PHASE-COMPARISON CARRIER-PILOT RELAYS

TYPES EDD12D AND EDD12E

A

CONTENTS

CONTENTS (Cont'd.)

Fig. 1. (8018032) & (8018030)

CRADLE

TAP BLOCK T-202
TEST JACK J-201
FD-H ADJ R-221
SELECTOR SWITCH S-201
FD-L ADJ R-209, R-210
V-202

V-201

R-202
R-203
R-230

FD-1
FD-2   PJC
FD-3

ARMATURE (A)

INNER BLOCK

LATCH

RESISTORS L-R
R-205, R-206,
R-227

T-202

R-201

C-204, C-203,
C-202
C-201
RS-201

RESISTOR STRIP
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R-223
R-208
R-207
R-224
R-212
R-218
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R-211

L-203

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T-201

Fig. 1   Network Unit Withdrawn From Case

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INNER
BLOCK

CRADLE

SEAL-IN
UNIT

TEST SWITCH
J-202

SELECTOR
SWITCH
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PHASE
SHIFTER
CONTROL
R-253

V-203

V-204

R-246

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TELEPHONE
RELAY UNITS

CATCH

T-203

C-206
C-207
C-210

C-211
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R-244

R-235

RESISTOR
STRIP L-R
R-233, R-234
R-256, RG-201
R-251, R-252
R-239

MALE PLUG

SA (PLUG-IN
UNIT)

R-236

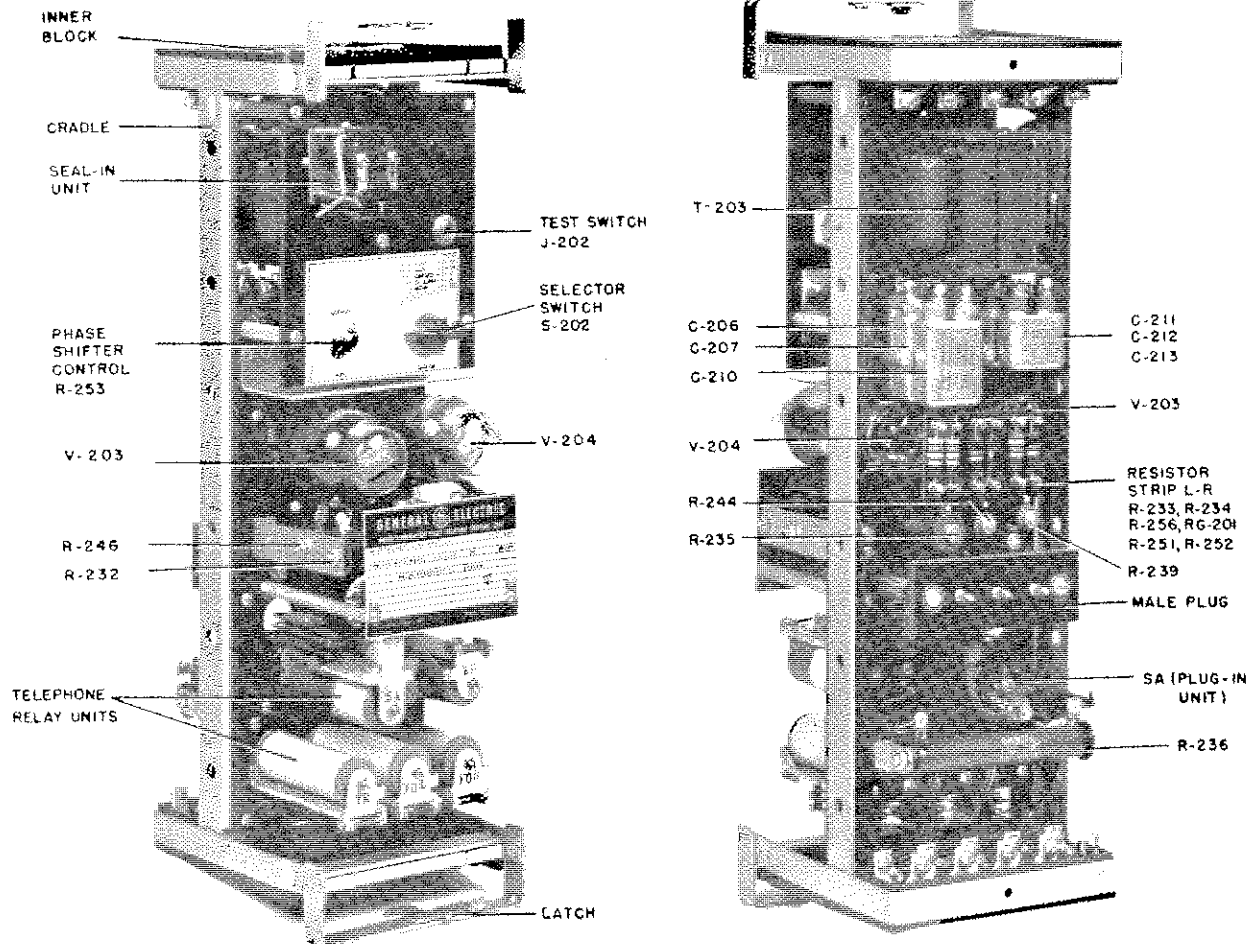Fig. 2 (8020070) & (8020071)

Fig. 2   Tripping Unit Withdrawn From Case

PHASE COMPARISON CARRIER PILOT RELAY
TYPE EDD12D AND TYPE EDD12E

INTRODUCTION (SECTION A)

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

The carrier current relaying system using this relay, is a differential system comparing the phase angles of the currents entering and leaving the protected transmission line section. Comparison is made by means of a carrier current channel.

A₁ 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.

Simultaneous tripping at all line terminals is obtained when the values of the CT secondary currents exceed those listed in Table IV. Refer to Section H3 to determine if tripping requirements are fulfilled.

When back-up protection is required, supplementary distance and directional ground relaying must be added.

TWO TERMINAL LINES

Protection is provided for two-ended transmission lines, with or without tapped loads, providing the conditions described in Section H1 and H2 are met.

THREE TERMINAL LINES

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.

GROUND CURRENT EXCITATION

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

The addition of ground current excitations for two terminal lines is required where the minimum negative-phase-sequence current for internal ground faults is less than 86 percent of the relay phase-to-phase trip setting. The method of calculating ground current tap setting is described in Section H3.

For three terminal lines, the addition of ground excitation requires special consideration.

COMBINED DIRECTIONAL AND PHASE COMPARISON RELAYING

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.

TELEMETERING-SUPERVISORY CONTROL

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

Telemetering requires an instantaneous signal alarm (SA) unit as described in Section G15.

A₂ RATINGS

A₃ Relay

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

A₄ TARGET-SEAL-IN UNIT

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 an 8.5 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	
Phase 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	300X 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 8.5 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 total (two trip circuits) 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 (8.5 Ohm)
Tripping Duty	30	5
Carry Continuously	4	0.4

A5   CONTACTS

The current-closing rating of the contacts is 15 amperes for each trip circuit or 30 amperes total, 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.

A6   A-C TEST SOURCE

The 15 second rating of the a-c test source is 6.5 amperes.

A7   BURDENS

The relay burdens are given in Table III.

TABLE III

FAULT		CT BURDEN-OHMS	
Phase Fault Any CT		Z 0.15 /42	R + j X 0.11 + j 0.1
	Tap (Mult. by)	Z	R + j X
GROUND FAULTS (Burden of highest phase)	2.0	0.23 /18	0.22 + j 0.07
	0.67	0.33 /36	0.26 + j 0.20
	0.47	0.40 /44	0.29 + j 0.28
	0.33	0.52 /50	0.33 + j 0.40
	0.23	0.74 /58	0.38 + j 0.63
	0.17	1.18 /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 can vary from 1.8 to 6.6 amps at 115 volts, 60 cycles. The actual test value depends on the phase to phase trip setting. For a normal setting the test load would be 3.5 amps for two-ended lines and 6.5 amps for three-ended lines.

A9   RELAY TRIPPING RANGES AND SETTINGS

The tripping settings, except for phase-to-ground tripping with ground-current excitation, are continuously adjustable within the limits specified in Table IV. The relay is normally set for values listed in the "FACTORY" column.

TABLE IV

Type of Fault	Current Transformer Secondary Amperes For Tripping				
	2 Terminal Operation			3 Terminal Operation	
	Min.	Factory	Max.	Min.	Max.
3 Ø trip	5.33	8.0	16	10.7	16
Ø FD. P.U.	4.0	6.0	12	4.0	6
Ø-Ø Trip	2.0	3.0	6	4.0	6
Ø-G Trip	4.0	6.0	12	8.0	12
Ø-G Trip with Ground Excitation**	0.33-1.33	0.5-2.0	1.0-4.0	Refer to General Office	
Load	3.3		5	3.3	5

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

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

Phase-to-Phase Faults

The trip settings are obtained by adjustment of rheostats FD-L (R209-R210 ganged) and FD-H (R221) as outlined in Sections E20 and E21. FD-H is normally set 50 percent higher than FD-L to provide a safety margin between blocking and tripping.

Three Phase Faults

The trip settings are obtained by adjustment of the phase fault detectors FD-1 to FD-3, network resistor R202 and FD-H rheostat R221. To obtain correct operation, the ratio between pickups of FD-1 to FD-3 and FD-H must be kept at 3 to 4 for 2 terminal lines and 3 to 8 for 3 terminal lines. The three phase trip setting will normally be approximately 2.7 times the average phase-to-phase trip setting. Adjustments are described in Section J7.

Phase-to-Ground Faults

Tripping settings are adjusted by the selection of taps on the ground current winding of transactor T_{202}. The tap setting selected depends on the magnitude of the negative sequence current available during internal ground faults as described in Section H_4. When ground-current excitation is not needed, $K = 2$ (refer to Section H_6 - Par. 11). The product of K times $\emptyset$-to-$\emptyset$ trip setting equals the $\emptyset$-G trip

setting. When ground excitation is required the magnitude of K can vary from 0.17 to 0.67 (refer to Section H_6 - Par. 17).

Phase Shifter Range

The phase-shifter settings are adjustable from 0 to 24 degrees. The extreme counterclockwise position of the rheostat R_{253} is the zero degree setting. The switch clicks off in this position.

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 un-

packing 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.
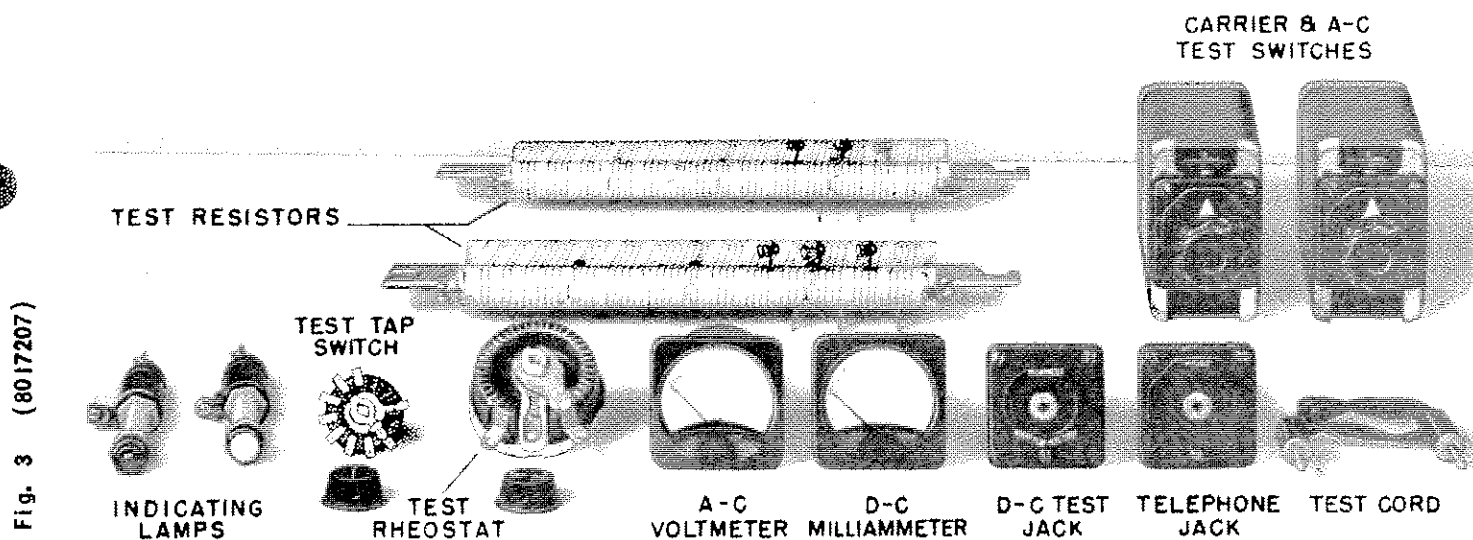
Fig. 3   EDD Equipment For Panel Mounting

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 L_2 case, a negative-phase-sequence network, three phase-overcurrent relays, a voltage amplifier, and fault detectors, low (L) and high (H). A heater resistor (R231) is mounted externally. The tripping unit, Fig. 2, contains, in a special L_2 case of 23 studs, a power amplifier, RC phase shifter, and five telephone-relay

elements identified as FD-L, FD-H, T, RB and SA. The d-c test equipment, Fig. 3 is composed of a d-c milliammeter and 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, voltmeter, and an amber indicating lamp. Also included are a carrier test switch and a white indicating lamp. External resistor R_{231} is not shown in Fig. 3.

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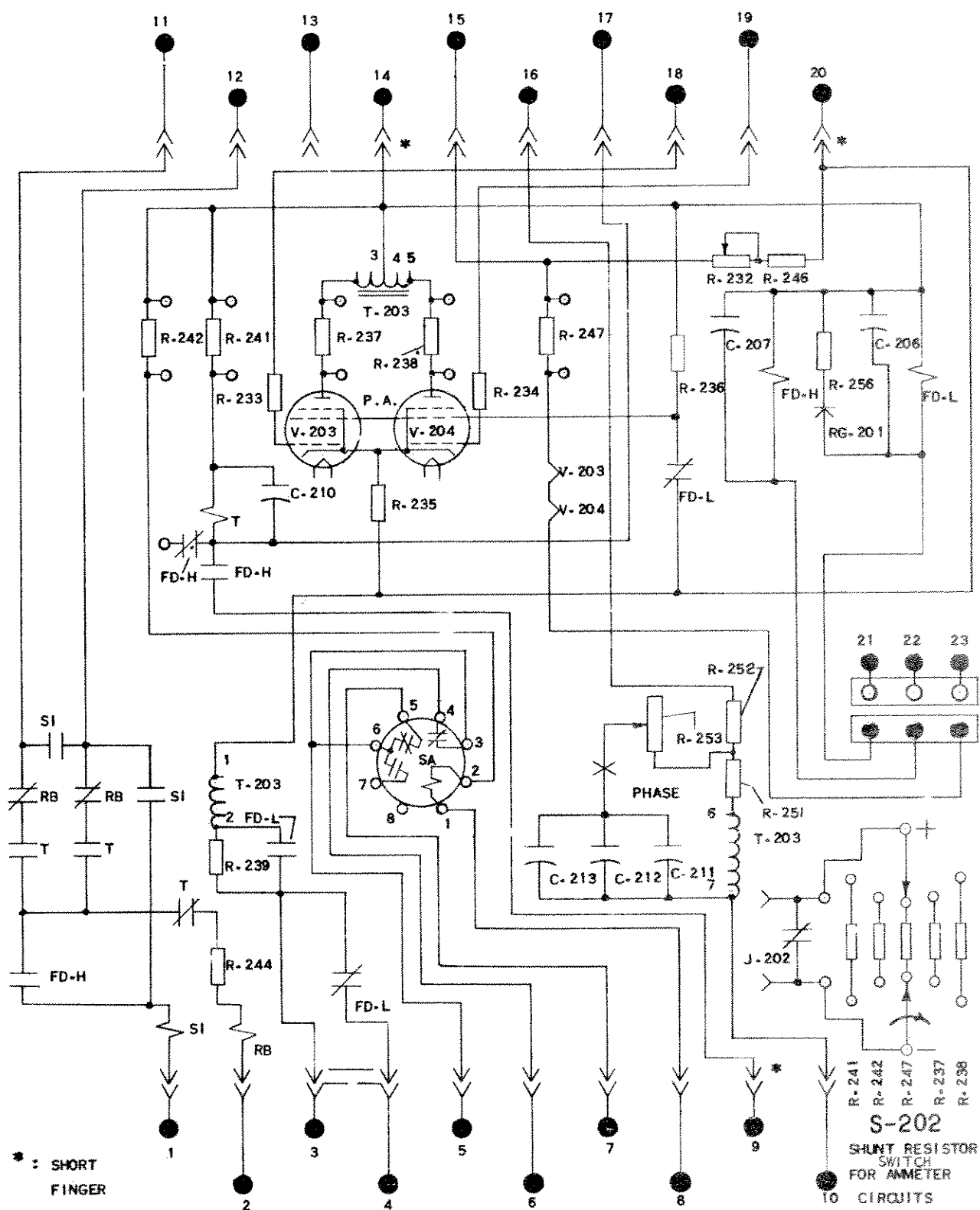
Fig. 4   Internal Connections For Type EDD Relay (Tripping Unit)

* : SHORT FINGER

Fig. 5   (389A718)

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

*:SHORT FINGER

S-201
SHUNT RESISTOR SWITCH
FOR AMMETER CIRCUITS

C₁   RELAY TYPES

The Type EDD12D relay, Figs. 1 and 2, is arranged for panel mounting. Additional auxiliary equipment furnished with the units is also shown in Fig. 3.

The Type EDD12E relay is similar to the Type EDD12D, except it is assembled in a subpanel for mounting in a carrier-current transmitter-receiver cabinet. In addition, a carrier test switch, a telephone jack, milliammeter, indicating lamp, and cord and plug are provided for mounting on the cabinet door. The subpanel assembly is 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 secondary circuits before they are opened. 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. The relay unit can also be drawn out and replaced by another which has been tested in the laboratory.

C₃   SEAL-IN UNIT

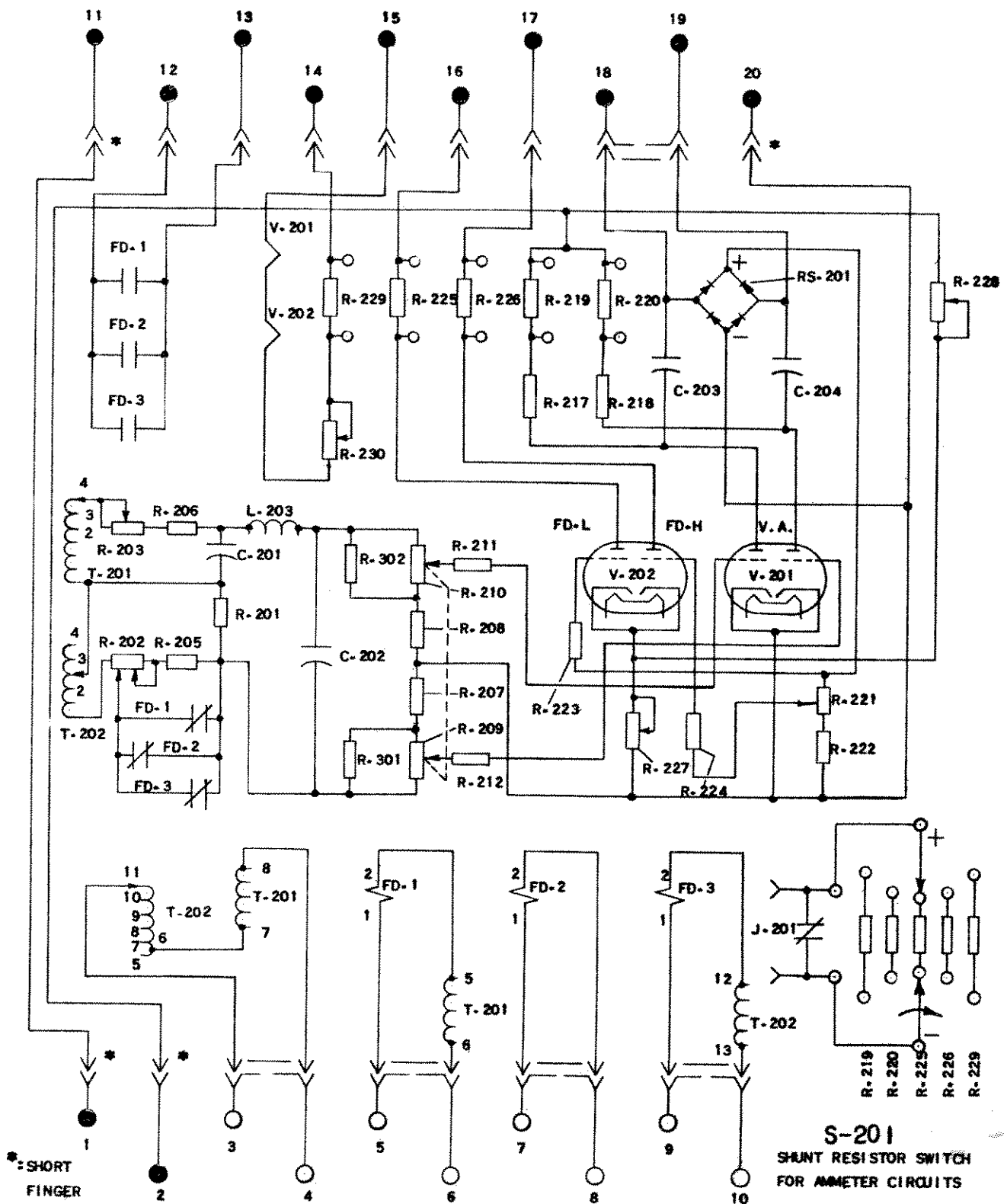The seal-in unit is connected to pick up when the FD-H and TR units operate. When picked up, its contacts seal-in across the normally open contacts of FD-H and TR insuring positive tripping action. The seal-in units' target is exposed and latched up when a trip operation has been initiated and is released by pressing the reset 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. Refer to Table IV A for outline and panel drilling figures.

D₃   CONNECTIONS

Figures for internal connections and external panel connections are listed in Table IV A.

Check external connections carefully for all externally mounted resistors such as R214 and R231.

One of the mounting studs or screws should be permanently grounded by a conductor not less than No. 12B & 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 accomodating 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 white indicating lamp when lit should indicate that the 'SA' telephone relay has dropped out.

TABLE IV A

Outline and Panel Drilling	Fig.
Network Unit	23
Tripping Unit	22
Subpanel Assembly	24
Relay Test Switch	25
Carrier Test Switch	25
Test Resistor	26
Indicating Lamp	37
Milliammeter (1/8-1/4 inch panel)	27
Milliammeter (1/4-2 inch panel)	28
Voltmeter (1/8-1/4 inch panel)	29
Voltmeter (1/4-2 inch panel)	30
D.C. Test Jack	31
Telephone Jack	32
Test Rheostat	33
Test Tap Switch	34
Resistor (250 Volt D.C. Relays) 2 Unit	35
Resistor (250 Volt D.C. Relays and R231) Single Unit	36

TABLE IV A (Cont'd.)

Internal Connections	Fig.
Tripping Unit	4
Network Unit	5
Subpanel - Type EDD12E	6
External Connections	
Type EDD12D - Panel Mounted	7
Elementary For Phase Comparison Pilot Relaying	16

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. 16.

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). Refer to "Relay Settings" (Section H) for limiting conditions and a method for calculating the ground current tap setting.

NOTE: Tests are for two-terminal lines using factory settings given in Table IV. All other numerical values given approximate original factory settings.

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

2.   Perform the following tests, SECTIONS E1 to E12, 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 E13 to E23.

4.   Perform tests, SECTIONS E24 to E28 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.

E1   D-C POLARITY (CHECK)

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

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

E2   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.

E3   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.   Simultaneously, manually operate the FD-H and TR units and observe the same results.

E4   ALARM CIRCUIT (CHECK)

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

2.   Remove carrier fuses, then see that contacts of the signal alarm element (SA) ring the proper alarm. The white indicating lamp should light. Replace carrier fuses.

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

E5   TEST SOURCE CURRENT (SET)

E6   Type EDD12D Relay (Panel Mounted)

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

2.   Turn the test switch to the "OUT" position. Holding the voltmeter at 100 volts by means of the tap switch (S-203) and the rheostat (R-216), adjust the lower tap connection of R-204 to obtain the desired FD-L test setting.

To insure positive pickup this value should be a little greater than the FD-L pickup setting for phase-to-phase faults. The test current range of adjustment is 1.8 to 6.5 amps. If the desired FD-L pickup is 2 amps, set the test value between 2.3 and 2.4 amps.*

3.   Turn the relay test switch to the "IN" position. Holding the voltmeter at 100 volts by means of the tap switch and rheostat, adjust the upper tap connection of R-204 (see Fig. 6) to obtain the desired FD-H test setting. If the FD-H trip setting is 3 amps set the test value between 3.4 and 3.5 amps.**

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

* Same values for three-terminal lines.
** 6.4 to 6.5 for 6 amp pickup on three-terminal lines.
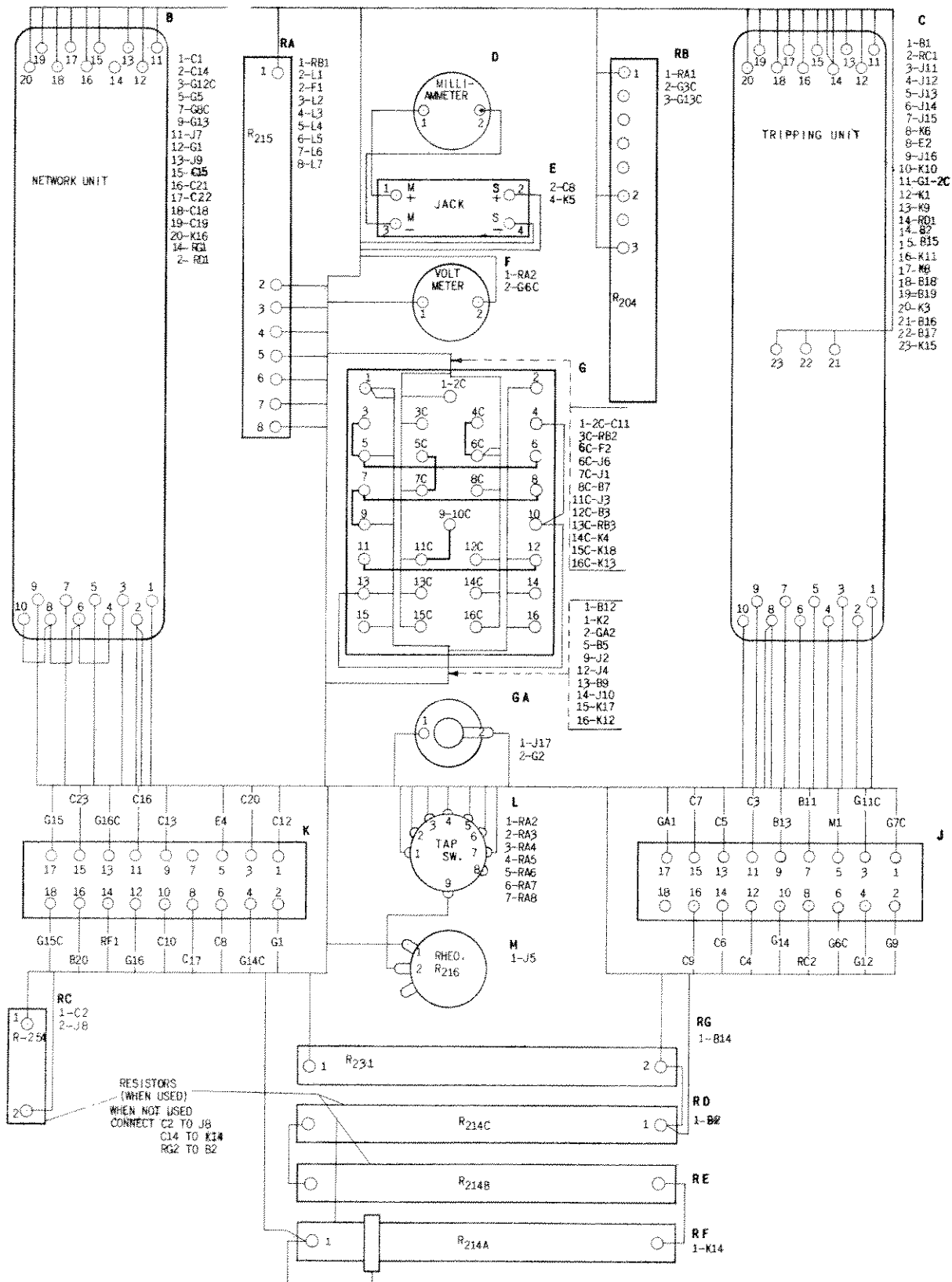
Fig. 6   Internal Connections For Type EDD Relay (Sub Panel) (Back View)
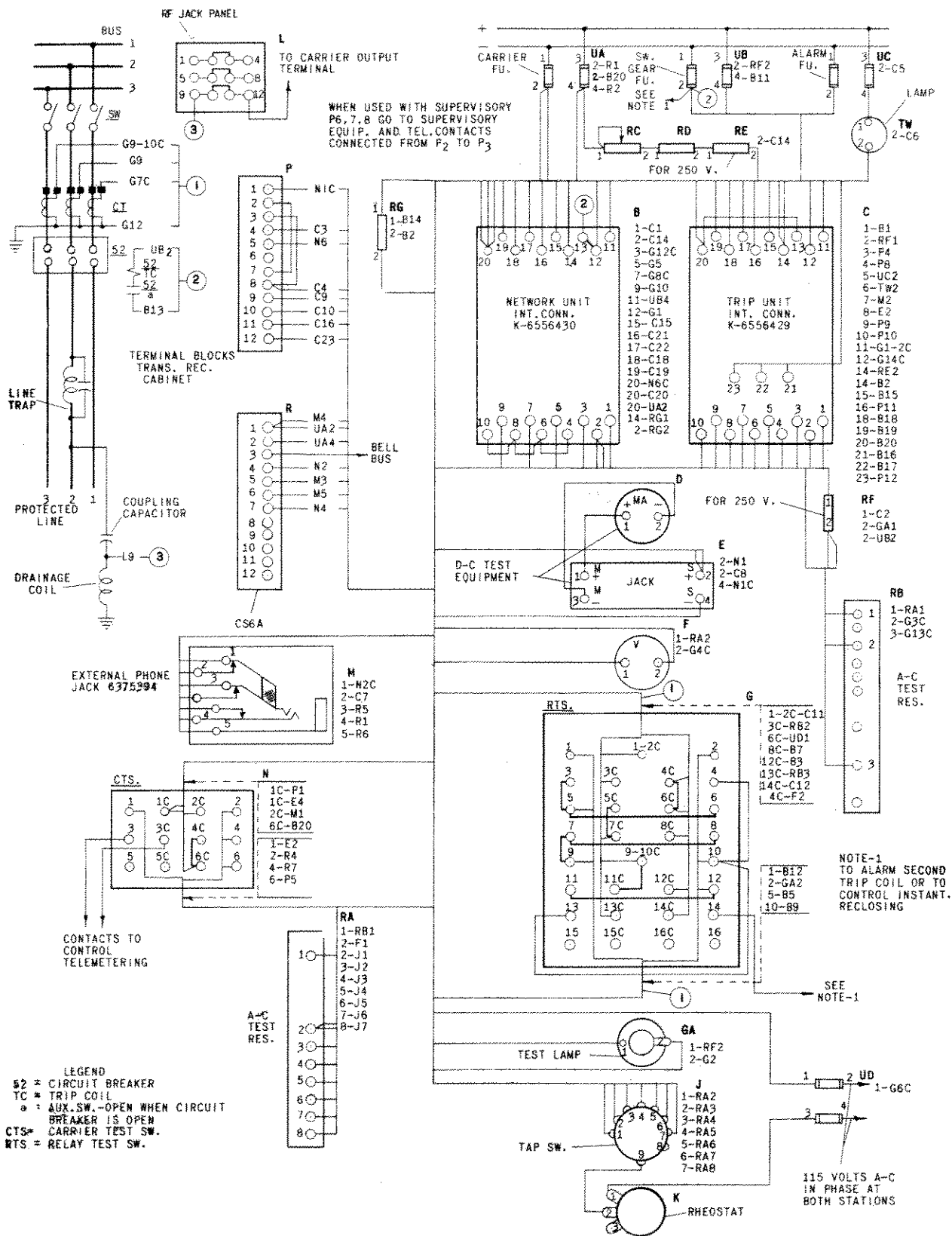
Fig. 7   External Connections For Type EDD Relay (Panel Mounted) (Back View)

CAUTION: RELAY TEST SWITCH MUST
NOT BE TURNED TO "NORMAL"
POSITION WHEN THIS CONNECTION
IS USED.
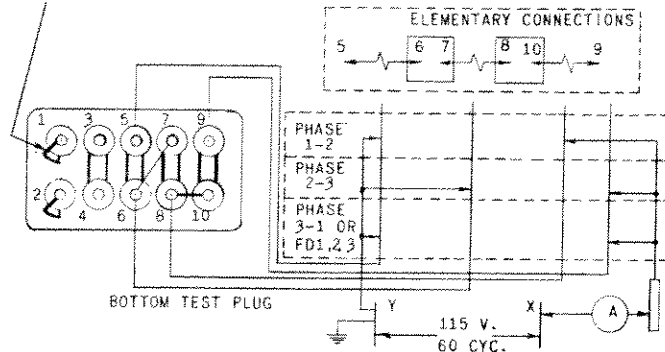
FAULT DETECTOR PICK-UP, PHASE-TO-PHASE TRIP POINT,
PICK-UP AND DROP-OUT PHASE FAULT DETECTORS NETWORK
UNIT L-6418096.

OUTER CIRCLES REPRESENT STUD CONNECTIONS (RED)
INNER CIRCLES REPRESENT RELAY CONNECTIONS (BLACK)
MAKE CONNECTIONS ENCLOSED IN DOTTED BLOCKS ONLY,
FOR EACH CASE.

**Fig. 8   Drawout Test Plug Connections For
Phase-To-Phase Pick-Up Check**

BOTTOM TEST PLUG
REVERSED PHASE SEQUENCE TEST
NETWORK UNIT L-6418096

OUTER CIRCLES REPRESENT STUD CONNECTIONS
(RED)

INNER CIRCLES REPRESENT RELAY CONNECTIONS
(BLACK)

Fig. 9   Drawout Test Connections

E7   Type EDD12B Relay (Sub-panel Mounted)

The a-c network unit in this relay has been pre-adjusted at the factory to draw the same current as the Type EDD12D relay when the voltmeter is set at 100 volts by means of the tap switch and rheostat as outlined for the Type EDD12D relay.

The factory adjustment is for two-terminal lines with an FD-L setting of 2 amps and FD-H setting of 3 amps.

E8   PHASE-FAULT DETECTOR (SET FD-1 TO FD-3)

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

   The ratio of pickup of the phase fault detectors to the FD-H setting for 3 phase faults is 3 to 4. Therefore, all three fault detectors should be picked up at approximately .75 times the FD-H setting and dropped out at approximately .9 times their pickup setting. Factory settings are 6.3 amperes pickup and 5.7 amperes dropout. The dropout value is not adjustable.

4. Pick-up adjustment may be made by turning the

knurled armature A shown in Fig. 1.

5. If any contact adjustment seems advisable, it should be made in accordance with SECTION J6.

6. Return test switches to "NORMAL" position.

E9   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. The secondary currents of each phase at both ends must also be equal if the correct taps of the CT's have been connected. This may be checked by placing an ammeter in series with each phase and noting if the currents are equal. Placing the ammeter in the neutral should show no current flows. 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

Fig. 8   (K-6556528)

Fig. 9   (K-6556528)

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terminals 3T and 20T, or cabinet terminals K3 and J11. If the phase sequence is incorrect and sufficient current flows to pickup FD-L, the voltage reading will be approximately 120 volts. With correct phase sequence and the same line current flowing, the voltage reading should be 15 volts or less. Check the results again 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.

E10   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. Check R231 external connections if heater current is too high.

E11   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 E10 and then SECTION E11 to obtain the correct values of heater current in both the network unit and tripping unit.

E12   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.

E13   SIGNAL ALARM AND COMPARER PLATE CURRENT (SET)

All installation tests and adjustments on both carrier transmitters should be completed before proceeding with the following tests.

1. Close grounding switch on carrier transmitter.

2. Adjust battery voltage within 2 percent 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 counter-clockwise until a point is found where signal-alarm current just begins to drop.

10. Open grounding switch on carrier transmitter.

11. An increase of comparer tube current to a value between 5 and 6 milliamperes may be achieved by a slight adjustment of R38 when the two relay terminals are in a simulated trip condition. When the relays are operated to produce a blocking signal a reduction of signal alarm current to less than 0.5 milliampere on receipt of steady carrier must be maintained by readjustment of R47, if necessary.

E14   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.

E15   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 (J12). Record the current reading and resistor setting for future comparison.

φ 2

φ 8

φ1 6 10 9 φ3
5

SERVICE CONDITIONS

φ 2

φ 1 φ 3

PHASE—TO—NEUTRAL
VOLTAGES

φ 2 I_{7-8}

I_{5-6} I_{9-10}
φ 1 φ 3
RELAY
CURRENTS
(PF — 1)

4 1
T201 T202
1 4

TRANSACTOR
OUTPUT
VOLTAGES*

*OUTPUT VOLTAGE 4-1 OF EITHER TRANSACTOR LEADS INPUT CURRENT
FROM 5 TO 6 OR 12 TO 13 BY 90 DEGREES.

VOLTAGE AND CURRENT CONDITIONS AT A GIVEN INSTANT

JUNCTION A MOVES
ALONG THIS SEMI-   T201,4
CIRCLE AS R203
IS CHANGED

AND R206
R203

T201

I_{5-6}
6
4 R-203 R-206 A
5
T201 1
T202 C201 B
13
12 4 R-201
1
I_{9-10} R-202 R-205 C

CONNECTIONS FROM
KK-62 77386

JUNCTION A WITH WRONG
SETTING OF R203

OUTPUT VOLTAGE WITH
WRONG SETTINGS OF
R202 AND R203

T202,1

JUNCTION C WITH
WRONG SETTING
OF R202

JUNCTION C WITH
RIGHT SETTING
OF R202

OUTPUT VOLTAGE WITH
RIGHT SETTING OF R202
AND R203 = 0

C201 R201

T201,1   T202,4
AND JUNCTION B

CONDITIONS WITH BALANCED LOAD
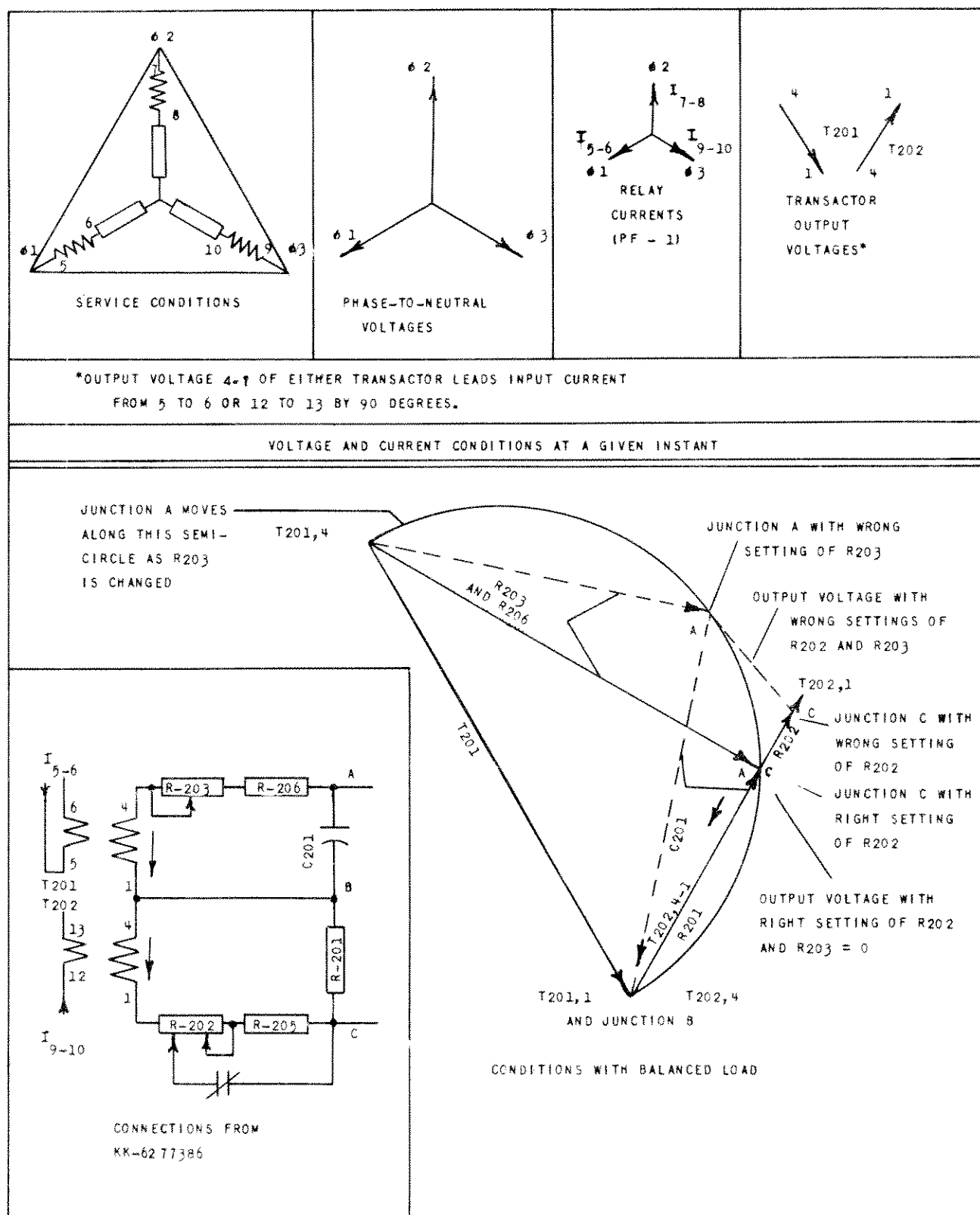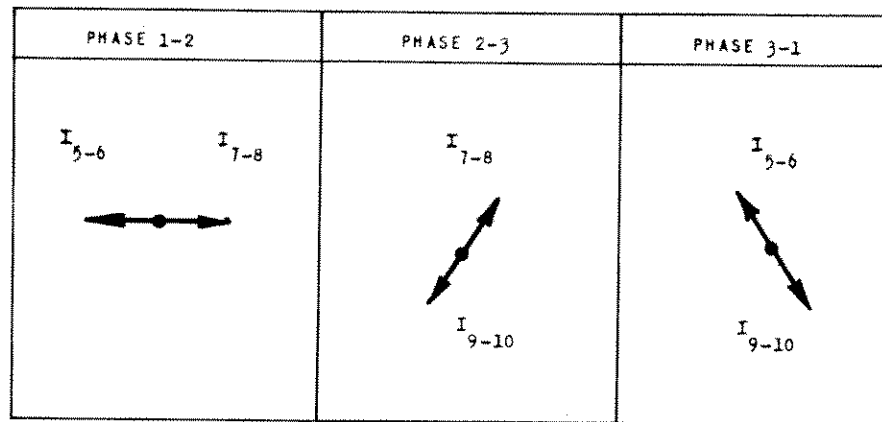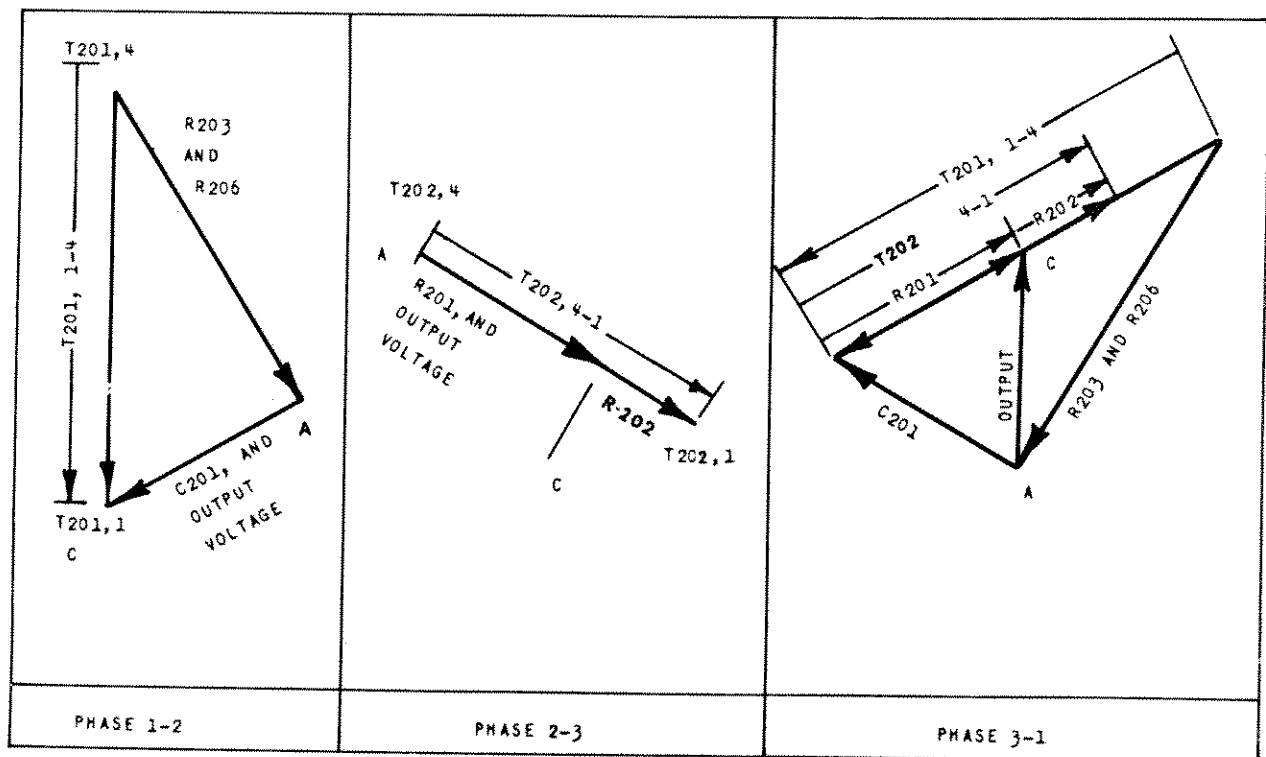
Fig. 10   Vector Relations In Negative-Sequence Network For Balanced Loads

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

Fig. II   (K-6204059)

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

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

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

E_{16} 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. Refer to oscilloscope pattern #1.

3. Turn relay test switch at one end of line to "OUT", other end to "IN". Oscilloscope should indicate approximately 180 degrees displacement. Refer to oscilloscope pattern #2.

4. If oscilloscope patterns are considerably different from 0 and 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. Refer to oscilloscope patterns #3 and #4.

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

E_{17} 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, or A10 and A11, 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.
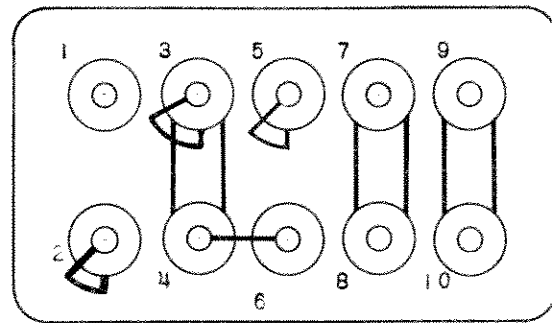
BOTTOM TEST PLUG
PHASE I CURRENT ONLY
NETWORK UNIT L-6418096

OUTER CIRCLES REPRESENT STUD CONNECTIONS (RED)

INNER CIRCLES REPRESENT RELAY CONNECTIONS (BLACK)

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

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 E_{17}-6.)

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, PHASE WIRE, 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.

3. If a cathode ray oscilloscope is available, connect its vertical input between ground and the
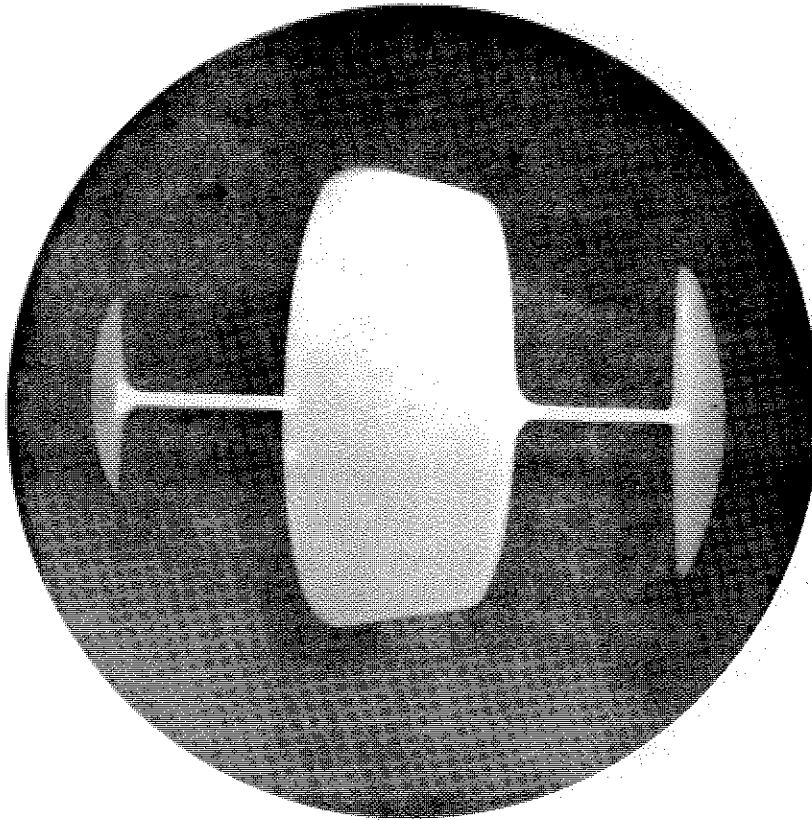
Oscilloscope Pattern #1   Local And Remote Signals In-Phase
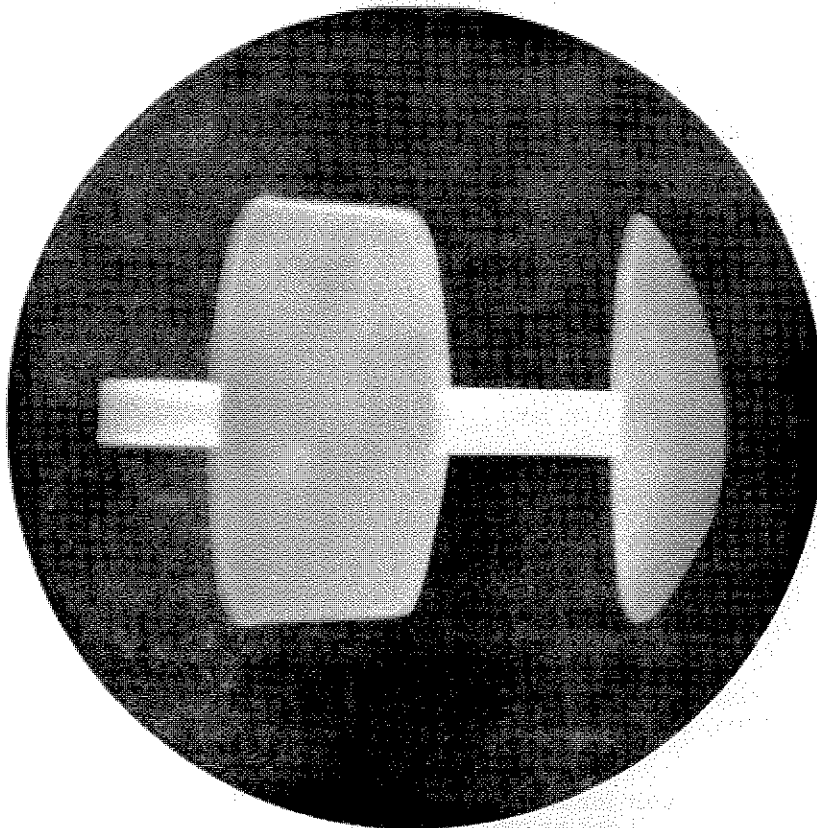
Oscilloscope Pattern #2   Local Signal Leading Remote Signal By 180°
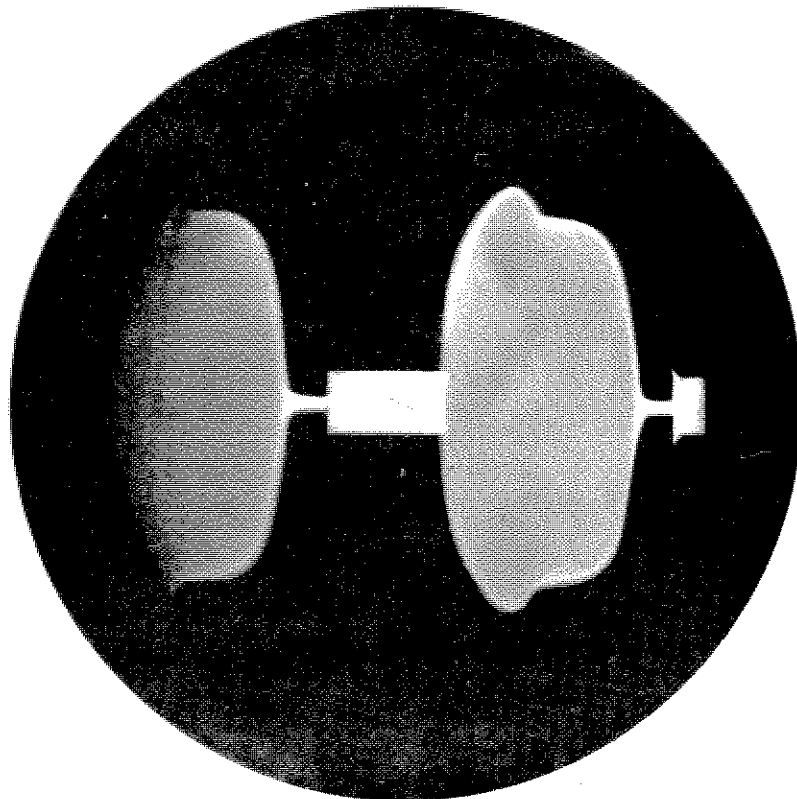
Oscilloscope Pattern #3   Local Signal Lagging Remote Signal By 120°
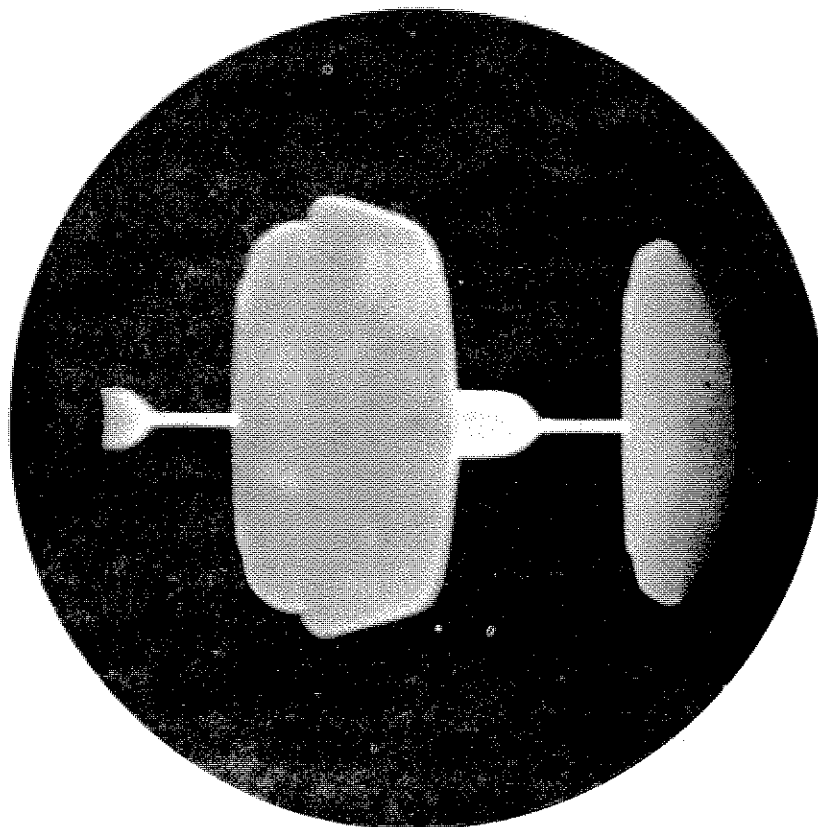
Oscilloscope Pattern #4   Local Signal Leading Remote Signal By 60°

CAUTION: RELAY TEST SWITCH MUST NOT BE
TURNED TO "NORMAL" POSITION WHEN THIS
CONNECTION IS USED.

BOTTOM TEST PLUG
PHASE-TO-PHASE PICKUP WITH
TEST RESISTOR, NETWORK UNIT
L-6418096.

OUTER CIRCLES REPRESENT STUD CONNECTIONS (RED)
INNER CIRCLES REPRESENT RELAY CONNECTIONS (BLACK)

Fig. 13 (K-6556528)
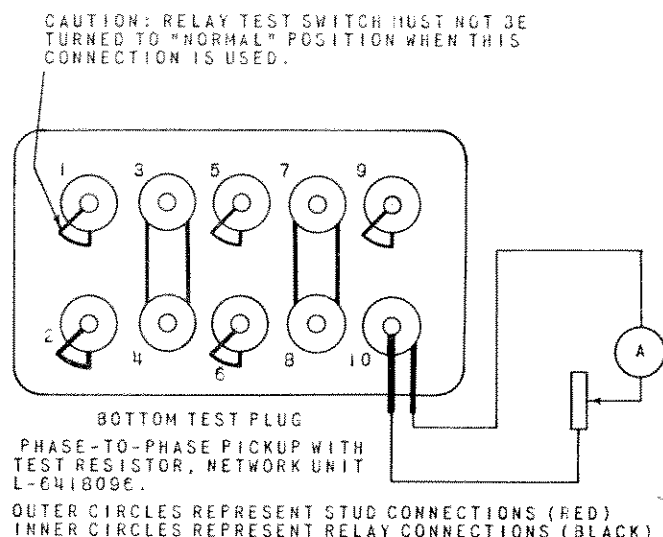
Fig. 13   Drawout Test Plug Connections For Phase-To-Phase Pickup

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. Refer to oscilloscope pattern #2.

If sufficient current is not available to pick up the FD-L element, which initiates sending of the blocking signal, it will be necessary to introduce additional current by using the ground current transformer T202. The connections shown in Fig. 12 make it possible to increase the current to the negative-phase-sequence network by using the lower taps of T202. The selected tap should provide sufficient additional current to pick up FD-L. Replace taps to proper settings after the test is completed.

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 E17 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 E9. 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.

E20   PHASE-TO-PHASE BLOCKING POINT (SET) (FD-L)

1. Turn relay test switches at both ends of the line to "OFF". Plug the test cord into the milliammeter and network 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 if the factory adjustment has not been changed.

3. If the pick-up current is incorrect or a different value is required, adjust the FD-L rheostat R-209 and R-210. The FD-L pickup should be 2/3 of FD-H pickup current to provide a definite margin between blocking and tripping.

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

E21   PHASE-TO-PHASE TRIP POINT (SET) (FD-H)

1. Turn the local relay test switch to the position "IN". Record the tripping unit output voltage across terminals K3 and J11 or studs 3T and 20T of the tripping unit. This voltage will be approximately 130 volts R. M. S. when the a-c test current is 3.5A and FD-L is picked up.

Remove the lead from 16T or the lead from K11 going to the carrier set and measure the open circuit, tripping voltage across terminals K10-K11 or 10T-16T using an a-c voltmeter of a 1000 ohms per volt or more. Normal readings (I = 3.5A) are 250 V. R. M. S. with R253 in the maximum counterclockwise position and 140 to 150 V. R. M. S. when the phase shifting rheostat R253 is in the maximum clockwise position.

2. Insert a drawout test plug, connected as shown in Fig. 13, in the bottom network unit. Turn the local test to "IN". Gradually decrease the test resistance and note the current at which the amber test lamp lights. This should be between 2.8 and 3.1 amperes or 93 and 103 percent of the desired phase-to-phase fault current setting.

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

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

E22   GROUND CURRENT PICKUP (SET)

1. Calculate the tap setting required as outlined in SECTION H3.

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

CAUTION: RELAY TEST SWITCH
MUST NOT BE TURNED TO
"NORMAL" POSITION WHEN
THIS CONNECTION IS USED.

BOTTOM TEST PLUG
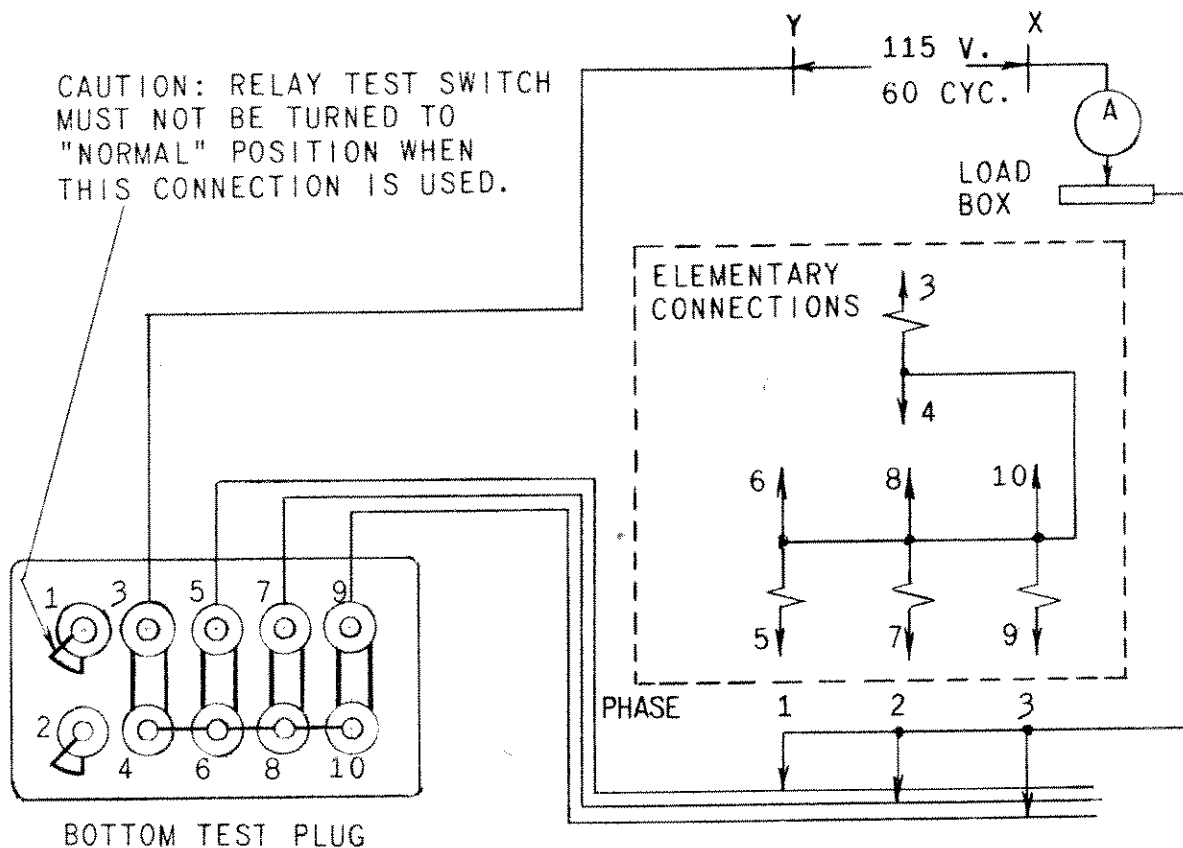
PHASE TO GROUND PICK-UP NETWORK UNIT L-6418096

OUTER CIRCLES REPRESENT STUD CONNECTIONS (RED)
INNER CIRCLES REPRESENT RELAY CONNECTIONS (BLACK)

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

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 the d-c amplifier plate current (meas-
ured at J8 for V10) with the remote relay test
switch on "IN" and the local relay test switch on
'NORMAL". This plate current in microam-
peres, multiplied by 0.68 is the blocking voltage
on the comparer control grid. 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 trans-
mitter, 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 pro-
cedure.

24

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 J14 of this book.

E25   GROUND-CURRENT PICKUP (CHECK)

With the relay test switches in the "OFF" position, apply 60 cycle current 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 times FD-H pickup. Phase 2 gives the highest pickup, therefore no check is necessary on phases 1 or 3. Tap values are multipliers of the FD-H relay element pick-up setting.

E26   NETWORK BALANCE (CHECK)

With the relay test switches at both ends of the line in the "OFF" position, and with the milliammeter switches 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 picked up at 1.05 times phase-to-phase pick-up setting increasing from zero, and dropped out at 0.8 times phase-to-phase pick-up setting. Normal values are 2.5 and 3.2 amps respectively. Pickup is the current at which the tripping unit lights the amber lamp.

This trip point should be checked with each of the three drawout plug connections indicated on Fig. 8. All three should be within 10 percent of the highest values. If the difference is excessive, the network should be rebalanced in accordance with SECTION J2 and the three trip points should be checked again.

E27   THREE-PHASE TRIP POINT (CHECK)

The three-phase trip point may be checked by means of a balanced ($\pm$ 2V) 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.

The test connection in effect produces a current (I_1) through T202 winding 12-13 which leads the current (I_2) through T201 winding 5-6 by 120 degrees.

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 provided proper phase sequence

CAUTION: RELAY TEST SWITCH MUST NOT BE TURNED TO "NORMAL" POSITION WHEN THIS CONNECTION IS USED.

BOTTOM TEST PLUG

3-PHASE TRIP POINT NETWORK UNIT L-6418096
OUTER CIRCLES REPRESENT STUD CONNECTIONS (RED)
INNER CIRCLES REPRESENT RELAY CONNECTIONS (BLACK)
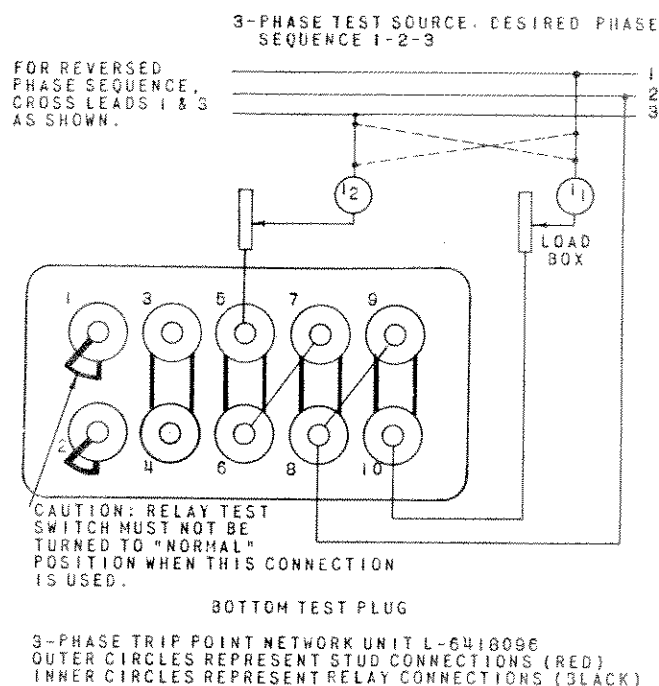
Fig. 15   Drawout Test Connections For Three-Phase Trip Point Check

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_1 at 7.5 amps or 0.95 times the desired 3 phase trip point, and read I_2. Compare the reading I_2 with the reading 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 they are energized with current above their pick-up setting.

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 or .95 times the three-phase trip point. The amber light going on or off during these adjustments does not indicate the three-phase trip point, but it should be off when the .95 and .50 times 3 phase pickup values have been obtained. Increase I_2 until the amber lamp lights and 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 (.95 X pu) to obtain a new trial value.
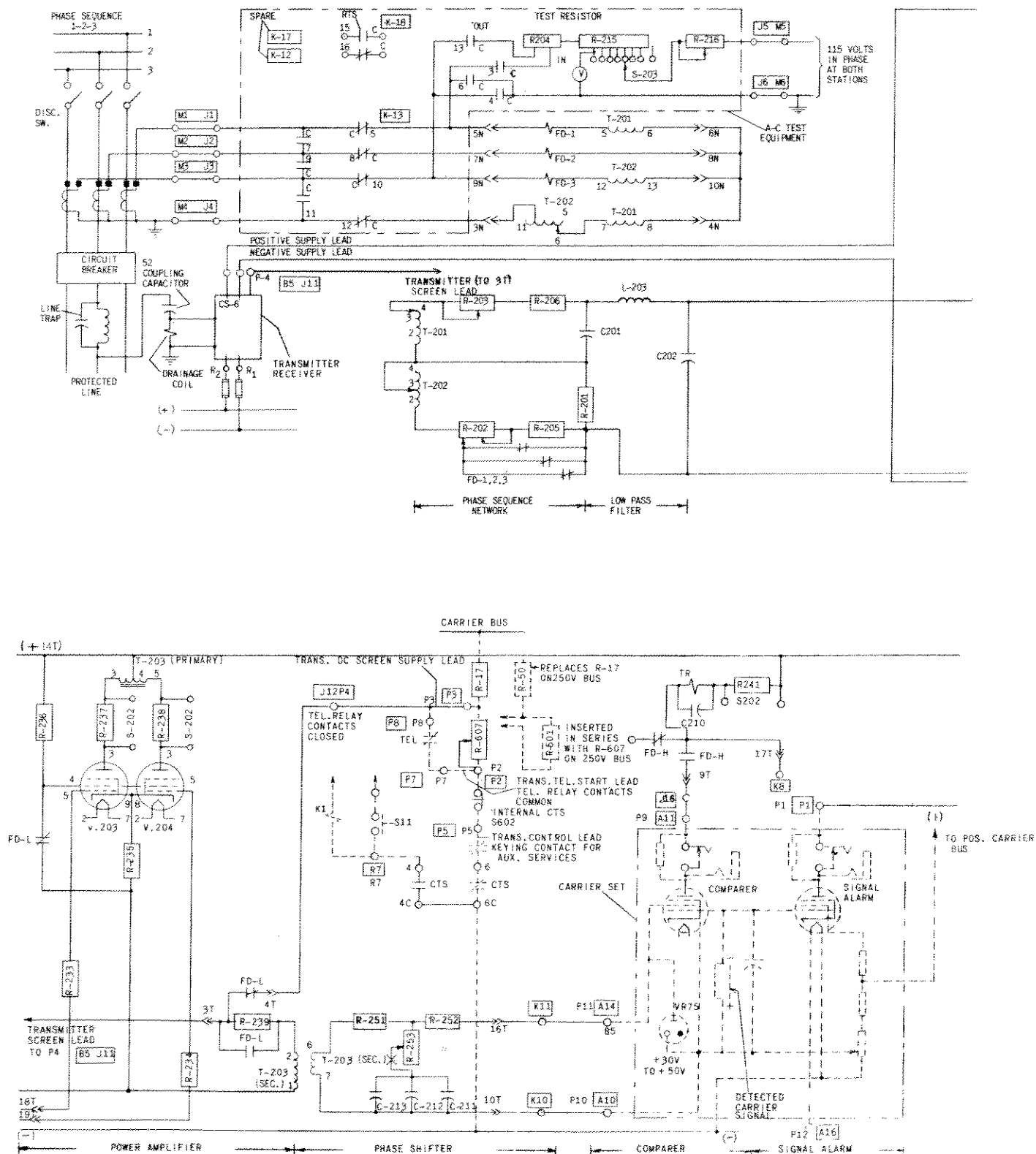
Fig. 16 Elementary Diagram For Phase-Comparison Pilot Relaying

Fig. 16   (702IB50)

Fig. 16 (Cont'd.)   Elementary Diagram For Phase-Comparison Pilot Relaying

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	TRIP COIL ON CIRCUIT BREAKER
TR	TRIPPING RELAY
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.
83 — 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 PER DD-7667325.

R₁ C₁ — NUMBERS NOT IN BLOCKS APPLY TO PANEL-MOUNTED RELAYS PER DD-7667352.

STUD LOCATION
NETWORK UNIT
(BACK VIEW)

STUD LOCATION
TRIP UNIT
(BACK VIEW)

Fig. 16 (7021B50)

Fig. 16 (Cont'd.)   Elementary Diagram For Phase-Comparison Pilot Relaying

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 the process until the correct 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 should nor-

mally be between 2.6 and 2.8 times the average phase-to-phase pickup current value. If adjustment is required, see SECTION J7 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.

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 40C 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.
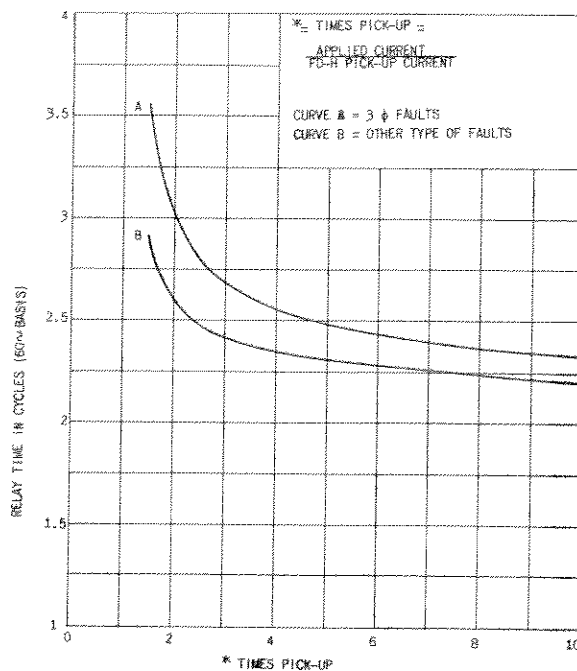
Fig. 17   Time Overcurrent Curve For Type EDD12 Relay

(side margin, rotated) Fig. 17 (K-6565510)

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 conditions at the two ends. See Figs. 18 and 19.

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 G3.

NETWORK UNIT

G2

G3 NEGATIVE-PHASE-SEQUENCE NETWORK FIG. 16

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

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

where K depends on the tap setting of T202 and K_3 is a constant of proportionality.

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.

G4 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 and inserting R205. By further analysis similar to that mentioned above, it can be shown that the network output for a fault not involving ground is then

$$E \text{ output} = K_3 a I_{3\emptyset} \ (C-1)$$

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 and "a" is the vector operator. This provides an output voltage in case of a balanced three-phase fault.

G5 OUTPUT FILTER FIGS. 16 AND 1

Since harmonics of the power-frequency current are magnified in the transactor, a simple 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. 16 AND 1

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. 16 AND 2

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 (R209-R210). A modulating signal is applied to the transmitter as soon as the FD-L 'b' contact

opens, which normally shorts the power amplifier screens to the negative bus. 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.

The connection of the diode RG201 and resistor R256 across the FD-L coil insures a 2 cycle delay in dropout of FD-L relative to that of FD-H.

G8   FAULT DETECTOR-HIGH (FD-H) FIGS. 16 AND 2

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. 16 AND 2

The power amplifier is driven by substantially a square wave from the voltage amplifier of the 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. 16 AND 2

The phase shifting network, consisting of R-251, R-252, R-253, C-211, C-212 and C-213 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-FIGS. 16 AND 2

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

The screen grid of the local 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. 18 and 19

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. 18 and 19

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. 20. Phase-comparison tripping time is shown in Fig. 17.

The 3 phase fault tripping time is greater then for other types of faults because the operating time of the phase fault detectors is added.

G15   SIGNAL ALARM AND SIGNAL ALARM-RELAY ELEMENT, SA., FIGS. 16 AND 2

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.

STATION F

CURRENT TRANSFORMERS

BREAKER

LINE TRAP

COUPLING CAPACITOR

LOCAL CARRIER

FAULT DETECTOR LOW (FD-L)

INCOMING CARRIER

NETWORK AND AMPLIFIER

CARRIER-CURRENT TRANSMITTER

A

MODULATION VOLTAGE

INTERNAL FAULT   EXTERNAL FAULT

B

CARRIER CURRENT

CARRIER-CURRENT RECEIVER

RESTRAINING VOLTAGE

OPERATING VOLTAGE

C

D

TRIPPING-RELAY CURRENT

COMPARER

E   FD-H

TO TRIPPING RELAY OF CIRCUIT BREAKER AT STATION F

NETWORK & AMPLIFIER   WHEN A FAULT OCCURS, THE SECONDARY CURRENTS FROM THE TRANSFORMERS ARE CONVERTED BY THE NET-WORK 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 CONTROL GRID OF THE COMPARER

FAULT DETECTOR LOW (FD-L) DETERMINES THE MINIMUM LEVEL OF FAULT CURRENT TO START TRANS-MISSION 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. 18   (K-6556482)

Fig. 18   Operation Of Phase Comparison Relaying

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Fig. 19   (K-6556482)

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 TRANS-
MITTER AT STATION G IS
REVERSED WITH RESPECT TO THAT
AT STATION F. THUS, FIRST ONE
END AND THEN THE OTHER TRANS-
MITS 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. 19   Operation Of Phase Comparison Relaying

Fig. 20   Phase-Angle Characteristics For Type EDD Relay

The SA element (L-6418025 G122) has a maximum of 0.16 seconds time delay dropout to prevent false operation by dropping out on transients. When SA is used in telemetering the instantaneous type element (L-6418025 G84) should be used. Since the relay is of a plug-in construction, replacement is simplified.

G16   TRANSIENT BLOCKING-RELAY ELEMENT, RB, FIGS. 16 AND 2

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, TR will pick up and thus de-energize RB before RB picks up.

G17   SEAL-IN UNIT, SI. FIGS. 17 AND 2

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 TR and RB to insure positive closing of 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.

G18   D-C TEST EQUIPMENT
FIGURES 3 AND 17

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.

G19   A-C   TEST   EQUIPMENT
FIGURES 3 AND 16

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 voltmeter. 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 and still allows a blocking signal to be transmitted. 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.
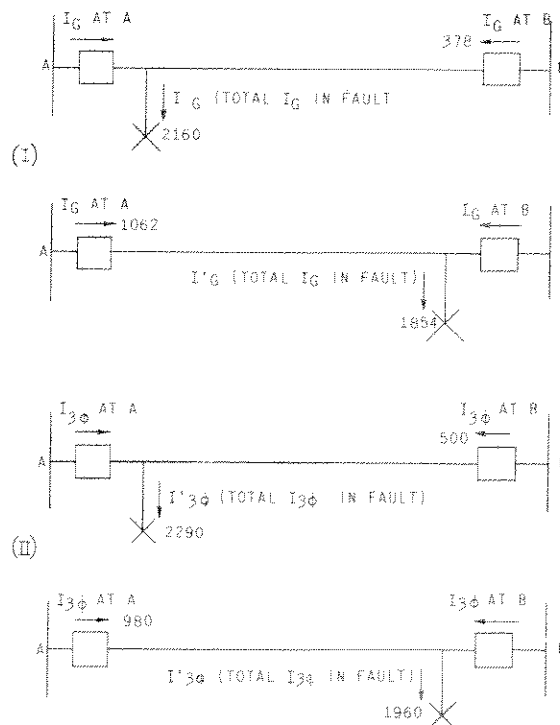
Fig. 21   (I) Ground Fault Currents And (II) Three-Phase Fault Currents

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 amber 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)

H1   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.

H2   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 unless a higher threshold value as determined by the phase fault detectors is used, 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 (one or more); the resulting higher minimum trip is considered satisfactory by the user; only one circuit breaker need be tripping at either end since it is possible for just one terminal Fault Detector-High (FD-H) to be picked up; sequential tripping is satisfactory.

This threshold value may be obtained by removing the panel wiring (jumper marked "For ground relay use" on Fig. 16) across the "a" contacts of the phase-fault detectors FD1, FD2, and FD3. If ground currents for a far end ground fault are less than the phase-fault detector pick-up settings, a more sensitive ground relay, such as a Type PJC, should be used. The "a" contacts of this ground-fault detector should be connected in parallel with the phase-fault detectors "a" contacts.

3. The maximum load current due to the line tap must not exceed 0.5 times the difference between

the pickup of the phase fault detectors FD1-3 and the 3$\emptyset$ fault pickup of FD-H.

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 ground current excitation. Under all other internal ground-fault conditions, the ground current 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 ground current are easily determined from the three-phase and single-phase-to-ground short-circuit currents, which must be known for any overcurrent relay application. The determination of these values does not require an understanding of 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	18
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 ground 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. The total ground current (I'$_G$) is three times the total zero-phase sequence component of current (I'$_0$) for single-phase-to-ground faults. In the example, ground current values will be used.

(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 ground currents flowing into the line at each end and the total ground 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 phase current magnitudes at both ends and in the fault. Use the transient reactance of generators to determine these current magnitudes.

CALCULATING SECONDARY FAULT CURRENTS

(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$_G$ = the ground current at the end under considerations for a single-phase-to-ground fault.

I'$_G$ = the total ground current in the single-phase-to-ground fault.

I$_{3\phi}$ = the phase current at the end under consideration for a three-phase fault.

I'$_{3\phi}$ = the total phase current in the three-phase fault.

I$_{PU}$ = phase-to-phase fault pick-up current of FD-H.

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.

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 conditions for which the results apply.

(2) Fig. 21(I) illustrates these quantities, and shows the particular values assumed for this example.

(3) Fig. 21(II) 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'$_G$ = 2160/60 = 36,   I$_G$ = 378/60 = 6.3

I'$_G$ - (I$_G$ at B) = (I$_G$ at A)

36 - 6.3 = 29.7

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

---

* 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).

H6   EXPLANATION (Cont'd)

TABLE V

Current Designation	Fault at A		Fault at B	
	Col. 1 Relay B	Col. 2 Relay A	Col. 3 Relay A	Col. 4 Relay B
I'_G	36	36	30.9	30.9
I_G	6.3	29.7	17.7	13.2
$I'_{3\phi}$	38.1	38.1	32.6	32.6
$I_{3\phi}$	8.3	29.8	16.4	16.2

Notice that the value of I'_G for a given fault location is listed for both relays. The value of $I'_{3\phi}$ 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.

CALCULATING CONSTANTS R AND D

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

$$R = \frac{3I'_{3\phi}}{I'_G} - 2$$

(5) For Column 1 of Table V

$$R = 3(38.1/36) - 2 = 1.175$$

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.

$$D = \frac{I'_G \times I_{3\phi}}{I_G \times I'_{3\phi}}$$

(6) Using the values I'_G, I_G, $I'_{3\phi}$ and $I_{3\phi}$ 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.

$$D = (36 \times 8.3)/(6.3 \times 38.1) = 1.25$$

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 $D = C_p/C_o$.)

CALCULATING MULTIPLE OF PICKUP (M) (NOT INTRODUCING GROUND CURRENT)

(7) THREE PHASE FAULTS

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:

$$M = \frac{0.375 I_{3\phi}}{I_{PU}}$$

(7) Using the values in the $I_{3\phi}$ row of Table V we get the following values of M:

$$M = 0.375 \times 8.3/3 = 1.04$$

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

H_6 EXPLANATION (Cont'd.)

(8) PHASE TO PHASE FAULTS

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

$$M = 0.865 I_{3\phi} / I_{PU}$$

H_7 EXAMPLE (Cont'd.)

(8) Using the values in the $I_{3\phi}$ row of Table V, we get the following values of M:

$$M = 0.865 \times 8.3/3 = 2.40$$

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

(9) SINGLE PHASE TO GROUND FAULTS

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

$$M = 0.577 \, D \, I_G / I_{PU}$$

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

$$M = 0.577 \times 1.25 \times 6.3/3 = 1.52$$

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) TWO PHASE TO GROUND FAULTS

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

$$M = 3\sqrt{3} \; R I_{3\theta} / (1 + 2R) (I_{P.U.})$$

(10) Using the values of R and $I_{3\theta}$ from Column 1 of (5) and (4), we get the following value of M:

$$M = (1.732 \times 1.175 \times 8.3) / \left[(1 + 2 \times 1.175) \, 3\right] = 1.68$$

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.

(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. For this condition, ground current tap adjustment for ground faults is not required and K = 0 as shown in (17). The multiplied-by-two tap is used in this case only.

(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.

H_6   EXPLANATION (Cont'd.)

(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 ground current flowing into the line at both ends for all ground faults on the line with the breakers at both ends closed.

CALCULATION OF MINIMUM VALUE OF K

(14) SINGLE-PHASE-TO-GROUND FAULT

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:

$$K = 2.45D$$

(15) TWO-PHASE-TO-GROUND FAULTS

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:

$$K = 2.45 DR$$

H_6   EXAMPLE (Cont'd.)

(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 $I_{3\phi}$ 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 2.45 D 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

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H6 EXPLANATION (Cont'd.)

(16) SINGLE-PHASE-TO-GROUND FAULTS

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:

$$K = \sqrt{3}\ D + 3MI_{PU}/I_G$$

where M = the desired multiple of pickup.

(17) TWO-PHASE-TO-GROUND FAULTS

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:

$$K = \sqrt{3}\ \frac{DR + DM\ (1 + /2R)\ I_{PU}}{I_{3\emptyset}}$$

K	21	15	11	8	6	0
Tap	0.17	0.23	0.33	0.47	0.67	2.0

(18) Determine by comparison the highest of the four highest values found in (14), (15), (16), and (17). Select the tap to use by the above table equal to this or higher.

For K = 0, use the multiplied-by-two tap.

(19) CALCULATING MULTIPLE OF PICKUP (INTRODUCING GROUND CURRENT)

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

$$M = \frac{(K - \sqrt{3}\ D)\ I_G}{3I_{PU}}$$

H7 EXAMPLE (Cont'd.)

(16) Using the values of D and I_G from Co 1 of (6) and (4), and assuming M = 2.0 to get tw three cycle tripping, we get:

$$K = 1.73 \times 1.25 + 3 \times 2 \times 3/6.3 = 5.01$$

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

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay
5.01	2.24	2.54	3.3

(17) Using the values of D, R, and $I_{3\emptyset}$ Column 1 of (6), (5), and (4), and assuming M we get:

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

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

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay
5.59	2.57	2.83	3.7

(18) The four highest values to be consi are 3.06, 3.61, 5.01, and 5.59, so the value o be used in setting the relay must be 5.59 or m

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

Tap = 0.67.

Relay ground current PU = 0.67 x 3
= 2.01 amp:

(19) Using the value of available K final lected in (18), and the values of D and I_G from umn 1 of (6) and (4), we get:

$$M = (6 - 1.73 \times 1.25)\ 6.3/(3 \times 3) = 2.6$$

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

Fault at A		Fault at B	
Relay B	Relay A	Relay A	Relay
2.68	14.5	8.81	5.8

40

H6   EXPLANATION (Cont'd.)

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

$$M = \frac{(K - \sqrt{3}\ DR)\ I_{3\emptyset}}{D\ (1 + 2\ R)\ I_{PU}}$$

H7   EXAMPLE (Cont'd.)

(20) Using the value of available K finally selected in (18), and the values of D, R, and $I_{3\emptyset}$ from Column 1 of (6), (5), and (4), we get:

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

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

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	Ground currents from ----		A	A	B	B
1d	Phase currents from ----		B	A	A	B
2a	I'_G Ground pri. Amp.	total for 2 ends	2160	2160	1854	1854
2b	I_G for 1-∅-G fault	this end only	378		762	
3a	$I'_{3\emptyset}$ Phase pri. Amp.	total for 2 ends	2290	2290	1960	1960
3b	$I_{3\emptyset}$ for 3∅ fault	this end only	500		980	
4a	C. T. Ratio		300/5	=60/1		
4b	I'_G Ground sec. Amp.	total for 2 relays	36	36	30.9	30.9
4c	I_G for 1-∅-G fault	this relay only	6.3	29.7	17.7	13.2
4d	$I'_{3\emptyset}$ Phase sec. Amps.	total for 2 relays	38.1	38.1	32.6	32.6
4e	$I_{3\emptyset}$ for 3∅ fault	this relay only	8.3	29.8	16.4	16.2
4f	I_{PU} ∅-∅ fault P.U. I of FD-H	this relay only	3	3	3	3
5a	$3I'_{3\emptyset}/I'_G$ (to 3 decimal places) = 3 (line 4d) / (line 4b)		3.175	3.175	3.165	3.165
5b	$R = (3I'_{3\emptyset}/I'_G) - 2$ = (line 5a)-2		1.175	1.175	1.165	1.165
6a	$3I_{3\emptyset}/I_G$ = (line 4e)/(line 4c)		3.95	3.01	2.78	3.68
6b	$D = (3I_{3\emptyset}/I_G) / (3I'_{3\emptyset}/I'_G)$ = (line 6a) / (line 5a)		1.25	0.948	0.88	1.16
7	M (for 3∅) = .375 $I_{3\emptyset} / I_{PU}$ =.375 (line 4e) / (line 4f)		1.04	3.72	2.05	2.02
8	M (for ∅-∅) = .865 $I_{3\emptyset} / I_{PU}$ = .865 (line 4e) / (line 4f)		2.40	8.61	4.74	4.68
9	M (for 1-∅-G) = .577 DI_G / I_{PU} = .577 (line 6b) (line 4c) /(line 4f)		1.52	5.40	3.00	2.95
10a	2R = 2 (line 5b)		2.35	2.35	2.33	2.33
10b	1 + 2 R = 1 + (line 10a)		3.35	3.35	3.33	3.33
10c	(1 + 2 R) I_{PU} = (line 10b) (line 4f)		10.05	10.05	10.0	10.0
10d	M (for 2-∅-G) = $\frac{\sqrt{3} \, RI_{3\emptyset}}{(1+2R) I_{PU}} = \frac{\sqrt{3} \, (line\ 5b)}{(line\ 10c)}$ (line 4e)		1.68	6.05	3.31	3.27

Calculations 14 to 20b Used Only If Ground Current Excitation Has To Be Used

		Col. 1	Col. 2	Col. 3	Col. 4
14	K (for 1-∅-G) = 2.45 D = 2.45 (line 6b)	3.06	2.32	2.16	2.84
15	K (for 2-∅-G) = 2.45 DR = (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	3 MI_{PU} / I_G = 3 M (line 4f)/(line 4c)	2.86	0.60	1.02	1.36
16c	K(for 1-∅-G) = $\sqrt{3}$ D+3 MI_{PU}/I_G = (line 16a) + (line 16b)	5.02	2.24	2.54	3.37
17a	$\sqrt{3}$ DR = (line 16a) (line 5b)	2.55	1.93	1.78	2.33
17b	I_{PU} D = (line 4f) (line 6b)	3.75	2.84	2.64	3.48
17c	I_{PU} D (1 + 2R) = (line 17b) (line 10b)	12.6	9.53	8.79	11.50
17d	I_{PU} MD (1 + 2R) / $I_{3\emptyset}$ = M (line 17c) / (line 4e)	3.04	0.64	1.07	1.42
17e	K(for 2-∅-G) = $\sqrt{3}$ DR+I_{PU} MD (1+2R)/$I_{3\emptyset}$= (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-∅-G)=(K-$\sqrt{3}$ D)I_G/(3I_{PU})=(line 19a)(line 4c)/3(line 4f)	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-∅-G) = (K- $\sqrt{3}$ DR)($I_{3\emptyset}$)/I_{PU}D (1+2R) = (line 20a) (line 4e) / (line 17c)	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, all of the following points should be observed in making adjustments. If tubes are to be replaced the adjustments as described in section J8 only need be considered. The current values used in the following paragraphs are normal factory settings. The current frequency is 60 cycles.

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

J1   NETWORK UNIT

J2   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.

J3   FAULT DETECTOR-LOW (FD-L)

Apply 2 amperes, or desired current value at which blocking should be initiated, from terminals J_1 to J_2 or studs 5N to 7N. Turn the selector switch, in the network unit to FD-L and adjust the potentiometer to obtain sufficient plate current to pick-up FD-L. If the plate current is 4.3 milliamperes or less and the dropout of 2 milliamperes or more the telephone relay requires no adjustment.

If adjustment is required refer to instructions described in Sections J_{12} and J_{16}.

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

J4   FAULT DETECTOR-HIGH (FD-H)

Set similar to FD-L as described in Section J3 except apply 3 amperes or the desired $\emptyset$ to $\emptyset$ tripping current. The drop-out current should be 2.7 milliamps or higher.

TUBE SOCKET VOLTAGES

These voltages may be measured, as in Section J3, and are the same as those listed for V-202.

J5   NETWORK BALANCE CHECK ($\emptyset$ to $\emptyset$ PICKUP)

Connect and check as outlined in Section E_{26}.

J6   PHASE-FAULT DETECTOR PICKUP (FD 1-3)

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 unit picks up at 6.3 amps or 70 to 80 percent of the FD-H pick-up setting as the current is gradually increased. The dropout should be 5.7 amps or approximately 90 percent of the phase fault detector pick-up value when the current is gradually decreased.

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.

J7   FAULT DETECTOR (FD-H), THREE-PHASE PICKUP

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 J5, will pick up at 7.6 to 8.2 amperes, or from 2.6 to 2.8 times the average $\emptyset$-$\emptyset$ trip setting. Follow the test procedure outlined in SECTION E27 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 J2. The T-202 tap lead is connected to the tap terminal of R-202 and is tagged. The other tap leads are tagged and secured available for use. Recheck the phase-to-phase pickup according to SECTION J5, after which it will be possible to set the right slider for a lower three-phase pickup.

J8   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 E10 and E11.

Recheck the phase-to-phase blocking and tripping points as outlined in Sections E20 and E21.

J9   VOLTAGE AMPLIFIER

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

Tube Socket Voltages

These voltages may be measured as described in SECTION J3. With no input in 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

J10

J11   SIGNAL ALARM-RELAY ELEMENT, SA.

The signal alarm-relay element is adjusted t pickup at 6.0 milliamperes d-c, plus or minu 1 milliampere; and to dropout at 2.8 milliamperes plus or minus 0.3 milliampere. Refer to SECTIO J16 for adjustments.

J12   FD-L AND FD-H

The pick-up and drop-out adjustments of th FD-L and FD-H relay elements are described i SECTIONS J3, J4, and J16.

J13   TRIP-RELAY ELEMENT, TR

The trip-relay element is adjusted to pick up 2.2 milliamperes d-c, plus or minus 0.2 milliam pere; and to drop out at 1.4 milliampere, plus o minus 0.1 milliampere d-c. Refer to SECTION J1 for adjustments.

J14   TRANSIENT BLOCKING RELAY ELEMENT, RB

The method of checking the operation of thi relay element is given in SECTION E24.

If the relay element must be replaced, the pick up time with rated voltage across the coil and re sistor should be 0.029 to 0.036 second (1.8 to 2. cycles), and the drop-out time should be 0.063 t 0.077 second (3.8 to 4.6 cycles). The minimum pick-up voltage should be less than 80% of rate d-c voltage, but need not be adjusted to a particula value.

J15   POWER AMPLIFIER

Tube Socket Voltages

These voltages may be measured as describe in SECTION J3. With no input to the Network uni (relay test switch "OFF"), approximate values ar 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 shoul be 34 to 44 milliamperes with the FD-L picked uj For future comparison, record the values read wit the relay test switch in both the "NOR" and "IN" po sitions.

TRIPPING UNIT

J₁₆   PROCEDURE FOR TELEPHONE RELAY
       ADJUSTMENT

It is not recommended these adjustments be made unless absolutely necessary and by competent personnel.

If the pickup must be changed without decreasing the dropout value, the armature stop and the normally closed stationary contacts must be bent. Bending these toward the coil will increase the armature gap and therefore the pickup value. Bending them away from the coil will decrease the gap and pickup value. The stationary contacts should not be bent more than necessary, keeping the "b" contact

pressure at 15 grams or more and the contact gap not less than 1/64".

To increase or decrease both pickup and dropout values the moving contact springs should be bent toward or away from the coil, thus increasing or decreasing the back pressure against the armature.

To increase or decrease the difference between pickup and dropout without changing the contact gap, the residual screw should be run out or in. The armature arm should be bent toward or away from the coil to restore the contact wipe. With normal wipe, the normally open (a) contacts will close with a 5 millimeter but not a 7 millimeter feeler between the armature and pole pieces.

MAINTENANCE (SECTION K)

K₁   **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.

When the d-c fuses are to be drawn for any reason, it is necessary to have the relay test switch turned to the "TCO" position at both terminals to eliminate any possibility of false tripping.

K₂   PROCEDURE FOR TEST

The relay test switch contacts are arranged to prevent false tripping at either terminal regardless of test switch position or operation if the following is observed.

Arrangements should be made by telephone to turn the relay test switches at both stations to the "TCO" position before either is turned to the "OFF", "IN" or "OUT" positions. The trip circuits will then be open before either blocking carrier is removed. When the relay test switch at either terminal is turned from the "NOR" position, that terminal will be unable to send a blocking signal. The other terminal may trip in response to an external fault unless the relay test switch at that terminal is in the "TCO" position. This position allows a blocking signal to be sent but opens the trip circuits.

K₃   CHECK OF TRIPPING

With both switches in "TCO" position for reasons described in K₂, turn the switches at both ends of the line to "IN" at a pre-arranged time. Watch for the amber lights at both ends and return both switches to "OFF". When the switches at both ends are in like positions, either "IN" or "OUT", an internal phase-to-phase fault is simulated.

When both ends are in the "IN" position the test current will be sufficient to operate FD-H and light

the amber lamp. When both ends are in the "OUT" position the current will be sufficient to operate FD-L but not FD-H and therefore the amber lamp will not be lit, 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, however there is a slight risk of false tripping while this is being done.

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

K₄   CHECK OF BLOCKING

Starting with both relay test switches in "TCO" and the "OFF", one maintainer (X) will direct the other maintainer (Y) to turn his switch to "IN", thus lighting Y's amber lamp. When X hears the resulting 60-cycle hum in his receiver, he will turn his own switch to "OUT", and see that his amber lamp is not lighted in that position. He will then return his switch to "OFF". During this interval, Y should observe that his amber lamp is extinguished, by the "blocking" signal sent when X has his switch in the out position. After he sees it light again, he will return his switch to the "OFF" position.

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 ("IN" and "OUT"), 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 amber lamps.

NOTE: In test SECTION K₃ and K₄, 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

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SECTION K3 and zero for the test in SECTION K4. 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.

K5   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 E10, and E11 for necessary tests and adjustments when replacing a tube. Also it is

desirable to recheck the phase-to-phase bloc and tripping points as outlined in SECTIONS E20 E21.

K6   CONTACT CLEANING

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

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

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

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 unforeseem failure of parts. This also permits greater convenience and thoroughness in repairs.

The relay units may be ordered as:

Network Unit - I-6418096 G-5
Tripping Unit - L-6418095 G-5

For systems where fewer of these relays installed, cost will require that spares be lin to selections from the following list L1, whic arranged in the order of decreasing estim probability of failure. Parts should be order description as well as drawing number to a wrong shipments results from transposed digits

In L2 additional component parts are liste reference to assist in identifying part numbers appear on the internal connection and elemer diagrams.

L$_1$ ELECTRICAL SPARE 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-124
SA	Signal Alarm Relay	L-6418025 P-122
FD-L	Fault Detector-Low Relay	L-6418025 P-100
FD-H	Fault Detector-High Relay	L-6418025 P-101A
T	Tripping Relay	L-6418025 P-101
SI	Seal-in Unit	L-6293203
RG-201	Rectifier	G-E Cat. #IN48
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 15,000 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 (External) 3887725 G24	75 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 10W 1000 ohms
C-201	Network Capacitor	G-E Cat. No. 21F802 0.5 Mfd.
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

L₂

REFERENCE COMPONENT VALUES

Resistor	Ohms	Resistor	Ohms	Capacitor	Mfd.
R204	35	R226	63.7	C210	0.5
R207	1000	R229	0.605	C211	0.05
R208	1000	R233	470,000	C212	0.05
R209	5000	R234	470,000	C213	0.05
R210	5000	R235	200		
R211	10,000	R237	6.08		
R212	10,000	R238	6.08		
R214 A-B	75-75	R239	1500		
R214 C	75				
R215	35	R241	63.7		
R216	10	R242	12.2		
R217	100,000	R243	12.2		
R218	100,000	R247	1.21		
R219	134.5	R251	39,000		
R220	134.5	R252	10,000		
R221	250,000	R253	50,000		
R222	270,000	R254	1,500		
		R256	10,000		
R223	220,000	R301	22,000		
R224	470,000	R302	22,000		
R225	63.7				

Fig. 22 (K-6556431)
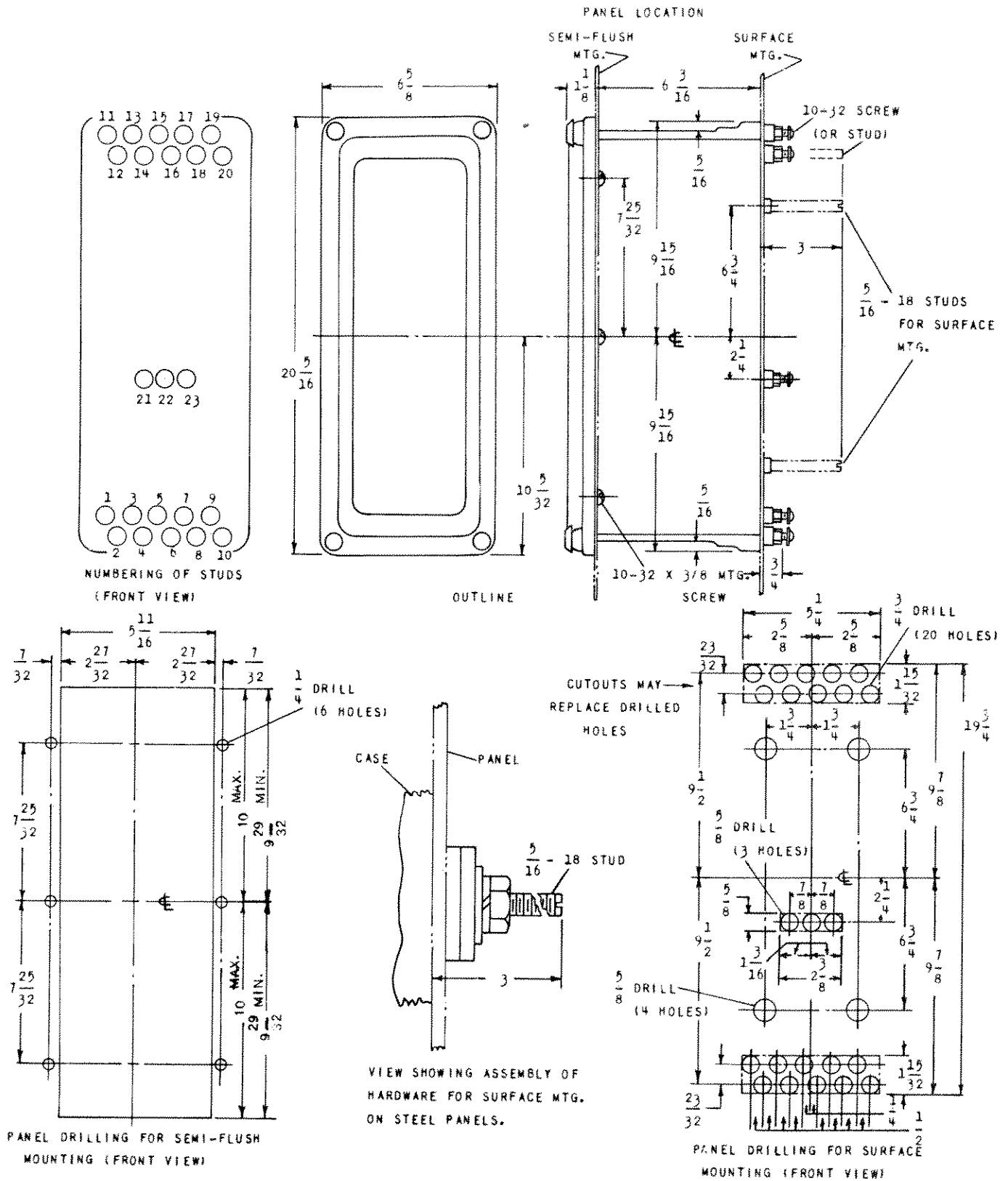
PANEL LOCATION

NUMBERING OF STUDS
(FRONT VIEW)

OUTLINE

VIEW SHOWING ASSEMBLY OF
HARDWARE FOR SURFACE MTG.
ON STEEL PANELS.

PANEL DRILLING FOR SEMI-FLUSH
MOUNTING (FRONT VIEW)

PANEL DRILLING FOR SURFACE
MOUNTING (FRONT VIEW)

Fig. 22 Outline and Panel Drilling Dimensions for Type EDD Relay Tripping Unit

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Fig. 23   Outline and Panel Drilling Dimensions for Type EDD Relay Network Unit
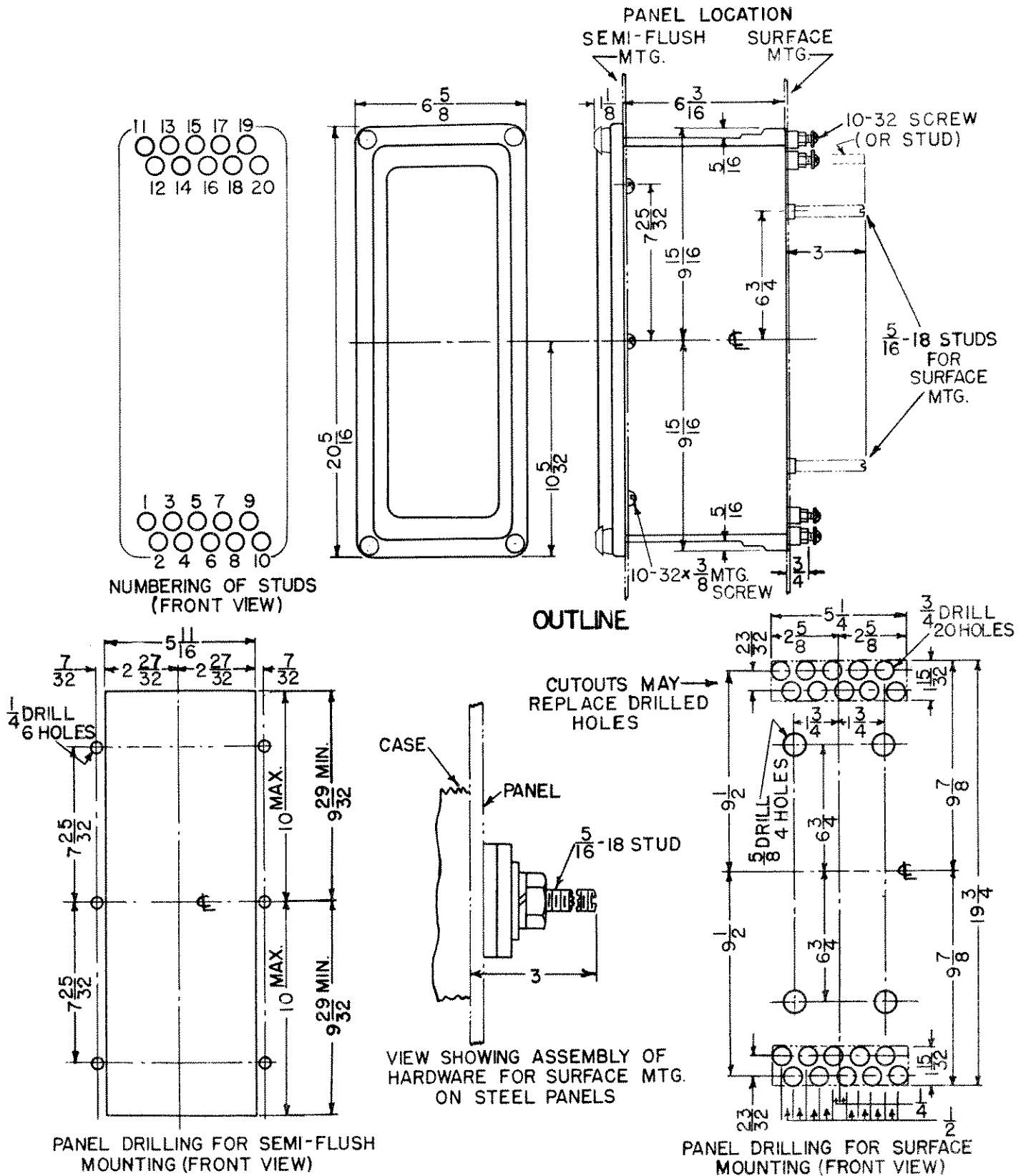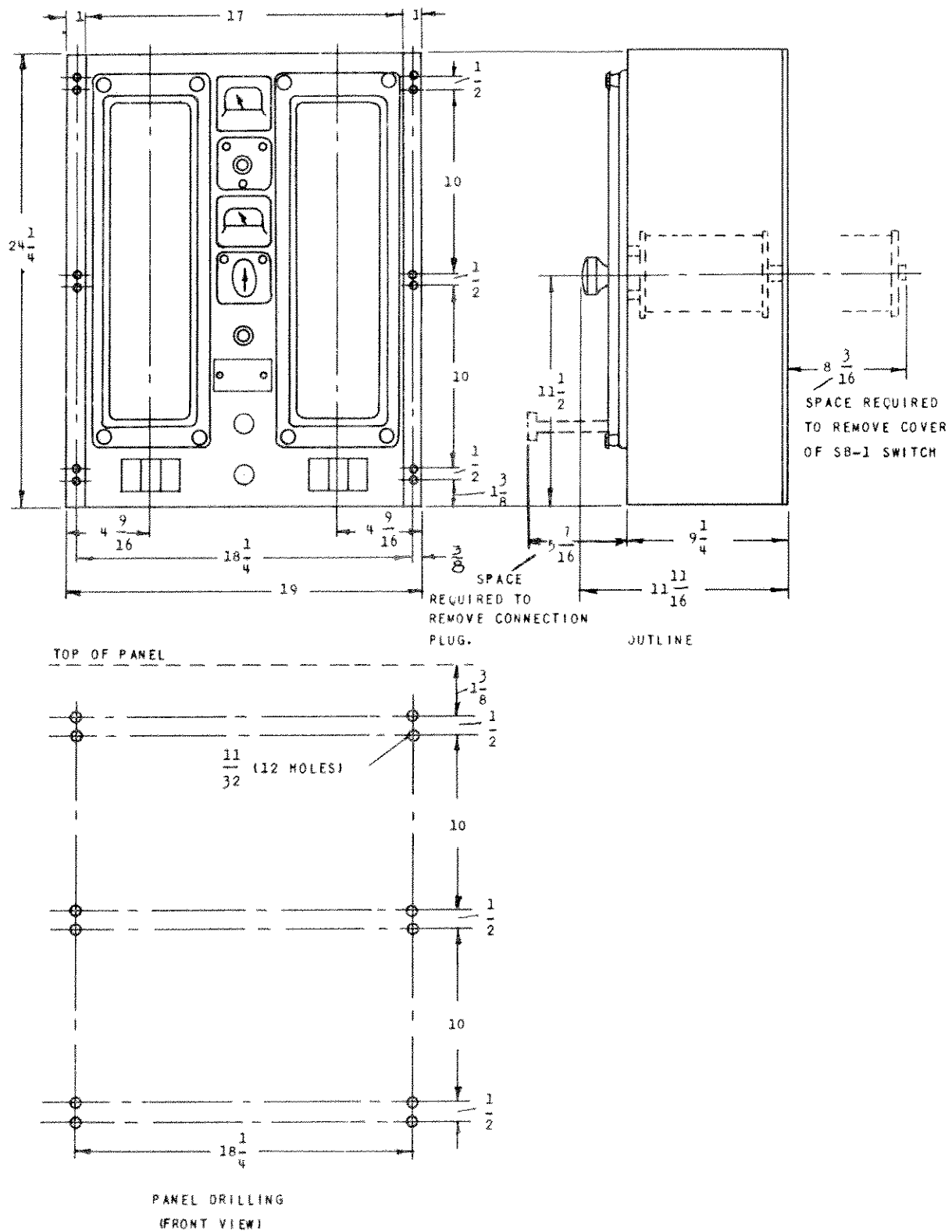
Fig. 24   (K-6556433)

Fig. 24   Outline and Panel Drilling Dimensions for Type EDD Relay Sub-Panel
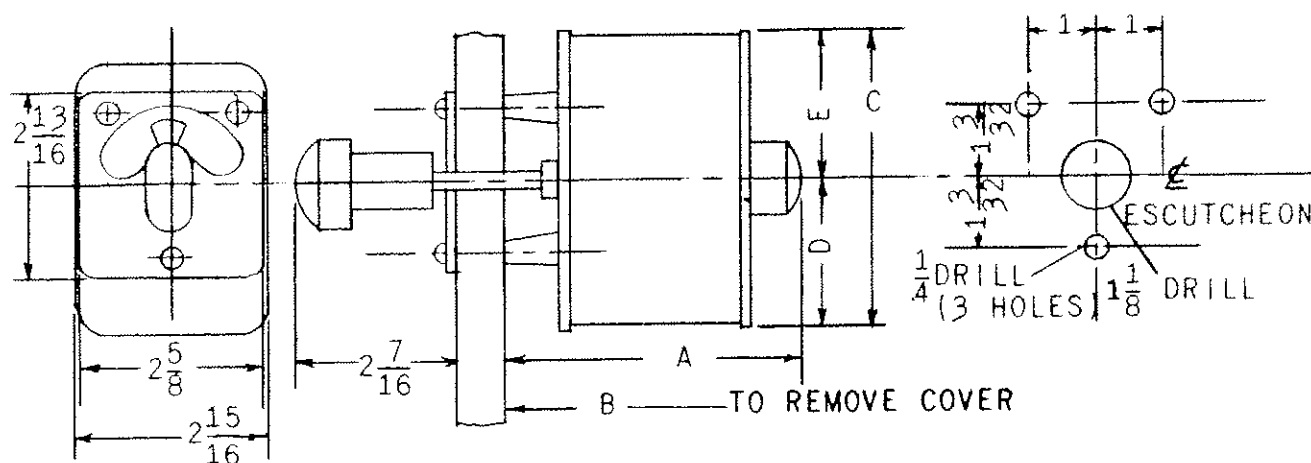
FIG	MODEL NO.	NO. OF STAGES	A	B	C	D	E
1	16SBICD455	3	$5\frac{13}{16}$	$10\frac{7}{16}$	$4\frac{1}{2}$	$2\frac{1}{2}$	2
2	16SBIHD512	8	$9\frac{1}{16}$	$16\frac{11}{16}$	$4\frac{15}{16}$	$2\frac{15}{32}$	$2\frac{15}{32}$

Fig. 25   Outline and Panel Drilling for Type EDD Relay Carrier Test Switch (3 Stage) and A.C. Test Switch (8 Stage)
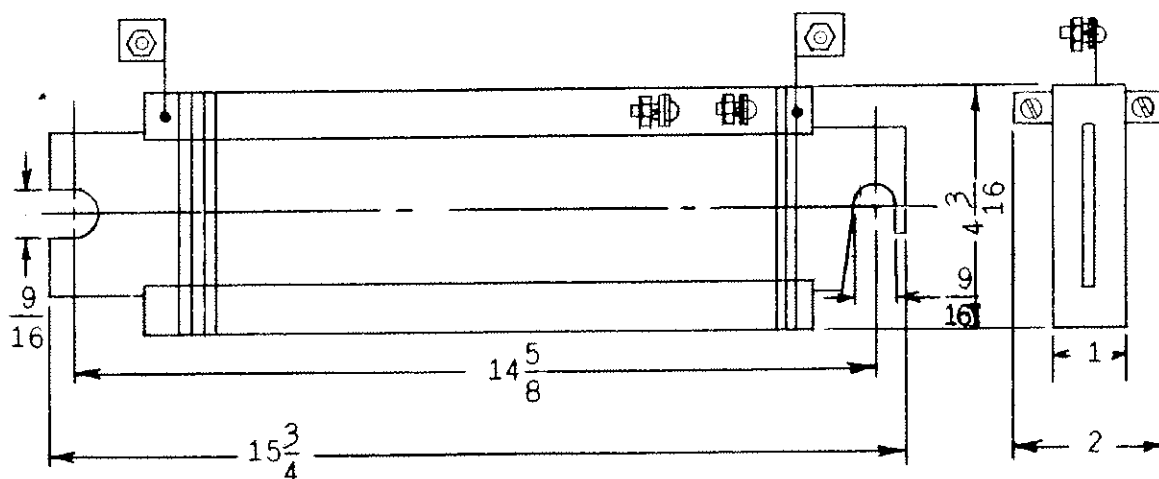
Fig. 26   Outline Dimensions for Type EDD Relay A.C. Test Resistor
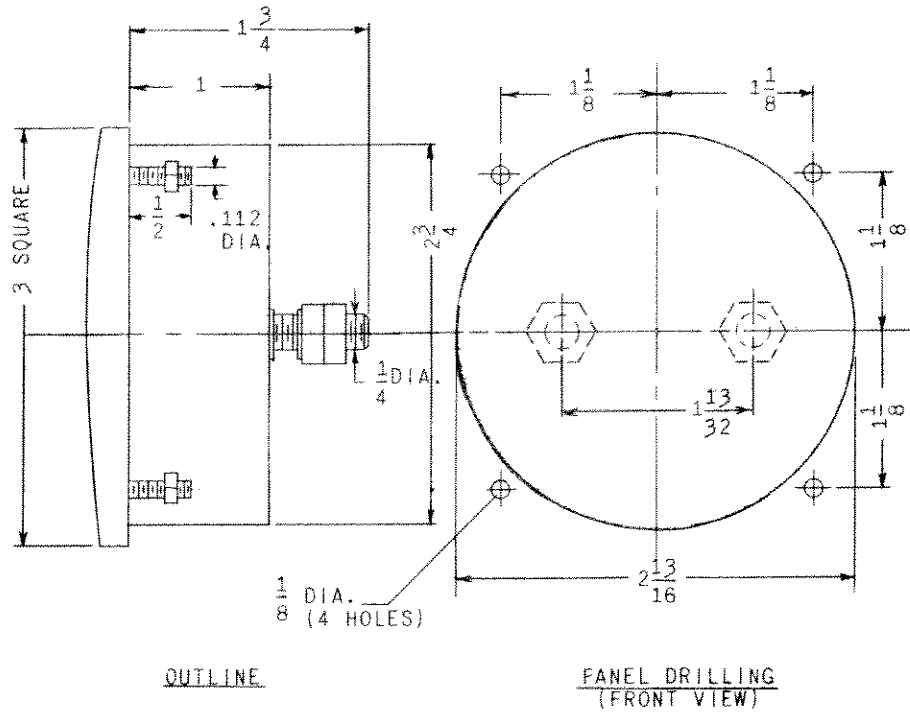
OUTLINE

PANEL DRILLING
(FRONT VIEW)

Fig. 27   Outline and Panel Drilling Dimensions for Type EDD Relay
Milliammeter Mounted on 1/8-1/4" Panels

OUTLINE ①

PANEL DRILLING ②

FOR MOUNTING ON INSULATING PANEL BY MEANS OF TERMINAL STUDS.
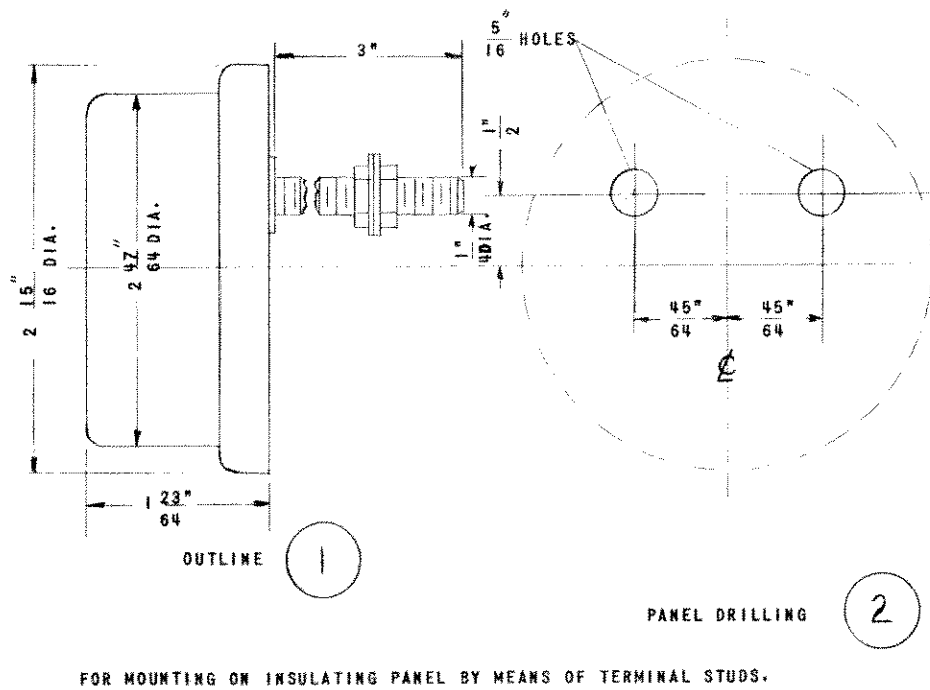
Fig. 28   Outline and Panel Drilling Dimensions for Type EDD Relay
Milliammeter Mounted on 1/4-2" Panels

Fig. 27   (377A198)

Fig. 28   (376A914)
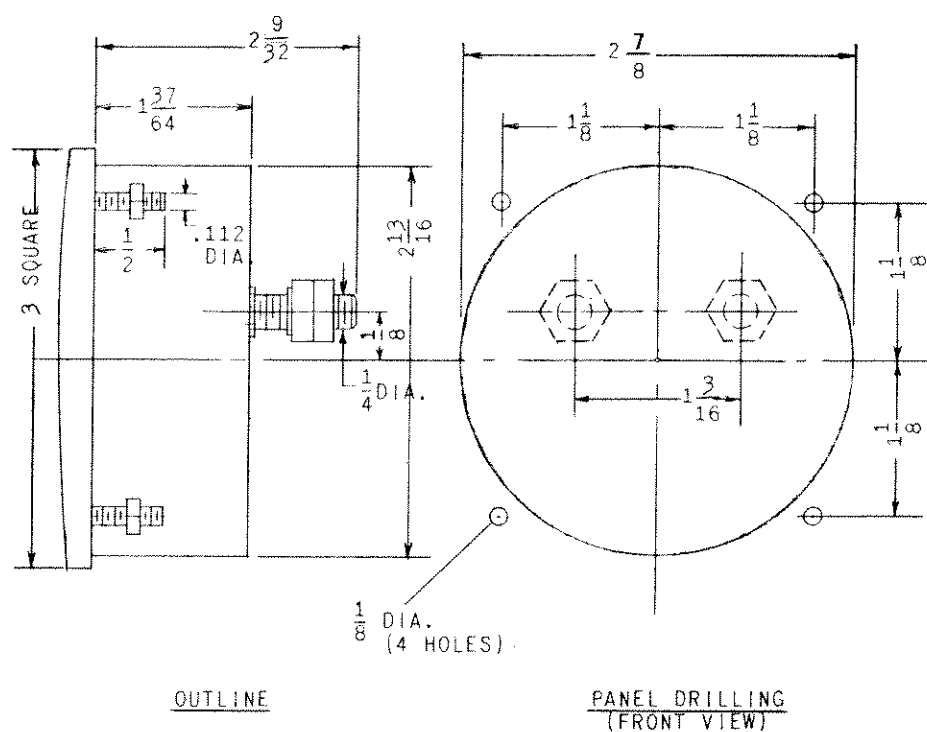
Fig. 29   Outline and Panel Drilling for Type EDD Relay Voltmeter Mounted On 1/8-1/4" Panels
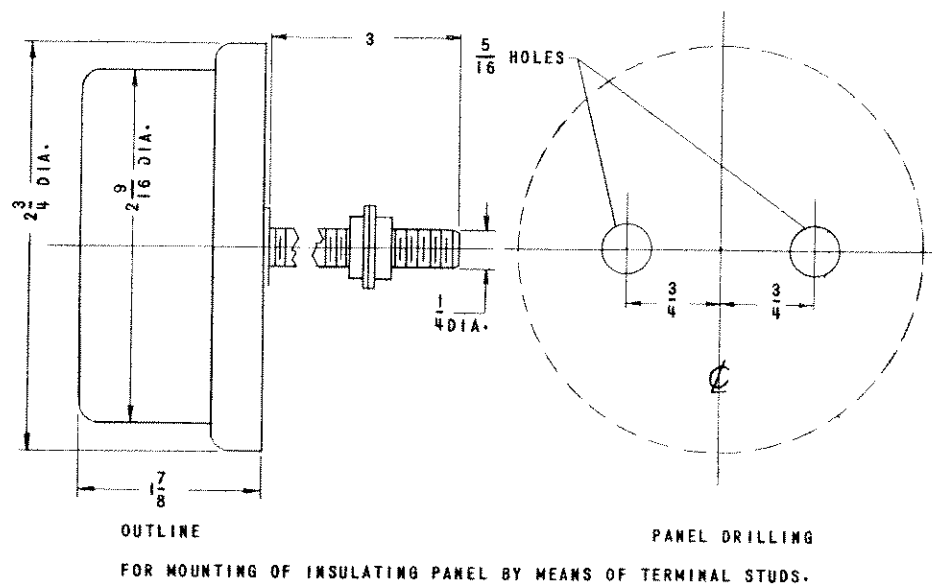
Fig. 30   Outline and Panel Drilling for Type EDD Relay Voltmeter Mounted On 1/4-2" Panels

Fig. 31   (K-6400638)

5 $\frac{1}{16}$

SCREWS FOR 1/8" TO 1" PANEL

OR FOR 1" TO 2" PANEL

$\frac{3}{8}$

$4\frac{1}{8}$

$\frac{1}{8}$

2 $\frac{13}{16}$

2 $\frac{5}{8}$

$\frac{1}{4}$" DRILL

(3 HOLES)

1

1

OUTLINE

1 $\frac{3}{32}$

1 $\frac{5}{8}$

1 $\frac{3}{16}$

1 $\frac{13}{16}$

2 $\frac{3}{8}$

1 $\frac{3}{32}$

$\frac{5}{16}$

M+

M-

RESISTOR

S+

S-

BOTTOM OF ESCUTCHEON

PANEL DRILLING

(FRONT VIEW)

INTERNAL CONN.

(BACK VIEW)
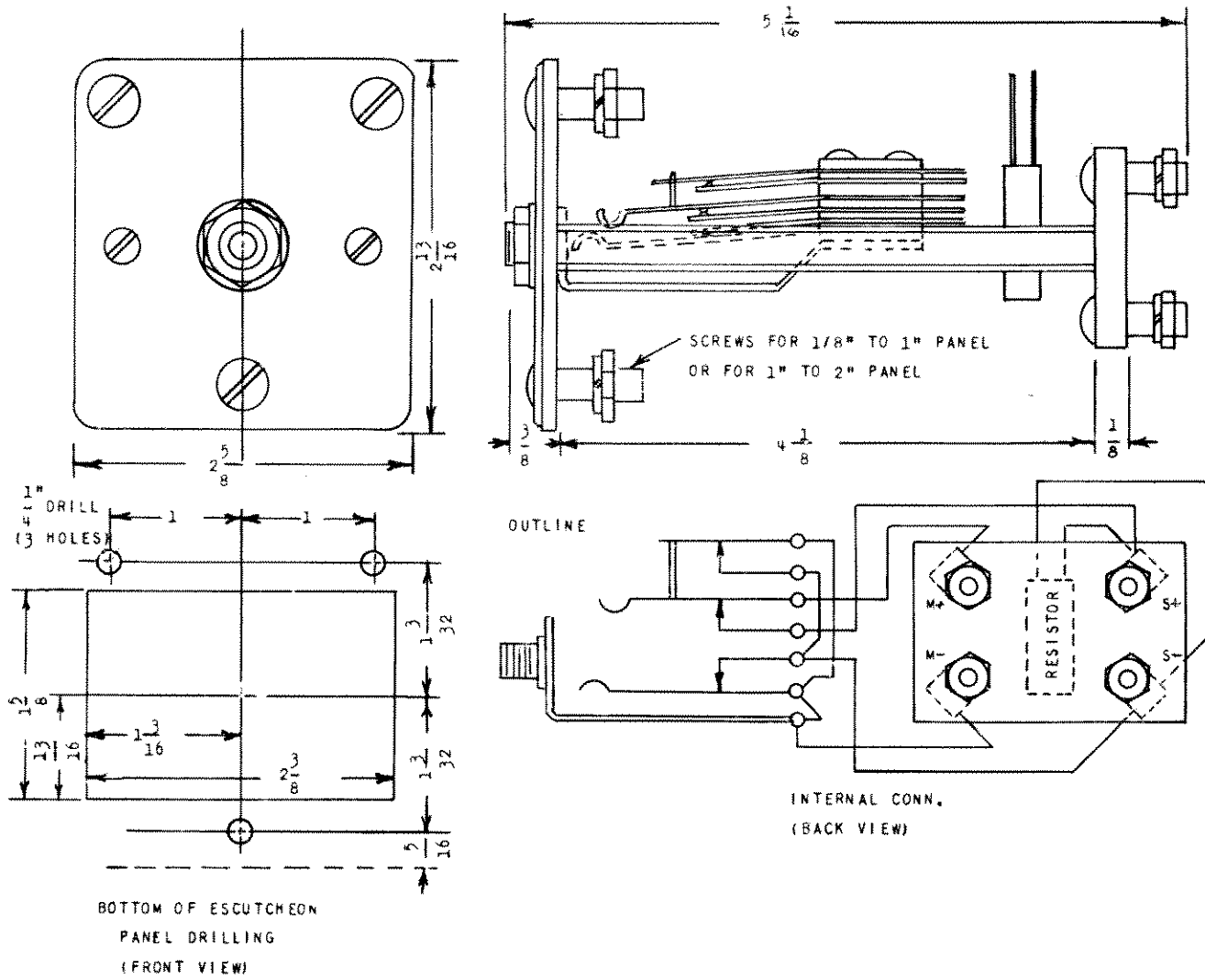
Fig. 31   Outline, Panel Drilling, and Internal Connections for Meter Jack
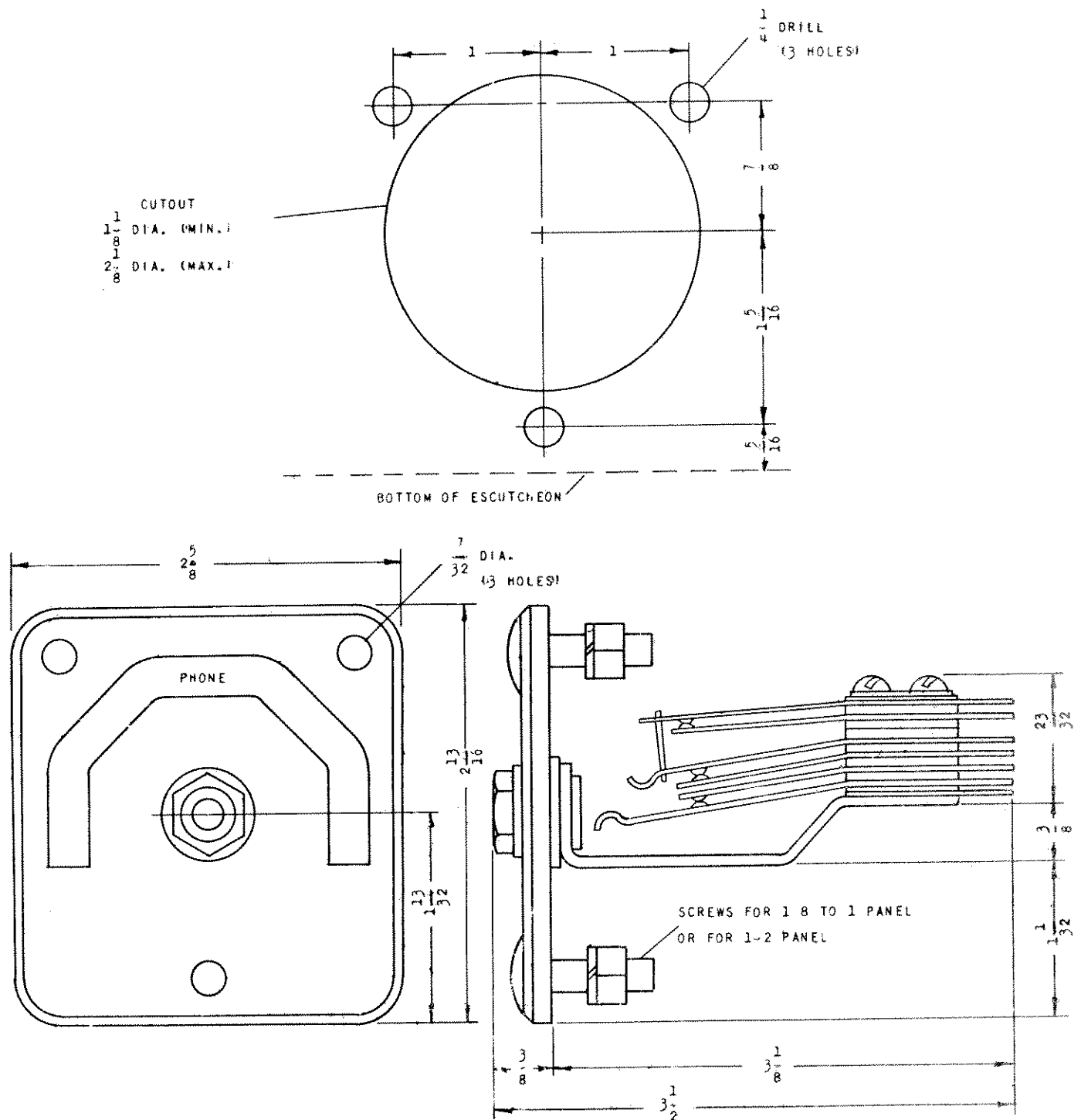
Fig. 32   Outline and Panel Drilling for Telephone Jack
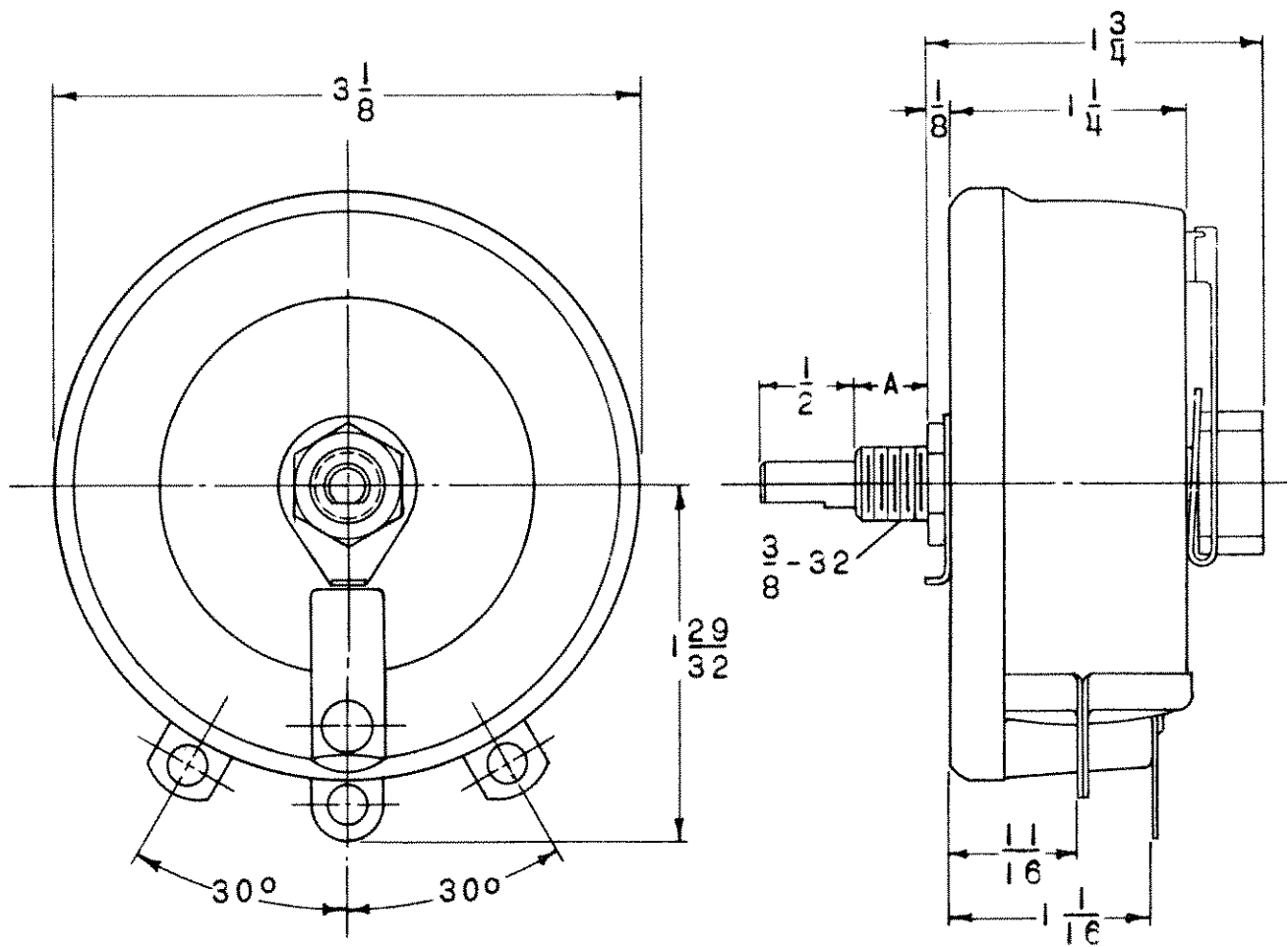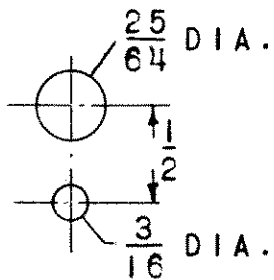
OUTLINE

PANEL DRILLING
(FRONT VIEW)

"A"	PANEL THICKNESS
3/8	1/8 TO 1/4
1 1/8	1"
2 1/8	2"

Fig. 33   Outline and Panel Drilling for Test Rheostat
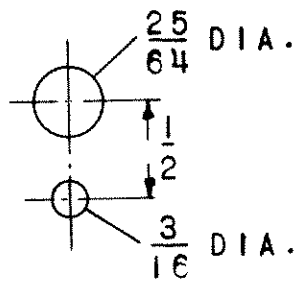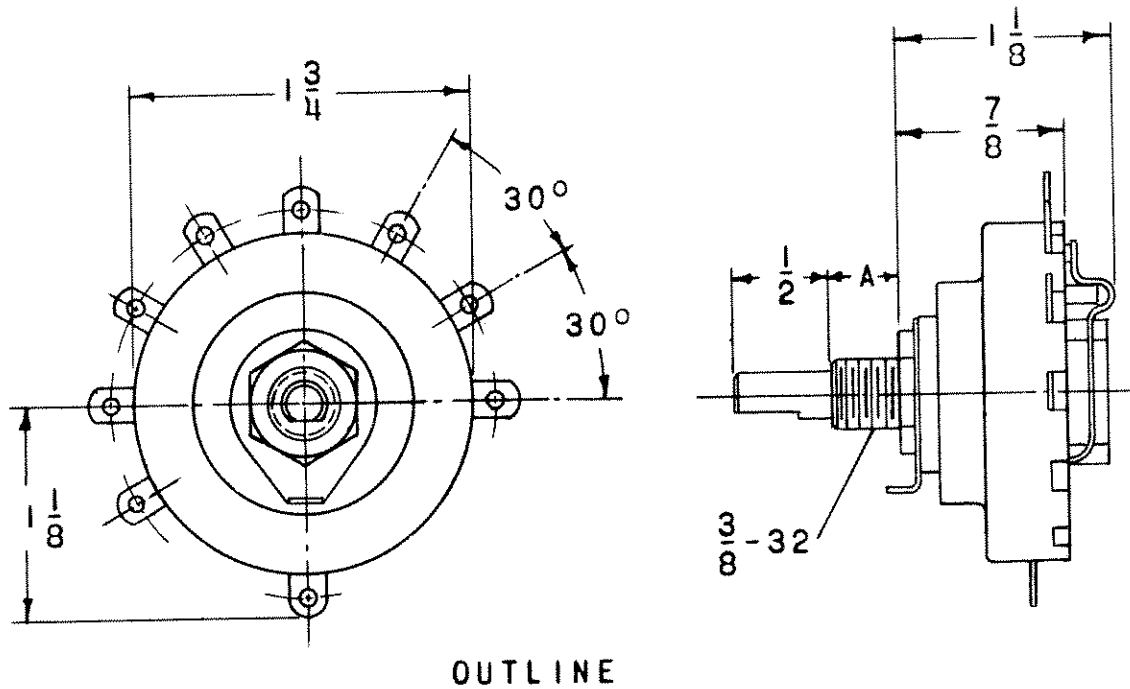
OUTLINE

PANEL DRILLING
(FRONT VIEW)

"A"	PANEL THICKNESS
3/8	1/8 TO 1/4
1 1/8	1"
2 1/8	2"

Fig. 34   Outline and Panel Drilling for Test Tap Switch

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