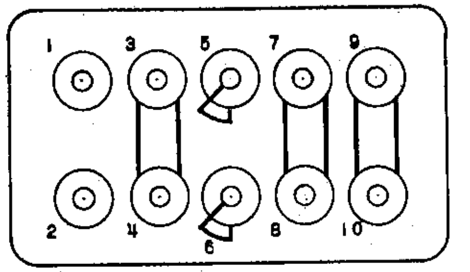
3. Repeat with the local relay test switch on "IN" and the remote relay test switch on "OFF". The plate current should be approximately 6 milliamperes.

NOTE: Comparer-plate current will vary with power transfer on a long line. For this reason, it is advisable to graph comparer-plate current under various kilowatt loads and use this graph whenever checks are made on comparer-plate current.

E_{19} CT PHASE AND POLARITY (CHECK)

1. CURRENT IDENTIFIED AS PHASE 1 MUST COME FROM THE ENDS OF THE SAME LINE, AND ITS POLARITY MUST BE THE SAME WITH RESPECT TO EACH STATION BUS.

2. Insert a drawout test plug, connected as shown in Fig. 12, in the bottom of the network unit at each end of the line.



BOTTOM TEST PLUG
PHASE 1 CURRENT ONLY
NETWORK UNIT L-6418096

OUTER CIRCLES REPRESENT STUD CONNECTIONS (RED)

INNER CIRCLES REPRESENT RELAY CONNECTIONS (BLACK)

Fig. 12 Drawout Test Plug Connections For Phase One Current Only

3. If a cathode ray oscilloscope is available, connect its vertical input between ground and the line terminal of the transmitter receiver. A phase displacement of nearly 180 degrees should be indicated between transmitted and received signals. Current flowing in one end of the line is flowing out at the other end.

4. If an oscilloscope is not available connect a phase angle meter to indicate the angle between phase 1 current (at the test plug) and the test source voltage. (This implies completion of tests in SECTION E_{16} at both ends of the line.) The same test with the same meter connections at the other end of the line should indicate an angle differing by 180 degrees.

5. If this test indicates a displacement at the two ends of 60 or 300 degrees, it will be necessary to give the three CT leads on one relay a barrel-roll forward or backward, maintaining the same sequence that has already been determined to be correct in SECTION E_9. If a displacement of 0 degrees is indicated, it will be necessary to reverse the secondary connections to each of the three CT's at one end of the line. If the displacement is 120 or 240 degrees, it will be necessary to make both of the above changes.

E_{20} PHASE-TO-PHASE BLOCKING POINT (SET)

1. Turn relay test switches at both ends of the line to "OFF". Plug the test cord into the milliammeter and tripping unit, and switch to Fault Detector-Low (FD-L).

2. Insert a drawout test plug, connected as shown in Fig. 13, in the bottom of the network unit. Turn the local relay test switch to "IN". Gradually decrease the test resistance and note the current at which FD-L picks up; this should be between 1.9 and 2.1 amperes.

3. If the pick-up current is incorrect, adjust the FD-L rheostat, R-209 and R-210.

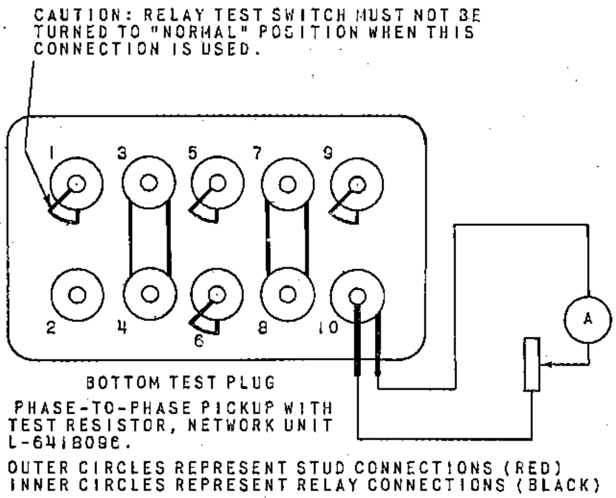


Fig. 13 Drawout Test Plug Connections For Phase-To-Phase Pickup

4. Record the pick-up current and the FD-L plate current.

E_{21} PHASE-TO-PHASE TRIP POINT (SET)

1. Turn the local relay test switch to "IN". Record the tripping unit output voltage (K3 to J11 or studs 20T to 3T of the tripping unit) and the tripping voltage (K10 to K11 or studs 10T to 16T), using an a-c voltmeter of 1000 ohms per volt or more.

2. Insert a drawout test plug, connected as shown in Fig. 13, in the bottom of the network unit. Turn the local relay test switch to "IN". Gradually decrease the test resistance and note the current at which the test lamp lights. This should be between 2.9 and 3.1 amperes.

3. If the pickup current is incorrect, adjust the FD-H rheostat, R-221.

4. Record the pickup current and the FD-H plate current.

E_{22} GROUND CURRENT PICKUP (SET)

1. Calculate the tap setting required as outlined in SECTION H_3.

2. Turn relay test switch at both ends of line to "OFF", then make proper tap setting in the network unit.

E_{23} OUTPUT VOLTAGE AND SIGNAL STRENGTH (RECORD)

1. Turn the local relay test switch to "IN". Record the tripping unit output voltage (K3 to J11 or studs 20T to 3T of the tripping unit) and the tripping voltage (K10 to K11 or studs 10T to 16T), using an a-c voltmeter of 1000 ohms per volt or more.

2. Record received signal voltage (measured between terminal 3 of tube V9 of the receiver and terminal R1) with the remote relay test switch on "IN" and the local relay test switch on "NORMAL", using a voltmeter of 1000 ohms per volt or more. Record also the RF current at the remote station.

3. Turn both relay test switches to "NORMAL". Record the signal voltage, (as in 2 above) first while pushing the local button "S11" in the transmitter, then while the remote button "S11" is depressed.

E_{24} TRANSIENT BLOCKING; RB (CHECK)

Set up the following conditions:

1. Relay test switches at both ends of the line in the "OFF" position.

2. Seal-in unit of tripping unit set on 0.2 ampere tap (temporarily). See SECTION E_2 for procedure.

3. 25 watt incandescent lamp (temporarily) across studs 2T and 11T of the tripping unit.

4. Maximum d-c control voltage (temporarily).

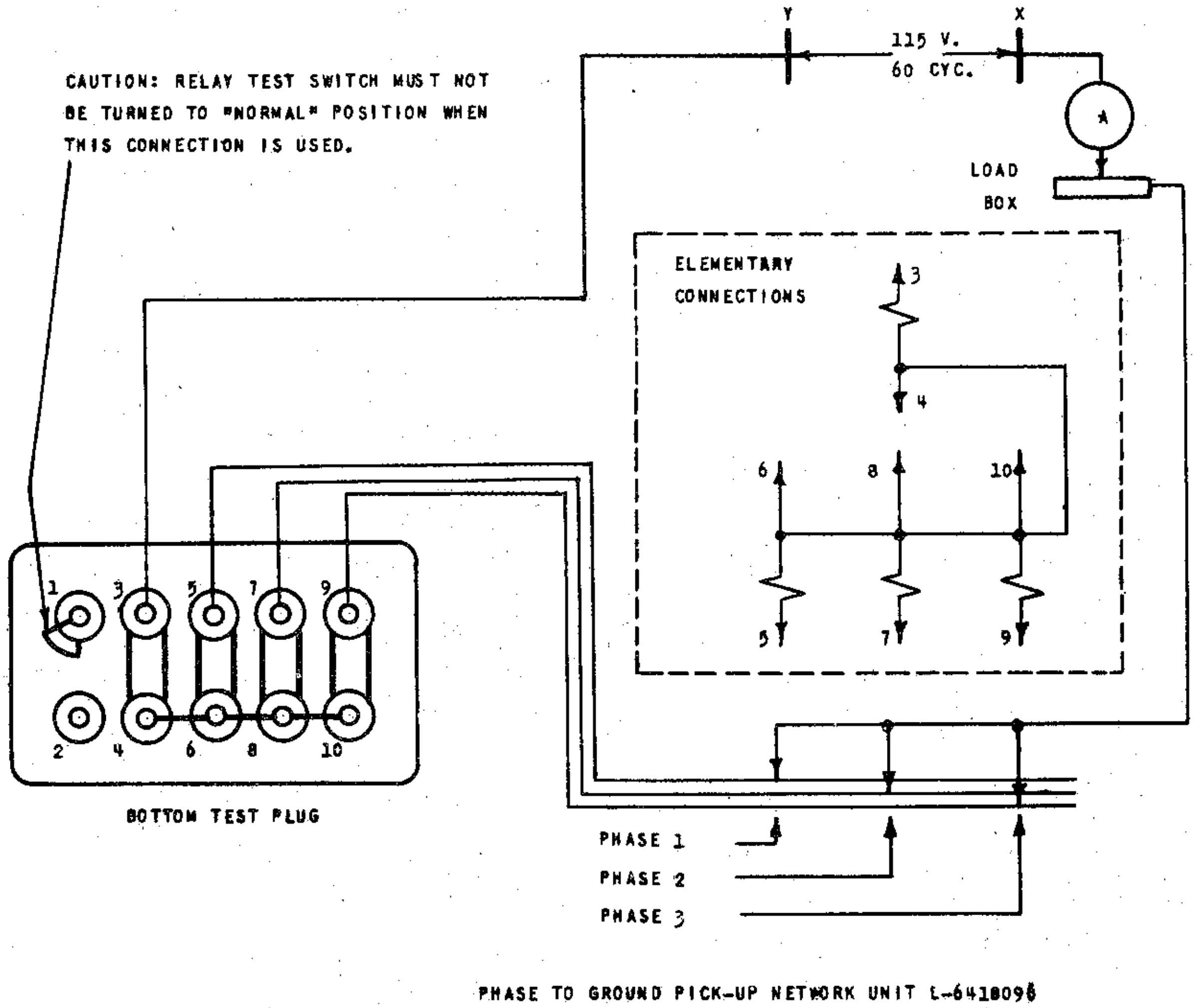
Then turn the relay test switch to the "IN" position so that FD-H picks up, and see that RB has sufficient delay so that it does not open its contacts before T picks up. If the proper time relation exists, the seal-in unit S1 will pick up and seal in apparently instantaneously, and the incandescent lamp will light. If the relay requires adjustment, refer to SECTION J_{15} of this book.

E_{25} GROUND-CURRENT PICKUP (CHECK)

With the relay test switches in the "OFF" position, apply 60 cycle current to the network unit through a drawout test plug connected according to Fig. 14, and see that the relay marked FD-H in the tripping unit picks up at a current equal to or less than the chosen tap value timer FD-H pickup. Phase 2 gives the highest pickup, so no check is necessary on phases 1 or 3. Tap values are multipliers of the FD-H relay element pick-up setting.

E_{26} NETWORK BALANCE (CHECK)

With the relay test switches at both ends of the line in the "OFF" position, and with the milliammeter switched to "FD-H", apply 60 cycle test current to the network unit with connections as shown in Fig. 8; and see that the relay marked FD-H in the tripping unit is dropped out at 2.5 amperes increasing from zero, and picked up at 3.2 amperes. Pickup is the current at which the tripping unit lights the amber lamp.



OUTER CIRCLES REPRESENT STUD CONNECTIONS (RED)

INNTER CIRCLES REPRESENT RELAY CONNECTIONS (BLACK)

Fig. 14 Drawout Test Plug Connections For Phase-To-Ground Pickup Check

Fig. 14 (K-6556528) Sh. 3

This trip point should be checked with each of the three drawout plug connections indicated on Fig. 8. All three should be alike within 0.3 ampere. If the difference is excessive, the network should be rebalanced in accordance with SECTION J2.

E27 THREE-PHASE TRIP POINT (CHECK)

The three-phase trip point may be checked by means of a balanced (± 2 V) external three-phase test source and two load boxes, with the relay test switches in the "OFF" position at both ends of the line. Two ammeters (10 or 15 A scale) are also necessary, rather than one, unless the voltage of the test source is steady. Fig. 15 shows the proper connections, including the drawout test plug of the network unit.

Since the operation of the relay depends on the phase sequence, the test results will be correct only if the connections between the test source and the relay are such as to provide proper phase sequence at the relay. To check this, set both currents alike at 4 to 5 amperes and read the current in the FD-H, first with the connections as originally made, and again with one pair of leads reversed at the test source. Use whichever connection gives zero on the milliammeter.

If two ammeters are being used, open phase 2, set I at 7.5 amperes, and read I_2. Compare the reading of I_2 with the 7.5 ampere reading of I_1, to determine how much to add or to subtract from any reading of I_2 in that range in order to reduce it to the same basis as I_1.

Block open all three normally closed contacts of FD-1, FD-2, and FD-3 in some way which will not allow them to come unblocked when the relays pick up.

After checking the phase sequence and the ammeter calibrations, and blocking the phase fault detector contacts open, set I_1 at the trial value of 7.5 amperes and I_2 at 4 amperes. The amber lamp going on or off during these adjustments does not indicate the three-phase trip point, but it should be off when the 7.5 and 4 ampere values have been obtained. Increase I_2 until the red lamp lights, apply the correction found with phase 2 open to reduce it to the same basis as I_1. Then average the corrected value with the original trial value of I_1 (7.5 A) to obtain a new trial value.

Reset I_1 to this new trial value, increase I_2 from 5 amperes until tripping occurs. Apply the correction, and average the new corrected value of I_2 with the present value of I_1, to obtain a new trial value of I_1.

Repeat this process until the corrected value of I_2 equals the latest trial value of I_1 within 0.1 ampere. This is the positive-phase-sequence pick-up, or the three-phase trip point, and it should be 7 to 8 amperes. If this requires adjustment, see SECTION J4 of this book.

E28 THREE-PHASE LOAD (CHECK)

With a three-phase balanced load on the line, of about the maximum value, the current read with the selector switch in the "FD-H" position is zero.

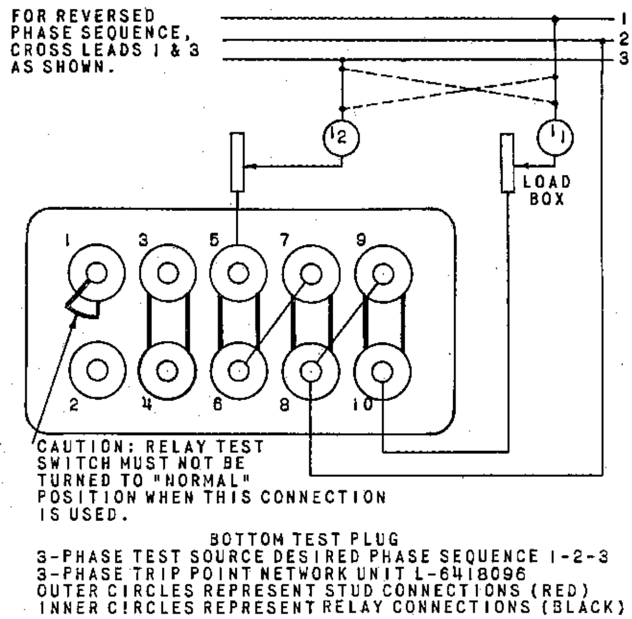


Fig. 15 Drawout Test Plug Connections For Three-Phase Trip Point Check

NOTE: Reconnect the trip leads to terminals 11T and 12T of the tripping unit.

OPERATING CONDITIONS (SECTION F)

F1 POWER SUPPLY

It is expected that the normal voltage of a 60-cell or 120-cell battery will be 129 or 258 volts, with a normal variation of plus or minus 5 percent. On overcharge periods, the voltage may rise to 140 or 280 volts; and occasionally on heavy loads, it may fall to 100 or 200 volts for one or two seconds. This latter condition is satisfactory for the operation of the tube heaters, which have sufficient thermal storage to operate for a few seconds at full output. During the overcharge or "equalization" period, the tube heaters will be operating slightly above normal current, which will reduce their life if continued over long periods. It is recommended that the maximum battery voltage on overcharge periods be limited to 140 or 280 volts.

F2 TEMPERATURE

This equipment is designed for operation in ambient temperatures of -20C to 40C.

Temperatures above 40 C may accelerate the formation of a cloudy deposit on the cover, contacts and bearings. This comes principally from the insulating materials, but does not indicate any significant deterioration of these materials. The deposits may be washed off the cover with soap and water. The rate of formation of the deposit will decrease as the volatile elements are driven off.

PRINCIPLES OF OPERATION (SECTION G)

G1 OPERATING PRINCIPLE

All carrier-pilot relaying systems utilize the carrier channel to transmit information from one end of the line to the other. This transmitted data is fed to a measuring element at each end which compares the corresponding conditons at the two ends. See Figs. 27 and 28.

LEGEND	
a	AUX. SW. CLOSED WHEN CIR. BREAKER IS CLOSED
C	CAPACITOR
CTs	CARRIER TEST SWITCH
FD-1-2-3	FAULT DETECTOR PHASES 1-2-3
FD-H	FAULT DETECTOR HIGH
FD-L	FAULT DETECTOR LOW
J.*	TEST JACK
L.*	REACTOR
R.*	RESISTOR
RB	TRANSIENT BLOCKING RELAY
S.	SWITCH
SA	SIGNAL ALARM RELAY
T-203	TRANSFORMER
T-201, 202	TRANSACTOR
TC	TRIPCOIL ON CIRCUIT BREAKER
V*	VACUUM TUBE
RTs	RELAY TEST SWITCH

*SUFFIX NUMBERS ARE FOR IDENTIFICATION ONLY AND HAVE NO OTHER SIGNIFICANCE.

TERMINAL DESIGNATION

7N — TERMINAL OF DRAWOUT RELAY

③ — PLUG IN POINT OF S. A.

B3 — TER. OF A UNIT MOUNTED IN CARRIER CABINET.

TER. BLOCKS "J" & "K" ARE ON THE RELAY UNIT. "R" IS ON THE REL. AUX. UNIT. TER. BLOCKS "M", "P", & "R" ARE FOR EXTERNAL CONNECTIONS TO THE CARRIER CABINET.

[M1 J1] NUMBERS IN BLOCKS APPLY TO CABINET. MOUNTED UNITS.

R1 [ ] C1 NUMBERS NOT IN BLOCKS APPLY TO PANEL. MOUNTED RELAYS.

RTS

CONTACTS HANDLE END		POSITIONS					
		OUT	IN	OFF	*	TCO	NOR
1–2	1						X
	2	X	X	X			
3–4	3		X				
	4		X				
5–6	5				X	X	X
	6	X					
7–8	7	X	X	X	X		
	8				X	X	X
9–10	9	X	X	X	X		
	10				X	X	X
11–12	11	X	X	X	X		
	12				X	X	X
13–14	13	X					
	14						X
15–16	15	X	X				
	16						X

CTS

CONTACTS HANDLE END		POSITIONS			
		SEND	NOR	REC	TEST
1–2	1		X		
	2		X		
3–4	3	X		X	X
	4				X
5–6	5		X	X	X
	6		X	X	X

SPRING RETURN (BACK VIEW)

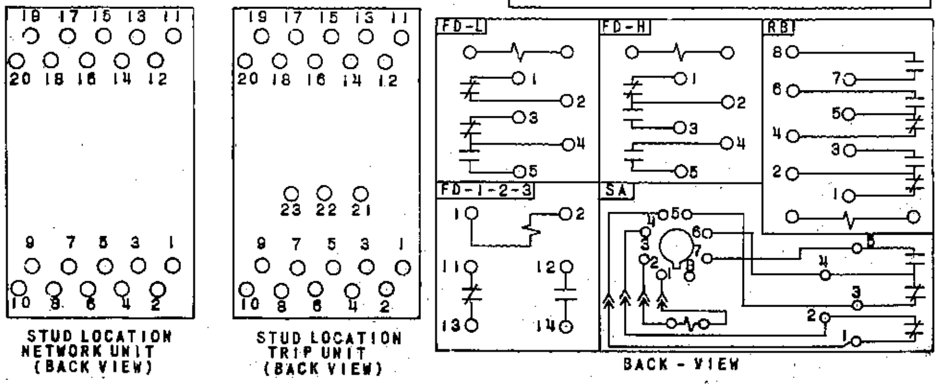


Fig. 16 Elementary Diagram For Phase-Comparison Pilot Relaying

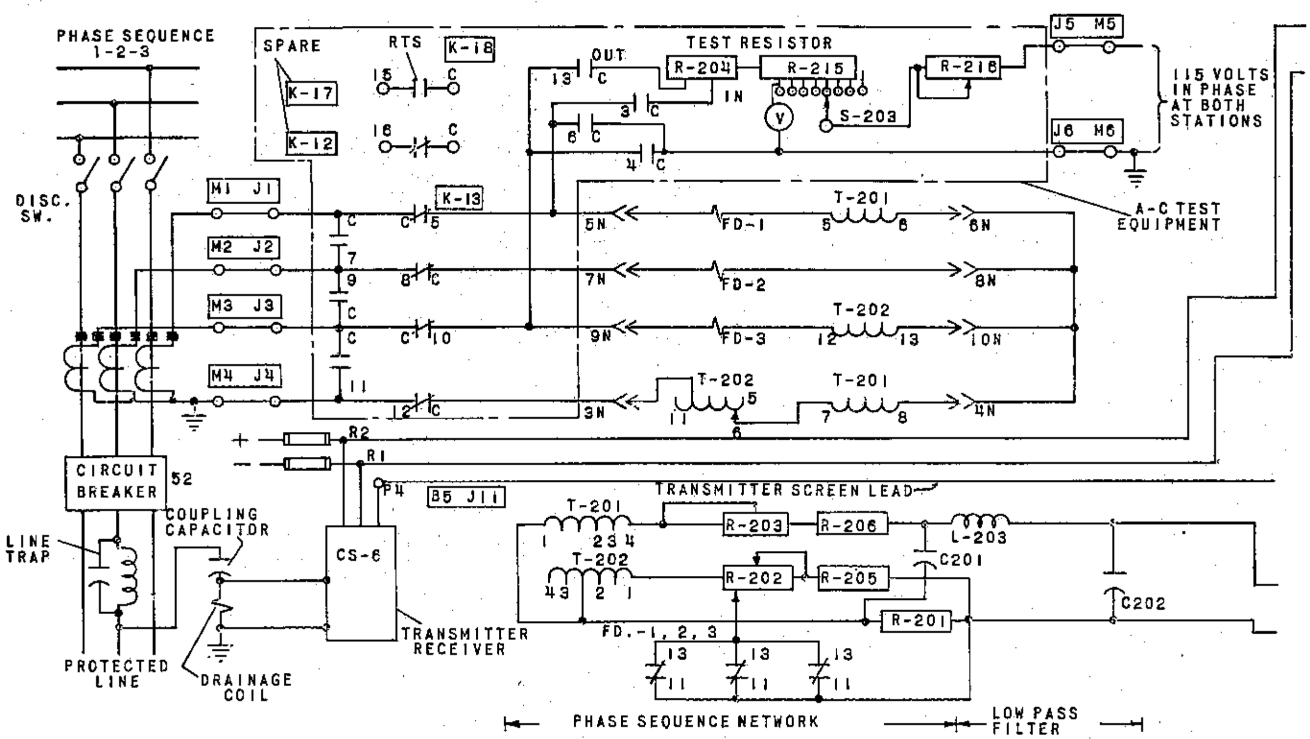


Fig. 17 Elementary Diagram For Phase-Comparison Pilot Relaying

Fig. 16 (KK-6277386) Sh. 1
Fig. 18 (KK-6277386) Sh. 3
Fig. 17 (KK-6277386) Sh. 2
Fig. 19 (KK-6277386) Sh. 4

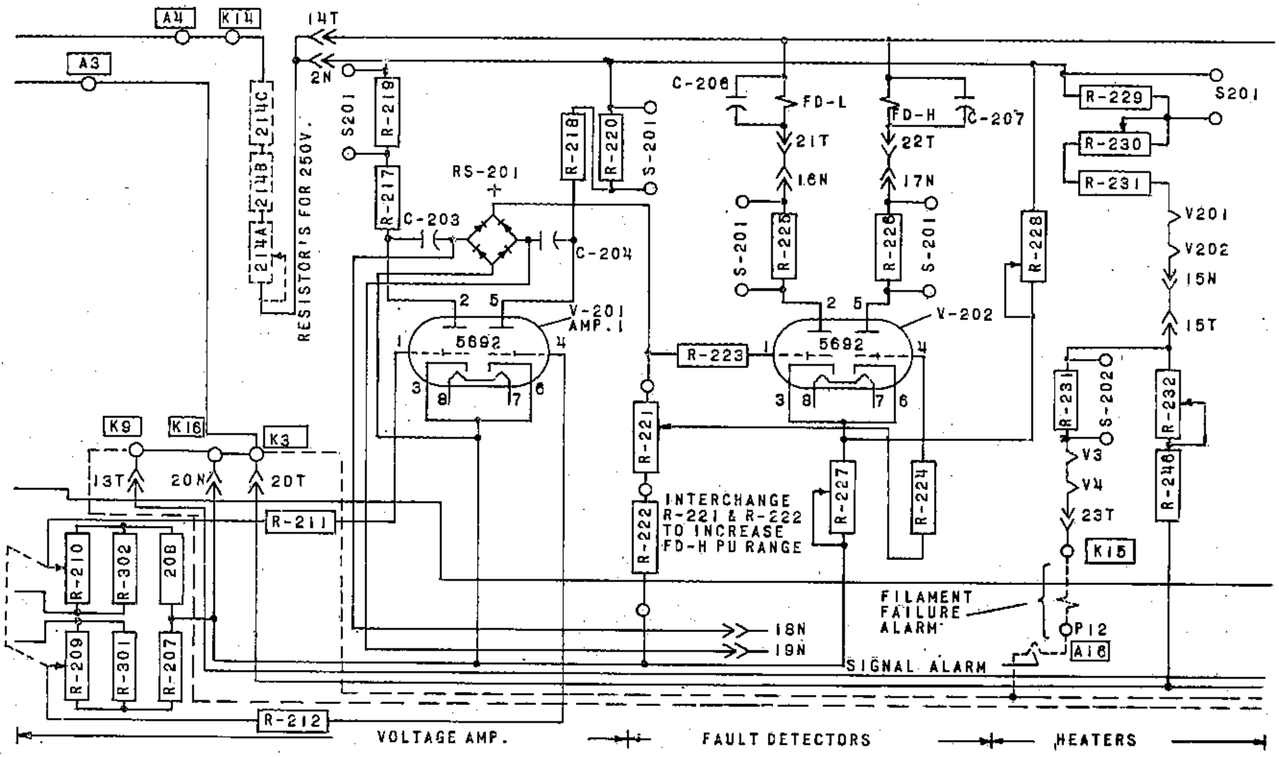


Fig. 18 Elementary Diagram For Phase-Comparison Pilot Relaying

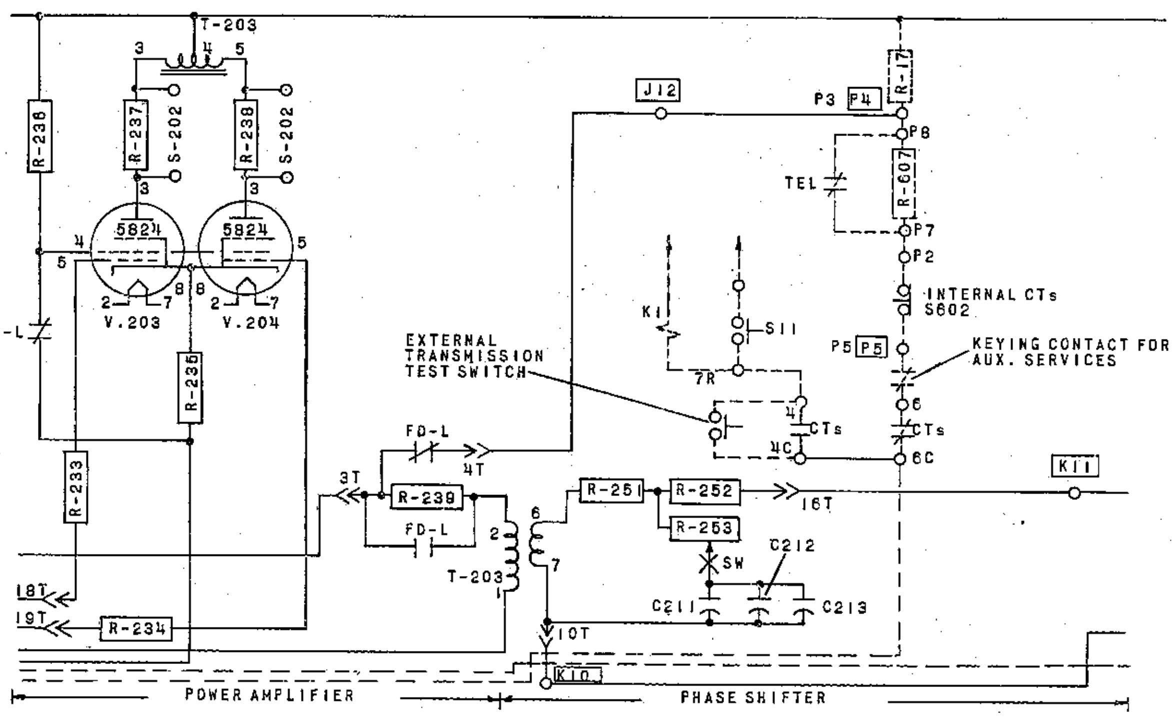


Fig. 19 Elementary Diagram For Phase-Comparison Pilot Relaying

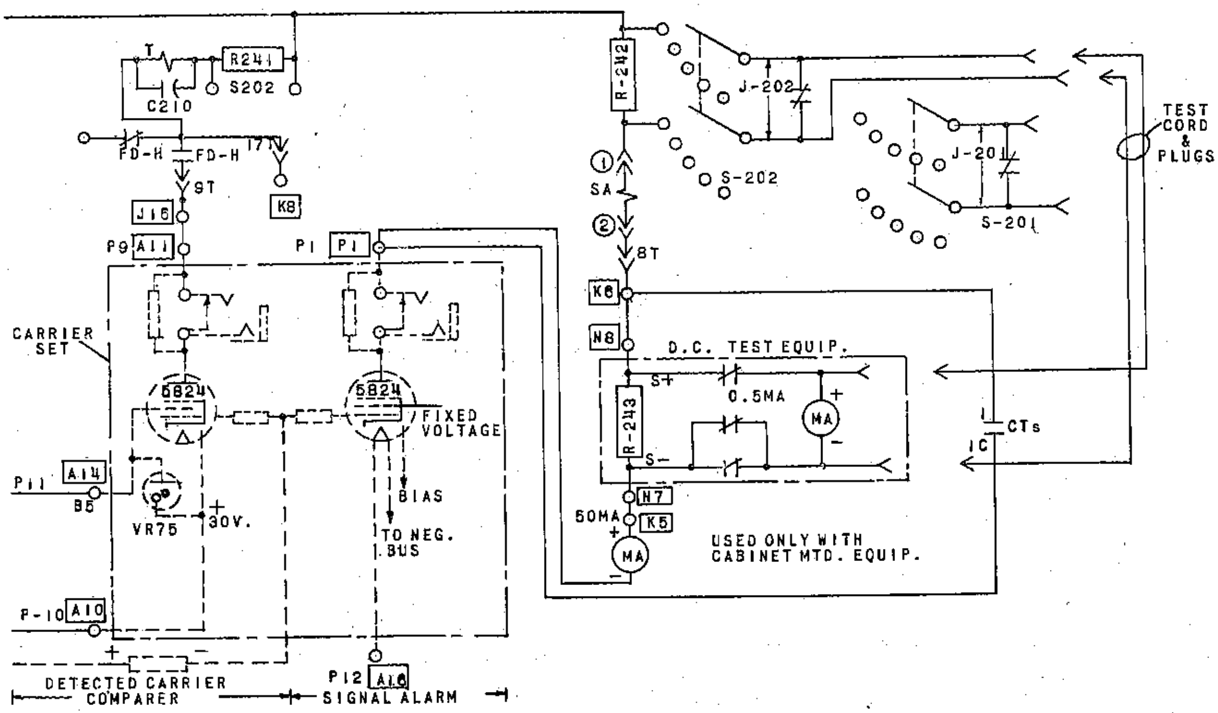


Fig. 20 Elementary Diagram For Phase-Comparison Pilot Relaying

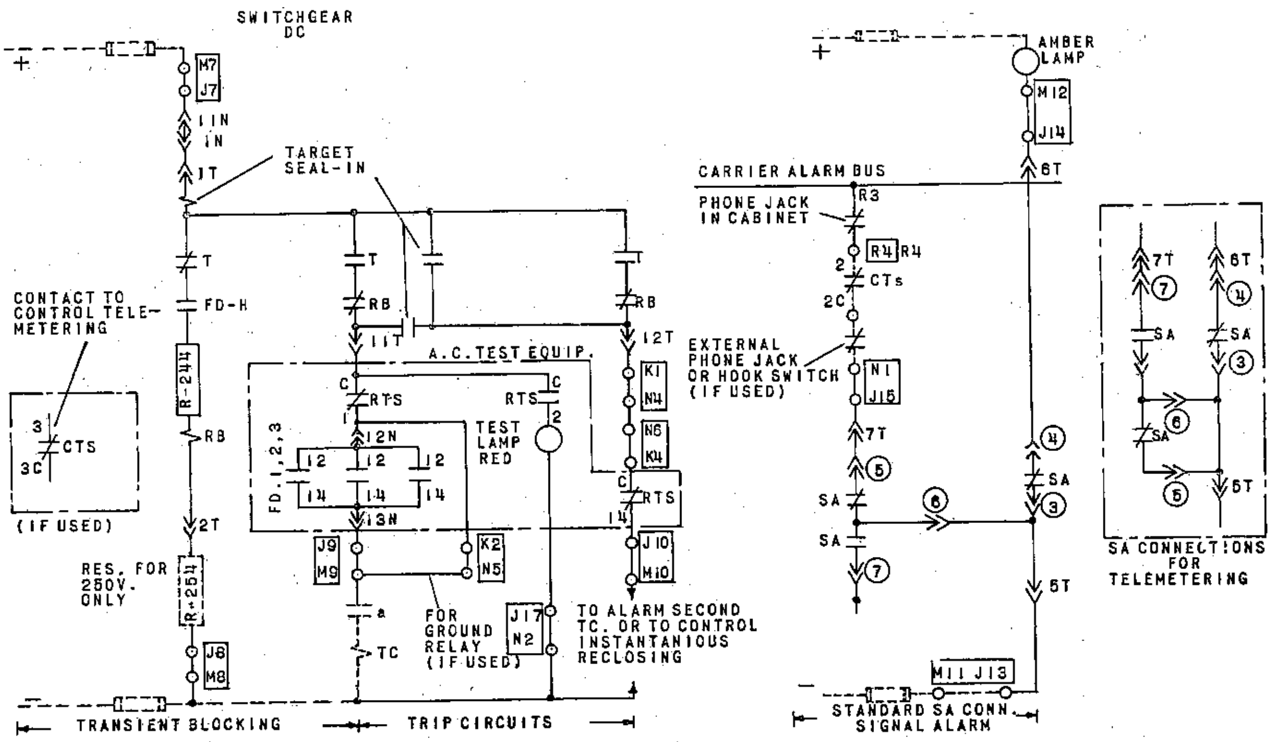


Fig. 21 Elementary Diagram For Phase-Comparison Pilot Relaying

Fig. 20 (KK-6277386) Sh. 5

Fig. 21 (KK-6277386) Sh. 6

In directional-comparison carrier-pilot relaying, the conditions compared are the contact positions of directional relays. In phase-comparison carrier-pilot relaying, the conditions compared are the phase positions of two composite voltages, each derived from the three line currents at its end of the line. If these two composite voltages are in phase, the two comparisons performed simultaneously at the two line ends indicate an internal fault. Tripping then occurs at both ends simultaneously, assuming currents greater than FD-H pick-up value are flowing into both ends. If the two composite voltages are 180 degrees different in phase, the comparisons performed at the two ends during alternate half cycles both indicate an external fault. Then tripping, which the relays would perform in the absence of a signal for comparison, is blocked.

The phase comparisons are performed by placing the local and received voltages on the screen grid and control grid respectively of a vacuum tube called the COMPARER. When the local voltage swings the screen grid positive, the tube will conduct plate current and cause tripping, unless it is blocked by the presence of a received negative voltage on the control grid during the same half cycle of time. Since lack of a signal from the remote terminal permits tripping, correct operation (tripping) is also obtained for an internal fault fed from one end only.

Cost prevents the use of more than one carrier channel for relaying a given line. No single directional relay is known which will respond correctly to all conditions of phase and ground faults in the presence of load currents. In the directional-comparison systems, it has been necessary to derive a single directional indication at each terminal by combining the directional indications for phase and ground faults, or to give one of these precedence over the other.

Similarly, in phase-comparison relaying, cost prevents the use of three separate relay units and carrier channels for the three-phase conductors. Because of this, the currents of the three phases are combined in a network designed to produce an output voltage for comparison for any type of fault. In order to permit good sensitivity on phase-to-phase faults, the network chosen is a negative-phase-sequence network. This network gives no output on normal balanced loads. It may be biased with ground current, and is also biased with positive-sequence current above a threshold level determined by fault detectors responding to phase currents. The operation of this network is described in SECTION G_3.

G_2 NETWORK UNIT

G_3 NEGATIVE-PHASE-SEQUENCE NETWORK FIGURE 17

The negative-phase-sequence network consists essentially of transactors T201 and T202, resistors R201, R202, R203, R205, and R206, and capacitor C201. (A transactor is a combination of a reactor and a transformer which gives an output voltage proportional to the input current.) Resistors R202 and R203 provide adjustments for balancing the network.

Transactor T201 receives phase 1 current (relay terminals 5N and 6N, transactor leads 5 and 6) and residual current (terminals 3N and 4N, leads 7 and 8). Transactor T202 receives phase 3 current (terminals 9N and 10N, leads 12 and 13) and residual current (terminals 3N and 4N, tap plate to lead 6). The tapped winding (taps 5 to 11) is used to introduce sufficient ground current ampere-turns into this transactor to overcome the effect of the negative-phase-sequence current during ground faults. This is necessary in applications where the negative-phase-sequence excitation provided by such faults is inadequate. Capacitor C201 and resistors R203 and R206 form a phase-shifting circuit so that the capacitor voltage lags the secondary voltage of transactor T202. Resistor R202 is adjusted to make the effective portion of this T202 secondary voltage equal to the capacitor voltage. The polarities, connections, and adjustments are such that the network output is substantially zero with balanced three-phase current.

It can be shown, by the method of symmetrical components, that the output voltage is proportional to a combination of the negative-sequence and zero-sequence currents according to the relation

$$E \text{ output} = K_3 \left(KI_0 - j \sqrt{3}\, I_N\right)$$

where K depends on the tap setting of T202.

This network gives the same magnitude of output voltage for a given magnitude of phase-to-phase fault current regardless of which pair of the three conductors is involved. Figs. 10 and 11 give vector diagrams for the three possible combinations.

G_4 POSITIVE-PHASE-SEQUENCE OUTPUT FOR THREE-PHASE FAULTS

A three-phase fault will operate all three of the phase-fault detectors, thus increasing the effective portion of R202. By further analysis similar to that mentioned above, it can be shown that the network output for a fault not involving ground is then

$$E \text{ output} = K_3 a I_p \,(C-1)$$

where C depends on the reduction of the effective portion of the output voltage of T202 caused by the operation of all three of the phase-fault detectors. This provides an output voltage in case of a balanced three-phase fault.

G_5 OUTPUT FILTER FIGURES 17 and 24

Since harmonics of the power-frequency current are magnified in the transactor, a simple

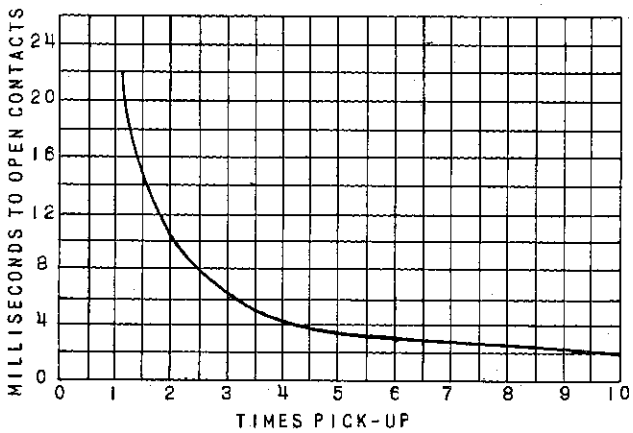


Fig. 22 Time-Current Curve of Phase-Over-Current Element

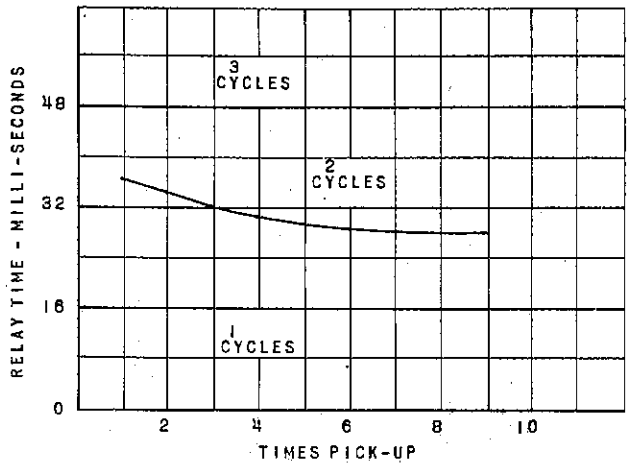


Fig. 23 Time Current Curve For Type EDD12 Relay

(K-6556510)

Fig. 22 (K-6556599)

low-pass filter consisting of L-203 and C-202 is added. This filter offers a low opposition to fundamental frequencies while attenuating harmonic frequencies.

G6 VOLTAGE AMPLIFIER FIGS. 18 AND 24

The output of the negative-phase-sequence network is amplified by a push-pull voltage amplifier. The amplifier tube, V-201, uses limiting circuits to form the sine wave input into a substantially square wave output. This square wave output is responsible for high-speed pickup of FD-L and FD-H as well as greater transmitter power. The gain of this stage is such that full power is obtained from the transmitter as soon as FD-L picks up. The square wave output is fed to a full wave selenium rectifier RS-201. The d-c output of the selenium rectifier is fed to the grids of the fault detectors (high and low) as their control voltage. The unrectified output of the voltage amplifier is used to drive the power amplifier.

G7 FAULT DETECTOR-LOW (FD-L) FIGS. 18 AND 25

Fault Detector-Low determines the magnitude of fault current at which the transmitter will be modulated and send a blocking signal to the opposite end to prevent tripping. A normally closed contact of the low level fault detector (FD-L) holds the screen grids of the power amplifier at negative bus potential preventing any output from the power amplifier until the Fault Detector-Low picks up. Another function of the Fault Detector-Low is to give preference to the relay function over all services immediately upon pickup (within one cycle after inception of fault). The pickup of this fault detector is independent of the carrier-current equipment. Pickup is controlled over a continuous range by means of the FD-L potentiometer on the front of the network unit. Modulating signal is applied to the transmitter as soon as the FD-L "b" contact, which shorts the power amplifier screens to the negative bus, opens. This is done through resistor R239 which is itself shorted out as soon as the normally open contact of the Fault Detector-Low closes. This feature gives positive operation of the transmitter regardless of whether or not the normally open contact closes properly.

G8 FAULT DETECTOR-HIGH (FD-H) FIGS. 18 AND 25

Fault Detector-High determines the fault current magnitude necessary to start phase-comparison and permit tripping. The normal setting of the fault detector-high is 50 percent above Fault Detector-Low to give a 50 percent safety margin between the blocking and the tripping function of the relay. The pickup of FD-H is controlled over a continuous range by means of the FD-H potentiometer on the front of the network unit. Circuit characteristics delay FD-H pickup from FD-L pickup by at least 0.004 second regardless of fault current magnitude.

G9 TRIPPING UNIT

G10 POWER AMPLIFIER FIGS. 19 AND 25

The power amplifier is driven by substantially a square wave from the voltage amplifier of the

(K-6556510)

Fig. 22 (K-6556599) Right

Fig. 24 (8011829)

Fig. 24 (8011831) Left

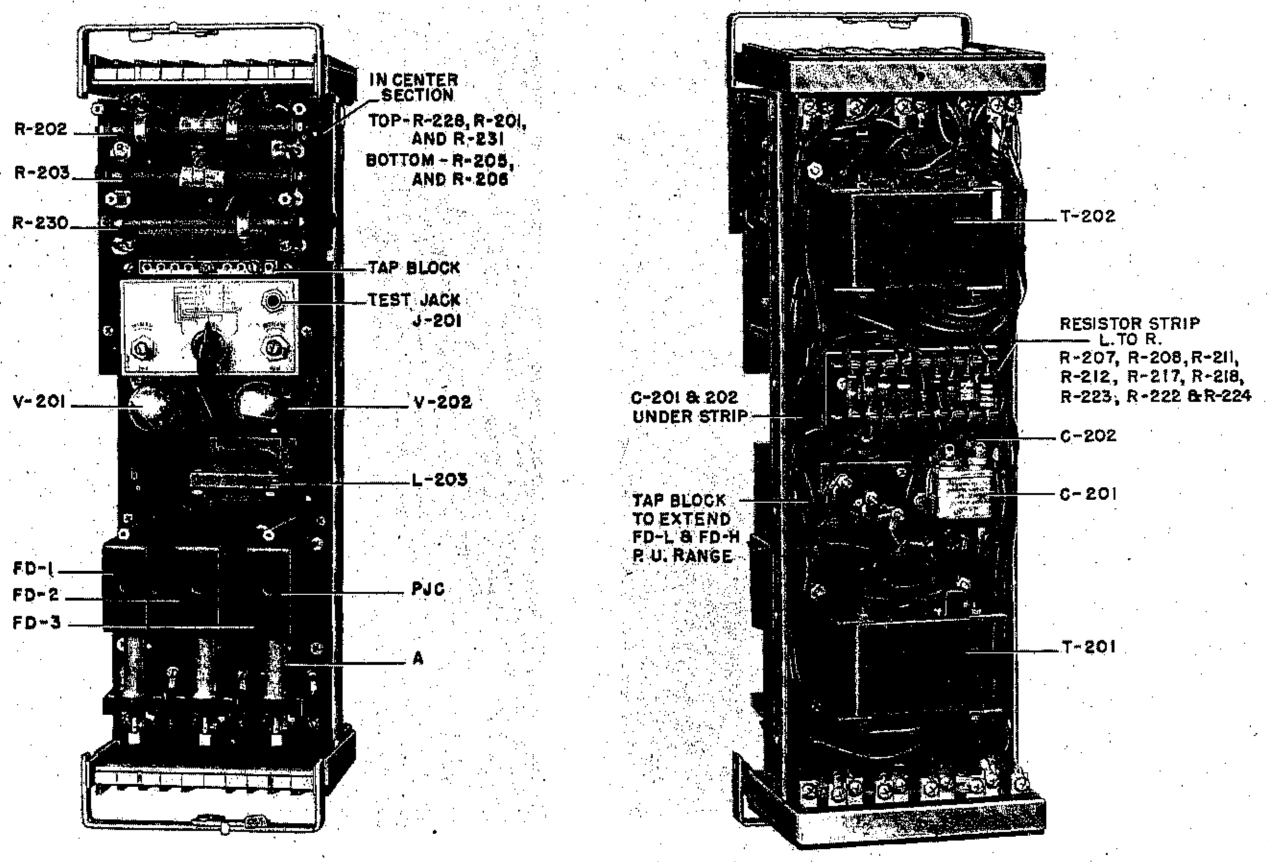


Fig. 24 Network Unit Withdrawn From Case

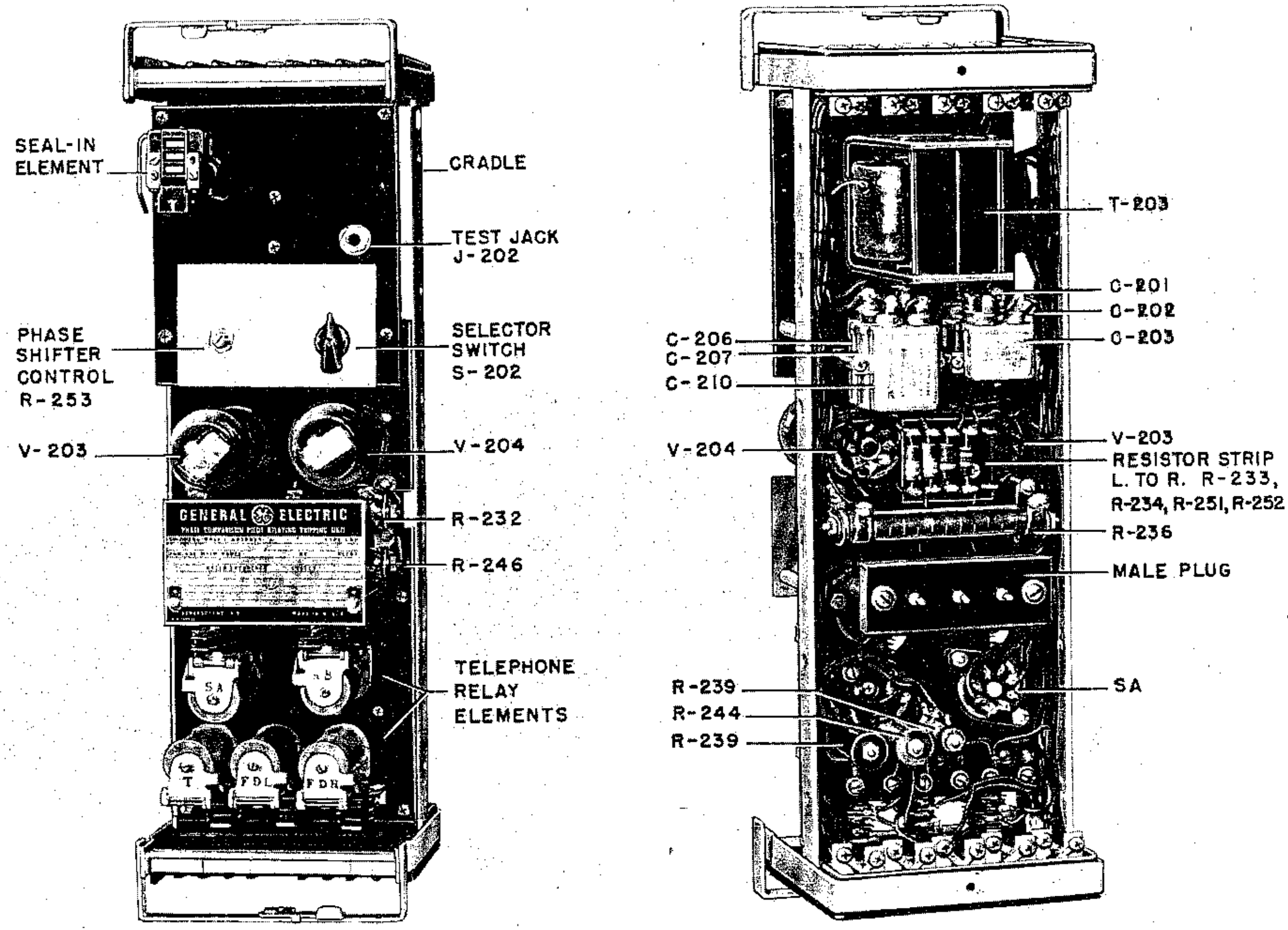


Fig. 25 Tripping Unit Withdrawn From Case

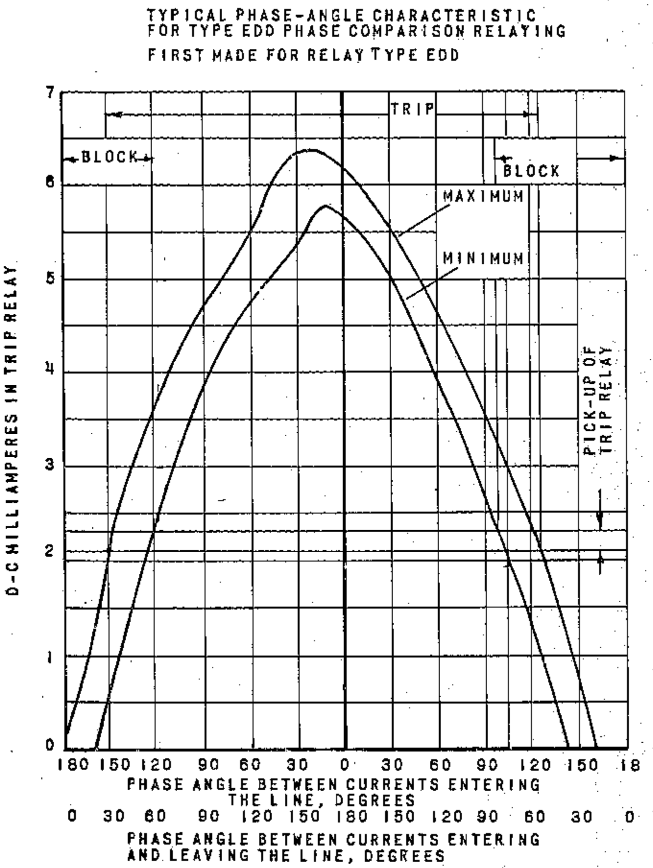


Fig. 26 Phase-Angle Characteristics For Type EDD Relay

network unit. This square wave effectively drives the power amplifier to saturation as soon as fault detector-low picks up. The power amplifier, through a modulating transformer, T-203, provides a modulating signal to the screen of the carrier-current transmitter. From another winding on this same transformer the power amplifier provides a signal to the comparer tube screen grid 180 degrees out of phase with that provided to the transmitter. The power amplifier draws no appreciable plate current until FD-L picks up. This gives the power amplifier tubes long emission life, as they therefore supply plate current only during fault conditions.

G11 PHASE SHIFTER, FIGS. 19 AND 25

The phase shifting network, consisting of R-251, R-252, R-253, C-211, C-212, and C-213 relays, delays the power amplifier signal to the comparer tube screen grid from the signal applied to modulate the transmitter. This time delay compensates for the time of propagation between terminals of long transmission lines.

G12 COMPARER AND TRIPPING RELAY ELEMENT FIGURES 20 AND 25

The comparer, located in the carrier-transmitter receiver unit, determines whether or not the circuit breaker shall be tripped upon the occurrence of a fault which results in sufficient current to pick up FD-H.

Secondary winding 1 and 2 of T-203 at the remote station modulates the remote transmitter. This signal is received and applied to the local comparer tube.

The screen grid of the comparer tube is supplied with a local a-c voltage from the secondary winding 6 and 7 of T-203. The control grid is supplied with half-cycle voltages from the remote relay via the carrier channel.

G13 External Fault Figs. 27 and 28

During an external fault, received carrier swings the control grid negative for the half-cycle when the local relay voltage swings the screen grid positive. Thus, the control grid blocks plate current and no tripping occurs. A normally open contact of FD-H is placed in series with the trip-relay element. This makes it impossible for the relay to trip before the remote end FD-L has had time to provide a blocking signal to the local comparer tube.

G14 Internal Fault Figs. 27 and 28

During an internal fault, the half-cycle signals received from the opposite terminal swing the comparer control grid negative for the same half-cycle the local relay voltage swings the screen grid negative. These received signals are absent, as there is no incoming signal, during the half cycles when the screen grid is positive. The comparer plate current, therefore, increases and picks up the tripping relay element through the FD-H contact.

In general, the currents entering the two ends of the line on an internal fault will not be exactly in phase. Therefore, comparer plate current will not flow throughout each half cycle. The average value of this current corresponds to differential protection. As in a differential system, tripping current varies from zero to a maximum with a change in phase angle from 180 to 0 degrees between the currents at the two ends of the line. A typical phase-angle characteristic is shown in Fig. 26. Phase-comparison tripping time is shown in Fig. 23. Phase-fault detector pickup curve is given in Fig. 22.

G15 SIGNAL ALARM AND SIGNAL ALARM-RELAY ELEMENT, SA., FIGS. 21 AND 25

The basic function of the signal alarm is for telemetering, supervisory control, and to indicate incoming phone calls. The signal alarm will sound an immediate alarm on loss of d-c supply voltage to the transmitter-receiver and relay, or failure of the heater of any of the tubes in the relay or signal alarm circuit. An additional use of the signal alarm is to provide means for reading the strength of the received signal. This reading gives an indication of the margin available for blocking on an external fault.

The screen grid of the signal alarm tube is connected to a fixed potential. When there is no incoming signal, i.e., no negative voltage applied to the control grid, the cathode bias is adjusted to obtain the desired current above pickup of the signal alarm-relay element, SA. A received carrier-current signal swings the control grid negative, decreases the plate current, and allows the signal alarm-relay element to drop out. A normally closed contact of SA then closes the alarm circuit.

G_{16} TRANSIENT BLOCKING-RELAY ELEMENT, RB, FIGURES 21 AND 25

This relay permits tripping without time delay, for about 4 cycles after the inception of a fault; but thereafter, it introduces a delay in tripping sufficient to outlast transients associated with circuit-breaker arcing, CT trapped flux, etc.

RB is energized by FD-H when the latter picks up. If the fault is internal, T will pick up and thus de-energize RB before RB picks up.

G_{17} SEAL-IN ELEMENT, SI. FIGS. 21 AND 25

This is connected in series with both trip circuits and is picked up by trip coil current when T picks up. The unit closes contacts around T and RB to prevent them from opening the trip circuit. A hand-reset target, to indicate that the EDD equipment was the cause of tripping, is exposed when the seal-in element picks up.

G_{18} D-C TEST EQUIPMENT FIGURES 3 AND 20

The test equipment consists of a multi-range milliammeter, jacks and test cord. By means of the selector switch in the network and tripping units, this equipment permits reading the plate currents of the six tubes used in the relay function. Also, this measures the heater currents of the tubes in the network unit, tripping unit and signal alarm tube.

G_{19} A-C TEST EQUIPMENT FIGURES 3, 17 AND 21

The a-c test equipment consists of a five-position relay test switch (RTS), two test resistors, an eight-position tap switch, a rheostat, and a volt meter. When the relay test switch is in "NOR", the relay equipment is in its functioning position.

Position "TCO" opens the trip circuits, but does not disconnect the relay from the CT's. This makes it possible to take the equipment out of service in cases where the loading on the line comes up to the point where carrier is being transmitted and FD-H is picked up. Removal of carrier before opening of the trip circuits would cause false tripping. For this case, the relay test switch at both stations must be turned to the "TCO" position before either switch is turned to the "OFF", "IN", or "OUT" positions.

The "OFF" position opens the trip circuits, short-circuits the CT's, and disconnects the relay from the CT's.

The "IN" or "OUT" position places current from the a-c test source through the test resistors and the two transactors. The currents through the transactors in the "IN" and "OUT" positions are opposite in phase. If the relay test switches at both ends of the line are turned to the "IN" position, the arrangement simulates an internal fault. In the "OUT" position, the a-c test equipment provides just enough current to operate FD-L giving a check on the blocking (FD-L) settings of the relay. An indicating lamp is connected to one trip terminal of the tripping unit to enable the tester to visually observe the resulting operation of the relay for simulated internal or external line faults.

RELAY SETTING (SECTION H)

H_1 LIMITING CONDITIONS

This equipment is based upon the over-current principle that maximum load current must be at or below the current rating of the equipment of 5 amperes secondary. Faults for which the equipment is expected to operate must provide current in excess of pickup. To be considered applicable, it is suggested that the relay should receive short-circuit current of at least 1.5 times pickup based on the transient reactance.

H_2 TAPPED LINES

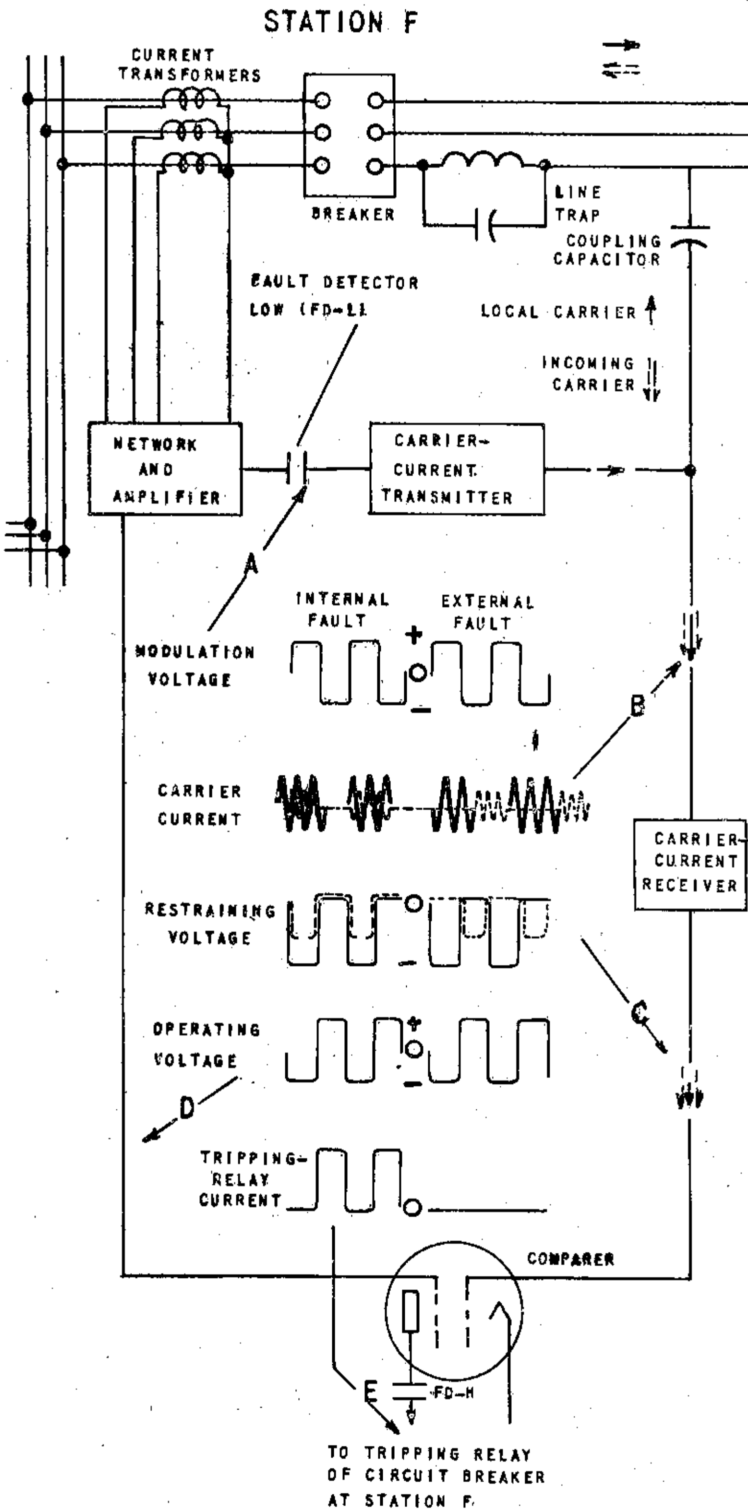
The equipment may be used on lines having tapped loads fed through transformer banks, if the following conditions, 1, 2 (A or B), and 3 are met:

1. The transformer primary is not grounded, except on special recommendations obtained from the relay manufacturer.

2A. The maximum relay current for any fault on the low side of the transformer bank will not exceed the pickup of the phase comparison Fault Detector-High except as outlined in 2B.

2B. The maximum relay current for any fault on the low side of the transformer bank will not exceed the pickup of the phase-fault detectors; and the resulting minimum trip is considered satisfactory by the user and only one circuit breaker need be tripping at either end.

This threshold value may be obtained by removing the panel-wiring across the "a" contacts of



NETWORK & AMPLIFIER WHEN A FAULT OCCURS, THE SECONDARY CURRENTS FROM THE TRANSFORMERS ARE CONVERTED BY THE NETWORK INTO A SINGLE-PHASE VOLTAGE AT SYSTEM FREQUENCY WHICH IS THEN AMPLIFIED. THIS VOLTAGE IS APPLIED WITH ONE PHASE (A) TO EXCITE THE CARRIER-CURRENT TRANSMITTER, AND PHASE (D) TO ENERGIZE THE COMPARER, WHEN THE FAULT IS LARGE ENOUGH TO PICK UP THE FAULT DETECTOR LOW (FD-L).

CARRIER-CURRENT TRANSMITTER GENERATES CARRIER CURRENT DURING THE POSITIVE HALF CYCLES OF MODULATING VOLTAGE (A). THIS CARRIER CURRENT IS TRANSMITTED THROUGH THE COUPLING CAPACITOR AND THE TRANSMISSION LINE TO THE CARRIER-CURRENT RECEIVER AT THE FAR END OF THE LINE. THE LOCAL RECEIVER ALSO RECEIVES SOME OF ITS LOCAL TRANSMITTER'S OUTPUT.

CARRIER-CURRENT RECEIVER DETECTS & AMPLIFIES RECEIVED CARRIER TO PROVIDE A NEGATIVE RESTRAINING VOLTAGE (C) AT THE SCREEN GRID OF THE COMPARER.

FAULT DETECTOR LOW (FD-L) DETERMINES THE MINIMUM LEVEL OF FAULT CURRENT TO START TRANSMISSION OF THE RESTRAINING CARRIER SIGNAL.

FAULT DETECTOR HIGH (FD-H) SETS THE MINIMUM FAULT CURRENT AT WHICH PHASE COMPARISON AND TRIPPING CAN BE MADE. THIS POINT IS AT A FAULT LEVEL ENOUGH HIGHER THAN FD-L PICKUP LEVEL TO INSURE A ADEQUATE RESTRAINING SIGNAL TO BE APPLIED BEFORE FD-H FUNCTIONS.

COMPARER PERMITS CURRENT TO FLOW IN THE TRIP RELAY DURING THE POSITIVE HALF CYCLES OF OPERATING VOLTAGE (D), PROVIDED THERE IS INADEQUATE RESTRAINING VOLTAGE (C) SIMULTANEOUSLY PRESENT.

Fig. 27 Operation of Phase Comparison Relaying

Fig. 27 (K-6556482) Sh. 1

OVER-ALL OPERATION DURING EXTERNAL FAULTS DURING EXTERNAL FAULTS BEYOND (TO THE RIGHT OF) STATION G, THE PHASE OF THE MODULATING VOLTAGE APPLIED TO THE THE CARRIER-CURRENT TRANSMITTER AT STATION G IS REVERSED WITH RESPECT TO THAT AT STATION F. THUS, FIRST ONE END AND THEN THE OTHER TRANSMITS CARRIER WITH THE RESULT THAT TRIPPING AT BOTH ENDS IS CONTINUALLY BLOCKED. FOR THIS CASE THE SOLID AND DOTTED ARROWS AND WAVES APPLY.

OVER-ALL OPERATION DURING INTERNAL FAULTS SINCE THE EXTERNAL FAULT WAS ASSUMED TO BE BEYOND STATION G, THE INTERNAL FAULT CURRENTS AT THAT END WILL BE REVERSED IN PHASE WITH RESPECT TO THE EXTERNAL FAULT CURRENTS. FOR THAT REASON, THE MODULATING VOLTAGE (A) AT STATION G WILL ALSO BE REVERSED IN PHASE. SINCE THE MODULATING VOLTAGE (A) WILL BE OF THE SAME PHASE AT STATION F FOR EITHER OF THE ASSUMED FAULTS, THE MODULATING VOLTAGES AT BOTH ENDS WILL BE IN PHASE FOR INTERNAL FAULTS. HENCE, BOTH ENDS WILL TRANSMIT CARRIER SIMULTANEOUSLY FOR ONE HALF CYCLE, BUT NEITHER END WILL TRANSMIT DURING THE OTHER HALF CYCLE. DURING THE HALF CYCLE WHEN THE TRANSMISSION IS STOPPED AT BOTH ENDS, THE OPERATING VOLTAGE (D) ON THE COMPARER TUBES AT BOTH ENDS WILL BE POSITIVE, AND CURRENT WILL FLOW IN BOTH TRIPPING RELAYS TO TRIP BOTH CIRCUIT BREAKERS. FOR THIS CASE THE SOLID AND DASHED ARROWS AND WAVES APPLY.

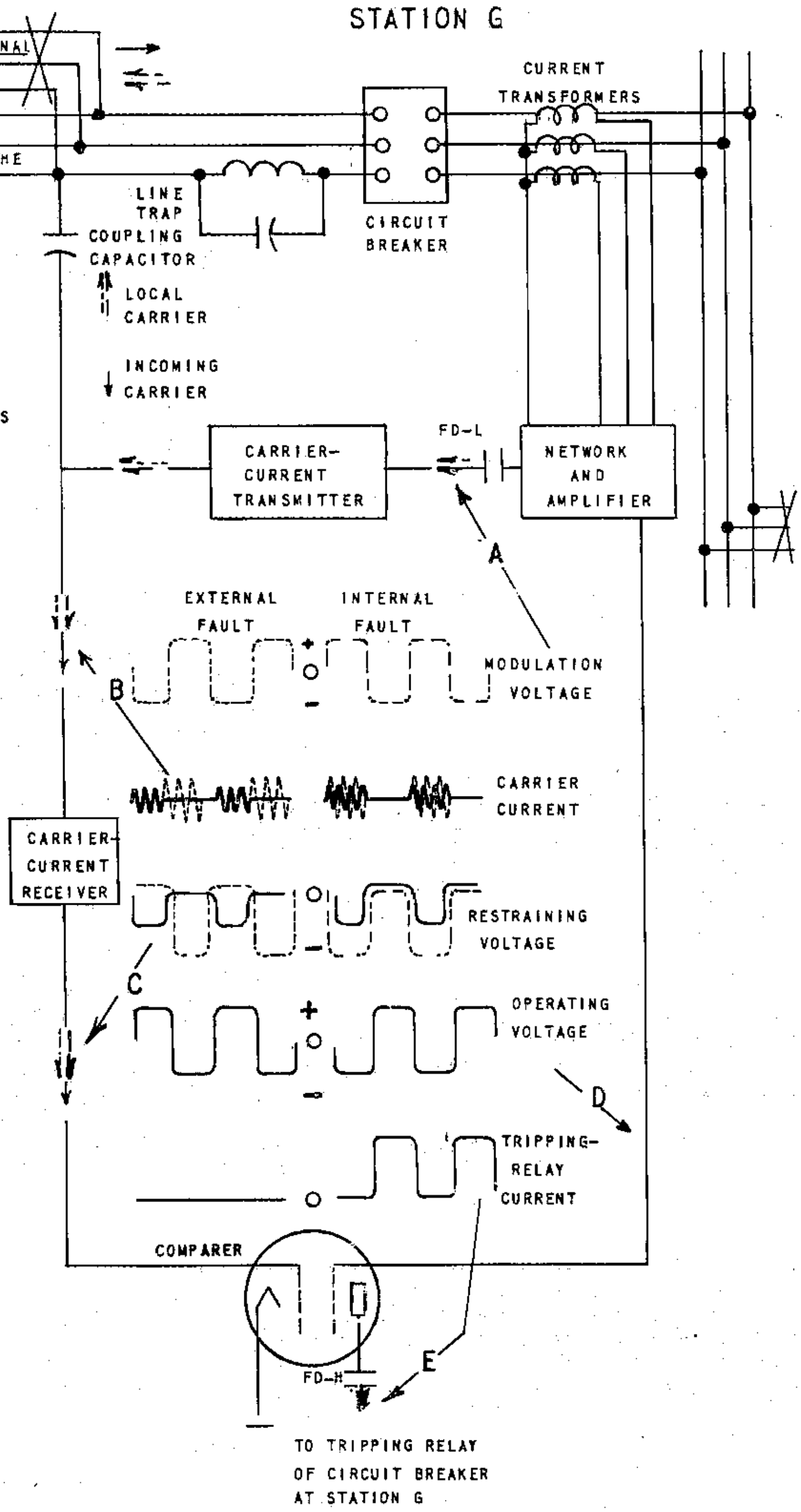


Fig. 28 Operation of Phase Comparison Relaying

Fig. 29 (K-6556514)

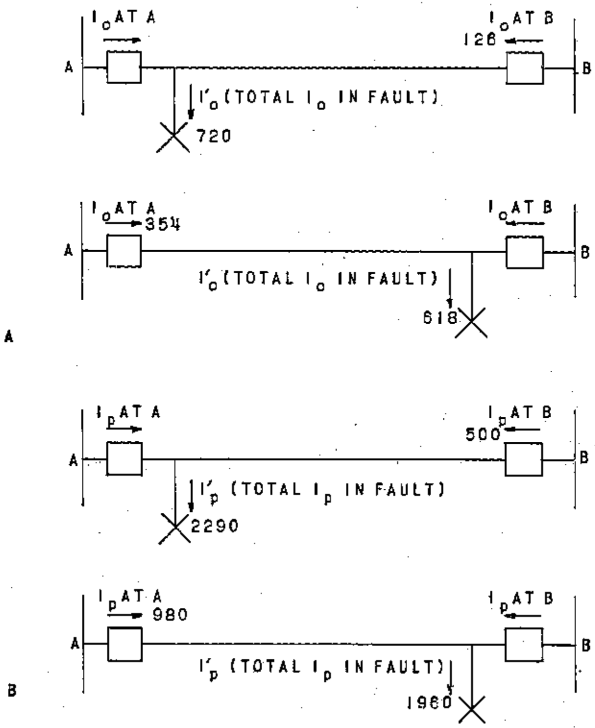


Fig. 29 (A) Ground Fault Currents And (B) Three-Phase Fault Currents

the phase-fault detectors. If ground faults require a pickup less than phase-to-phase pickup of the phase-fault detectors, a Type PJC ground-fault detector may be mounted separately with its "a" contacts connected in parallel with these "a" contacts.

3. The maximum load current due to the line tap must not exceed one ampere from the current transformer. This limit is imposed by the two ampere difference between the pickup of the phase-fault detectors and FD-H.

Fig. 28 (K-6556482) Sh. 2

H3 METHOD OF CALCULATION

H4 GROUND CURRENT TAP SETTING

If the minimum negative-phase-sequence current for internal ground faults is greater than 86 percent of the relay phase-to-phase setting, it is not necessary to add zero-phase sequence excitation. Under all other internal ground-fault conditions, the zero-phase-sequence excitation predominates at each line terminal by a sufficient margin to obviate the possibility of blind spots. It is not necessary to give any consideration to the current magnitudes resulting from external faults.

The amount of negative-phase-sequence current available and the ratio of negative-phase-sequence to zero-phase-sequence current are easily determined from the three-phase and single-phase-to-ground short-circuit currents, which must be known for any over-current relay application. The determination of these values does not require an understanding of the theory of symmetrical components, but merely the performance of the simple algebraic operations indicated by the formulas given below.

The formulas used in the following method of calculation have been derived from those developed in AIEE paper No. 45-148 entitled "Phase-comparison Carrier-current Relaying", published in Electrical Engineering for Dec. 1945. The following table relates the equations used in the various steps with those developed in the paper.

Step number in detailed calculation	Equation number in AIEE No. 45-148
5	28
9	24
10	34
14	43 & 25
15	43 & 29
16	41 & 25
17	18 & 29 & 34
19	41 & 25
20	18 & 29 & 34

H5 EXAMPLE OF CALCULATION*

H6 EXPLANATION

(1) Determine the system-operating condition which gives the least total zero-phase-sequence current in a single-phase-to-ground fault on the line at either end where phase-comparison relaying would be applied, and for which condition satisfactory relaying is required.

H7 EXAMPLES

(1) Assume conditions that might reasonably be expected, such as the removal from service of certain generators, the possible disconnection of certain grounding transformers or generator-neutral-grounding devices, and the temporary removal from service of certain transmission lines. It is desirable to record in rows 1c and 1d of Table VI the sources of the data in rows 2 to 5, so as to define the operating conditons for which the results apply.

*Numbers in parentheses refer to row in tabular calculation Table VI. The calculations are based on normal phase-to-phase fault pickup of 3 amperes. (See Table IV).

(2) For the system-operating condition of (1), and for a single-phase-to-ground fault on the line at one end with the circuit breakers closed at both ends, determine and record the magnitudes of the zero-phase-sequence currents flowing into the line at each end and the total zero-phase-sequence current in the fault. Use the transient reactance of generators to determine these current magnitudes.

Repeat for a single-phase-to-ground fault at the other end, with the same operating conditions.

(3) For exactly the same system-operating conditions as in (2), but for a three-phase fault, first at one end and then at the other, determine and record the positive-phase-sequence current magnitudes at both ends and in the fault. Use the transient reactance of generators to determine these current magnitudes.

(4) Reduce all the above values to CT secondary amperes by dividing by CT ratio. Use these secondary-current magnitudes from now on. To simplify the terminology, we shall henceforth define these secondary-current magnitudes as follows:

I_0 = the zero-phase-sequence current at the end under consideration for a single-phase to-ground fault.

I'_0 = the total zero-phase-sequence current in the single-phase-to-ground fault.

I_p = the positive-phase-sequence current at the end under consideration for a three-phase fault.

I'_p = the total positive-phase-sequence current in the three-phase fault.

If only the total current and the portions at the end away from the fault are given in the short-circuit study, the portion at the end near the fault may be obtained by subtraction.

(5) Calculate to three decimal places the constant R which will be used later.

$$R = (I'_p/I'_0) - 2$$

(2) Fig. 29A illustrates these quantities, and shows the particular values assumed for this example.

(3) Fig. 29B illustrates these quantities, and shows the particular values assumed for this example.

(4) The ratios of all six CT's on the two ends of a given line section must be alike.

For example,

CT ratio = 300/5 = 60/1

$I'_0 = 720/60 = 12.0$, $I_0 = 126/60 = 2.1$

$I'_0 - (I_0 \text{ at B}) = (I \text{ at A})$

$12.0 - 2.1 = 9.9$

Let us assume that by following the preceding instructions, the remaining secondary currents in amperes have been obtained as listed in Table V.

TABLE V

Current Designation	Fault at A		Fault at B	
	Col. 1	Col. 2	Col. 3	Col. 4
	Relay B	Relay A	Relay A	Relay B
I'_0	12.0	12.0	10.3	10.3
I_0	2.1	9.9	5.9	4.4
I'_p	38.1	38.1	32.6	32.6
I_p	8.3	29.8	16.4	16.2

Notice that the value of I'_0 for a given fault location is listed for both relays. The value of I'_p is similarly listed. This procedure serves to put in the same column all four values that will subsequently be used for determining the operation of the relay that heads the column.

(5) For Column 1 of Table V

$$R = (38.1/12.0) - 2 = 1.175$$

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
1.175	1.175	1.165	1.165

(6) Calculate the constant D which will be used later.

$$D = I_o' \times I_p / I_o \times I_p'$$

(6) Using the values I_o', I_o, I_p', and I_p in Column I of Table V, we get the values of D for the relay at B with a fault at A as follows, and also the other three values from the other columns.

$$D = 12.0 \times 8.3 \ / \ 2.1 \times 38.1 = 1.25$$

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
1.25	0.95	0.88	1.16

(If the short-circuit study gives current-distribution factors C_p and C_o, D can be calculated from $D = C_p/C_o$.)

(7) Determine, for three-phase faults, the multiple of pickup (M) of the relays at A and B for both fault locations, using the following formula:

$$M = I_p \ / \ [2.67 \ (pu)] \ *$$

$$M = I_p \ / \ 8$$

(7) Using the values in the I_p row of Table V we get the following values of M:

$$M = 8.3/8 = 1.04$$

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
1.04	3.72	2.05	2.02

(8) Determine, for phase-to-phase faults the multiple of pickup (M), using the following formula:

$$M = I_p \sqrt{3} \ / \ [2 \ (pu)] \ \ *$$

$$M = I_p \ / \ 3.46$$

(8) Using the values in the I_p row of Table V, we get the following values of M:

$$M = 8.3 / 3.46 = 2.40$$

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
2.40	8.61	4.74	4.68

(9) Determine, for single-phase-to-ground faults, the multiple of pickup (M), using the following formula:

$$M = DI_0 \sqrt{3} \ / \ (pu) \ *$$

$$M = DI_0 \ / \ \sqrt{3}$$

(9) Using the values of D and I_o from Column 1 of (6) and (4), we get the following value of M:

$$M = 1.25 \times 2.1 / 1.732 = 1.52$$

Similarly, we get the other three values:

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
1.52	5.40	3.00	2.95

(10) Determine, for two-phase-to-ground faults, the multiple of pickup (M), using the following formula:

$$M = RI_p \sqrt{3} \ / \ [(1+2R) \ \ (pu)] \ \ *$$

$$M = RI_p \ / [\sqrt{3} \ (1+2R)]$$

(10) Using the values of R and I_p from Column 1 of (5) and (4), we get the following value of M:

$$M = 1.175 \times 8.3 \ / \ 1.732 \ (1+2 \times 1.175) = 1.68$$

Similarly, we get the other three values:

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
1.68	6.05	3.31	3.27

Do not be perplexed that the currents that have been used were obtained for single-phase-to-ground and for three-phase faults. The formulas using these currents give M also for phase-to-phase and for two-phase-to-ground faults. The derivation of the formulas has taken these things into account.

* pu = phase-to-phase fault pickup current of FD-H.

(11) If there is sufficient short-circuit current, phase-comparison relaying is applicable, and no further studies are required. Sufficient current is available if all multiples of pickup (M) are 1.5 or more.

(12) If the multiple of pickup at one end of the line is less than 1.5 in the case of a three-phase fault, and if at the other end of the line the multiple of pickup is 1.5 or more for the same fault, phase-comparison relaying will be applicable if sequential tripping is assured and is acceptable under those circumstances.

(13) Instructions (12) apply equally well to the cases of single-phase-to-ground and two-phase-to-ground faults, but in these cases it is possible that, by use of the ground-current tap adjustment, any consideration of sequential tripping can be avoided. This ground-current-tap adjustment can be used if there is zero-phase-sequence current flowing into the line at both ends for all ground faults on the line with the breakers at both ends closed.

(14) Determine, for single-phase-to-ground faults, the minimum value of K that can be used from the standpoint of phase angle, where this minimum value of K is the largest of the four possible values obtained by using the following formula:

$K = 2.45\ D$

(15) Determine, for two-phase-to-ground faults, the minimum value of K that can be used from the standpoint of phase angle, where this value is the largest of the four possible values obtained by using the following formula:

$K = 2.45\ DR$

(16) Determine, for single-phase-to-ground faults, the minimum value of K that can be used from the standpoint of magnitude, where this is the largest of the four possible values obtained by using the following formula:

$K = \sqrt{3} \quad D \quad 3M/I_0$

where

M = the desired multiple of pickup.

(11) Further study is indicated since the multiple of pickup for the relay at B for the three-phase fault at A is only 1.04. Moreover, should three cycle operation not be acceptable for the same relay and fault location in the case of single-phase-to-ground and two-phase-to-ground faults (multiple of pickup 1.52 and 1.68 respectively), further study will be necessary for these cases also.

(12) Since the multiple of pickup of the relay at A for the three-phase fault at A was 3.72, high-speed tripping at this end is assured. Therefore, sequential tripping is possible if the current at B increases sufficiently after A has tripped. For this example, the value of I_0 at end B is assumed to become 17.2 amperes after the breaker at A has tripped, and M will therefore become 2.15, which assures prompt tripping.

(13) For the example given, it is unnecessary to consider the use of the ground-current-tap adjustment unless three cycle operation is not satisfactory for the relay at B with ground faults at A. Let us assume, however, that this operation is unsatisfactory, and that advantage should be taken of the ground-current- tap adjustment.

(14) Using the value of D from Column 1 of (6), we get:

$K = 2.45 \times 1.25 = 3.06$

Similarly, we get the other three values, and then underline the highest.

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
3.06	2.32	2.16	2.84

(15) Using the values of 2.45D and of R from Column 1 of (14) and (5), we get:

$K = 3.06 \times 1.175 = 3.61$

Similarly we get the other three values, and then underline the highest.

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
3.61	2.74	2.51	3.31

(16) Using the values of D and I_0 from column I of (6) and (4), and assuming M = 2.0 to get two-to-three cycle tripping, we get:

$K = 1.73 \times 1.25 + 3 \times 2 / 2.1 = 5.01$

Similarly we get the other three values, and then underline the highest.

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
5.01	2.24	2.54	3.37

(17) Determine, for two-phase-to-ground faults, the minimum value of K that can be used from the standpoint of magnitude, where this is the largest of the four possible values obtained by using the following formula:

$$K = \sqrt{3}\ DR + \frac{3DM\ (1 + 2R)}{I_p}$$

(17) Using the values of D, R, and I_p from Column 1 of (6), (5), and (4), and assuming M = 2.0, we get:

$$K = 1.73 \times 1.25 \times 1.175 + \frac{3 \times 1.25 \times 2(1+2 \times 1.175)}{8.3} = 5.59$$

Similarly we get the other three values, and then underline the highest.

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
5.59	2.57	2.83	3.75

(18) Determine by comparison the highest of the four highest values found in (14), (15), (16), and (17). Calculate the tap to use by the following formula:

Tap = 11/(K) (FD-H phase-to-phase pickup setting.)

Select the calculated tap or the next lower multiple-of-pickup tap.

The multiplied-by-two tap is used when only the negative-sequence component of the current is to be used in the negative-sequence network.

(18) The four highest values to be considered are 3.06, 3.61, 5.01, and 5.59, so the value of K to be used in setting the relay must be 5.59 or more.

There is no tap for K = 5.59, so use K = 6. Then for FD-H set to pickup at 3 amperes phase-to-phase,

$$\text{Tap} = \frac{11}{6.0(3)} = 0.59. \quad \text{Use } 0.47.$$

(19) If desired, the multiple of pick-up for single-phase-to-ground faults may be determined by using the following formula:

$$M = (K - \sqrt{3}\ D)\quad I_0/3$$

(19) Using the value of available K finally selected in (18), and the values of D and I_0 from Column 1 of (6) and (4), we get:

$$M = (6 - 1.73 \times 1.25)\quad 2.1/3 = 2.68$$

Similarly we get the other three values, and then underline the lowest.

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
2.68	14.5	8.81	5.85

(20) If desired, the multiple of pick-up for two-phase-to-ground faults may be determined by using the following formula:

$$M = (K - \sqrt{3}\ DR)\quad I_p/[3D(1 + 2R)]$$

(20) Using the value of available K finally selected in (18), and the values of D, R, and I_p from column I of (6), (5), and (4), we get:

$$M = \frac{(6 - 1.73 \times 1.25 \times 1.175)\ 8.3}{[3 \times 1.25\ (1 + 2 \times 1.175)]} = 2.28$$

Similarly we get the other three values, and then underline the lowest. Since the lowest is more than 2, the two-to-three cycle operation will be obtained for all faults.

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay B
2.28	12.7	7.88	5.17

H8

TABULAR METHOD OF CALCULATION

The following tabular form will serve to summarize the foregoing instructions and to provide a convenient means for tabulating data. Intermediate steps are included so that no calculation on loose sheets of paper will be necessary. The operations are broken down so that any multiplication and division required can be made with a single setting of a polyphase slide rule. When performing operations involving quantities not on adjacent lines, it is helpful to lay down straight edges to locate the lines in the operation.

NOTE: These calculations are for normal settings of the relay Table IV.

H8

TABLE VI EXAMPLE OF TABULAR CALCULATION FOR TAP SETTING

Row			Col. 1	Col. 2	Col. 3	Col. 4
1a	Fault location		A	A	B	B
1b	Relay location		B	A	A	B
1c	O-seq. currents from -----			Assumed for		
1d	Pos. - seq. currents from--			this example.		
2a	I'_o O-seq. pri. Amp.	total for 2 ends	720	720	618	618
2b	I_o for 1-ϕ-G fault	this end only.	126	---	354	---
3a	I'_p Pos. -seq. pri. Amp.	total for 2 ends	2290	2290	1960	1960
3b	I_p for 3-ϕ-fault	this end only.	500	---	980	---
4a	CT Ratio		300/5 = 60/1			
4b	I'_o O-seq. sec. Amp.	total for 2 relays	12.0	12.0	10.3	10.3
4c	I_o for 1-ϕ-G fault	this relay only.	2.1	9.9	5.9	4.4
4d	I'_p Pos. -seq. sec. Amp.	total for 2 relays	38.1	38.1	32.6	32.6
4e	I_p for 3-ϕ fault	this relay only.	8.3	29.8	16.4	16.2
5a	I'_p/I'_o (to 3 decimal places)	= (Line 4d) / (Line 4b)	3.175	3.175	3.165	3.165
5b	$R = (I'_p/I'_o) - 2$ (")	= (Line 5a) -2	1.175	1.175	1.165	1.165
6a	I_p/I_o	= (Line 4e) / (Line 4c)	3.95	3.01	2.78	3.68
6b	$D = (I_p/I_o) / (I'_p/I'_o)$	= (Line 6a) / (Line 5a)	1.25	0.948	0.88	1.16
7	M(for 3-ϕ) = $I_p/8$	= (Line 4e) /8	1.04	3.72	2.05	2.02
8	M(for ϕ-ϕ) = $I_p/3.46$	= (Line 4e) /3.46	2.40	8.61	4.74	4.68
9	M(for 1-ϕ-G) = $\frac{D\,I_o}{\sqrt{3}}$	= $\frac{\text{(Line 6b)}}{\sqrt{3}}$ (Line 4c)	1.52	5.40	3.00	2.95
10a	2R	= 2 (Line 5b)	2.35	2.35	2.33	2.33
10b	1 + 2R	= 1 + (Line 10a)	3.35	3.35	3.33	3.33
10c	$\sqrt{3}$ (1 + 2R)	= $\sqrt{3}$ (Line 10b)	5.80	5.80	5.75	5.75
10d	M(for 2-ϕ-G) = $\frac{R\,I_p}{[\sqrt{3}(1+2R)]}$	= $\frac{\text{(Line 5b)}}{\text{(Line 10c)}}$ (Line 4e)	1.68	6.05	3.31	3.27

Calculations 14 to 20b used only if 0-seq. excitation has to be used.

Row			Col. 1	Col. 2	Col. 3	Col. 4
14	K(for 1-ϕ-G) = 2.45D	= 2.45 (line 6b)	3.06	2.32	2.16	2.84
15	K(for 2-ϕ-G) = 2.45DR	= (Line 14) (Line 5b)	3.61	2.74	2.51	3.31
16a	$\sqrt{3}$ D	= $\sqrt{3}$ (Line 6b)	2.16	1.64	1.52	2.01
16b	$3M/I_o$	= 3M/(Line 4c)	2.85	0.60	1.02	1.36
16c	K(for 1-ϕ-G) = $\sqrt{3}$ D + $(3M/I_o)$	= (Line 16a) + (Line 16b)	5.01	2.24	2.54	3.37
17a	$\sqrt{3}$ DR	= (Line 16a) (Line 5b)	2.55	1.93	1.78	2.33
17b	3 D	= 3 (Line 6b)	3.75	2.84	2.64	3.48
17c	3 D (1 + 2 R)	= (Line 17b) (Line 10b)	12.6	9.53	8.79	11.5
17d	M3D (1 + 2 R)/I_p	= $\frac{M}{\text{(Line 4e)}}$ (Line 17c)	3.04	0.64	1.07	1.42
17e	K(for 2-ϕ-G) = $\sqrt{3}$ DR + $\frac{[M3D(1+2R)]}{I_p}$	= (Line 17a) + (Line 17d)	5.59	2.57	2.83	3.75
18a	Highest required K (of 4 underlined values).		5.59			
18b	Use K=		6.0	6.0	6.0	6.0
19a	K $-\sqrt{3}$ D	= (Line 18b) - (Line 16a)	3.84	4.36	4.48	3.99
19b	M(for 1-ϕ-G) = (K $-\sqrt{3}$ D) $I_o/3$	= $\frac{\text{(Line 19a)}}{3}$ (Line 4c)	2.68	14.5	8.81	5.85
20a	K $-\sqrt{3}$ DR	= (Line 18b) - (Line 17a)	3.45	4.07	4.22	3.67
20b	M(for 2-ϕ-G) = $\frac{(K-\sqrt{3}DR)\,I_p}{[3D(1+2R)]}$	= $\frac{\text{(Line 20a)}}{\text{(Line 17c)}}$ (Line 4e)	2.28	12.7	7.88	5.17

FACTORY TEST AND ADJUSTMENTS (SECTION J)

The relay has been adjusted at the factory. If there is evidence of tampering or rough handling, or if tubes have to be put into the sockets the following points should be observed in making readjustments.

CAUTION: Before making any of these tests the relay test switch (RTS) at both ends of the line should be in the "OFF" position.

J_1 NETWORK UNIT

J_2 BALANCING THE NETWORK

Connect according to Fig. 15, using ammeters of 5 or 10 amperes full scale. Unless the test power source is very steady, two ammeters should be used. Their relative calibrations should be checked by opening phase 2, setting I_1 to 5 amperes, and reading I_2. Reclose phase 2, set I_1 to 5 amperes and I_2 to the reading noted above. Check the source voltages, phases 1-2, 2-3, and 3-1 to see that they are balanced within one volt. Adjust the slider on resistor R-203, to give minimum output voltage across K3 and J11 of the sub-panel or studs 20T and 3T on the tripping unit with Fault Detector-Low blocked in the picked-up position. Use an a-c voltmeter of at least 1000 ohms per volt. Lock this slider temporarily, set the right slider (front view) on the resistor R-202 to the extreme right, and adjust the left slider of the resistor to give minimum output voltage. Reset slider on R-203 and left slider on R-202 alternately to determine the actual minimum. The voltage that remains with correct adjustment is substantially all third harmonic.

If either adjustment reaches the end of the available range on its resistor, it may be possible to bring it within range by changing the secondary tap connection on one of the other transactors. If desired results can be obtained by using more of one secondary winding, this is preferable to using less of the other secondary winding.

J_3 PHASE-FAULT DETECTOR PICKUP

Since the pickup depends on the contact setting, this setting should be checked before making the pickup setting.

The normal adjustment of contacts is 3/64 inch wipe. This may be adjusted by bending the contact stops that lie between the stationary contact springs and the ribs on the molded base. The bend should be made about 1/4 inch from the front tip of the stop so as to obtain an exact setting more easily than could be obtained by bending next to the base. A change in wipe on a "b" contact affects the pickup for a given armature setting. An increase in wipe on either the "a" or the "b" contacts decreases the contact gap and lessens the difference between pickup and dropout, and vice versa.

The contact pressure in the fully picked up or dropped-out position may be adjusted to about 15 grams by bending the stationary contact springs near their point of attachment to the base. This adjustment may change the contact gap and contact wipe slightly. Adjustments of the contact stops within the normal range do not affect the contact pressure in the fully picked up or dropped out position, as the closed-contact springs are separated from the stops in these positions.

To check the pickup, use connections as shown in Fig. 8. The plunger should be set so that the relay picks up between 6.1 and 6.3 amperes as the current is gradually increased. The dropout should then be 5.7 to 6.1 amperes with a gradual decrease in current.

The desired setting may be obtained by turning the armature on the plunger rod. The armature is provided with an internal locking spring which requires no manipulation.

J_4 PHASE-FAULT DETECTOR, THREE-PHASE PICK-UP

Connect as shown in Fig. 15 and adjust the right slider of R-202 (front view) so that FD-H, with proper phase-to-phase pickup, set as outlined in SECTION J_3, will pick up at 7.2 to 7.8 amperes. Follow the test procedure outlined in SECTION E_{28} to determine pickup. If the extreme right position of the slider does not give enough adjustment, a little additional range can be obtained by turning the slider so that it does not touch the bare strip of resistance wire. If this does not give sufficient range, it will be necessary to use a lower tap on T-202 and rebalance the network according to SECTION J_3. Reset the phase-to-phase pickup according to SECTION J_3, after which it will be possible to set the right slider for a lower three-phase pickup.

J_5 TUBE REPLACEMENT

Whenever a tube is replaced in the network unit, tripping unit, or the signal-alarm element, the heater currents should be checked to see if their values have changed from the original setting. If the values are now out of limits, readjust as described in SECTIONS E_{10} and E_{11}.

J_6 VOLTAGE AMPLIFIER

Plate current, with no fault, should read approximately 1 milliampere.

J_7 Tube Socket Voltages

If desired, tube socket voltages may be measured with a d-c voltmeter of 1000 ohms per volt by using an adapter between the tube and its socket. Measure from the adapter terminals to the negative bus. With no input to the network unit, approximate values are as follows:

SOCKET NUMBER V-201								
PIN NO.	1	2	3	4	5	6	7	8
VOLTAGE	-0.3	2.5-11	0	-0.3	2.5-11	0	78	72

J_8 FAULT DETECTOR-LOW (FD-L)

Apply 2 amperes, 60 cycles, from terminal J1 to J2. Turn the selector switch in the network unit to "FD-L" and adjust the potentiometer marked "FD-L" to obtain 4 milliamperes, plus or minus 0.3 milliampere, plate current. Adjust the telephone-relay element (FD-L) to pick up at 4 milliamperes, plus or minus 0.3 milliampere; and to drop out at 2.2 milliamperes, plus or minus 0.2 milliampere.

To increase the telephone-relay pickup, increase the armature gap or the contact pressure, or both. To decrease the pickup, reverse this procedure.

Screw in the residual screw to decrease the drop-out time.

J_9 Tube Socket Voltages

These voltages may be measured as described in SECTION J_7. With no input in the network unit, approximate values are as follows:

SOCKET NUMBER V-202								
PIN NO.	1	2	3	4	5	6	7	8
VOLTAGE	0	113	11.5	0	113	11.5	67	72

J_{10} FAULT DETECTOR-HIGH (FD-H)

Apply 3 amperes, 60 cycles, from terminals J1 to J2 or studs 5N to 7N. Turn the selector switch in the network unit to "FD-H" and adjust the potentiometer marked "FD-H" to obtain 4 milliamperes, plus or minus 0.3 milliampere. Adjust the telephone relay element (FD-H) to pick up at 4 milliamperes, plus or minus 0.3 milliampere; and to drop out at 2.2 milliamperes plus or minus 0.2 milliampere.

J_{11} Tube Socket Voltages

These voltages may be measured, as in SECTION J_9, and are the same as those listed for V-202.

J_{12} TRIPPING UNIT

J_{13} SIGNAL ALARM-RELAY ELEMENT, SA.

The signal alarm-relay element is adjusted to pickup at 6.0 milliamperes, plus or minus 1 milliampere; and to dropout at 2.8 milliamperes, plus minus 0.3 milliampere.

J_{14} FD-L and FD-H

The pick-up and drop-out adjustments of the FD-L and FD-H relay elements are described in SECTIONS J_8 and J_{10}.

J_{15} TRIP-RELAY ELEMENT, T

The trip-relay element is adjusted to pick up at 2.2 milliamperes, plus or minus 0.2 milliampere; and to drop out at 1.4 milliampere, plus or minus 0.1 milliampere d-c.

J_{16} TRANSIENT BLOCKING RELAY ELEMENT, RB

The method of checking the operation of this relay element is given in SECTION E_{24}.

If the relay element must be replaced, the pickup time with rated voltage across the coil and resistor should be 0.03 to 0.04 second (1.8 to 2.4 cycles), and the drop-out time should be 0.17 to 0.35 second (10 to 20 cycles). The minimum pick-up voltage should be less than 80 volts d-c, but need not be adjusted to a particular value.

J_{17} POWER AMPLIFIER

J_{18} Tube Socket Voltages

These voltages may be measured as described in SECTION J_7. With no input to the Network unit (relay test switch "OFF"), approximate values are as follows:

SOCKET NUMBER V-203								
PIN NO.	1	2	3	4	5	6	7	8
VOLTAGE	0	43	127	0	0.1	0	22	2

SOCKET NUMBER V-204								
PIN NO.	1	2	3	4	5	6	7	8
VOLTAGE	0	68	127	0	0.1	0	44	2

The plate current for V-203 and V-204 should be 34 to 44 milliamperes with the FD-L picked up, For future comparison, record the values read with the relay test switch in both the "NOR" and "IN" positions.

MAINTENANCE (SECTION K)

K_1 PERIODIC TESTS

It is suggested that this overall test be made approximately once a month by members of the relay maintenance group rather than members of the station operating staff. Normally, no other testing is necessary until the tripping or blocking tests fail.

K_2 PROCEDURE FOR TEST

The relay test switch is arranged to open the trip circuit before it short circuits the terminals of the local network unit. The only way it can affect the remote terminal is by sending a blocking signal, which can only prevent tripping. Therefore, it is impossible to operate either switch in such a way as to cause tripping of the other terminal.

If the relay test switch at either terminal is turned away from the "NORMAL" position, that terminal will be unable to send a blocking signal and the other terminal may trip in response to any fault either internal or external. It is advisable to arrange by telephone for the movement of the switches at the two ends of the line, from "NORMAL" to the "OFF" positions or vice versa, so as to minimize the time when one end of the other is liable to false tripping due to the switches being in different positions.

K_3 CHECK OF TRIPPING

Turn the switches at both ends of the line from "NORMAL" to "IN" at a pre-arranged time. Watch for the amber lights at both ends and return both switches slowly to "OFF". When the switches at both ends are in like positions, either "IN" or "OUT", an internal phase-to-phase fault is simulated. The lighting of the red lamp indicates that the circuit breaker would have tripped for this condition. Either end may be checked separately for its ability to trip if no one is available to operate the switch at the other end.

Check by telephone that both red lamps have lighted, otherwise the blocking test will mean nothing.

K_4 CHECK OF BLOCKING

Starting with both relay test switches "OFF", one maintainer (X) will direct the other maintainer (Y) to turn his switch to "IN", thus lighting Y's red lamp. When X hears the resulting 60-cycle hum in his receiver, he will turn his own switch to "OUT", and see that his red lamp is not lighted in that position. He will then return his switch slowly to "OFF". When Y sees his red lamp extinguished by the blocking signal, he will turn his switch slowly to "OFF". X will check with Y by telephone, to make sure the blocking was successful. Then (Y) interchanges the procedure with (X) and repeats the test.

When the test switches are in opposite positions, the test currents at the two ends flow in opposite directions through the relays, as during an external fault. The blocking signals sent in both directions act thru the control grids of the comparer tubes to drop out tripping elements T, thus extinguishing the red lamps.

NOTE: In test SECTION K_3 and K_4, additional information may be obtained by reading the current in the milliammeter when the selector switch in the tripping unit is turned to "COMPARER". This current should be about 6 milliamperes for the test in SECTION K_3 and zero for the test in SECTION K_4. Also, the fault detector tube plate current may be read while the relay test switch is in the "IN" position by placing the selector switch in the FD-H position.

K_5 TUBES

All the tubes involved in the relay function have their heaters energized continuously. The end of their useful life is usually determined by a falling off in cathode emission. Failure by heater burnout is rare, but will be indicated at once by the signal alarm, SA.

All tubes should be checked about once every two months. Tube checkers of the mutual conductance type are recommended. The mutual conductance reading obtained should be recorded for comparison with the reading at the next test interval. When the test indicates that a tube is approaching the end of its useful life, it should be replaced.

See SECTION E_{10}, and E_{11} for necessary tests and adjustments when replacing a tube.

K_6 CONTACT CLEANING

For cleaning fine silver contacts, a flexible burnishing tool should be used. This consists of a flexible strip of metal with an etched roughened surface, resembling in affect a superfine file. The polishing action is so delicate that no scratches are left, yet corroded material will be removed rapidly and thoroughly. The flexibility of the tool insures the cleaning of the actual points of contact.

Fine silver contacts should not be cleaned with knives, files, or abrasive paper or cloth. Knives or files may leave scratches which increase arcing and deterioration of the contacts. Abrasive paper or cloth may leave minute particles of insulating abrasive material in the contacts and thus prevent closing.

The burnishing tool described is included in the standard relay tool kit obtainable from the factory.

RENEWAL PARTS (SECTION L)

For systems having a considerable number of these relays installed, a pair of complete relays (including standard cases, for transportation and bench test) provides the most complete protection against prolonged outage due to unforeseen failure of parts. This also permits greater convenience and thoroughness in repairs.

The relay units may be ordered as:

Network Unit - L-6418096
Tripping Unit - L-6418095

For systems where fewer of these relays are installed, cost will require that spares be limited to selections from the following list, which is arranged in the order of decreasing estimated probability of failure. Parts should be ordered by description as well as drawing number to avoid wrong shipments resulting from transposed digits, etc.

L1

ELECTRICAL PARTS LIST

CIRCUIT COMPONENT	DESCRIPTION	DWG. NO., CAT. NO., OR TYPE
V-201 & V-202	Vacuum Tube	Type 5692
V-203 & V-204	Vacuum Tube	Type 5824
RB	Transient Blocking Relay	L-6418025 P-1
SA	Signal Alarm Relay	L-6418025 P-84
FD-L	Fault Detector-Low Relay	L-6418025 P-100
FD-H	Fault Detector-High Relay	L-6418025 P-101
T	Tripping Relay	L-6418025 P-101
SI	Seal-in Unit	L-6293203
RS-201	Rectifier	G-E Cat. #6RS47K1
S-201	Selector Switch	K-6507854
S-202	Selector Switch	K-6507853
R-202 & R-203	Network Adjusting Resistor	Ohmite 50W 5000 ohms
R-201	Network Resistor	Ohmite 50W 10,000 ohms
R-205	Network Resistor	Ohmite 25W 6,000 ohms
R-206	Network Resistor	Ohmite 25W 6,000 ohms
R-227	Cathode Bias Resistor	Ohmite 25W 150 ohms
R-228	Cathode Bias Resistor	Ohmite 50W 1250 ohms
R-230	Heater Resistor	Ohmite 50W 50 ohms
R-231	Heater Resistor	Ohmite 50W 50 ohms
R-232	Heater Resistor	Ohmite 50W 200 ohms
R-246	Heater Resistor	Ohmite 50W 100 ohms
R-236	Screen Resistor	Ohmite 50W 1000 ohms
R-244	RB Resistor	Ohmite 20W 2000 ohms
C-201	Network Capacitor	G-E Cat. No. 67x19 0.5 Mfd. 440 V.
C-202	Filter Capacitor	G-E Cat. No. 21F801 0.25 Mfd.
C-203	Coupling Capacitor	G-E Cat. No. 21F801 0.25 Mfd.
C-204	Coupling Capacitor	G-E Cat. No. 21F801 0.25 Mfd.
C-206	Smoothing Capacitor	G-E Cat. No. 21F802 0.5 Mfd.
C-207	Smoothing Capacitor	G-E Cat. No. 21F802 0.5 Mfd.
C-210	Smoothing Capacitor	G-E Cat. No. 21F802 0.5 Mfd.
J-201	Jack	Mallory Midget A-2
J-202	Jack	Mallory Midget A-2

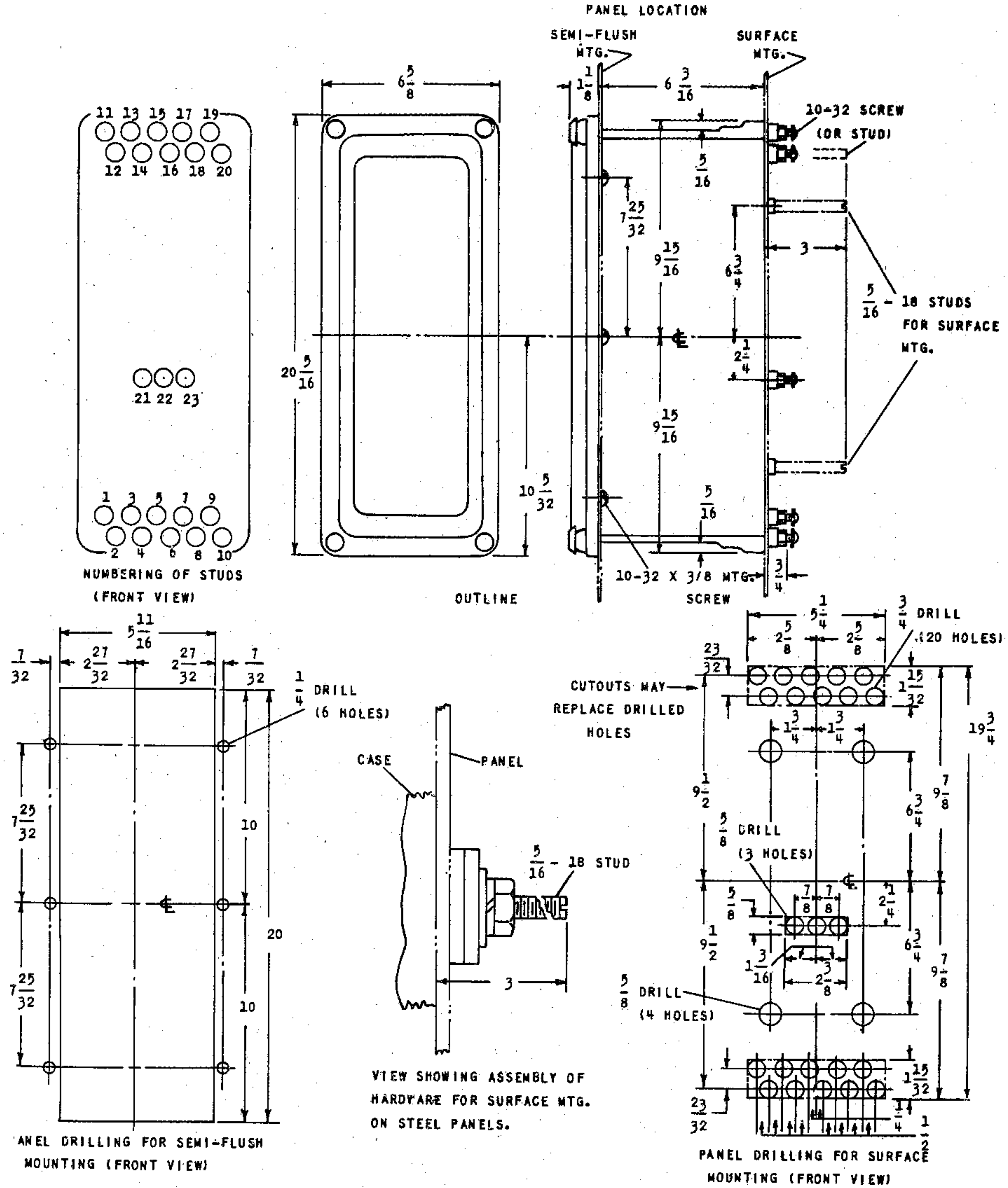


Fig. 30 (K-6556431)

Fig. 30 Outline & Panel Drilling Dimensions For Type EDD Relay (Tripping Unit)

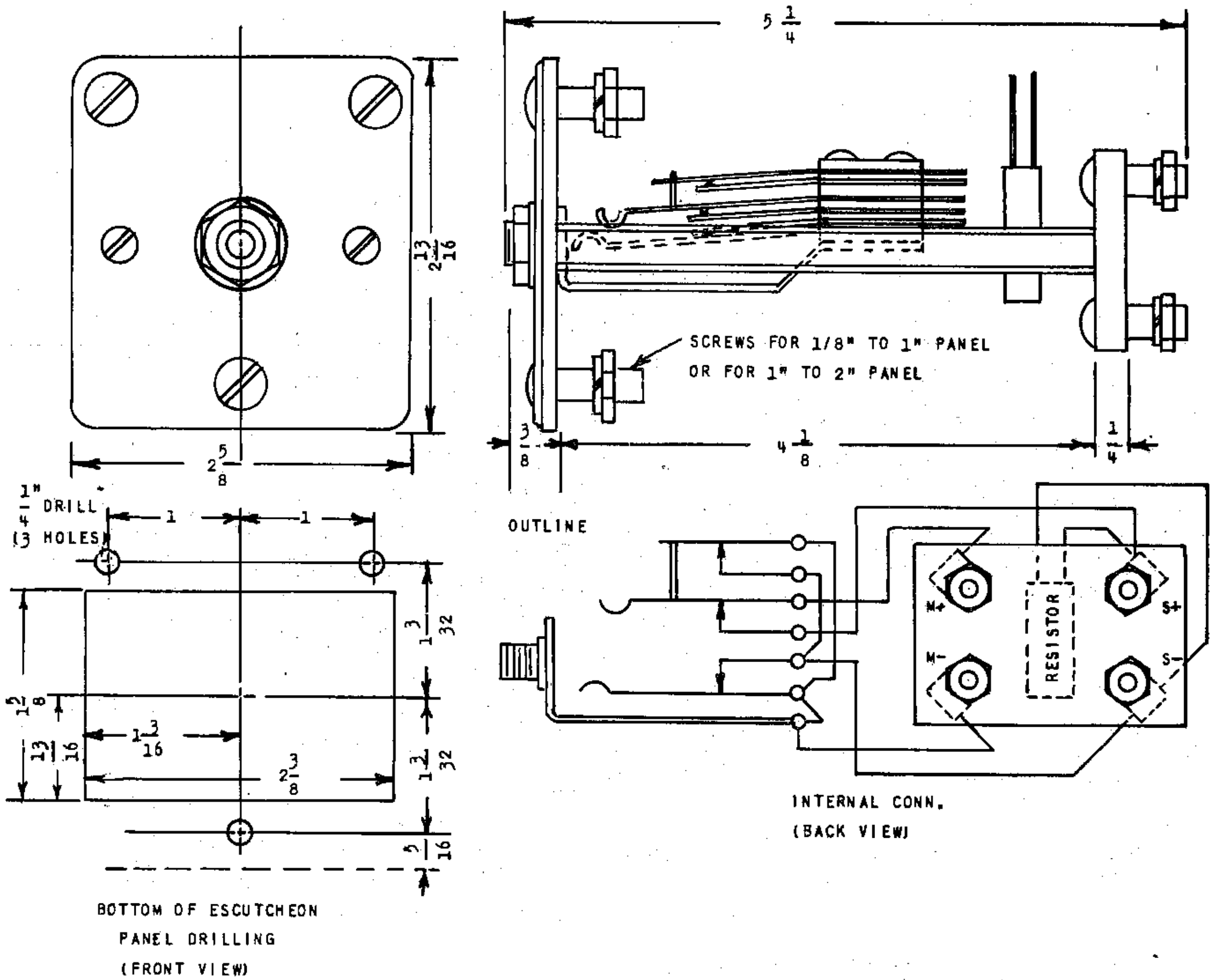


Fig. 31 (K6400633)

Fig. 31 Outline, Panel Drilling, And Internal Connections For Meter Jack

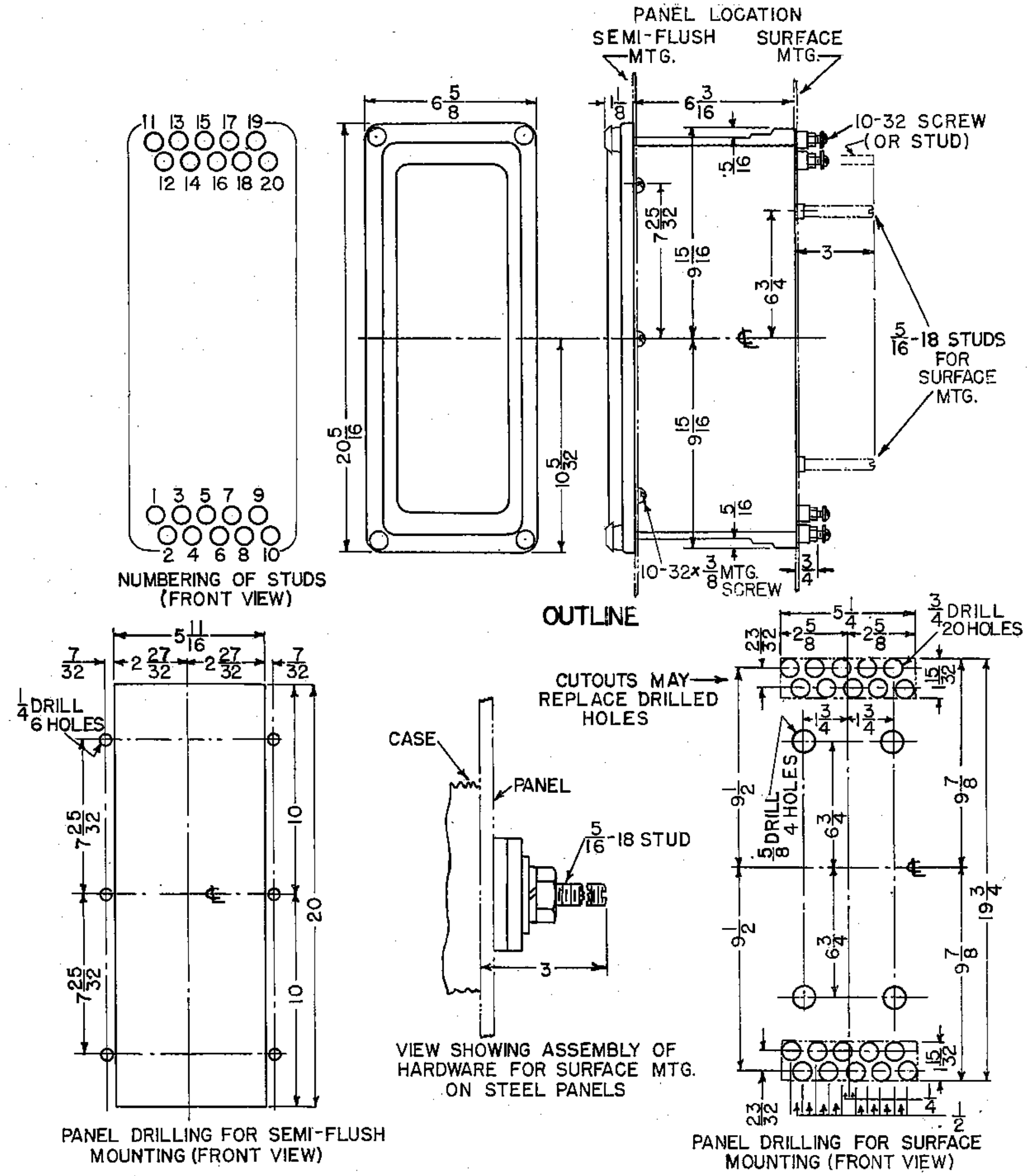
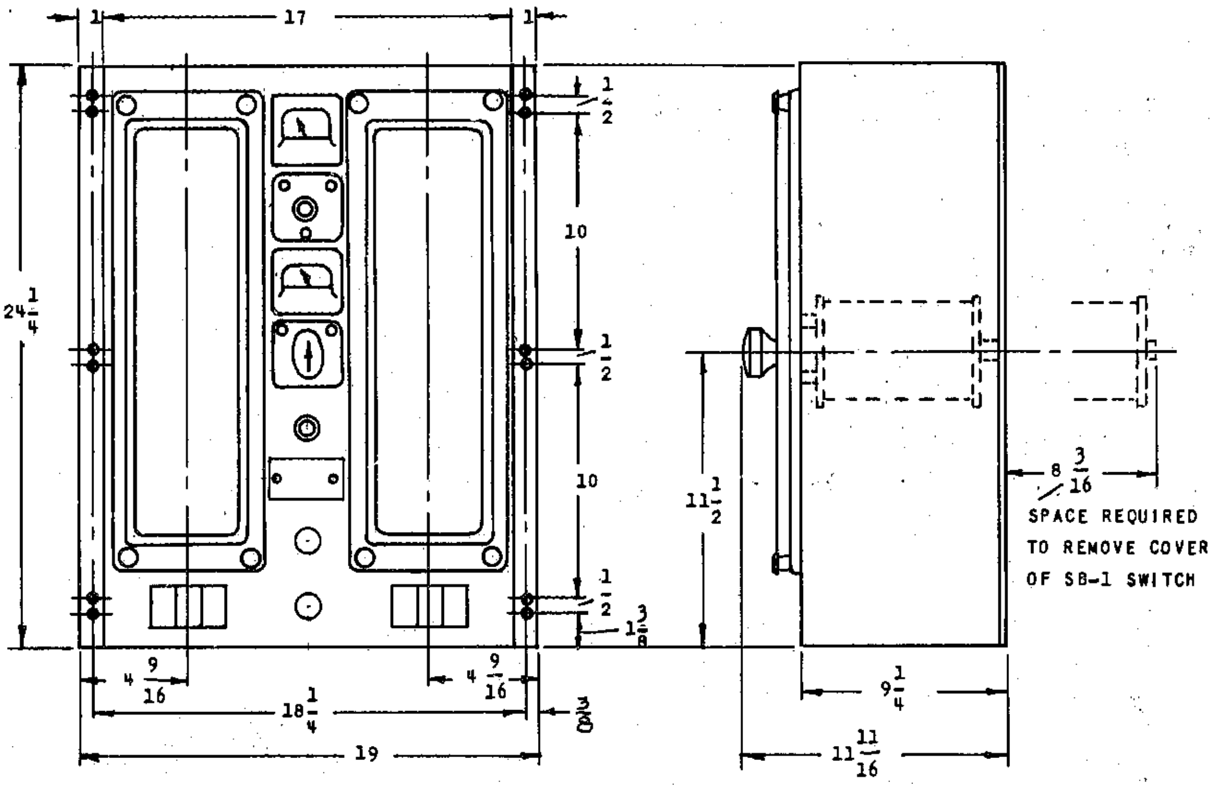


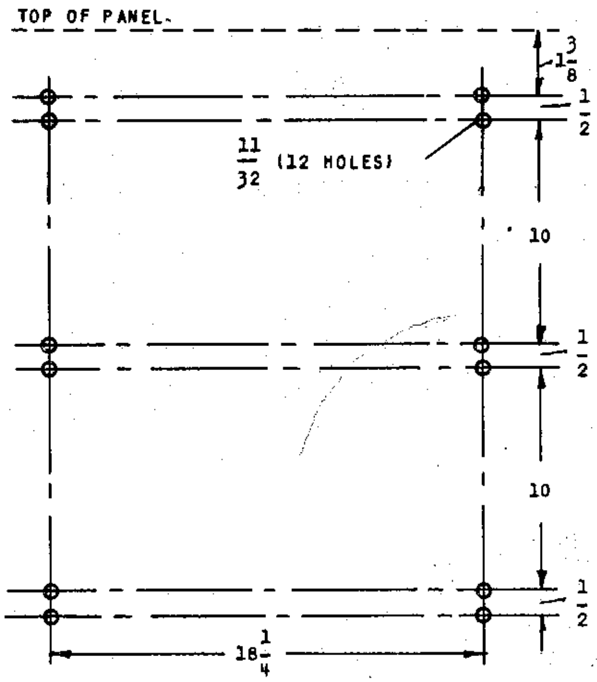
Fig. 31 (K6400633)

Fig. 32 (K-6209276)

Fig. 32 Outline & Panel Drilling Dimensions For Type EDD Relay (Network Unit)



OUTLINE



PANEL DRILLING
(FRONT VIEW)

Fig. 33 Outline & Panel Drilling Dimensions For Type EDD Relay (Sub-Panel)

Fig. 33 (K-6556433)