INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SDB STATIC BLINDER RELAY

Caution: It is recommended that the user of this equipment become acquainted with the information in this instruction leaflet before energizing the equipment. Failure to observe this precaution may result in damage to the equipment.

APPLICATION

The SDB is a static compensator relay used to:

1) Supervise a static distance relay to provide a restricted reach during load or swing conditions.

2) Provide sensing intelligence for the OS-1 or OS-2 out-of-step logic.

3) Operate a low energy level auxiliary relay to provide a contact closure for supervising an electromechanical distance relay to restrict the reach in the load area on an R-X plot.

The SDB characteristic consists of two essentially parallel lines (actually arcs of extremely large circles) which form an angle with respect to the R axis on an R-X plot which is adjustable from 60° to 90°. The factory adjustment is 75°. The parallel lines are equally spaced on each side of the origin of the R-X diagram. It has a normally conducting NPN transistor that ties the output terminal to negative when the relay is in the non-operate state. It operates when subjected to an ohmic value that falls between its two characteristic lines, providing a positive low energy level output.

The setting of the SDB defines the ohmic reach from the origin in a direction perpendicular to the characteristic lines.

CONSTRUCTION

The SDB relay consists of three air gap transformers (compensators), two center tapped auto-transformers, three phase shifting circuits, and three isolating transformers. The isolating transformers couple the ac quantities into the phase angle comparison unit. One large printed circuit assembly provides the characteristics of a dual polarized phase angle comparison unit and has a transistor output.

Compensator

The compensators which are designated I_{POL}, $+T_{AB}$, $-T_{AB}$ are three winding air-gap transformers (Fig. 4). There are two primary current windings, each having seven taps which terminate at the tap block. They are marked 1.51, 2.00, 2.50, 3.50, When Q10 conducts, a portion of the current goes through resistor R24. This current, I_{R24}, may take either of two paths to the negative bus. If QS1 is in a conducting state, I_{R24} passes through it directly to the negative bus. If QS1 is in a blocking state, I_{R24} passes through D16 and then through DZ4 to transistor Q9 to cause tripping. Thyristor QS1 is located in the "polarizing" circuit of the phase-to-phase unit. This circuit is driven by transformer T2.

To prevent the operate circuit from causing tripping, the polarity marked terminals of T2 must go positive before the polarity terminals of T1 do. This causes Q3 to conduct current through R22 and drive the base of Q13. Q13 then conducts current from the 13V bus through R9 to gate QS1 into conduction. When QS1 conducts, it short circuits the current which might otherwise pass through D16 to cause tripping. Once QS1 begins to conduct, the gate loses control and it remains in the conducting state until the current is turned off by Q10. No tripping output can develop as long as the T2 voltage leads the T1 voltage.

The operate circuit switches for the next half cycle so that transistors Q2 and Q11 conduct in an attempt to cause tripping. In the polarizing circuit, Q4, Q14, and QS2 seek to prevent tripping by short circuiting the current which might otherwise pass through D21, DZ4, Q9.

Restraint Squelch

When the operate circuit transistor Q10 conducts, approximately 18V is applied through diode D13 to back bias D14 and prevent Q13 from turning on. Thus a trip signal, initiated because the T1 voltage is leading, cannot be improperly interrupted when the T2 voltage goes positive. A full half cycle tripping output is therefore produced by Q10. This back biasing connection is called the restraint squelch circuit. The same is true for D18, D14, and Q11 & Q14 combination.

Voltage Detector

If for some reason a condition developed so that no polarizing voltage appears at transformer T2, then no gating signal would be available to switch QS1 and short circuit the Q10 current. This, of course, could cause incorrect tripping. A voltage detector circuit prevents this from happening. Transistor Q12 is maintained in the conducting state by Q3 and Q4 alternately when a useful voltage level is supplied by T2. When conducting, Q12 short circuits current which flows through R5 from the 20V bus. When the voltage from T2 drops too low to drive Q3 and Q4, then Q12 turns off and the R5 current flows through DZ2 to switch Q7 into conduction. This in turn drives Q13 through D11, R22, and D14 causing Q13 to switch QS1 into conduction to short circuit D16 and prevent tripping. Similar action drives Q14 through D12 and R23.

The operate circuit and the polarizing circuit are both duals having identical circuits which operate on alternate half cycles. The restraint squelch and the voltage detector both work into each of the duals in the same way.

Transformer T3 receives a polarizing signal from the circuit which is identical to the one supplied by transformer T2. The phase angle relation between the T1 voltage and the T3 voltage is compared in the same manner as described above and tripping signals are supplied through D21 and D15, through DZ4 and to Q9. This polarizing circuit contains a restraint squelch and a voltage detector identical to those described for the T2 circuit. QS1 and QS3, QS2 and QS4 are connected in parallel so that two tripping outputs are needed to make operation of Q9 possible.

In the SDB relay, Q9 turns on to short circuit current from the base of Q18 and to provide base current flow for Q18. An output voltage appears at terminal 10 through Q18.

CHARACTERISTICS

The relay responds to phase-to-phase voltage and delta currents while being energized by phase-to-phase voltage and phase currents. It measures the same impedance for phase-to-phase or three-phase faults.

Tap plate settings are related to the line designated as $+T_{AB}$ or $-T_{AB}$. This reach is related to the "R" component on the R-X diagram by equation $R = \frac{Z}{\cos \theta}$

θ is angle difference between the X-axes and the maximum sensitivity angle of the relay. Relay is shipped with maximum sensitivity angle of 75° and can be readjusted continuously between 60° and 90°, as outlined in calibration procedure.
For 75° adjustment, R = 1.04T
For 60° adjustment, R = 1.16T, where T is relay tap setting "$+T_{AB}$" or "$-T_{AB}$".
"$+T_{AB}$" and "$-T_{AB}$" can be set independently for different reach.

Tap plate markings are as follows:

1.51, 2.00, 2.50, 3.50, 5.00, 7.10 and 10.0. Tap settings differ by a maximum of 33% thus making it possible to make relay settings within $\pm$ 16.5% of the desired value.

Sensitivity

A plot of relay reach in percent of tap block setting vs. relay terminal voltage is shown on Fig. 7. With no voltage applied (current only) relay has minimum sensitivity of I T_{AB} = 1.0.

Time of Operation

The operating time of the relay varies from 2 ms. to 9 ms. for faults near the balance point.

CURRENT CIRCUIT RATING IN AMPERES

TAP SETTING	CONTINUOUS	1 SECOND
10.0	5.	240
7.1	6	240
5.0	8	240
1.51 - 3.50	10	240

BURDEN DATA

Current Burden per Phase 5 Amp. $\angle 0^\circ$
V = 120 V. $\angle 0^\circ$

TAP SETTING T	IMPEDANCE Z	RESISTANCE R	REACTANCE X
10.0	.342	.240	.244
7.10	.274	.190	.196
5.00	.230	.161	.165
3.50	.203	.142	.146
2.50	.184	.128	.132
2.00	.169	.118	.122
1.51	.160	.112	.116

Potential Circuit Burden

At $120\angle 0^\circ$ volts ac and current circuits energized with $5\angle 0^\circ$ amps. the potential burden is 14.2 voltamperes, 8 watts and 11.2 vars.

Setting Calculations

Relay reach is set on the tap plate. The tap plate markings are:

			T_A T_B			
1.51	2.00	2.50	3.50	5.0	7.1	10.0

Maximum sensitivity angle is set for 75° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angle 65° or higher. For line angles below 65°, set θ for a 60° maximum torque angle by adjusting P1. The tap plate setting represents the reach perpendicular to the characteristic line of the relay.

SETTING THE RELAY

The SDB relay requires setting for the two compensators ($+T_{AB}$ and $-T_{AB}$) which requires in total 4 compensator settings since each compensator receives two currents, one from each phase. If the $+T_{AB}$ and $-T_{AB}$ settings are the same all compensators are set for the same tap value. If $+T_{AB}$ compensator should be set differently from $-T_{AB}$, the left-hand tap block marked $+T_A$ and the lower middle tap block marked $+T_B$ are used to make this setting. For $-T_{AB}$ settings upper block marked $-T_A$ and the extreme left tap block marked $-T_B$.

Compensators ($+T_{AB}$ and $-T_{AB}$)

Each set of compensator taps terminates in inserts which are grouped on a socket and form approximately three quarters of a circle around a center insert which is the common connection for all of the taps. Electrical connections between common insert and tap inserts are made with a link that is held in place with two connector screws, one in the common and one in the tap. There are two T_B settings to be made since phase B current is passed through two compensators. A compensator tap setting is made by loosening the connector screw in the center. Remove the connector screw in the tap end of the link, swing the link around until it is in position over the insert for the desired tap setting, replace the connector screw to bind the link to this insert, and retighten the connector screw in the center. Since the link and connector screws carry operating current, be sure that the screws are turned to bind snugly.

Setting Examples

1. Where used for restricted trip (RT) function set the relay to accommodate maximum fault resistance R_p.

   where $R_p = \dfrac{400 \text{ (phase spacing in feet)}}{I_{3\phi}}$

   For example, phase spacing = 20 feet.

   $$I_{3\phi} = 10{,}000 \text{ amperes}$$

   $$R_p = \frac{400\ (20)}{10{,}000} = .8 \text{ ohms}$$

   If the relay has a maximum sensitivity angle of 75°, then the effective

   $$R_p = .8 \cos.\ (90^\circ - 75^\circ) = .773$$

   $$\text{Secondary } R_s = (R_p)\ \frac{R_c}{R_v} \text{ where}$$

   $$R_c = \text{C.T. ratio} = 240$$

   $$R_v = \text{P.T. ratio} = 2000$$

   $$R_s = (.773)\ \frac{240}{2000} = .0926 \text{ ohms}$$

   With a 50% margin, the $Z_s = 1.5\ R_s = 1.5\ (.0926) = .139$ The next higher relay tap setting will be $+T_A = -T_A = +T_B = -T_B = 1.51$ ohms.

2. Where used with OS-1 out-of-step tripping (OST) logic, the SDB should be set with adequate seperation between the blinder characteristics to assume that the swing ohms remain in the operate area for at least 20 ms. on an out-of-step condition.

For example, if the out-of-step swing ohms advance at an average rate of 20 ohms per cycle, near the maximum accelerating point during the first slip cycle, R_c = 240 and R_v = 2000.

$$\text{Rate of change} = \frac{\text{20 ohms per cycle}}{\text{.0167 sec. per cycle}} = \text{1200 ohms per second}$$

Primary change in 20 ms. = Z_p = .020 (1200) = 24 ohms

Secondary change in 20 ms. = $Z_s = 24 \frac{R_c}{R_v} = (24) \frac{240}{2000} = 2.88$ ohms

For a 50% margin, the $Z = (1.5) \frac{Z_s}{2} = .75\ (2.88) = 2.16$ ohms. The next higher relay tap setting will be $+T_A = -T_A = +T_B = -T_B = 2.51$ ohms.

3. Where two SDB relays are used with the OS-2 out-of-step logic, the inner SDB (on an R-X plot) should be set in accordance with setting example No. 1. The outer SDB should be set with adequate separation from the inner SDB to assure that the swing ohms reamin between the inner and outer blinder characteristics for at least 50 ms. on an out-of-step swing.

For example, if the out-of-step swing ohms advance at an average rate of 10 ohms per cycle in the region immediately outside the inner blinder reach, R_c = 240, R_v = 2000 and the inside $+T_A = -T_A = +T_B = -T_B = 1.51$ ohms

$$\text{Rate of change} = \frac{\text{10 ohms per cycle}}{\text{.0167 sec. per cycle}} = \text{600 ohms per second.}$$

Primary change in 50 ms. = Z_p = .050 (600) = 30 ohms

Secondary change in 50 ms. = $Z_s = (30) \frac{240}{2000} = 3.6$ ohms

For a 50% margin, the $Z = T_A + 1.5\ (3.6) = 1.51 + 5.4 = 6.91$ ohms. The next higher outer SDB tap setting will be $+T_A' = -T_A' = +T_B' = -T_B' = 7.1$ ohms.

Line Angle Adjustment

Maximum sensitivity angle is set for 75° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angles of 65° or higher. For line angles below 65° set for a 60° maximum sensitivity angle by adjusting the potentiometer P1. Refer to calibration procedure when a change in maximum sensitivity angle is desired.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay by means of the mounting stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush tupe FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detail information on the FT case refer to I.L. 41-076.

EXTERNAL CONNECTIONS

The SDB relay is connected to phase-to-phase voltage and the corresponding currents as in Fig. 10.

RECEIVING ACCEPTANCE

Acceptance tests consist of:

1. A visual inspection to make sure there are no loose connections, on damaged components.

2. An electrical test to make certain that the relay measures the balance point impedance accurately.

   Tripping of the relay at the balance point is indicated by a voltmeter reading above 5 volts dc and 15-20 V. d.c. when fully tripped. Electrical response of the relay should be checked using test connections shown in Fig. 12. Set all T = 10.0

Step 1. Apply 40 volts a.c. to terminals 8 and 9 with polarity mark on terminal 8.

Step 2. Apply current in phase with voltage with pos. polarity into terminal 5 and out terminal 7, jumpering 4 and 6 together. The relay should operate at 1.90-2.06 amperes.

Step 3. Set phase shifter at 40° current lagging voltage. The trip current should be 1.10-1.20 amperes.

Step 4. Set phase shifter for 40° current leading voltage. It should be 1.75-1.90 amperes.

Step 5. Reverse current connections to the relay. Set phase shifter for 40° current lagging voltage. The operating current should be 1.10-1.20 amperes.

If some other setting than T = 10 is made relay reach is checked according to the equations $T = \frac{V}{2I} \cos.(-\theta \mp \alpha)$ where V is relay voltage, I is relay current, $\theta = 90 - \alpha_m$ where α_m is maximum sensitivity angle, α is angle between relay current and voltage. When current is lagging voltage use a negative sign for For current leading voltage use a positive sign for

For Step 5 test $\theta = 90^\circ - 75^\circ = 15^\circ$

$$T = \frac{40}{2.0 \times 1.15} \cos.(-15^\circ - 40^\circ - 180^\circ)$$

$$T = \frac{40}{2.0 \times 1.15} \cos.(-55^\circ - 180^\circ) =$$

$$= 17.4 \times -.575 = -10.0 \text{ ohms.}$$

If the relay is set for $\alpha_m = 60^\circ$, $\theta = 90^\circ - 60^\circ = 30^\circ$ in the above example.

If the electrical response is radically outside the limits a more complete series of tests is outlined in the section under "Calibration Procedure".

ROUTINE MAINTENANCE

The relays should be inspected periodically, at such time intervals as may be dictated by experience, to insure that the relays have retained their calibration and are in proper operating condition.

CAUTION:

Before making "Hi-pot" tests, jumper terminals 2, 3, 10 together to avoid destroying components in the static network.

Repeat acceptance test steps 1 and 2 for relay setting with current and voltage in phase. The current test value should be determined using the following equation:

$$I_{test} = \frac{V}{2\,T} \cos. (-\theta \pm \alpha)$$

where V = relay test voltage, $\theta = 90 - \alpha_m$ where α_m is maximum sensitivity angle of the relay set for 75°, α is the angle between relay current and voltage. Use negative sign for α if current lags voltage and positive sign for current leading voltage.

REPAIR CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. For best results in checking calibration the relay should be allowed to warm up for approximately one hour at rated voltage. However, a cold relay will check to within two per cent of the warm relay.

Potentiometer Adjustments

Connect relay as per test drawing Fig. 12.

1. Remove printed circuit board and apply rated DC voltage to terminals 3 and 2 with positive on 3. Measure DC voltage from relay terminal 2 to the bottom terminal of the zener regulating diode located just below the tap plate. It should read 18-24 volts. Reinsert the board into the relay.

2. Set all compensators taps for T = 10.00

3. Make the following settings of potentiometer P1, P2, and P3:

   NOTE: Loosen the nuts before rotating the brush

   P1 (Left Hand)

   Connect ohmmeter to the middle terminal (brush) and the free terminal (without any connections) and adjust the potentiometer for 2800 ohms.

P2 (Center)

Connect ohmmeter to the middle terminal (brush) and the free terminal and adjust potentiometer for 1000 ohms.

P3 (Right Hand)

Make the same setting as for P2 above.

ELECTRICAL TESTS AND PROCEDURES

Preliminary Connections

1. Monitor relay output by using high impedance (at least 20,000 ohms/volt) DC voltmeter suitable for reading 0-25 volts DC. Connect the voltmeter to relay terminals 2 and 10 with positive polarity mark on terminal 10. Consider as positive relay output voltmeter deflection of 5 volts or more.

2. Apply AC voltage to terminals 8 and 9 as shown on Fig. 12. Use variac to control input voltage.

3. Apply AC current to terminals 5 and 7 (jumper terminals 4 and 6 together).

4. Apply rated DC voltage to terminal 3 and 2, observing polarity.

CALIBRATION PROCEDURE

1. Apply 40 volts AC and about 2 amps. of AC current with the phase shifter at 0^o current lagging voltage. Adjust current until relay output is obtained. It should occur between 1.8-(1.94)-2.00 amps. If not, readjust Potentiometer P1 until the current limit is met.

2. Apply 40 volts AC, set phase shifter at 40^o-current lagging voltage. The operating current should be between 1.10-(1.15)-1.20 amps. If not, readjust Potentiometer P2 until current limit is met. Recheck 0^o phase shifter setting. It should be within the limits of 1.86-(1.90)-2.00. If not, readjust P1 again, and recheck 40^o setting. The 0^o and 40^o setting should check out within the limits. Retighten the potentiometer nut (P1 and P2) without disturbing the settings.

   a) Set phase shifter for 40^o current leading voltage. The operating current at 40 volts AC should be 1.74-(1.80)-1.87 amp.

   b) Set phase shifter for 75^o ($\pm 5^o$) current lagging voltage. Increase the voltage to 120 volts AC. The pickup current should be below 0.4 amp.

3. Reverse current connections to the relay (polarity mark on terminal 7). Set phase shifter for 40^o current lagging voltage. The operating current at 40 volts AC should be 1.10-(1.15)-1.20 amps. If not, readjust Potentiometer P3 for correct pickup current.

4. Set phase shifter for 0^o. The pickup current should be 1.86-(1.94)-2.00 amp. at 40 volts AC input. Retighten the P3 nut. Set phase shifter for 40^o current leading voltage. The operating current at 40 volts AC should be between 1.74-(1.80)-1.87 amps.

5. Set phase shifter for 75° ($\pm 5^\circ$) current lagging voltage. Increase voltage to 120 volts AC. The pickup current should be below 0.4 amps.

60° - Calibration

For 60° calibration or any other maximum sensitivity angle, the relay should be adjusted as above. Apply 40 volts ac, set phase shifter for 30° current lagging voltage. Set current through the relay for I_{test} = 1.0 amp. and readjust Potentiometer P1 until relay operates.

This value is equal to $I_{test} = \frac{V}{2.0 \times 10} \cos.(-\theta \pm \alpha) =$

$$= \frac{40}{2.0 \times 10} \cos.(-30^\circ - 30^\circ) = \frac{40 \times 0.5}{2 \times 10} = 1 \text{ amp.}$$

For any other maximum sensitivity angle the value of test current should be determined using the above equation, except $\theta = 90^\circ - \alpha'_m$, where α'_m is the desired maximum sensitivity angle. The angle α at which the test is performed is $\alpha_m - 30^\circ$. Reverse current 180° and recheck trip value. It should be between .97 - (1.00)-1.03 amperes for 60° adjustment. For any other angle this value should be within $\pm$ 3 per cent of the first test.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data. For components mounted on the printed circuit board, give the circuit symbol, electrical value and style number.

ELECTRICAL PARTS LIST

Circuit Symbol	Description	Westinghouse Style Number
Printed Circuit Board (Fig. 11)		898C007G02
	RESISTORS	
R9-R11-R17-R19	2.7K OHM, ½W.	629A531H42
R10-R12-R14-R15 R16-R18-R20-R24 R25-R28-R29-R52	2.7K OHM, ½W.	184A763H37
R22-R23-R26 R27-R3-R4	8.2K OHM, ½W.	184A763H49
R50	K OHM, ½W.	184A763H61
R8-R33-R34-R53	22K OHM, ½W.	184A763H59
R35	220K OHM, ½W.	184A763H83
R36-R54	56K OHM, ½W.	184A763H69
R37 TO R40	100K OHM, ½W.	184A763H75

ELECTRICAL PARTS LIST

Printed Circuit Board (Fig. 11) (Continued) — Westinghouse Style Number 898C007G02

Circuit Symbol	Description	Westinghouse Style Number
	RESISTORS	
R41-R42	100 OHM, ½W.	184A763H03
R21	1K OHM, ½W.	184A763H27
R1A-R2A-R3A	2,120 OHM, ½W.	1210089
RDC	1.500 OHM, 25 W.	1267293
R1-R2-R6-R7	120K ½W.	184A763H77
R5	33K ½W.	184A763H63
R31-R32	1 MEG, ½W.	184A763H99
	POTENTIOMETER	
P1-P2-P3	5000 OHM, 25 W.	836A635H02
	CAPACITORS	
C1	18 MFD.	187A508H10
C2	1.5 MFD.	187A508H09
C4	.015 MFD.	187A624H10
CA1	1.1 MFD.	14C9400H21
CA2-CA3	.6 MFD.	14C9400H10
	DIODES	
D1 TO D14-D16 D18-D19-D21-D22 D23-D28-D29-D33 D34-D36 TO D48 D52 TO D57	CER-69	188A342H06
	TRANSISTORS	
Q1 TO Q6	2N3391	848A851H01
Q7-Q9-Q20-Q21	2N697	184A638H18
Q10 TO Q14-Q16 Q17-Q18	2N1131	184A638H20
	ZENER DIODES	
DZ1-DZ2-DZ4	1N957B	186A797H06
DZP	1N2984B	762A631H01
DZ7	1N3686B	185A212H06
DZ8	1N758	186A797H01

ELECTRICAL PARTS LIST

		Westinghouse Style Number
Printed Circuit Board (Fig. 11) (Continued)		898C007G02
Circuit Symbol	Description	
	THYRISTORS	
QS1 TO QS4	2N884	185A517H05
	TRANSFORMERS	
T1		292B563G03
T2-T3		292B563G02

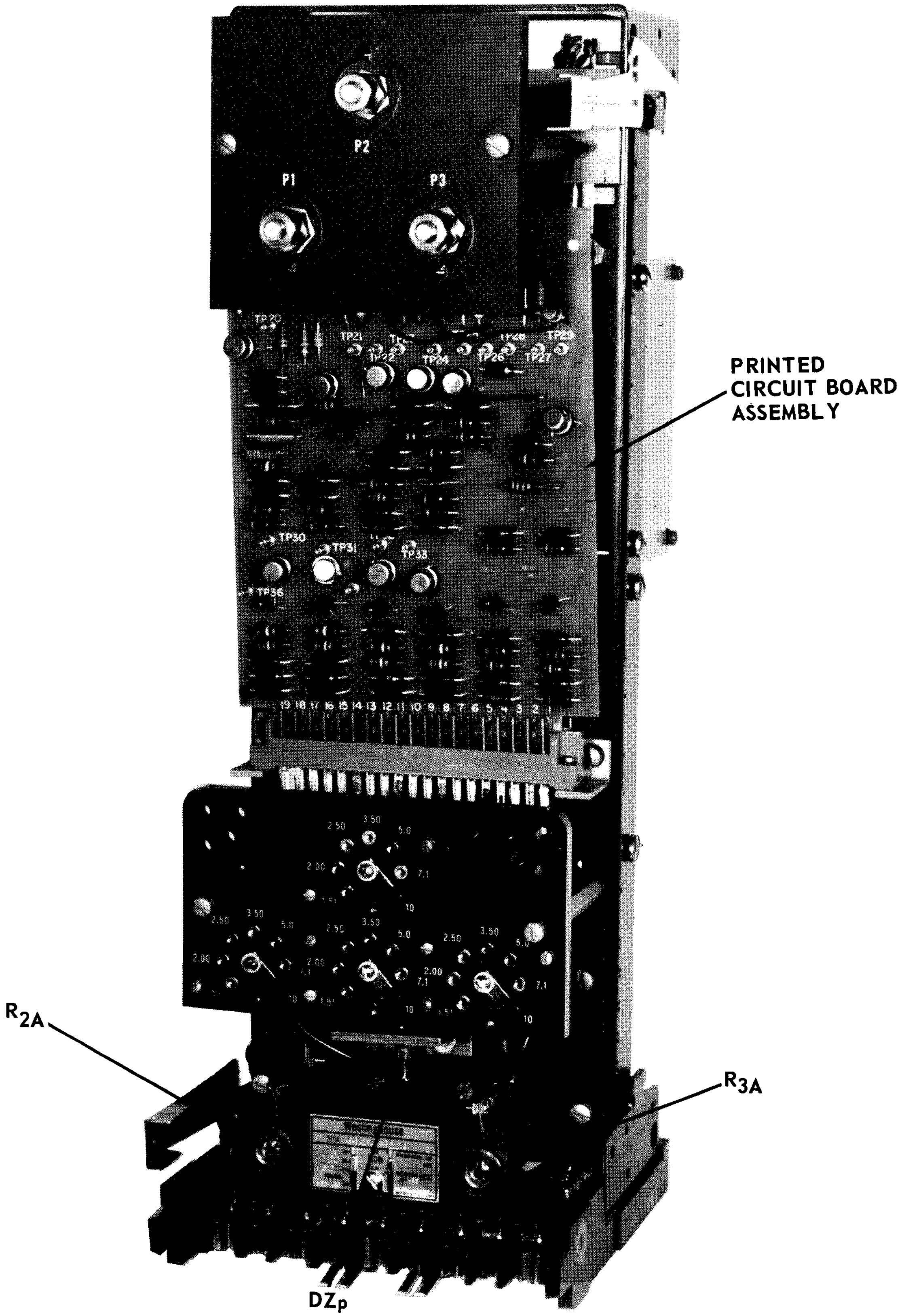

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Fig. 1 Type SDB Relay without Case (Front View).

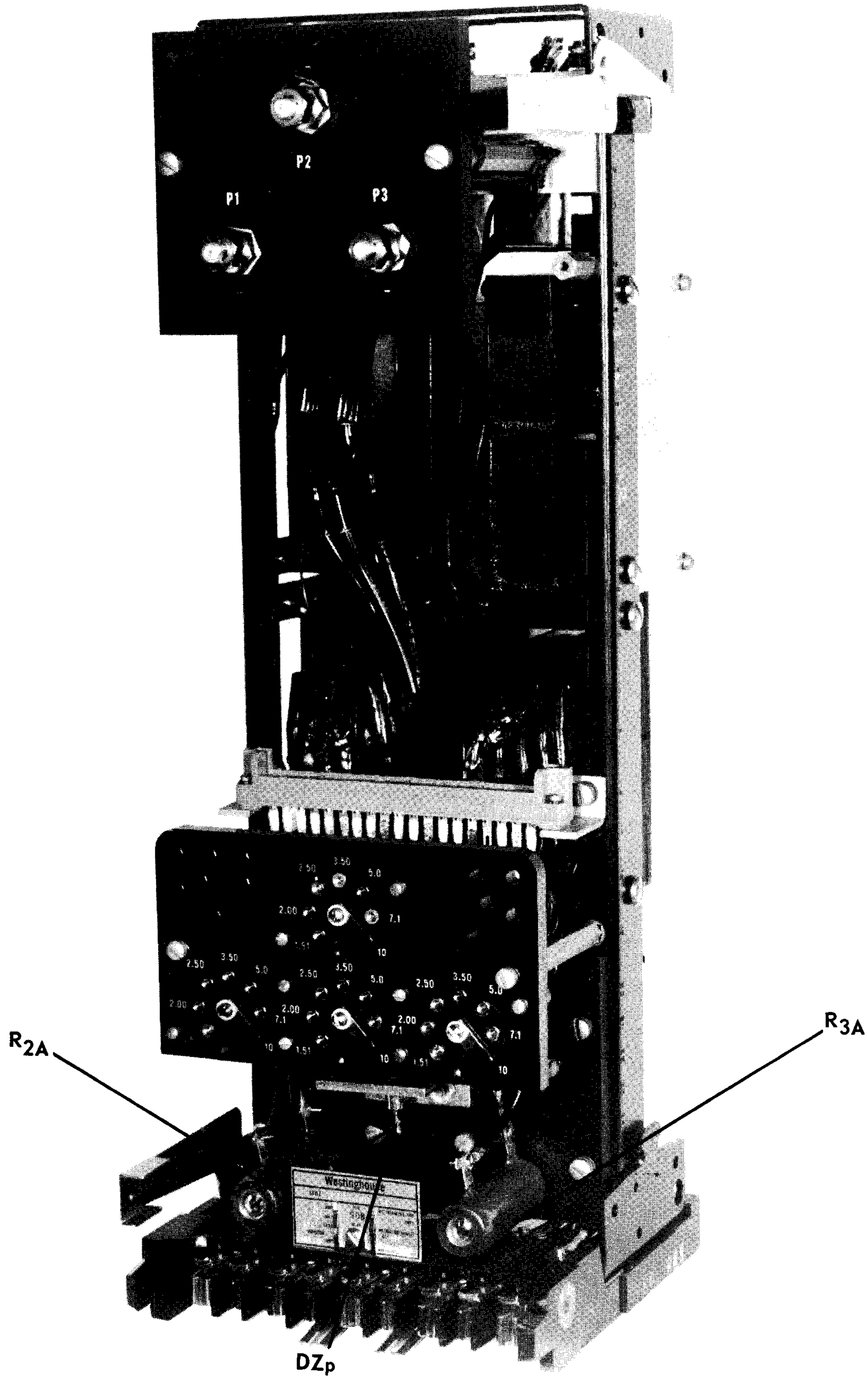

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Fig. 2 Type SDB Relay without Case (Front View without Printed Circuit Board).

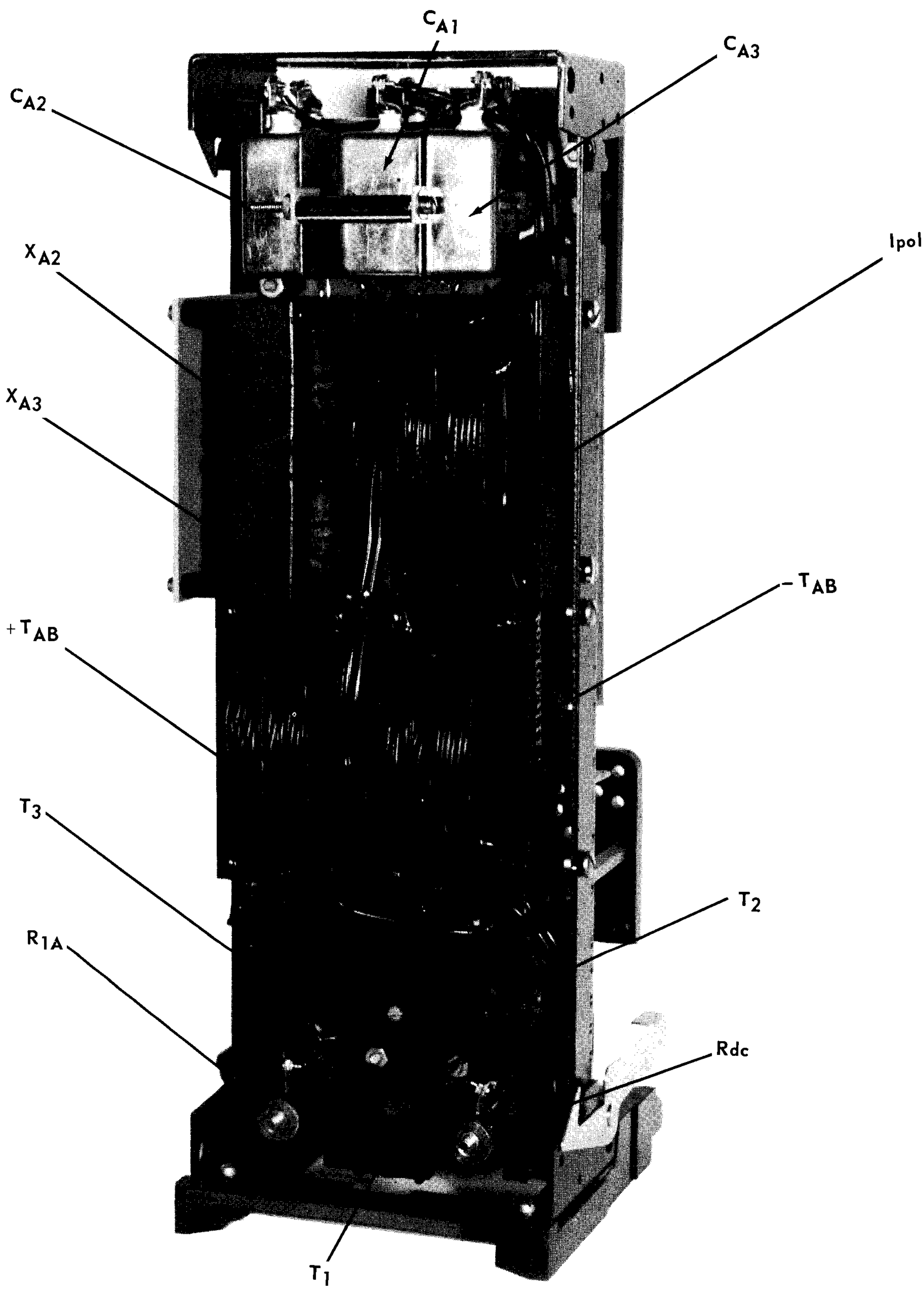

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Fig. 3 Type SDB Relay without Case (Rear View)

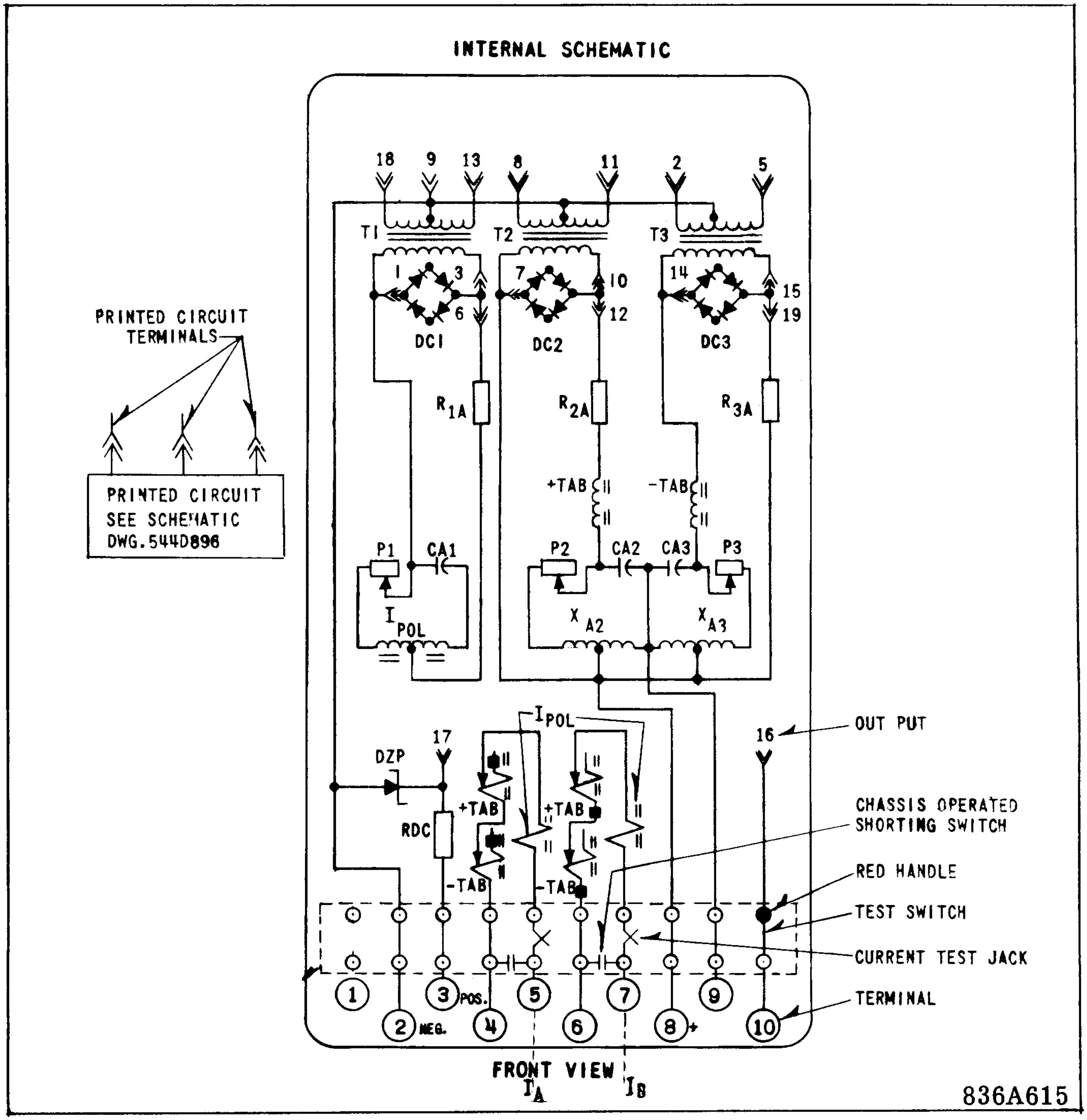

Fig. 4 Internal Schematic of the Type SDB Relay in FT-41 Case.

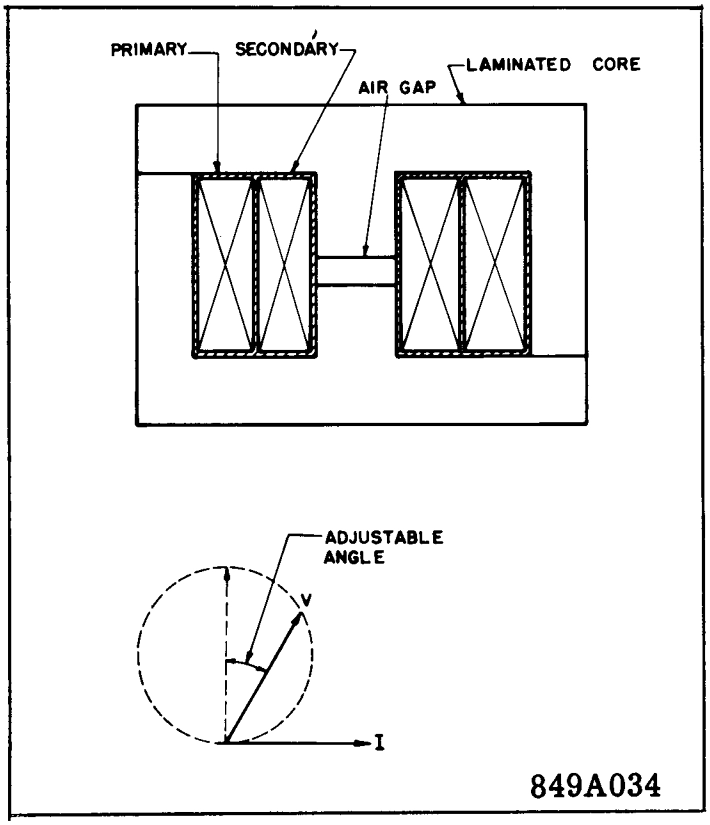

Fig. 6 Compensator Construction

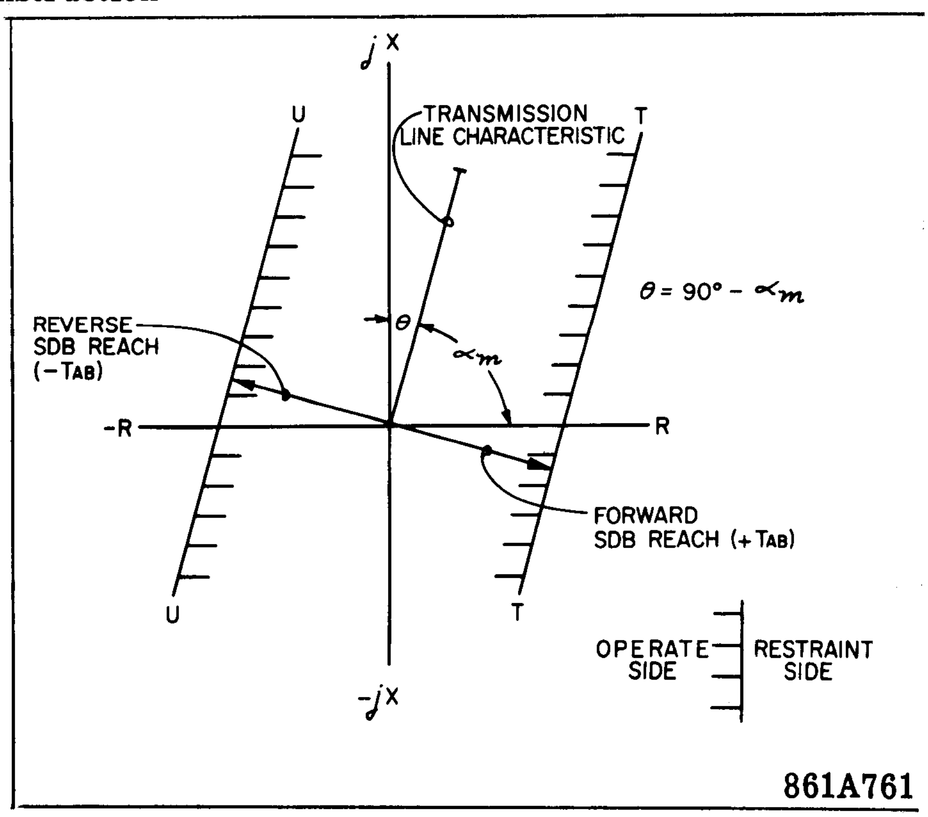

Fig. 7 SDB Relay R-X Diagram Characteristics.

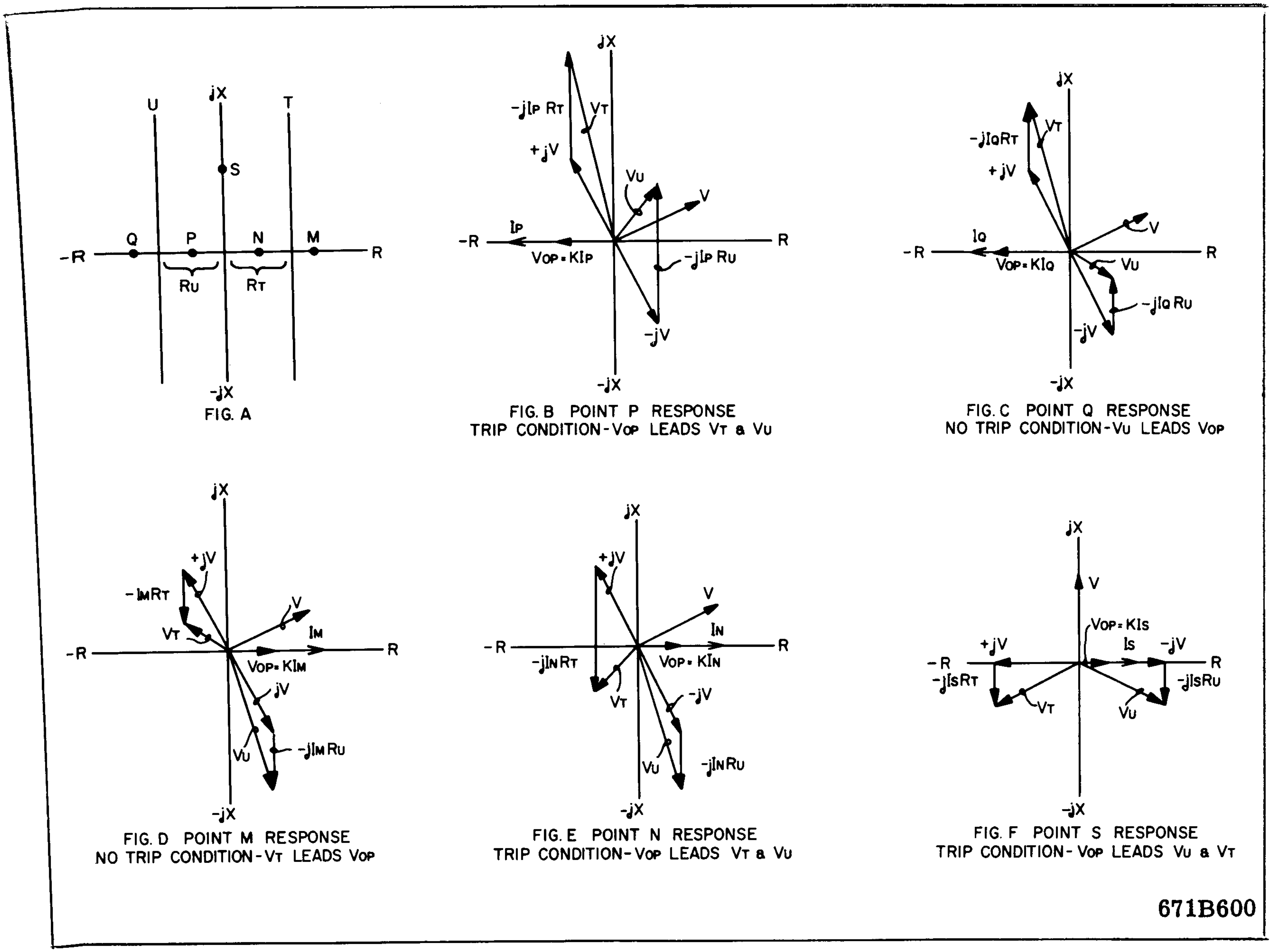

Fig. 8 SDB Relay Phasor Relations for Selected Conditions.

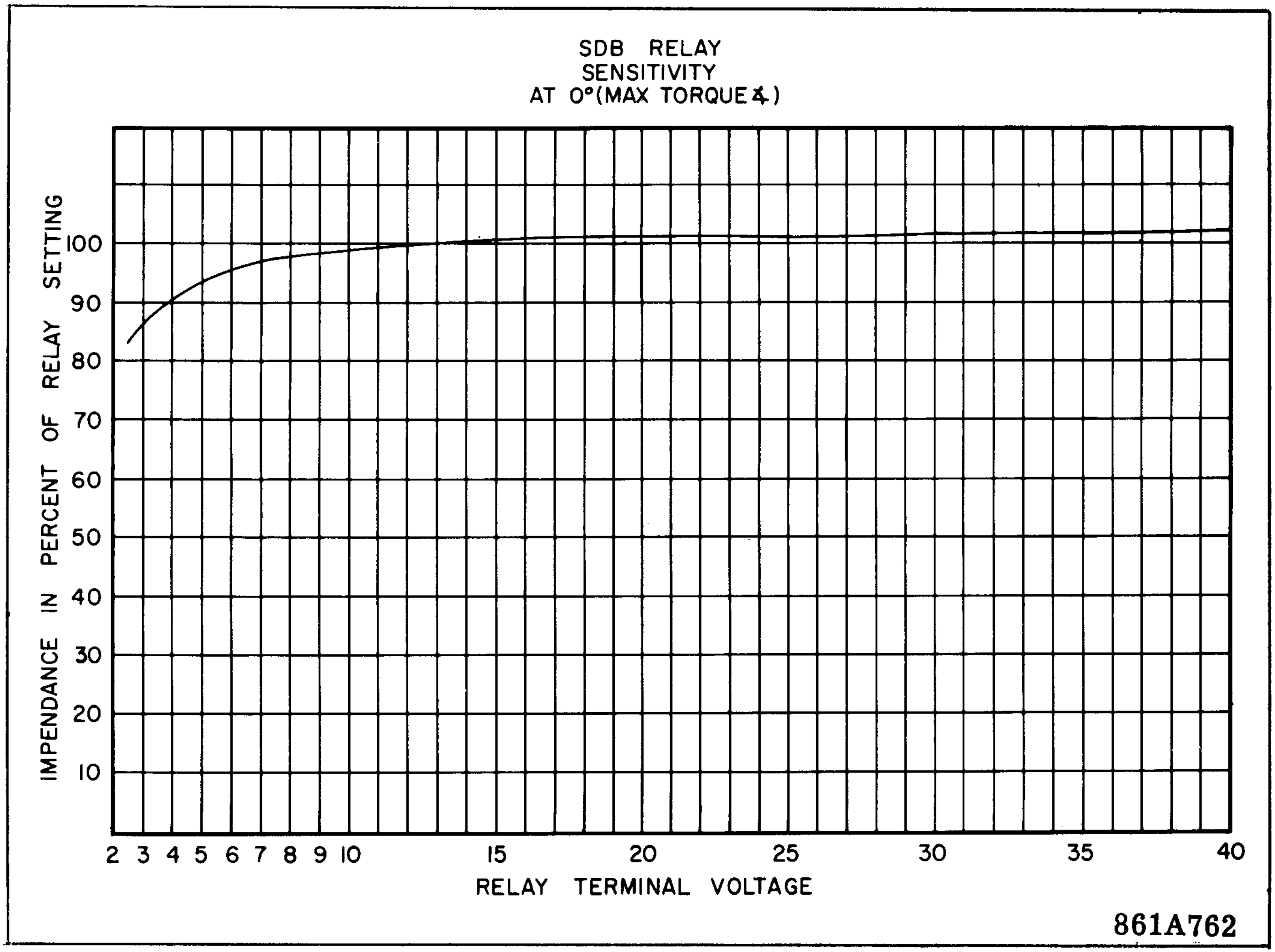

Fig. 9 Impedance-Restraint Voltage Curve for Type SDB Relay.

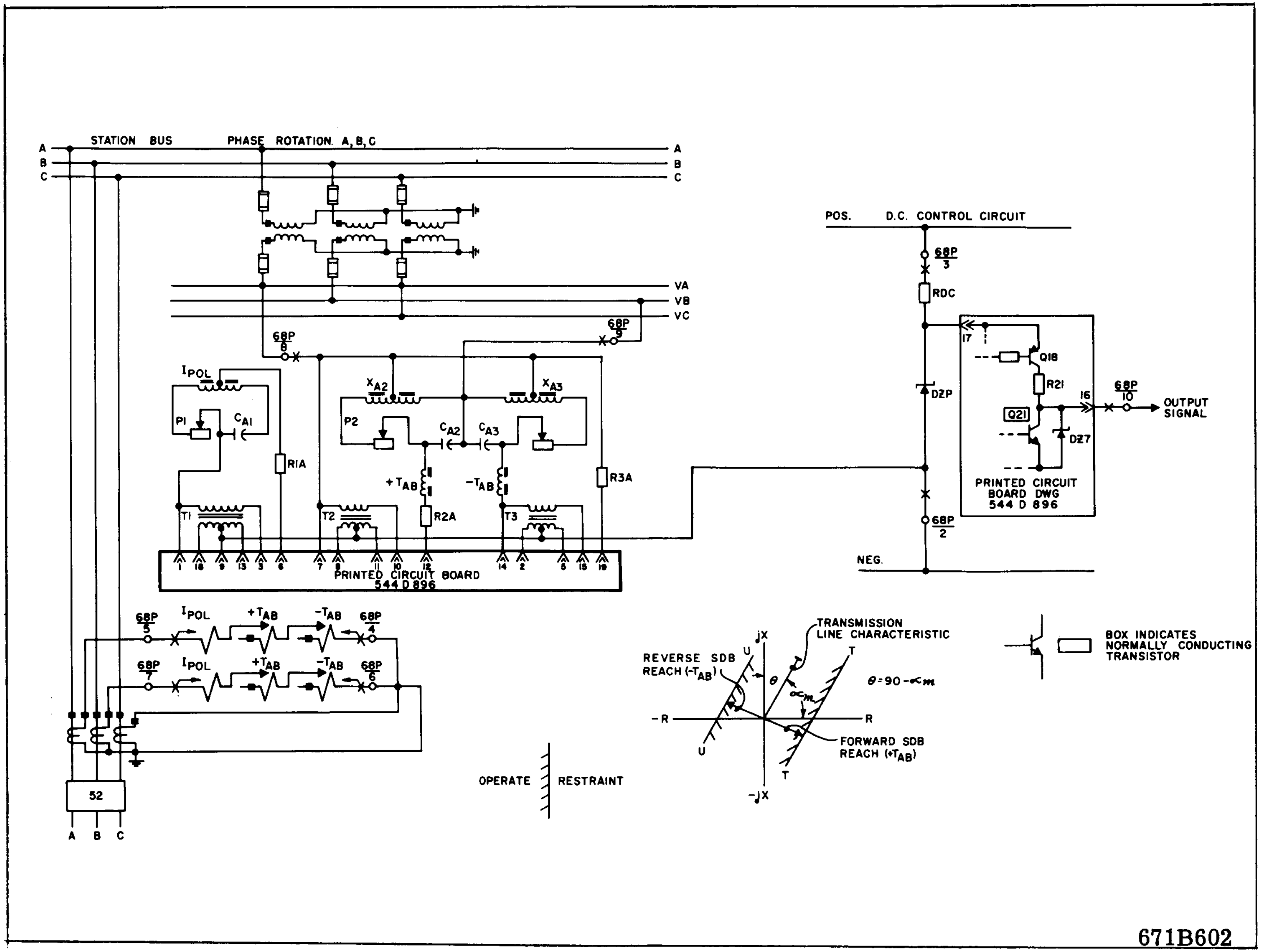

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Fig. 10 External Schematic of the Type SDB Relay

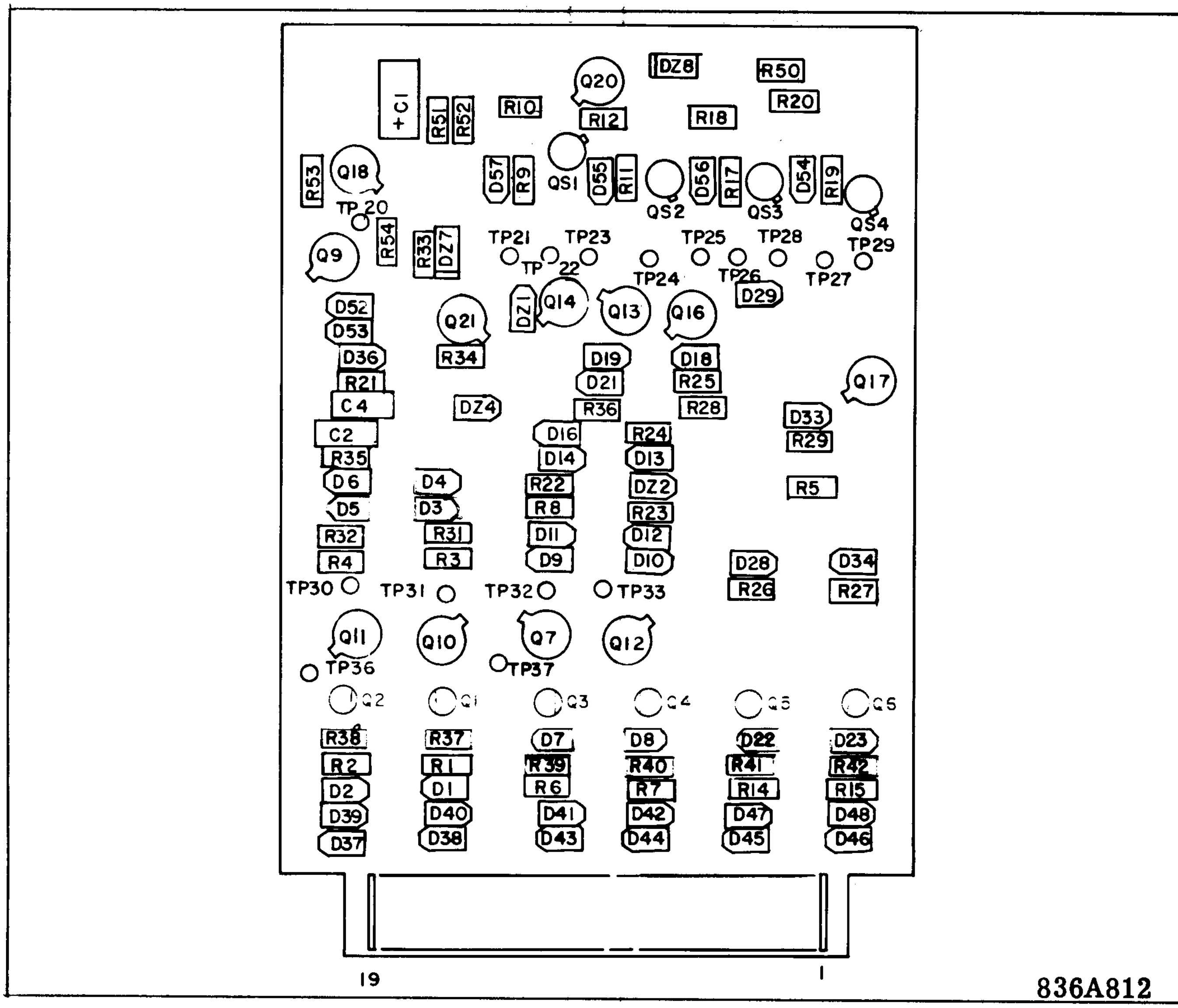

Fig. 11 Printed Circuit Board Assembly for the SDB Relay

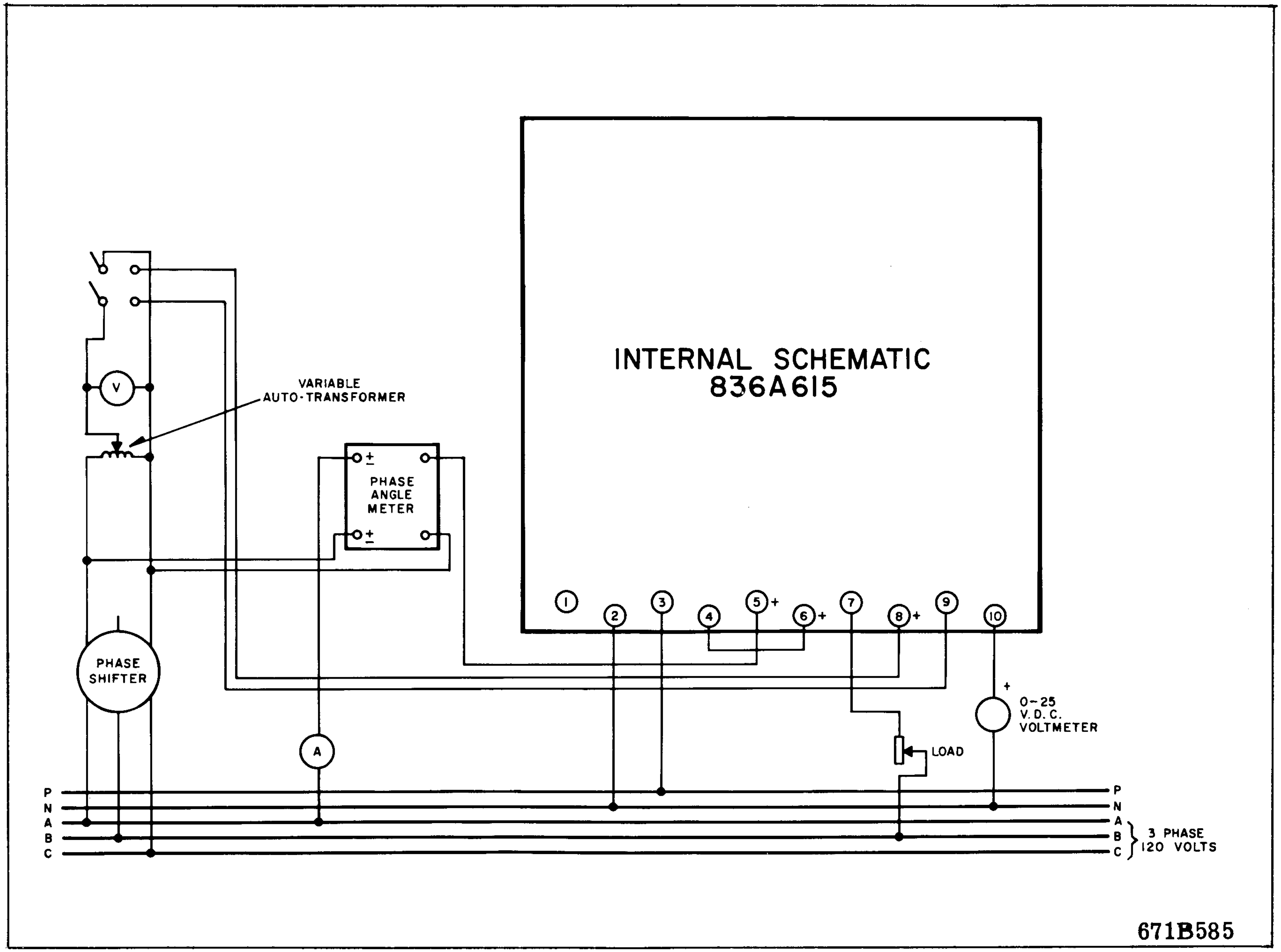

Fig. 12 Test Connections for Type SDB Relay

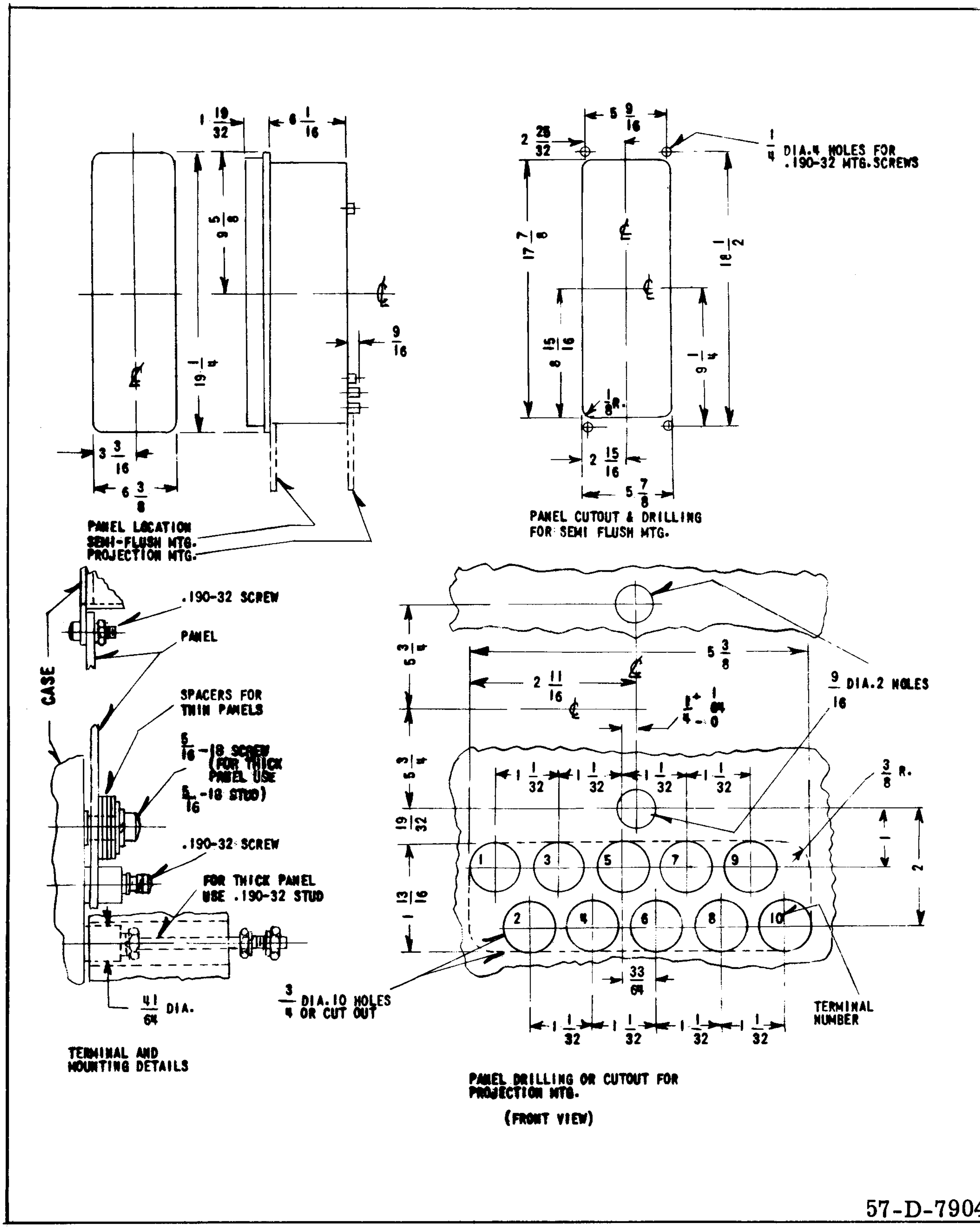

Fig. 13 Outline and drilling Plan for the Type SDB Relay in the Type FT-41 Case.

WESTINGHOUSE ELECTRIC CORPORATION
RELAY-INSTRUMENT DIVISION **NEWARK, N. J.**
Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SDB STATIC BLINDER RELAY

CAUTION: It is recommended that the user of this equipment become acquainted with the information in this instruction leaflet before energizing the equipment. Failure to observe this precaution may result in damage to the equipment.

APPLICATION

The SDB is a static compensator relay used to:

1. Supervise a static distance relay to provide a restricted reach during load or swing conditions.

2. Provide sensing intelligence for the OS-1 or OS-2 out-of-step logic.

3. Operate a low energy level auxiliary relay to provide a contact closure for supervising an electromechanical distance relay to restrict the reach in the load area on an R-X plot.

The SDB characteristic consists of two essentially parallel lines (actually arcs of extremely large circles) which form an angle with respect to the R axis on an R-X plot which is adjustable from 60° to 90°. The factory adjustment is 75°. The parallel lines are equally spaced on each side of the origin of the R-X diagram. It has a normally conducting NPN transistor that ties the output terminal to negative when the relay is in the non-operate state. It operates when subjected to an ohmic value that falls between its two characteristic lines, providing a positive low energy level output.

The setting of the SDB defines the ohmic reach from the origin in a direction perpendicular to the characteristic lines.

CONSTRUCTION

The SDB relay consists of three air gap transformers (compensators), two center tapped autotransformers, three phase shifting circuits, and three isolating transformers. The isolating transformers couple the ac quantities into the phase angle comparison unit. One large printed circuit assembly provides the characteristics of a dual polarized phase angle comparison unit and has a transistor output.

Compensator

The compensators which are designated I_{POL}, +TAB, −TAB are three winding air-gap transformers (Fig. 4). There are two primary current windings, each having seven taps which terminate at the tap block. They are marked 1.51, 2.00, 2.50, 3.50, 5.00, 7.1, and 10.0. I_{POL} compensator has no taps. A voltage is induced in the secondary which is proportional to the primary tap and current magnitude. This proportionality is established by the cross-sectional area of the laminated steel core, the length of the air gap which is located in the center of the coil, and the tightness of the lamination. All of these elements have been precisely set at the factory. The clamps which hold the laminations should not be disturbed by either tightening or loosening the clamp screws.

The secondary winding of the I_{POL} compensator is center tapped to provide a voltage supply for the phase shifting network. The phase shifting network produces voltage in phase with the primary compensator current.

Phase Shifting Circuits

Phase shifting of the input voltages is obtained through a circuit that consists of center tapped autotransformers, X_{A2} and X_{A3}, resistors R_{2A} and capacitor C_{A2}, and resistor R_{3A} and capacitor C_{A3} respectively.

In the current polarizing circuit the compensator voltage output is phase shifted by means of resistor R_{1A} and capacitor C_{A1}. The compensator voltage is supplied through the center tapped secondary of I_{POL} compensator.

SUPERSEDES I.L. 41-489
*Denotes change from superseded issue.

EFFECTIVE JULY 1968

Isolating Transformers

Transformers T1, T2, and T3 serve two purposes. First, they isolate the ac circuits from the dc circuit. Second, they amplify the clipped ac signal to make the relay sensitive to low level input signals.

Printed Circuit Board Assembly

The printed circuit board assembly shown in Fig. 11 contains all the resistors, diodes, transistors, and thyristors necessary to perform the functions of a dual polarized phase angle comparison unit. In Fig. 11 resistors are identified by the letter R followed by a number. Similarly, diodes are identified by a D and the cathode (the end out of which conventional current flows) is marked with a bar across the unit. Zener diodes are identified by DZ. Transistors are identified by a Q, thyristors by QS, capacitors by C, and test points by TP. Boxed-in Q numbers indicate normally conducting transistors.

When facing the component side with terminals at the bottom, terminals are numbered from right to left starting at 1 and going through number 19. These terminal numbers are shown within brackets on the internal schematic and will be referred to as Printed Circuit Terminals, PCT, in the trouble shooting section.

OPERATION

Two identical logic systems are used in the SDB-relay. Each of the systems modifies the distance relay reach along the lines (T & U) as shown on Fig. 7. One system restricts the distance relays operation to the area above T and the second system to area below U. Each of the two systems presents a voltage to the static phase angle comparison unit which checks their phase angle relation to the V_{OP} voltage. Each system voltage is composed of the phase shifted phase-to-phase voltage and the compensator output voltage that is proportional to the R component of the transmission line characteristic.

Complete operation of the relay is best illustrated by the set of phasor relations for selected conditions, as shown on Fig. 8. For simplicity assume the impedance line characteristic at 90°.

Fig. 8 (A) shows R-X diagram and several points Q, P, N, M, S located within and outside the operating area of the SDB relay designated by lines U and T. Depending on fault location currents are designated as I_p, I_q, I_m, I_n, or I_S.

Relay tripping conditions occur when the phasor designated V_{OP} leads phasor V_U and V_T simultaneously. Phasor $V_{OP} = kI_p$ is derived from the compensator designated "I_{POL}" and phase shifted by means of phase shifting circuit P1 and C1 to be in phase with the primary current I. Phasor V_U controls the relay characteristic along the line designated as U. V_T phasor controls the characteristic along the line "T". "V_U" phasor consists of reversed relay terminal voltage (V) phase shifted by 90° and modified by compensator output $-jI_pR_U$. R_U represents the reach of the compensator designated as "$-T_{AB}$" that is set for the desired value "R_U" along the R-axis. "V_T" vector controls relay terminal voltage ("V") phase shifted by 90° and modified by compensator output $-jI_pR_T$. R_T represents the reach of the compensator designated as "$+T_{AB}$" that is set for the desired value "R_T", along the R-axis.

For a fault at point "P" (Fig. 8 (B) within the relay trip characteristic) the "$-T_{AB}$" compensator voltage I_pR_U is added to jV phasor so that the sum of these two phasors results in a phasor V_U that lags the V_{OP} phasor fulfilling the tripping conditions. Since phasor V_T was already in the lagging condition and the compensator voltage from $+T_{AB}$ compensator I_pR_T has only increased its magnitude without changing its relative position with respect to V_{OP}.

Fig. 8 (C) shows relay response to a fault at point "Q" (located beyond the relay characteristic) since there is not enough current to produce reversal of the V_U phasor there will be no tripping output because V_U phasor leads phasor V_{OP}.

Fig. 8 (D) shows similar relay response (no trip) for point "M" (located beyond the relay characteristic) since there is not enough compensation to cause phasor V_T to lag phasor V_{OP}.

Fig. 8 (E) shows the relay response to a fault at point "N". In this case relay response is similar to the point "P" response. The compensator output voltage I_nR_T is large enough to produce a phasor V_T that lags phasor "V_{OP}".

Fig. 8 (F) point "S" illustrates response of the relay to a 90° lag fault. When there is no fault current, the relay is inoperative since $V_{OP} = 0$. In the presence of a small amount of current, V_{OP} appears and a small compensation makes V_T and V_U lag V_{OP} and produce a tripping condition.

Phase Angle Comparison Unit

Referring to Fig. 5 the phase angle comparison unit is tripped when current flows into the base of transistor Q9 through zener diode DZ4. Such tripping current must come from the 20V bus through either transistor Q10 or Q11 located in the "operate" circuit. The operate circuit, driven by transformer T1, is continually trying to trip the unit by supply current through Q10 on alternate half hertz. Q10 conducts when the polarity marked terminals of T1 are positive.

When Q10 conducts, a portion of the current goes through resistor R24. This current, I_{R24}, may take either of two paths to the negative bus. If QS1 is in a conducting state, I_{R24} passes through it directly to the negative bus. If QS1 is in a blocking state, I_{R24} passes through D16 and then through DZ4 to transistor Q9 to cause tripping. Thyristor QS1 is located in the "polarizing" circuit of the phase-to-phase unit. This circuit is driven by transformer T2.

To prevent the operate circuit from causing tripping, the polarity marked terminals of T2 must go positive before the polarity terminals of T1 do. This causes Q3 to conduct current through R22 and drive the base of Q13. Q13 then conducts current from the 13V bus through R9 to gate QS1 into conduction. When QS1 conducts, it short circuits the current which might otherwise pass through D16 to cause tripping. Once QS1 begins to conduct, the gate loses control and it remains in the conducting state until the current is turned off by Q10. No tripping output can develop as long as the T2 voltage leads the T1 voltage.

The operate circuit switches for the next half hertz so that transistors Q2 and Q11 conduct in an attempt to cause tripping. In the polarizing circuit, Q4, Q14, and QS2 seek to prevent tripping by short circuiting the current which might otherwise pass through D21, DZ4, Q9.

Restraint Squelch

When the operate circuit transistor Q10 conducts, approximately 18V is applied through diode D13 to back bias D14 and prevent Q13 from turning on. Thus a trip signal, initiated because the T1 voltage is leading, cannot be improperly interrupted when the T2 voltage goes positive. A full half hertz tripping output is therefore produced by Q10. This back biasing connection is called the restraint squelch circuit. The same is true for D18, D14, and Q11 and Q14 combination. DZ1-zener lowers collector voltage of Q13 to make back biasing effective.

Voltage Detector

If for some reason a condition developed so that no polarizing voltage appears at transformer T2, then no gating signal would be available to switch QS1 and short circuit the Q10 current. This, of course, could cause incorrect tripping. A voltage detector circuit prevents this from happening. Transistor Q12 is maintained in the conducting state by Q3 and Q4 alternately when a useful voltage level is supplied by T2. When conducting, Q12 short circuits current which flows through R5 from the 20V bus. When the voltage from T2 drops too low to drive Q3 and Q4, then Q12 turns off and the R5 current flows through DZ2 to switch Q7 into conduction. This in turn drives Q13 through D11, R22, and D14 causing Q13 to switch QS1 into conduction to short circuit D16 and prevent tripping. Similar action drives Q14 through D12 and R23.

The operate circuit and the polarizing circuit are both duals having identical circuits which operate on alternate half hertz. The restraint squelch and the voltage detector both work into each of the duals in the same way.

Transformer T3 receives a polarizing signal from the circuit which is identical to the one supplied by transformer T2. The phase angle relation between the T1 voltage and the T3 voltage is compared in the same manner as described above and tripping signals are supplied through D21 and D15, through DZ4 and to Q9. This polarizing circuit contains a restraint squelch identical to the one described for the T2 circuit. QS1 and QS3, QS2 and QS4 are connected in parallel so that two tripping outputs are needed to make operation of Q9 possible.

In the SDB relay, Q9 turns on to short circuit current from the base of Q21 causing it to stop conducting and to provide base current flow for Q18. An output voltage appears at terminal 10 through Q18.

CHARACTERISTICS

The relay responds to phase-to-phase voltage and delta currents while being energized by phase-to-phase voltage and phase currents. It measures the same impedance for phase-to-phase or three-phase faults.

Tap plate settings are related to the line designated as $+T_{AB}$ or $-T_{AB}$. (Fig. 7) This reach is related to the "R" component on the R-X diagram as follows:

For 90° - angle setting R = 1.01T

For 75° - angle setting R = 1.04T

For 60° - angle setting R = 1.12T,

where $T = +T_{AB}$ or $-T_{AB}$

Relay is shipped with maximum sensitivity angle of 75° and can be readjusted continuously between 60° and 90°.

"$+T_{AB}$" and "$-T_{AB}$" can be set independently for different reach.

Tap plate markings are as follows:

1.51, 2.00, 2.50, 3.50, 5.00, 7.10 and 10.0. Tap settings differ by a maximum of 33% thus making it possible to make relay settings within ± 16.5% of the desired value.

Sensitivity

A plot of relay reach in percent of tap block setting vs. relay terminal voltage is shown on Fig. 9. With no voltage applied (current only) relay has minimum sensitivity of $I\ T_{AB} = 1.0$.

Time of Operation

The operating time of the relay varies from 2 ms. to 9 ms. for faults near the balance point.

CURRENT CIRCUIT RATING IN AMPERES

Tap Setting	Continuous	1 Second
10.0	5	240
7.1	6	240
5.0	8	240
1.51-3.50	10	240

BURDEN DATA

Current Burden per Phase 5 Amp. $\angle 0°$

V = 120 V. $\angle 0°$

Tap Setting T	Impedance Z	Resistance R	Reactance jX
10.0	.196	.138	.138
7.10	.127	.099	.073
5.00	.093	.076	.053
3.50	.072	.062	.036
2.50	.063	.056	.030
2.00	.057	.051	.026
1.51	.057	.047	.025

Potential Circuit Burden

At 120 $\angle 0°$ volts ac and current circuits energized with 5 $\angle 0°$ amps. the potential burden is 14.2 voltamperes, 8 watts and 11.2 vars.

Setting Calculations

Relay reach is set on the tap plate. The tap plate markings are:

			T_A	T_B		
1.51	2.00	2.50	3.50	5.0	7.1	10.0

Maximum sensitivity angle is set for 75° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angle 65° or higher. For line angles below 65°, set θ for a 60° maximum torque angle by adjusting Pl. The tap plate setting represents the reach perpendicular to the characteristic line of the relay.

SETTING THE RELAY

The SDB relay requires setting for the two compensators ($+T_{AB}$ and $-T_{AB}$) which requires in total 4 compensator settings since each compensator receives two currents, one from each phase. If the $+T_{AB}$ and $-T_{AB}$ settings are the same all compensators are set for the same tap value. If $+T_{AB}$ compensator should be set differently from $-T_{AB}$, the left-hand tap block marked $+T_A$ and the lower middle tap block marked $+T_B$ are used to make this setting. For $-T_{AB}$ settings upper block marked $-T_A$ and the extreme left tap block marked $-T_B$.

Compensators ($+T_{AB}$ and $-T_{AB}$)

Each set of compensator taps terminates in inserts which are grouped on a socket and form approximately three quarters of a circle around a center insert which is the common connection for all of the taps. Electrical connections between common insert and tap inserts are made with a link that is held in place with two connector screws, one in the common and one in the tap. There are two T_B settings to be made since phase B current is passed through two compensators. A compensator tap setting is made by loosening the connector screw in the center. Remove the connector screw in the tap end of the link, swing the link around until it is in position over the insert for the desired tap setting, replace the connector screw to bind the link to this insert, and retighten the connector screw in the center. Since the link and connector screws carry operating current, be sure that the screws are turned to bind snugly.

Setting Examples

1. Where used for restricted trip (RT) function set the relay to accommodate maximum fault resistance R_p.

   where $R_p = \dfrac{400 \text{ (phase spacing in feet)}}{I_{3\phi}}$

   For example, phase spacing = 20 feet.

   $$I_{3\phi} = 1{,}000 \text{ amperes minimum}$$

   $$R_p = \frac{400\ (20)}{1{,}000} = 8.0 \text{ ohms}$$

   If the relay has a maximum sensitivity angle of 75°, then the effective

   $$R_p = 8.0 \cos.(90° - 75°) = 7.73$$

   $$\text{Secondary } R_s = (R_p) \frac{R_c}{R_v} \text{ where}$$

   $$R_c = \text{C.T. ratio} = 240$$

   $$R_v = \text{P.T. ratio} = 2000$$

   $$R_s = (7.73) \frac{240}{2000} = 0.926 \text{ ohms}$$

   With a 50% margin, the $Z_s = 1.5\ R_s = 1.5\ (0.926) = 1.39$. The next higher relay tap setting will be $+T_A = -T_A = +T_B = -T_B = 1.51$ ohms.

2. Where used with OS-1 out-of-step tripping (OST) logic, the SDB should be set with adequate separation between the blinder characteristics to assure that the swing ohms remain in the operate area for at least 20 ms. on an out-of-step condition.

   For example, if the out-of-step swing ohms advance at an average rate of 20 ohms per cycle, near the maximum accelerating point during the first slip cycle, $R_c = 240$ and $R_v = 2000$.

   $$\text{Rate of change} = 20 \text{ ohms per cycle}$$

   $$\text{Rate of change} = \frac{20 \text{ ohms per cycle}}{.0167 \text{ sec. per cycle}}$$

   $$= 1200 \text{ ohms per second}$$

   $$\text{Primary change in 20 ms.} = Z_p = .020\ (1200)$$

   $$= 24 \text{ ohms}$$

   $$\text{Secondary change in 20 ms.} = Z_s = 24 \frac{R_c}{R_v}$$

   $$= (24) \frac{240}{2000} = 2.88 \text{ ohms}$$

   For a 50% margin, the $Z = (1.5) \dfrac{Z_s}{2} = .75\ (2.88) = 2.16$ ohms. The next higher relay tap setting will be $+T_A = -T_A = +T_B = -T_B = 2.51$ ohms.

3. Where two SDB relays are used with the OS-2 out-of-step logic, the inner SDB (on an R-X plot) should be set in accordance with setting example No. 1. The outer SDB should be set with adequate separation from the inner SDB to assure that the swing ohms remain between the inner and outer blinder characteristics for at 50 ms. on an out-of-step swing.

   For example, if the out-of-step swing ohms advance at an average rate of 10 ohms per cycle in the region immediately outside the inner blinder reach, $R_c = 240$, $R_v = 2000$ and the inside $+T_A = -T_A = +T_B = -T_B = 1.51$ ohms.

   $$\text{Rate of change} = \frac{10 \text{ ohms per cycle}}{.0167 \text{ sec. per cycle}}$$

   $$= 600 \text{ ohms per second.}$$

   $$\text{Primary change in 50 ms.} = Z_p = .050\ (600)$$

   $$= 30 \text{ ohms}$$

   $$\text{Secondary change in 50 ms.} = Z_s = (30) \frac{240}{2000}$$

   $$= 3.6 \text{ ohms}$$

In general, for a 50% margin, the $Z = T_A + 1.5 (3.6) = 1.51 + 5.4 = 6.91$ ohms. The next higher outer SDB tap setting will be $+T_A' = -T_A' = +T_B' = -T_B' = 7.1$ ohms.

4. If calculation of relay settings shows a lower value than the minimum (1.5 ohm) set the relay at 1.5 ohms.

Line Angle Adjustment

Maximum sensitivity angle is set for 75° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angles of 65° or higher. For line angles below 65° set for a 60° maximum sensitivity angle by adjusting the potentiometer Pl. Refer to calibration procedure when a change in maximum sensitivity angle is desired.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay by means of the mounting stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detail information of the FT case refer to I.L. 41-076.

EXTERNAL CONNECTIONS

The SDB relay is connected to phase-to-phase voltage and the corresponding currents as in Fig. 10.

RECEIVING ACCEPTANCE

Acceptance tests consist of:

1. A visual inspection to make sure there are no loose connections, on damaged components.

2. An electrical test to make certain that the relay measures the balance point impedance accurately. Use a d-c voltmeter 0-25 volts range for trip indication.

Electrical response of the relay should be checked using test connections shown in Fig. 12. Set all T = 10.0. Tripping of the relay at the balance point may be as low as 1-2 volts d-c indicating that relay is only partially tripped. Increase trip current about 5% for full 15-20 volt output.

Step 1. Apply 40 volts a.c. to terminals 8 and 9 with polarity mark on terminal 8.

Step 2. Apply current 345° lagging voltage with pos. polarity into terminal 5 and out terminal 7, jumpering 4 and 6 together. The relay should operate at 1.90-2.10 amperes. Reverse current leads. Pick up current should be 1.90-2.10 amp. Reverse leads again.

Step 3. Set phase shifter at 40° current lagging voltage. The trip current should be 1.10-1.20 amperes.

Step 4. Set phase shifter for 290° current lagging voltage. It should be 1.10-1.20 amperes. Reverse current leads. Pickup current should be 1.10-1.20 amp.

Step 5. Reverse current connections to the relay. Set current for .400 amp. current lagging voltage. Voltage should be 120 V. a.c. Trip should occur between 73° and 78°.

If some other setting than T = 10 is made relay reach is checked according to the equation $I = \frac{V}{2T} \cos. (-\theta + \propto)$ where V is relay voltage, I is relay current, $\theta = 90 - \propto_m$ where $\propto_m$ is maximum sensitivity angle, $\propto$ is angle between relay current and voltage. When current is lagging voltage use a negative sign for $\propto$. For current leading voltage use a positive sign for $\propto$.

For Step 4 test $\theta = 90° - 75° = 15°$

$$I = \frac{40}{2.0 \times 10.0} \cos. (-15° - 40° - 180°)$$

$$I_{test} = \frac{40}{(20)(10.0)} \cos. (-55° - 180°) =$$

$$(20)(-.575) = .115 \text{ amp.}$$

If the electrical response is radically outside the limits a more complete series of tests is outlined in the section under "Calibration Procedure".

ROUTINE MAINTENANCE

The relays should be inspected periodically, at such time intervals as may be dictated by experience, to insure that the relays have retained their calibration and are in proper operating condition.

CAUTION:

Before making "Hi-pot" tests, jumper terminals 2, 3, 10 together to avoid destroying components in the static network.

Repeat acceptance test steps 1 and 2 for relay setting with current and voltage in phase. The current test value should be determined using the following equation:

$$I_{test} = \frac{V}{2T} \cos. (-\theta \pm \propto)$$

where V = relay test voltage, $\theta = 90 - \propto_m$ where $\propto_m$ is maximum sensitivity angle of the relay set for 75°, $\propto$ is the angle between relay current and voltage. Use negative sign for $\propto$ if current lags voltage and positive sign for current leading voltage.

REPAIR CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. For best results in checking calibration the relay should be allowed to warm up for approximately one hour at rated voltage. However, a cold relay will check to within two per cent of the warm relay.

Potentiometer Adjustments

Connect relay as per test drawing Fig. 12.

1. Remove printed circuit board and apply rated DC voltage to terminals 3 and 2 with positive on 3. Measure dc voltage from relay terminal 2 to the bottom terminal of the zener regulating diode located just below the tap plate. It should read 18-24 volts. Reinsert the board into the relay.

2. Set all compensators taps for T = 10.0.

3. Make the following settings of potentiometer P1, P2, and P3:

NOTE: Loosen the nuts before rotating the brush.

P1 (Left Hand)

Connect ohmmeter to the middle terminal (brush) and the free terminal (without any connections) and adjust the potentiometer for 2800 ohms.

P2 (Center)

Connect ohmmeter to the middle terminal (brush) and the free terminal and adjust potentiometer for 1000 ohms.

P3 (Right Hand)

Make the same setting as for P2 above.

ELECTRICAL TESTS AND PROCEDURES

Preliminary Connections

1. Monitor relay output by using dc voltmeter suitable for reading 0-25 volts dc. Connect the voltmeter to relay terminals 2 and 10 with positive polarity mark on terminal 10. Consider as positive relay output voltmeter deflection of 1-2 volts or more. At balance point, increase trip current about 5% for full 15-20 V. d.c. output.

2. Apply ac voltage to terminals 8 and 9 as shown on Fig. 12. Use variac to control input voltage.

3. Apply ac current to terminals 5 and 7 (jumper terminals 4 and 6 together).

4. Apply rated dc voltage to terminal 3 and 2, observing polarity.

CALIBRATION PROCEDURE

1. Apply 40 volts ac and 1.15 amps. current with the phase shifter at 40° current lagging voltage. Adjust P1 until relay output is obtained.

2. Set phase shifter for 290° current lagging voltage. Set the operating current for 1.15 amps. Adjust potentiometer P2 until relay just trips.

3. Repeat Step 1 and Step 2 until limits of Step 1 and 2 are met without readjustment of P1 and P2. Retighten P2 and P1 nuts.

4. Reverse current connections to the relay (polarity mark on terminal 7). Set phase shifter for 290° current lagging voltage. Set operating current for 1.15 amps. Readjust Potentiometer P3 until relay just trips.

5. Set phase shifter for 345° current lagging voltage. The pickup current should be 1.90-2.10 amp. at 40 volts ac input. Retighten the P3 nut. Reverse current leads again. Pickup current should 1.90-2.10 amps.

6. Set phase shifter for 75° (±5°) current lagging voltage. Increase voltage to 120 volts ac. The pickup current should be below 0.4 amps.

60° – Calibration

1. Apply 40 volts ac and 1.03 amps. current with phase shifter at 270° and adjust P2 until relay just trips.

2. Set the phase shifter for 30° current lagging voltage. Set current for 1.03 amps. Adjust P1 until relay just trips.

3. Repeat steps 1 and 2 until limits of Step 1 and 2 are met without readjustment of P1 and P2. Retighten P1 and P2 nuts.

4. Reverse current connections to the relay (polarity mark on terminal 7). Set phase shifter for 270° current lagging voltage. Set operating current for 1.03 amps. Adjust Potentiometer P3 until relay just trips.

5. Set phase shifter for 330° current lagging voltage. The pickup current should be 2.00-2.15 amps at 40 volts ac input. Retighten P3 nut.

6. Set phase shifter for 60° (±5) current lagging voltage. Increase voltage to 120 volts ac. The pickup current should be below 0.4 amps.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data. For components mounted on the printed circuit board, give the circuit symbol, electrical value and style number.

ELECTRICAL PARTS LIST

PRINTED CIRCUIT BOARD (FIG. 11)

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NUMBER 898C007G02
	RESISTORS	
R9-R11-R17-R19	2.7K Ohm, ½W.	629A531H42
R10-R12-R14-R15 R16-R18-R20-R24 R25-R28-R29-R52	2.7K Ohm, ½W.	184A763H37
R22-R23-R26 R27-R3-R4	8.2K Ohm, ½W.	184A763H49
R50	27K Ohm, ½W.	184A763H61
R8-R33-R34-R53	22K Ohm, ½W.	184A763H59
R35	220K Ohm, ½W.	184A763H83
R54	56K Ohm, ½W.	184A763H69
R37 To R40	100K Ohm, ½W.	184A763H75
R41-R42	100 Ohm, ½W.	184A763H03
R21	1K Ohm, ½W.	184A763H27
R1A-R2A-R3A	2,120 Ohm, ½W.	1210089
RDC	1.500 Ohm, 25W. – 125V.D.C.	1267293
R1-R2-R6-R7	120K ½W.	184A763H77
R5	33K ½W.	184A763H63
R31-R32	1 Meg., ½W.	184A763H99
	POTENTIOMETER	
P1-P2-P3	5000 Ohm, 25W.	836A635H02
	CAPACITORS	
C1	18 MFD.	187A508H10
C2	1.5 MFD.	187A508H09
C4	.015 MFD.	187A624H10
CA1	1.1 MFD.	14C9400H21
CA2-CA3	.6 MFD.	14C9400H10
	DIODES	
D1 To D14-D16 D18-D19-D21-D22 D23-D28-D29-D33 D34-D36 To D48 D52 To D57	CER-69	188A342H06
	TRANSISTORS	
Q1 To Q6	2N3391	848A851H01
Q7-Q9-Q20-Q21	2N697	184A638H18
Q10 To Q14-Q16 Q17-Q18	2N1131	184A638H20
	ZENER DIODES	
DZ1-DZ2	1N957B	186A797H06
DZP	1N2984B	762A631H01
DZ7	1N3686B	185A212H06
DZ8, Z36 (Marked R36)	1N758	186A797H01
DZ4	1N752	186A797H12
	THYRISTORS	
QS1 To QS4	2N884	185A517H05

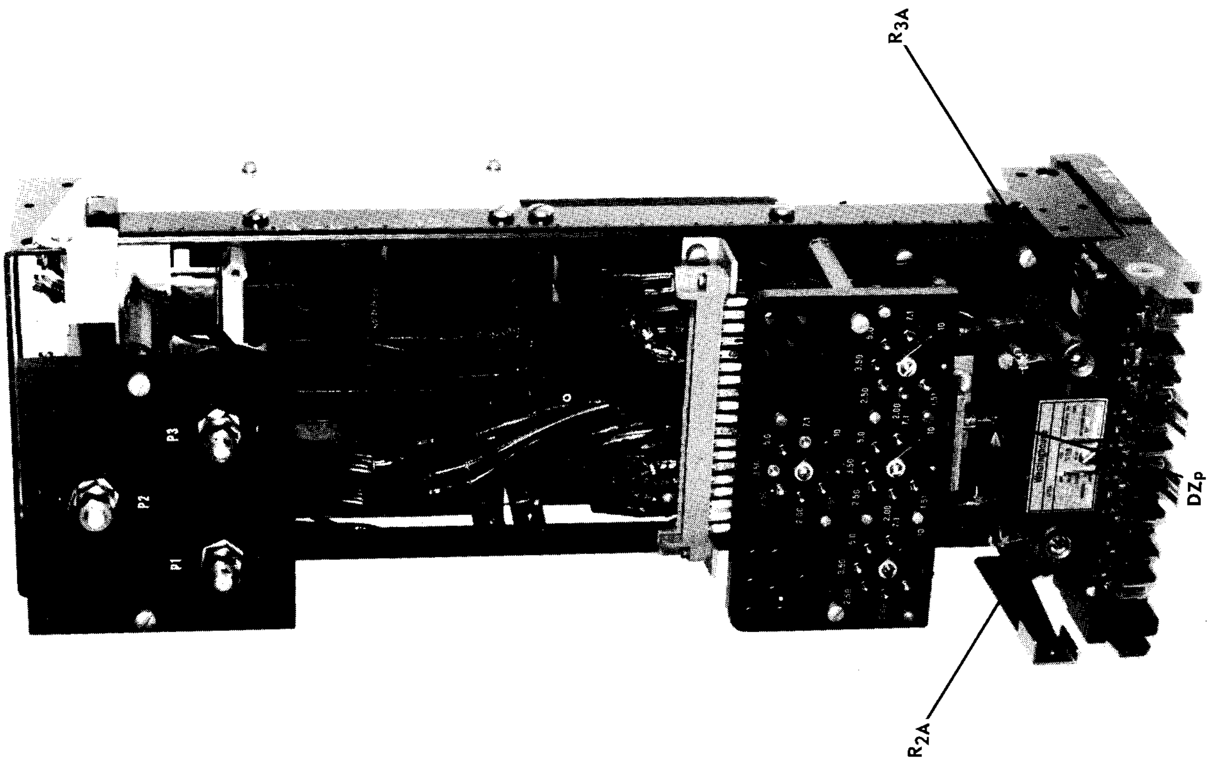

Fig. 2. Type SDB Relay Without Case (Front View Without Printed Circuit Board).

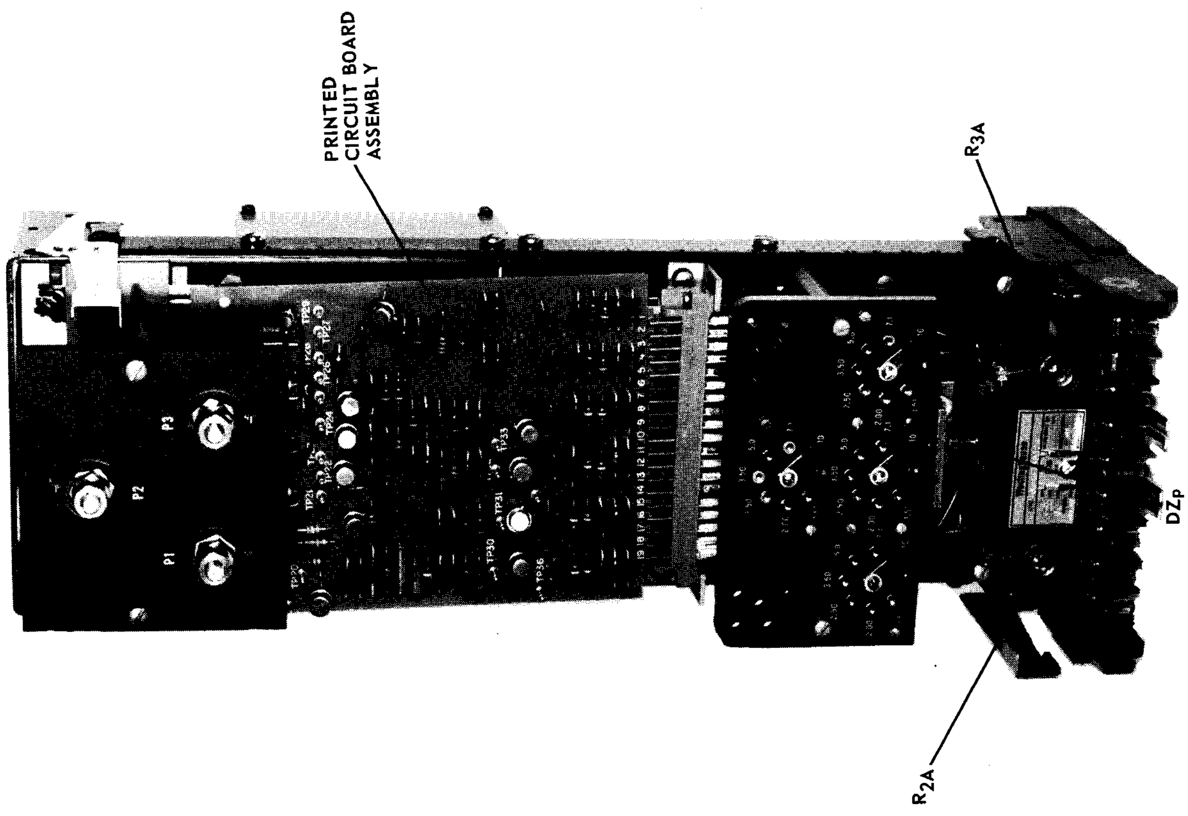

Fig. 1. Type SDB Relay Without Case (Front View).

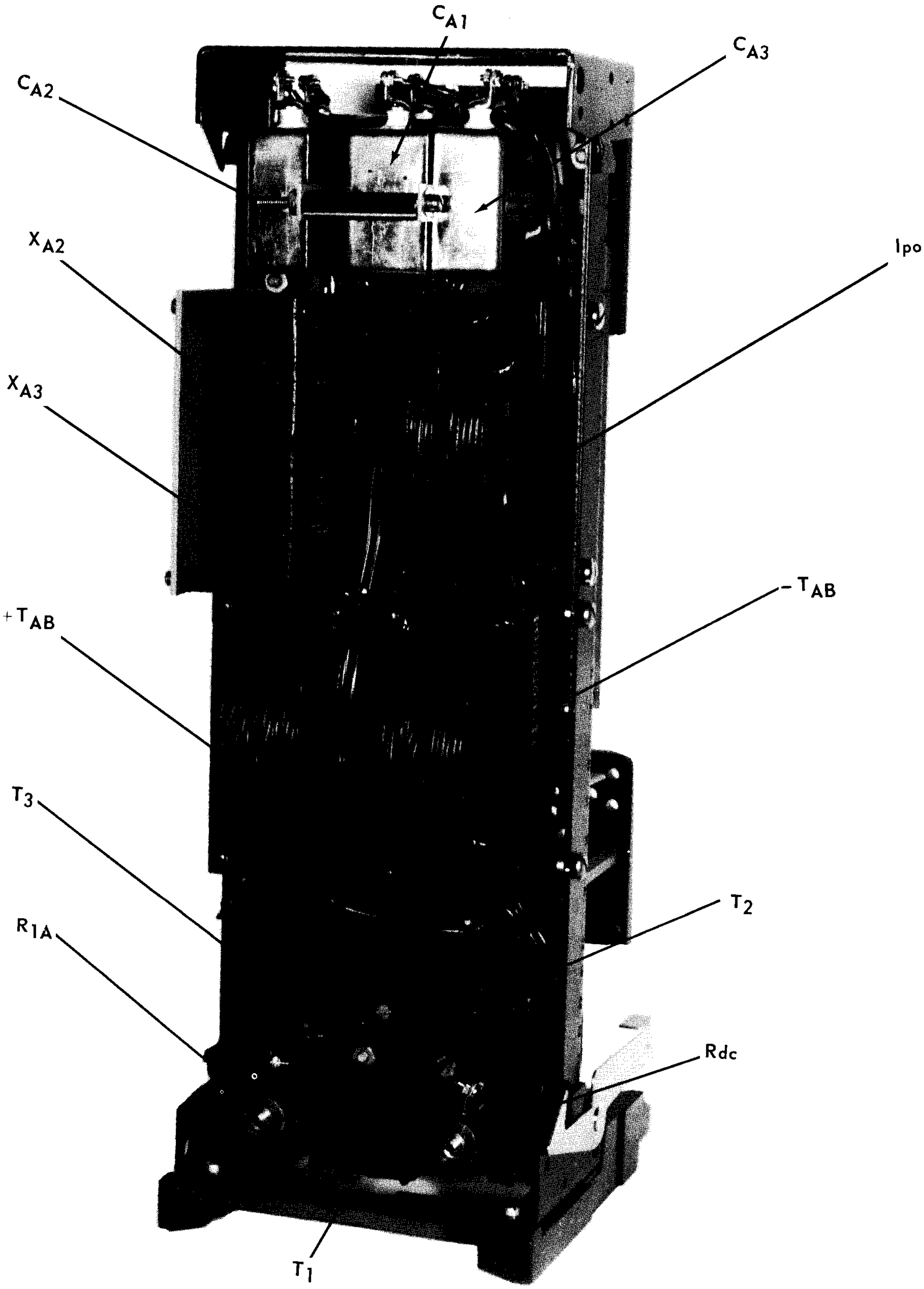

Fig. 3. Type SDB Relay Without Case (Rear View).

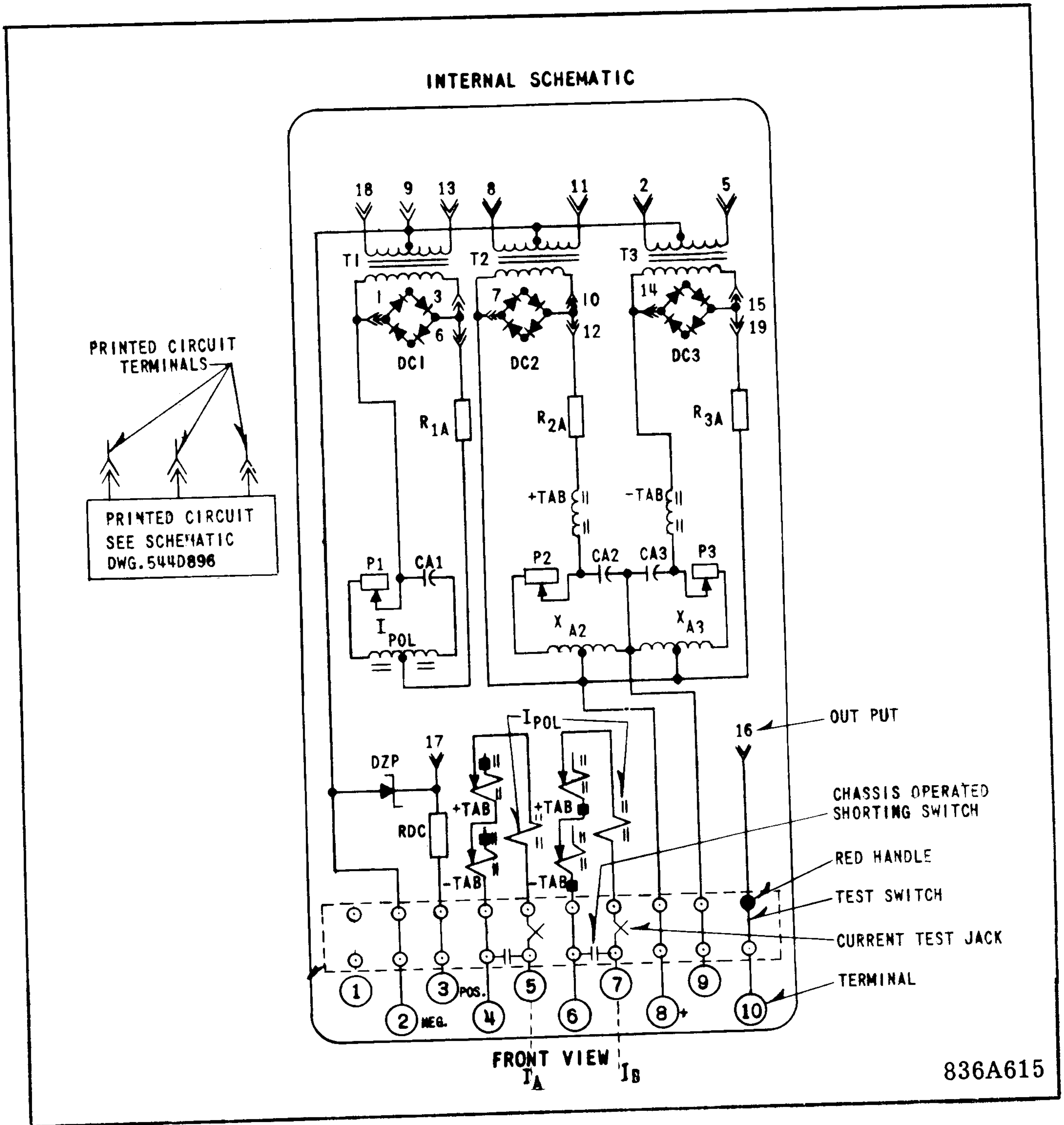

Fig. 4. Internal Schematic of the Type SDB Relay in FT-41 Case.

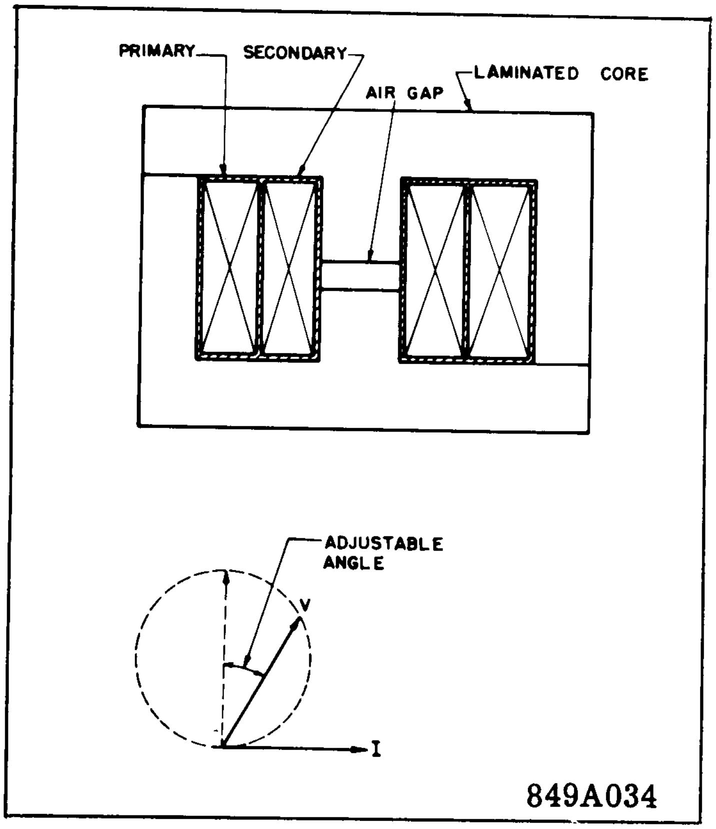

Fig. 6. Compensator Construction

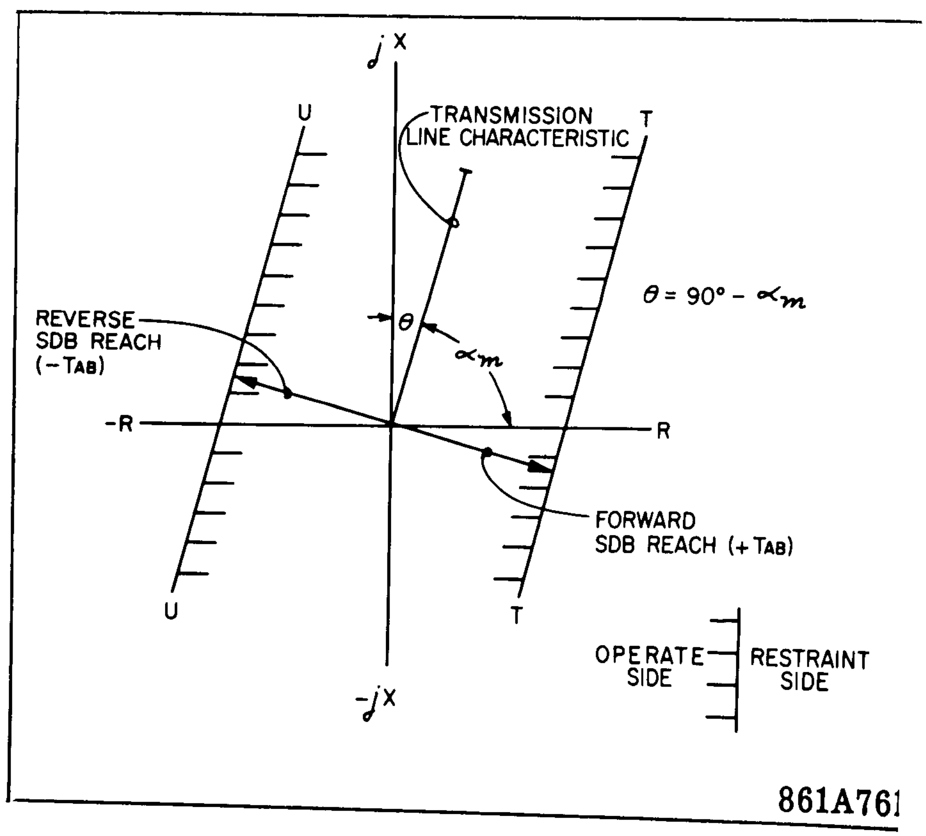

Fig. 7. SDB Relay R-X Diagram Characteristics.

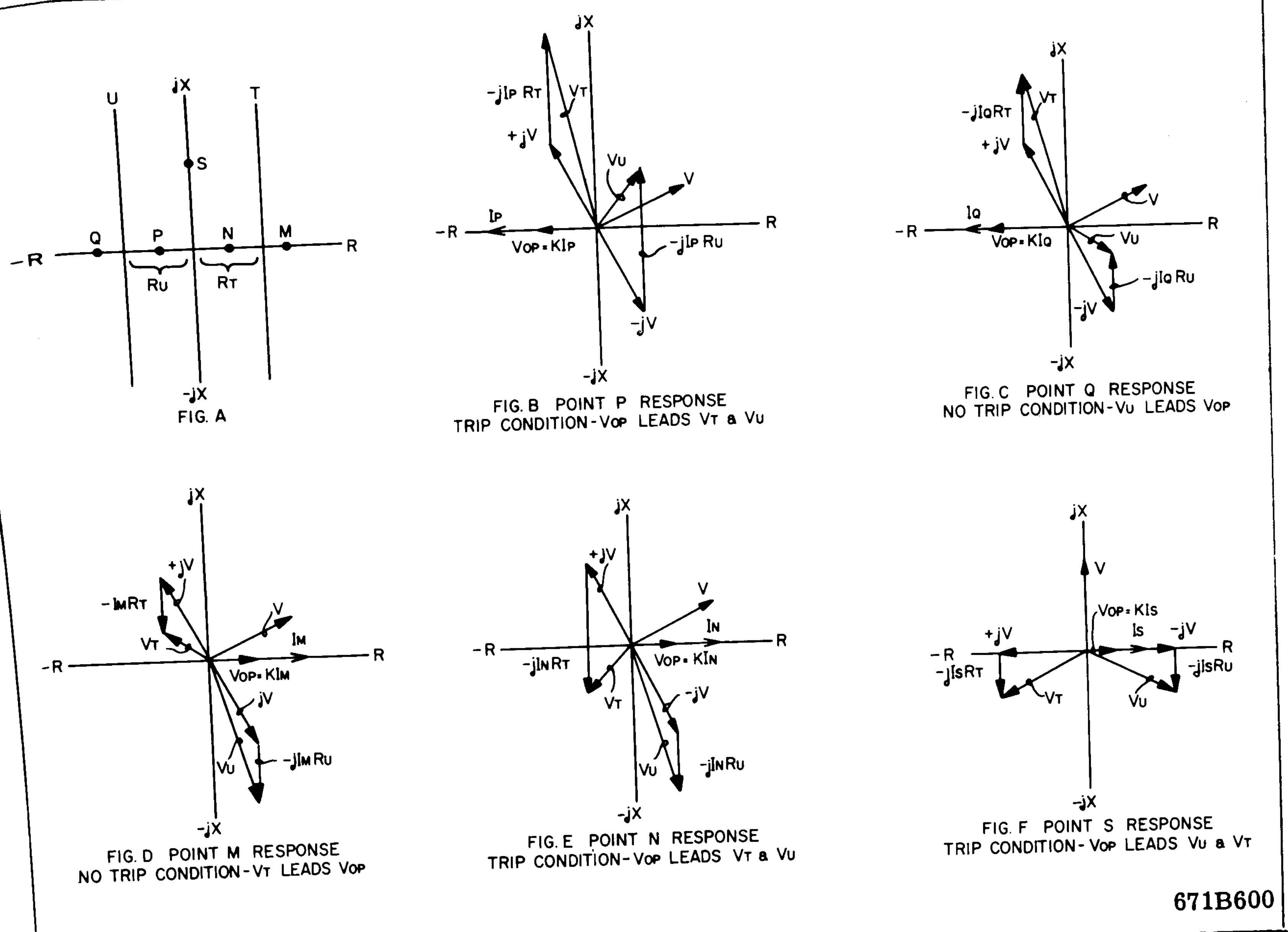

Fig. 8. SDB Relay Phasor Relations for Selected Conditions.

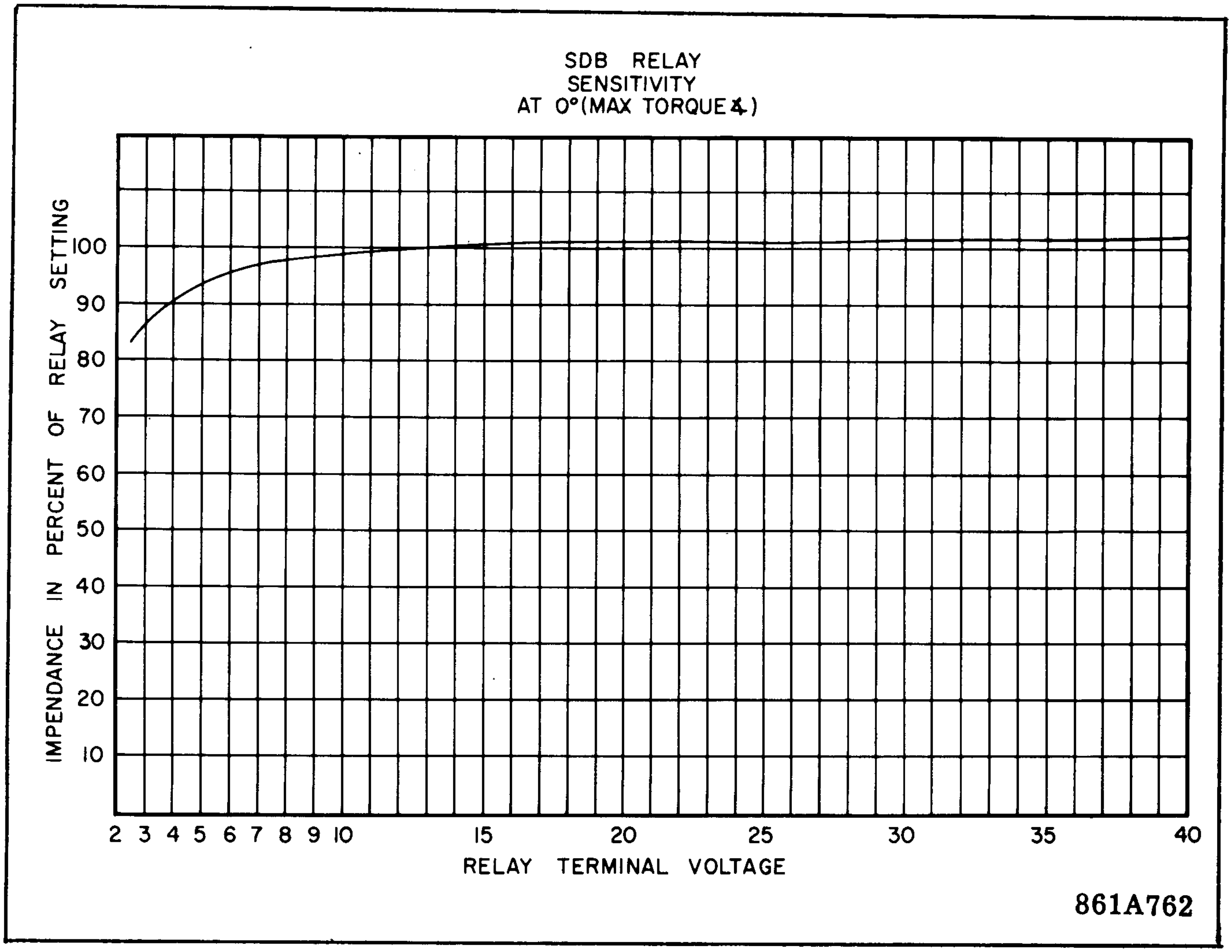

Fig. 9. Impedance-Restraint Voltage Curve for Type SDB Relay.

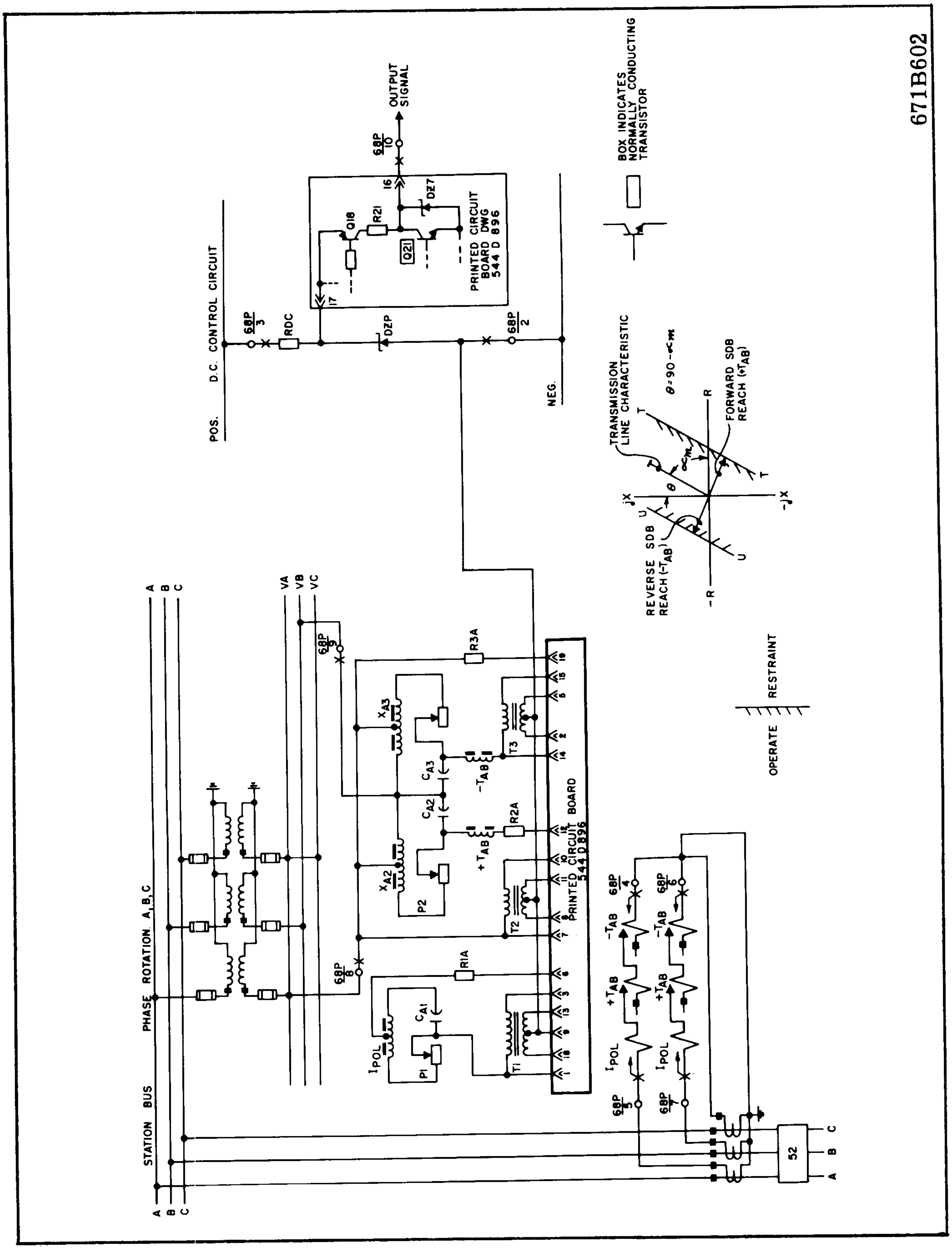

Fig. 10. External Schematic of the Type SDB Relay.

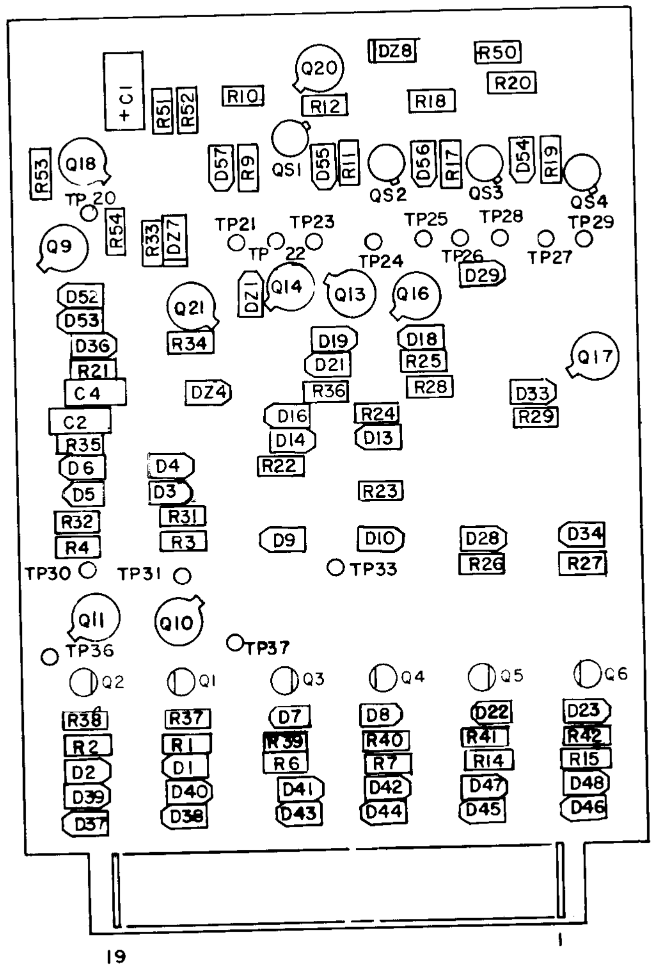

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Fig. 11. Printed Circuit Board Assembly for the SDB Relay.

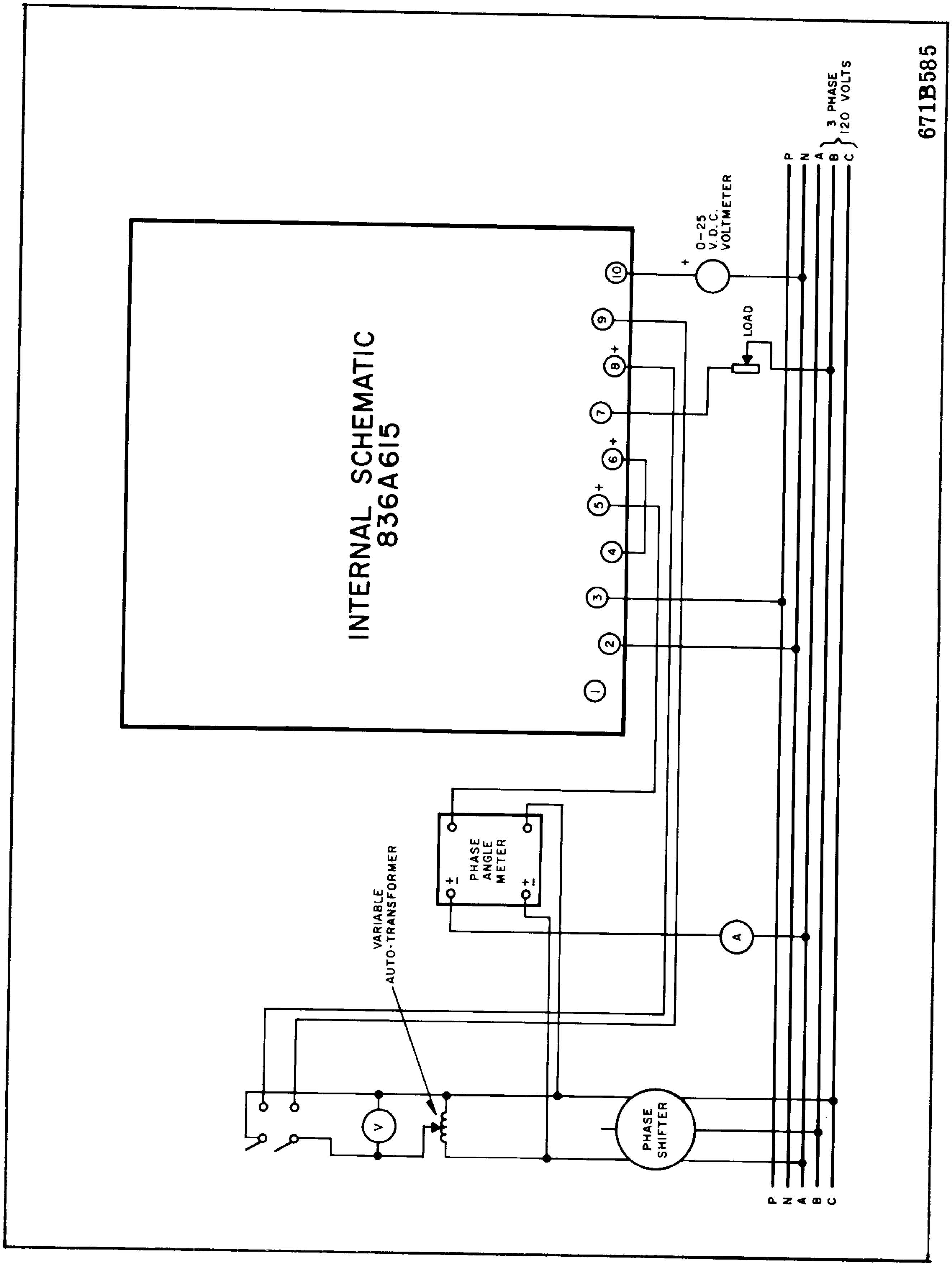

Fig. 12. Test Connections for Type SDB Relay.

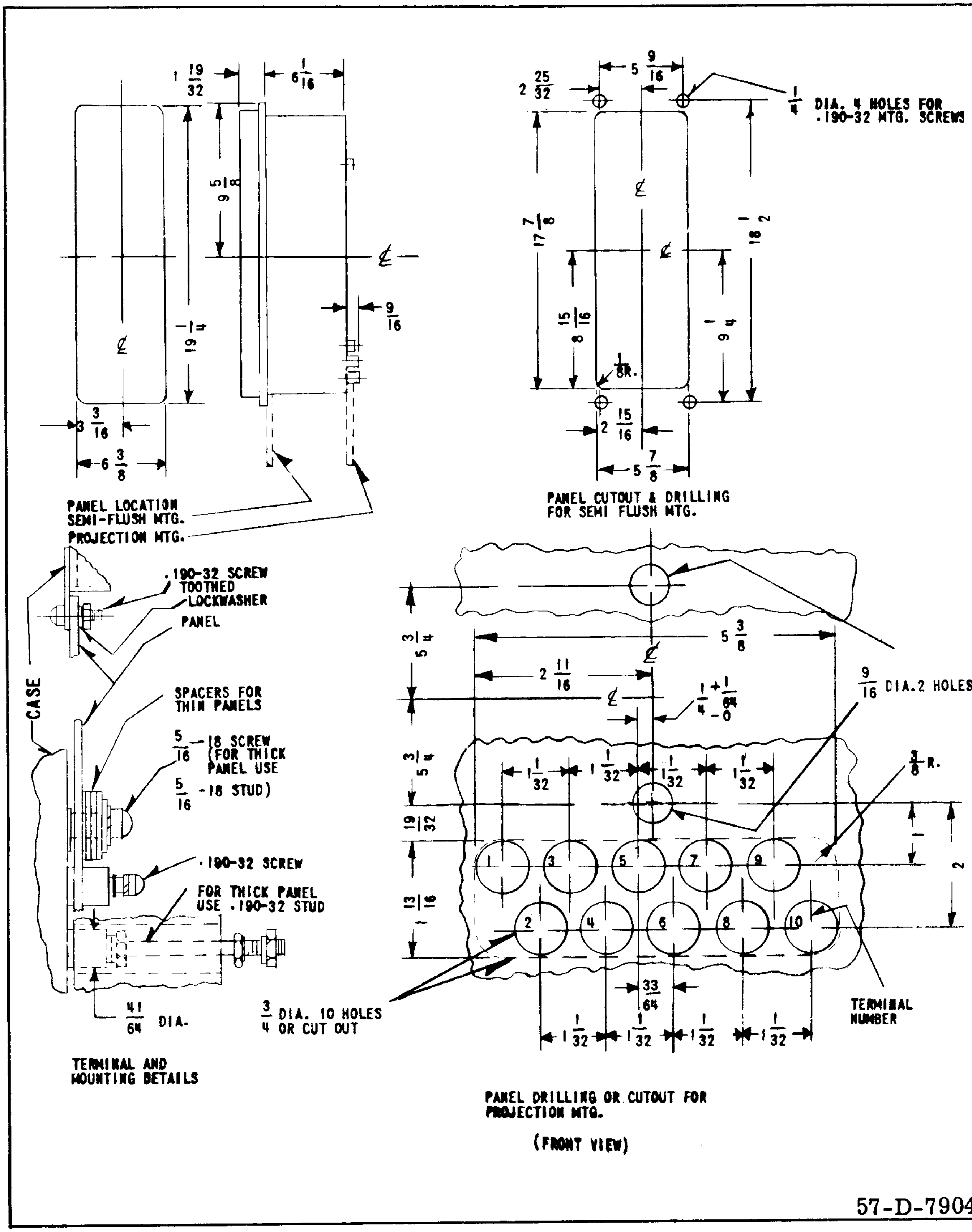

Fig. 13. Outline and Drilling Plan for the Type SDB Relay in the Type FT-41 Case.

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