ABB Power T&D Company Inc.
Relay Divisions
Coral Springs, FL 33065

Instruction Leaflet
I.L. 41-495.51B

Type SKD-T, SKD-IT Compensator Distance Relays

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CAUTION

Before putting protective relays into service, remove all blocking which may have been inserted for the purpose of securing parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

1. APPLICATION

The type SKD-T and SKD-IT relays, Figure 1, are polyphase compensator type distance relays which provide a single zone of phase protection for all three phases. They provide essentially instantaneous tripping for all combinations of phase-to-phase faults, two-phase-to-ground faults, and three-phase faults within the reach setting and sensitivity level of the relay.

Types SKD-T and SKD-IT relays contain electromechanical indicating contactor switches as operation indicators and provide telephone relay contact outputs. The characteristic of the SKD-IT is slightly different from the SKD-T in that the impedance circle of the three-phase unit includes the origin.

2. CONSTRUCTION

Types SKD-T and SKD-IT relays are available in ranges of .1-3.45 ohms, .2-4.35 ohms, .73-21 ohms, and 1.1-31.8 ohms. They consist of two air gap transformers (compensators), two tapped auto-transformers, a phase shifting circuit, a memory circuit, and three isolating transformers which couple the ac quantities into the static network. One large printed circuit assembly provides the characteristics of a dual polarized phase angle comparison unit and contains the drive circuitry for the output telephone relays.

2.1 Compensator

The compensators which are designed T_{AB} and T_{CB} are three-winding air-gap transformers. There are two primary current windings, each current winding having seven taps which terminate at the tap block, Figure 2. The “T” values are marked (.118, .177, .236, .354, .531, .708, and .944), (.23, .307, .383, .537, .69, .92, and 1.23), (0.87, 1.16, 1.45, 2.03, 2.9, 4.06, and 5.8) and (1.31, 1.74, 2.18, 3.05, 4.35, 6.1, and 8.7) for the .1-3.45 ohms, .2-4.35 ohms, .73-21 ohms, and 1.1-31.8 ohms ranges respectively.

A voltage is induced in the secondary which is proportional to the primary tap value and the current magnitude. This proportionality is established by the cross sectional area of the laminated steel core, the length of an air gap which is located in the center of the coil, and the tightness of the laminations. All of these factors which influence the secondary voltage proportionality 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 has a single tap which divides the winding into two sections. One section is connected subtractively in series with the relay terminal voltage. Thus a voltage which is proportional to the phase current is subtracted vectorially from the relay terminal voltage. The second section is connected to an adjustable loading resistor and provides a means of adjusting the phase angle relation between correct and the induced secondary voltage. The phase angle may be set for any value between 60° and 80° by adjusting the resistor between its minimum and maximum value respectively or for 89° by open circuiting

All possible contingencies which may arise during installation, operation or maintenance, and all details and variations of this equipment do not purport to be covered by these instructions. If further information is desired by purchaser regarding this particular installation, operation or maintenance of this equipment, the local ABB Power T&D Company, Inc. representative should be contacted.

the resistor. The factory setting is for a maximum sensitivity angle of 75° ± 3° current lagging voltage.

2.2 Auto-Transformer

The auto-transformer has three taps on its main winding, S, which are numbered 1,2, and 3 on the tap block Figure 2. A tertiary winding M has four taps which may be connected additively or subtractively to inversely modify the S setting by any value from -18 to +18 percent in steps of 3 percent.

The sign of M is negative when the R lead is above the L lead. M is positive when L is in a tap location which is above the tap location of the R lead. The M setting is determined by the sum of per unit values between the R and L lead. The actual per unit values which appear on the tap plate between taps are 0., .03, .09, and .06.

The auto-transformer makes it possible to expand the basic range of T ohms by a multiplier of $\frac{S}{1 \pm M}$. Therefore, any relay ohm setting can be made within ± 1.5 percent from the maximum value of a given range by combining the compensator taps T_{AB} and T_{BC} with the auto-transformer taps S_A-M_A and S_C-M_C.

2.3 Phase Shifting Circuit

"Polarization" is the reference against which the "operate" signal is compared. Polarization for the three-phase unit is obtained by shifting phase 1-2 voltage 90°. The phase shifting circuit consists of a center tapped step-up auto-transformer, XS, which supplies voltage to a series connected resistor and capacitor, RS and CS respectively (Figures 5 and 6). Voltage between the resistor-capacitor junction and the auto-transformer center tap leads the applied voltage by 90°.

2.4 Memory Circuit

The memory circuit consists of a large inductive reactance, XL, and a large capacitive reactance, C3C, which are series connected and are tuned very closely to 60 hertz. In the event of a close-in fault which drops the relay terminal voltage to zero, the energy trapped in the memory circuit will decay relatively slowly, while oscillating at 60 hertz frequency. This will maintain a polarizing signal long enough for the relay to operate with an accurate reach and directional sense.

2.5 Isolating Transformers

Transformers T1, T2, and T3 serve two purposes. First, they isolate the ac circuits from the dc circuit. Secondly, they amplify the clipped ac signal by a factor of 1:8 to make the relay sensitive to low level input signals.

2.6 Printed Circuit Board Assembly

The printed circuit board assemblies shown in Figures 3 and 4 contain all the resistors, diodes, transistors, necessary to perform the functions of a dual polarized phase angle comparison unit. In Figures 3 and 4, resistors are identified by the letter R followed by a number. The same combination is used to identify the same resistor in the internal schematics, Figures 5 and 6. Similarly, diodes are identified by a D and the cathode (the end out of which conventional current flows) is identified by a bar across the point of an arrow. Zener diodes are identified by the letter Z, transistors are identified by a Q, silicon controlled switches by SCR, capacitors by C, and test points by TP.

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.

3. OPERATION

The SKD-T and SKD-IT relays utilize identical ac input circuits. Therefore, an explanation for the SKD-T will suffice for both.

Two distinctly different logic systems are used in the SKD-T & SKD-IT relays. One detects all except three-phase faults and is called the phase-to-phase unit. The other system detects three-phase faults and is called the three-phase unit. Each of the two systems present two voltages to the static phase angle comparison unit which checks the phase angle relation between the two. A non-trip, or restraint condition exists when V_{YB} leads V_{XB}, is referred to in Figure 7(a). A trip condition results when V_{YB} lags V_{XB}.

The three-phase unit can be blocked by external means to prevent tripping during load conditions of system swing conditions which enter the electrical trip zone. Blocking is accomplished by supervising the three-phase output contacts at terminal 20.

3.1 Phase-to-Phase Unit

For phase-to-phase fault detection, the system monitors the three phase-to-phase voltages and compares them with the related I_{ZR} drops computed by the relay compensators. The compensators are set to replicate the protected line section as seen by the secondary side and have the same relative current flowing through them as flows through the total line impedance. If a fault is external to the protected line section as shown in Figure 7(b) at point 1, it can be seen that the voltage V_{BC} is greater than the permissible minimum $(I_C-I_B)\ Z_R$ computed by compensator T_{CB}. The difference voltage V_{YB} shown as a heavy line still leads voltage V_{XB} and the phase angle comparison unit remains in a non-trip or restraint condition.

For a fault within the protected line section at point 2, the voltage V_{CB} is less than the permissible minimum computed by the compensator. This results in the difference voltage V_{YB} being flipped 180° so that it lags V_{XB} and causes the phase angle comparison unit to trip.

Faults behind the relay produce a restraint condition as shown for a fault at point 3. In this case the fault current polarity is the reverse of that for faults at points 1 and 2. The compensator voltage is added to V_{CB} and the resulting voltage V_{YB} leads V_{XB} to maintain the restraint condition.

For each fault illustrated in Figure 7(c), it is assumed that the angle of the protected line is 90° and that the relay is set for a maximum sensitivity angle of 90°.

The phase-to-phase unit will not trip for any balanced three-phase condition whether it be a three-phase fault, an out-of-step or swing condition, or a heavy load. For this reason, an additional circuit is provided which will detect and trip for three-phase faults.

3.2 Three Phase Unit

The three-phase unit is basically a single phase unit operating from delta voltage and current. Since a three-phase fault produces nearly identical conditions in all three phases, any set of phase-to-phase voltage and current may be used to detect a three-phase fault.

Figure 8(a) illustrates the connections which apply voltages to the static phase angle comparison unit. Voltage V_{AB} is modified by the compensator output voltage $(I_A\ I_B)\ Z_R$ to produce voltage V_{XB}. (This is identical to the phase-to-phase unit). A polarizing voltage V_{YB} is obtained by advancing V_{AB} 90° through the phase shifting circuit. A restraint condition exists when V_{YB} leads V_{XB} and a trip condition exists when V_{YB} lags V_{XB}.

A simple diagram in Figure 8(b) shows the protective zone for the three-phase unit and indicates three locations for faults which will present a different set of voltage conditions to the phase-angle comparison unit. Figure 8(c) illustrates the three conditions.

For a fault at location 1, external to the protected line section, V_{AB} is greater than the permissible minimum $(I_A-I_B)\ Z_R$ computed by the compensator T_{AB}. The phase shifted polarizing voltage V_{YB} leads the difference voltage V_{XB} and a restraint condition exists.

When a fault occurs within the protected line section such as at point 2, V_{AB} becomes smaller than the permissible minimum computed by the compensator. This results in V_{XB} being flipped 180° so that the polarizing voltage V_{YB} lags V_{XB} and the phase-angle-comparator unit trips.

For a fault behind the relay such as at point 3, current through the relay has a polarity opposite from that for faults at points 1 and 2. The compensator voltage is added to V_{AB} so that polarizing voltage V_{YB} leads the resulting V_{XB} to maintain the restraint condition.

In Figure 8(c), it is assumed that the angle of the protected line is 90° and that the relay is set for a maximum sensitivity angle of 90°.

The three-phase unit will trip for some phase-to-phase faults and some ground faults as well as for three-phase faults. However, it will not overreach the phase-to-phase setting for any type of fault. Note that the phase-to-phase unit and the three-phase unit use the same compensator, T_{AB}. Thus, the two units have identical reach settings. The three-phase unit may trip for an out-of-step or swing condition. To prevent such tripping, the three-phase unit may be externally supervised at the three-phase output contacts as previously indicated.

3.3 Phase Angle Comparison Unit

Referring to Figure 5, the phase-angle comparison unit for the phase-to-phase unit trips when current flows into the base of transistor Q17 through zener diode Z7. Such tripping current must come from the 20V bus through either transistor Q12 or Q14 located in what might be called the “operate” circuit. This circuit driven by the transformer, T1, is continually trying to trip the unit by supplying current through Q12 or Q14. Each conducts on alternating half-cycles.

When Q14 conducts, a portion of the current goes through resistor R9. This current, I_{R9}, may take either of the two paths to the negative bus. If SCR1 is in a conducting state, I_{R9}, passes through it directly to the negative bus. If SCR1 is in a blocking state, I_{R9} passes through D13 and then through Z7 to transistor Q17 to cause tripping. Restraint thyristor SCR1 is located in what might be called the “polarizing” circuit of the phase-to-phase unit. This circuit is driven by transformer T2.

To prevent the operate circuit from tripping, the polarity-marked terminals of T2 must go positive before the polarity terminals of T1 do. This causes Q2 to conduct current through D5, D6 and D10 to drive the base of Q4. Q4 then conducts current from the 13V bus through R11 to drive the gate SCR1 into conduction. When SCR1 conducts, it short circuits the current which might otherwise pass through D13 to cause tripping. Once SCR1 begins to conduct, the gate loses control and it remains in the conducting state until the current is turned off by Q14. 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 Q11 and Q12 conduct in an attempt to cause tripping. In the polarizing circuit, Q1, Q5 and SCR2 seek to prevent tripping by short circuiting the current which might otherwise pass through D14, Z7 and Q17.

3.3.1 Restraint Squelch

When the operate circuit transistor Q14 conducts, approximately 18V is applied through diode D9 to back bias D10 and prevent Q4 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 Q14. This back-baising connection is called the restraint squelch circuit.

3.3.2 Restraint-Signal Detection

If a condition should develop so that no polarizing voltage appears at transformer T2, then no gating signal would be available to switch SCR1 and short circuit the Q14 current. This, of course, could cause incorrect tripping. A signal detector circuit prevents this from happening. When a useful voltage level is supplied by T2, Q1 and Q2, alternately short circuit the current which flows through R3 from the 20V bus. When the voltage from T2 drops too low to drive Q1 and Q2, the R3 current flows through Z2 to switch Q3 into conduction. This in turn drives Q4 through D7, R5 and D10 causing Q4 to switch SCR1 into conduction to short circuit D13 and prevent tripping.

The operate circuit, driven by T1, and the polarizing-circuits, driven by T2 and T3, are duals having identical circuits which operate on alternate half cycles. The restraint squelch and the restraint-signal detector both work into each of the duals in the same way.

Transformer T3 receives a polarizing signal from the three-phase circuit and drives a polarizing 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 D27 and D28, through Z9 and to Q20. This polarizing circuit contains a restraint squelch and a restraint-signal detector identical to those described for the T2 circuit.

3.3.3 SKD-IT Relay

The SKD-IT relay has a characteristic circle which includes the origin. That is, it will trip on current when the voltage is zero. This feature is obtained by omitting the restraint-signal detector from the T3 circuit. This omission reduces the accuracy of the SKD-IT relay at low-voltage test levels.

3.3.4 Voltage Detector

Operation of the phase-angle comparison unit is based upon a comparison of the phase relation between two amplified signals. If either the ac input signal or the dc amplifying voltage is absent, then no phase relation can be established. Therefore, at the instant either quantity is applied, the logic does not know whether it would trip or restrain since it has no prior knowledge of phase relations. The voltage detector sends a gating pulse from Q15 to all restraint thyristors SCR1, SCR2, SCR3 and SCR4 to block tripping long enough for the true phase-angle relation between input signals to be established. After approximately one-half cycle, Q15 turns on to remove the gating signal unit the relay is deenergized again.

The zener diode Z6 monitors the dc voltage level. if the dc voltage drops too low for the logic to operate properly, it will cause Q16 to turn off and thereby send a gate signal to the restraint thyristors. This will block tripping as long as the dc voltage is at a level which would otherwise cause an incorrect operation.

3.3.5 Output Circuits

The outputs of the SKD-T and SKD-IT are dry telephone relay contacts (normally open). The phase-to-phase output for both relays appears at the TR1 contact (Terminal 11) while the three-phase output is at the TR2 contact (Terminal 20).

4. CHARACTERISTICS

4.1 Distance Characteristic

Phase-to-Phase Unit

This unit responds to all phase-to-phase faults and most two-phase-to-ground faults. It does not respond to load current, synchronizing surges, or out-of-step conditions. While a characteristic circle can be plotted for this unit on the RX diagram as shown in Figure 9, such a characteristic circle has no significance except in the first quadrant where resistance and reactance values are positive. A small portion of the fourth quadrant, involving positive resistance values and negative reactance values, could have some significance in the event that the transmission line includes a series capacitor. The portion of the circle in the first quadrant is of interest because it describes what the relay will do when arc resistance is involved in the fault. The phase-to-phase unit operating on an actual transmission system is inherently directional.

An inspection of Figure 9 indicates that the circle of the phase-to-phase unit is dependent on source impedance Z_S. However, the circle always goes through the line balance point impedance. The reach at the compensator (and line) angle is constant, regardless of the system source impedance. The broadening out of the characteristic circle with a relatively high source impedance gives the phase-to-phase unit the advantageous characteristic that for short lines, it makes a greater allowance for resistance in the fault. Stated another way, the characteristics approach that of a reactance relay more and more closely as the line being protected become shorter and shorter with respect to the source impedance back of the relaying location.

4.2 Sensitivity

Phase-to-Phase Unit

A plot of relay reach, in percent of tap block setting, versus relay terminal voltage is shown in Figure 10. The unit will operate with the correct directional sense for zero voltage phase-to-phase faults. For this condition the product of fault current times T setting must be not less than 0.40 with rated voltage on the unfaulted phase.

The relays may be set without regard to possible overreach due to dc transients. Compensators basically are insensitive to dc transients which attend faults on high-angle systems. The long time-constant of a high-angle system provides a minimum rate of change in flux-producing transient current with respect to time, and therefore induces a minimum of unidirectional voltage in the secondary.

4.3 Distance Characteristic

SKD-T, Three-Phase Unit

The three-phase unit has a characteristic circle which passes through the origin as shown in Figure 11. This circle is independent of source impedance. The three-phase unit is also inherently directional.

If a solid-three-phase fault should occur right at the relay location, the voltage will collapse to zero to give a balance point condition, as implied by the relay characteristic (Figure 11) passing through the origin. When the YB voltage (Figure 13) drops to zero, the relay is unable to determine whether an internal or external fault existed. To avoid this condition, a resonant circuit causes the Y voltage to collapse gradually at a frequency of 60 hertz. This characteristic called memory action provides a reference voltage long enough to determine whether the fault is inside the protected line section or behind the relay.

4.4 Sensitivity

Three-Phase Unit

The impedance curve for the three-phase unit is shown in Figure 16. The unit will operate with the correct directional sense for zero voltage three-phase faults when normal voltage exists at the relay terminals prior to the fault. This operation occurs due to memory action as described above. For this condition, the product of fault current times T setting must be not less than 0.40. The minimum steady state voltage below which the three-phase unit probably will be disabled by the voltage detector circuit is

$1.5V_{L-L}$.

4.5 Distance Characteristics

SKD-IT Three-Phase Unit

The three-phase unit of the SKD-IT relays has a characteristic circle which includes the origin. This feature results from the omission of the restraint-signal detector in the polarizing circuit. The unit will trip for an “IT” product of 0.40 or more when the input voltage is zero.

4.6 General Characteristics

Impedance settings in ohms reach can be made in steps of 3 percent for any range, the .1-3.45 ohm relay, the .2-4.35 ohm relay, the .73-21 ohm relay, and the 1.1-31.8 ohm relay. The maximum sensitivity angle, which is set for 75 degrees at the factory, may be set for any value from 60 degrees to 80 degrees. A change in maximum sensitivity angle will produce a slight change in reach for any given setting of the relay. The compensator secondary voltage output V is larger when V leads the primary current, I, by 90°. This 90° relationship is approached, if the compensator loading resistor (R2A or R2C) shown in Figure 5 and 6 is open-circuited. The effect of the loading resistor, when connected, is to produce an internal drop in the compensator, which is out-of-phase with the induced voltage, IT_{AB} or IT_{AC}. Thus, the net voltage, V, is phase-shifted to change the compensator maximum sensitivity angle. As a result of this phase shift the magnitude of V is reduced.

Tap markings in Figure 2 are based upon a 75° compensator angle setting. If the resistors R2A and R2C are adjusted for some other maximum sensitivity angle the nominal reach is different than indicated by the taps. The reach Z_θ varies with the maximum sensitivity angle, θ, as follows:

$$Z\theta = \frac{TS\sin\theta}{(1+M)\sin 75^\circ}$$

4.7 TIME CURVES AND BURDEN DATA

4.7.1 Operating Time

The speed of operation for the SKD-T and SKD-IT relays is shown by the time curves in Figure 12. The curves indicate the time in milliseconds required for the relay to provide an output for tripping after the inception of a fault at any point on a line within the relay setting.

4.7.2 Burden

The burden which the relays impose upon voltage and current transformers in each phase is listed in Table 1. The potential burden and burden phase angle are based on 69.3 volts line-to-neutral applied to the relay terminals.

5. SETTINGS

5.1 Setting Calculations

Relay reach is set on the tap plate shown in Figure 2. The tap markings are:

Current Circuit Ratings in Amperes

“T” TAP SETTING				CONTINUOUS			1 SEC.
				S = 1	S = 2	S = 3	
.944	1.23	5.8	8.7	5.0	8.5	9.5	240
.708	.92	4.2	6.1	6.0	10.0	10.0	240
.531	.69	3.0	4.35	8.0	10.0	10.0	240
.354	.537	2.2	3.05	10.0	10.0	10.0	240
.236	.383	1.6	2.18	10.0	10.0	10.0	240
.177	.307	1.16	1.74	10.0	10.0	10.0	240
.118	.23	0.87	1.31	10.0	10.0	10.0	240

(T_A, T_B, and T_C)

.1-3.45 Ohms	.118	.177	.236	.354	.531	.708	.944
.2-4.35 Ohms	.23	.307	.383	.537	.69	.92	1.23
.73-21 Ohms	.87	1.16	1.45	2.03	2.9	4.06	5.8
1.1-31.8 Ohms	1.31	1.74	2.18	3.05	4.35	6.1	8.7

(S_A and S_C)

1 2 3

± Values (M_A and M_C)

between taps .03 .09 .06

Maximum sensitivity angle, θ, 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 θ for 60° maximum sensitivity angle, by adjusting R2A and R2C. Set Zone 1 reach to be 90% of the line (85% for line angles of less than 50°).

$$Z\theta = \frac{Zpri\ 0.9\ Rc}{Rv} \qquad \text{EQ. (1)}$$

The terms used in this formula and thereafter are defined as follows:

Calculations for setting the SKD-T and SKD-IT relays are straightforward and apply familiar principles.

Assume a desired balance point which is 90 percent of the total length of line. The general formula for setting the ohms reach of the relay is:

Z_θ = the ohmic reach of the relay in secondary ohms when the maximum sensitivity angle is set for θ degrees.

$$Z = \frac{TS}{1 + M} = \text{the tap plate setting} \qquad \text{EQ. (2)}$$

T = Compensator tap value

S = Auto-transformer primary tap value

θ = Maximum sensitivity angle setting of the relay (Factory setting of θ = 75°)

± M = Auto-transformer secondary tap value. (This is a Per Unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to lower the Z setting. The sign is negative when "R" is above "L" and acts to raise the Z setting).

Zpri = Ohms per phase of the total line section.

0.9 = The portion of the total line for which the relay is set to trip.

Rc = Current transformer ratio

Rv = Voltage transformer ratio

The following procedure should be followed in order to obtain an optimum setting of the relay:

A. Establish the value of Z_θ, as above.

B. Determine the tap plate value Z using the formula:

$$Z = Z_\theta \frac{\sin 75°}{\sin \theta°} \qquad \text{EQ. (3)}$$

$$\text{When } \theta = 75°,\ Z = Z_\theta$$

Now refer to Table II, Table III, Table IV, and Table V for the optimum tap settings.

C. Locate a Table value for relay reach nearest the desired value Z. (It will always be within 1.5% of the desired value.)

D. Select from the Table "S", "T", and "M" settings. "M" column includes additional information for "L" and "R" leads setting for the specified "M" value.

E. Recheck the selected "S", "T" and "M" settings to assure the correct value of Z by using equation (2).

$$Z = \frac{TS}{1 \pm M}$$

For Example:

Step (A) Assume the desired reach, Z_θ for a .73-21 ohm relay is 7 ohms at 60°.

Step (B). The line angle of 60° requires that the relay maximum sensitivity angle be changed from a factory setting of 75° to the new value of 60°. Using equation (3), we find the corrected value for the relay tap settings:

$$Z = 7 \text{ x } \frac{\sin 75°}{\sin 60°} = 7.8 \text{ ohms}$$

Step (C). In Table IV, we find nearest value of 7.8 ohms is 7.88. That is

$$100 \times \frac{7.88}{7.8} = 101.0$$

percent of the desired reach

Step (D). From Table IV, read off:

S = 2
T = 4.06
M = +.03

and "L" lead should be connected over "R" lead, with "L" lead connected to "03" tap and "R" lead to tap "0".

Step (E). Recheck Settings:

$$Z = \frac{TS}{1 \pm M} = \frac{4.06\text{x}2}{1 + 0.03} = 7.88 \text{ From Eq. (2)}$$

$$Z\angle(60°) = Z\frac{\sin 60°}{\sin 75°} = 7.88 \times 0.896 = 7.06$$

from Eq. (3) which is 101.0 percent of the desired setting.

5.2 SETTING THE RELAY

The SKD-T and SKD-IT relays require settings for the two compensator (T_{AB} and T_{CB}), the two auto-transformer primaries (S_A and S_C) and secondaries (M_A and M_C). All of these settings are made with taps on the tap plate.

5.3 Compensator (T_{AB} and T_{CB})

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 TB 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 of 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 but not so tightly as to break the tap screw.

5.4 Auto-Transformer Primary (S_A and S_C)

Primary tap connections are made through a single lead for each transformer. The lead comes out of the tap plate through a small hole located just below or above the taps and is held in place on the tap by a connector screw (Figure 2).

An "S" setting is made by removing the connector screw, placing the connector in position over the insert of the desired setting, replacing and tightening the connector screw. The connector should never make electrical contact with more than one tap at a time.

5.5 Auto-Transformer Secondary (M_A and M_C)

Secondary tap connections are made through two leads identified as L and R for each transformer. These leads come out of the tap plate each through a small hole, one on each side of the vertical row of "M" tap inserts. The lead connector screws.

Values for which an "M" setting can be made are from -.18 to +.18 in steps of .03. The value of a setting is the sum of the numbers that are crossed when going from the R lead position to the L lead position. The sign of the "M" value is determined by which lead is in the higher position on the tap plate. The sign is positive (+) if the L is higher and negative (-) if the R lead is higher.

An "M" setting may be made in the following manner. Remove the connector screws so that the L and R leads are free. Refer to Table II, Table III, Table IV or Table V to determine the desired "M" value. Neither lead connector should make electrical contact with more than one tap at a time.

5.6 Line Angle Adjustment

Maximum sensitivity angle is set for 75° ± 3° (current lagging voltage) at 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 compensator loading resistor R2A and R2C. Refer to **Section 7.3, REPAIR CALIBRATION**, steps 7.3.3 a to f and 7.3.6 a when a change in maximum sensitivity angle is desired.

6. 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 vertically by means of the rear mounting stud or studs 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. External toothed washers are provided for use in the locations shown on the outline and drilling plan to facilitate making a good electrical connection between the relay case, its mounting screws or studs, and the relay panel. Ground Wires are affixed to the mounting screws or studs as required for poorly grounded or insulating panels. Other electrical connections may be made directly to the terminals by means of screws for steel panel mounting or 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 detailed information on the FT case refer to I.L. 41-076.

6.1 External Connections

Figure 13 shows the connections for three zone protection using an SKD-T and SKD-IT Relay.

7. ADJUSTMENTS AND MAINTENANCE

7.1 Acceptance Test

Acceptance tests consist of a visual inspection to make sure there are no loose connections, broken resistors, or broken resistor wires; and an electrical test to make certain that the relay measures the balance point impedance accurately.

7.1.1 Recommended Instruments for Testing

1. Portable high resistance analog or digital ac voltmeter.
2. Portable analog ac ammeter.
3. Ohmmeter,
   Tripping is indicated when the ohmmeter in Figure 14 shows the first indication of contact closure. For best results use one of the high ohm ranges on the ohmmeter.

7.1.2 Distance Units – Electrical Tests

1. Check the electrical response of the relay by using the test connections shown in Figure 14. Set T_A, T_B and T_C for the maximum tap value: S_A and S_C for 1; M_A and M_C for +0.15.
2. Connect the relay for a 1-2 fault as indicated for Test #5 in Figure 14 and adjust the voltage between PH.1 and 1F and between PH.2 and 2F for 45 volts each so that the resultant voltage V_{1F2F} equals 30 volts. (120-45V-45V = 30V.)
3. Supply current necessary to trip the phase-to-phase unit at 45° and swing the phase shifter to determine the two angles, θ_1 and θ_2 at which the unit just trips. The maximum sensitivity angle θ is $\frac{\theta_1 + \theta_2}{2}$. This should be 75° ± 3°. Go from non-trip to trip area.
4. The current required to make the phase-to-phase unit trip should be within the limits given in Table V at an angle of 75° current lag.
5. Repeat Step 4 while using connections for Test #6 and Test #7. The difference in values of current that makes the unit trip for each of the three test connections should not be greater than 5% of the smallest value.
6. Repeat the above test for the three-phase unit. The current required to trip the three-phase unit would be within the limits given in Table V at the maximum sensitivity angle of 75°.

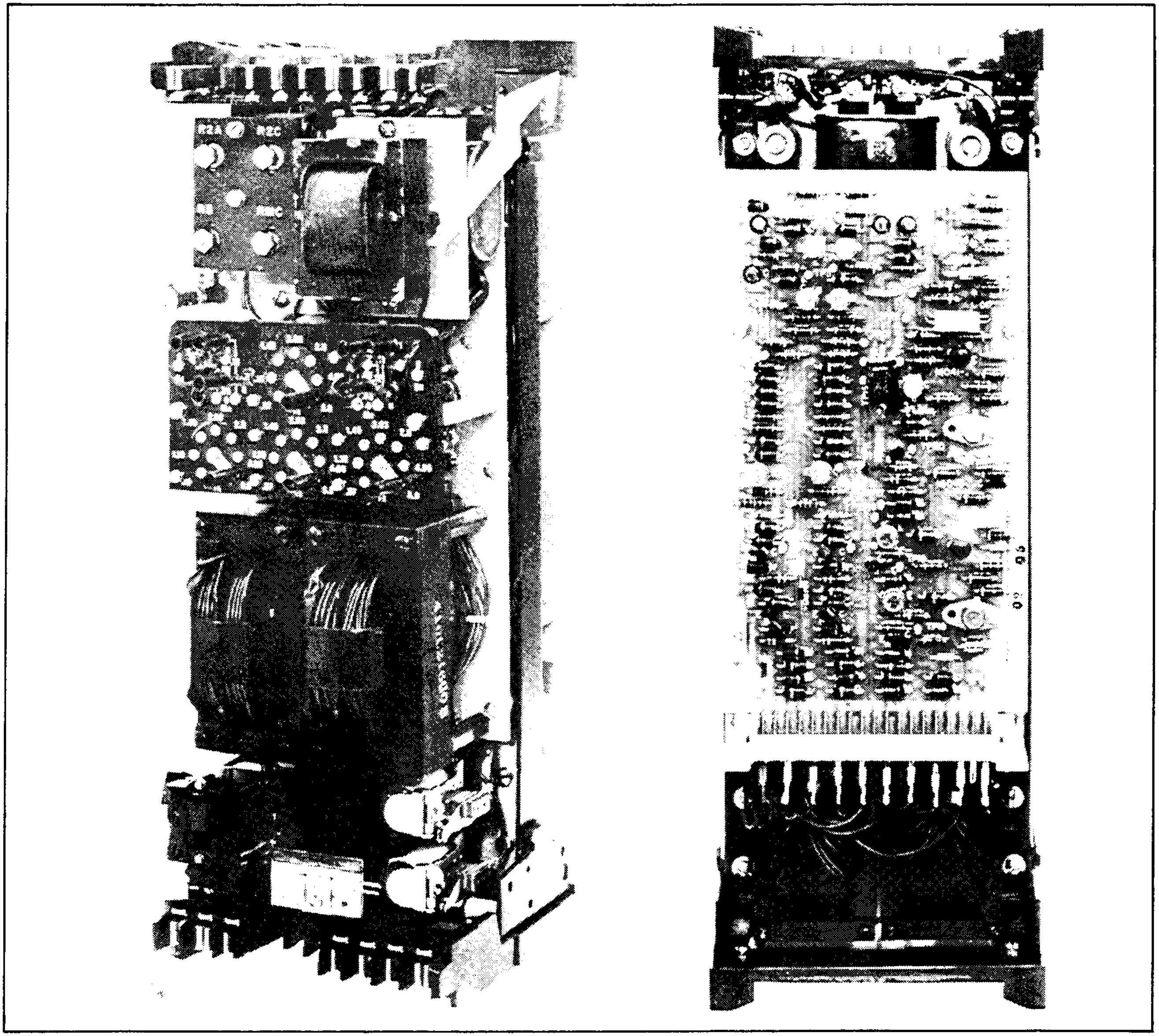


Fig. 1. Type SKD-T and SKD-IT Relays Without Case.

TABLE I

† POTENTIAL BURDEN IN VOLT-AMPERES

	Tap Setting	Phase A-N			Phase B-N			Phase C-N		
	M	VA	Watts	Vars	VA	Watts	Vars	VA	Watts	Vars
I = 0	+.18	3.80	3.06	-2.26	6.40	6.38	0.45	3.1	2.38	1.99
69.3 V_{L-N} 3 ø	0	2.98	2.38	-1.92	4.98	4.97	0.30	2.27	1.69	1.52
S =1	-.18	2.22	1.57	-1.57	3.68	3.68	0.13	1.57	1.13	1.09
I = 0	+.18	1.47	0.80	-1.24	2.27	2.24	-0.33	0.72	0.55	0.46
69.3 V_{L-N} 3 ø	0	1.33	0.62	-1.17	1.93	1.89	-0.37	0.55	0.42	0.36
S = 2	-.18	1.24	0.48	-1.14	1.61	1.57	-0.38	0.38	0.28	0.26
I = 0	+.18	1.22	0.44	-1.14	1.57	1.52	-0.41	0.33	0.25	0.21
69.3 V_{L-N} 3 ø	0	1.16	0.34	-1.11	1.44	1.38	-0.40	0.25	0.19	0.16
S = 3	-.18	1.11	0.27	-1.08	1.31	1.24	-0.42	0.18	0.14	0.12
‡ 5A.∠−75° 3 ø	+.18	1.72	1.66	-0.46	3.52	1.60	-3.14	1.30	0.36	-1.25
69.3 V_{L-N} 3ø	0	1.34	1.33	-0.14	2.53	1.26	-2.19	0.83	0.27	-0.79
S = 1	-.18	1.03	1.03	-0.07	1.68	0.89	-1.42	0.45	0.20	-0.40
‡ ‡ 5A.∠+105° 3 ø	+.18	6.65	4.7	-4.70	10.3	5.75	-10.1	5.00	1.30	-4.84
69.3 V_{L-N} 3 ø	0	5.0	3.94	-3.08	7.90	2.04	-7.60	3.76	0.91	-3.65
S = 1	-.18	3.46	3.14	-1.46	5.70	2.41	-5.17	2.67	0.65	-2.59

† CURRENT BURDEN IN OHMS

(† † MAXIMUM BURDEN CONDITIONS)

S = 1 M = 0	CURRENT CIRCUIT IMPEDANCE AT 5 TO 100 AMPERES (V_{L-L} = 120V)								
	TA (TERM'S 13-12)			TB (TERM'S 15-14)			TC (TERM'S 17-16)		
TAP .73-21 OHM RANGE	Imp. Z	Res. R	Reac. jX	Imp. Z	Res. R	Reac. jX	Imp. Z	Res. R	Reac. jX
.87	.019	.0188	.0026	.0356	.0349	.0068	.0162	.0159	.0031
1.16	.021	.0203	.0054	.039	.0379	.0094	.0194	.0188	.005
1.45	.026	.0243	.0093	.0432	.0411	.0133	.0206	.0189	.0068
2.03	.0344	.0295	.0177	.0569	.0507	.0257	.0294	.0252	.0152
2.9	.0514	.0382	.0344	.081	.0647	.0487	.047	.0344	.0320
4.06	.085	.0523	.067	.130	.087	.0965	.074	.0456	.0583
5.8	.153	.081	.130	.230	.129	.191	.135	.0675	.117

† Typical potential and current burden data applies for all relays and all relay ranges.
† † Maximum burden is produced by phase-to-phase fault involving TA & TB compensators or TB & TC.
‡ Fault current flowing into the line.
‡ ‡ Fault current flowing out of the line.

TABLE II

Relay Setting for 0.1 - 3.45 Ohm Range Relay

	"S" = 1							"S" = 2		"S" = 3		"M"		LEAD CONNECTIONS		
T =	.118	.177	.236	.354	.531	.708	.944	.708	.944	–	1.23	+ M	- M	"L" LEAD	"R" LEAD	
	.100	.150	.200	.300	.450	.600	.800	1.20	1.60	–	2.40	+.18		.06	0	
	.103	.154	.205	.308	.462	.616	.821	1.23	1.64	–	2.46	+.15		.06	.03	
	.105	.158	.211	.316	.474	.632	.843	1.26	1.69	–	2.53	+.12		.09	0	"L" Over "R"
	.108	.162	.217	.325	.487	.650	.866	1.30	1.73	–	2.60	+.09		.09	.03	
	.111	.167	.223	.334	.501	.668	.890	1.34	1.78	–	2.67	+.06		.06	.09	
	.114	.172	.229	.344	.516	.687	.916	1.37	1.83	–	2.75	+.03		.03	0	
	.118	.177	.236	.354	.531	.708	.944	1.42	1.89	–	2.83	0	0	0	0	
	1.22	.182	.243	.365	.547	.730	.973	1.46	1.95	–	2.92		-.03	0	.03	
	1.26	.188	.251	.376	.565	.753	1.00	1.51	2.00	–	3.00		-.06	.09	.06	
	1.30	.194	.259	.389	.584	.778	1.04	1.56	2.08	–	3.12		-.09	.03	.09	"R" Over "L"
	1.34	–	.268	.402	–	–	1.07	–	2.14	–	3.21		-.12	0	.09	
	1.39	–	.278	.416	–	–	1.11	–	2.22	–	3.33		-.15	.03	.06	
	1.44	–	.288	.432	–	–	1.15	–	2.30	–	3.45		-.18	0	.06	

TABLE III

Relay Setting for 0.2 - 4.5 Ohm Range Relay

	"S" = 1							"S" = 2		"S" = 3		"M"		LEAD CONNECTIONS		
T =	.23	.307	.383	.537	.69	.92	1.23	.92	1.23	.92	1.23	+M	-M	"L" LEAD	"R" LEAD	
	.195	.26	.324	.455	.585	.78	1.04	1.56	2.08	–	3.13	+.18		.06	0	"L" Over "R"
	.20	.267	.333	.466	.6	.8	1.07	1.6	2.14	–	3.21	+.15		.06	.03	
	.205	.274	.342	.48	.615	.82	1.1	1.64	2.2	–	3.29	+.12		.09	0	
	.211	.281	.352	.493	.633	.845	1.13	1.69	2.26	–	3.38	+.09		.09	.03	
	.217	.289	.362	.506	.65	.868	1.16	1.74	2.32	–	3.48	+.06		.06	.09	
	.223	.298	.372	.521	.67	.893	1.2	1.79	2.39	–	3.58	+.03		.03	0	
	.23	.307	.383	.537	.69	.92	1.23	1.84	2.46	–	3.69	0	0	0	0	
	.237	.316	.395	.554	.71	.948	1.27	1.9	2.54	–	3.8		-.03	0	.03	"R" Over "L"
	.245	–	.407	.571	.735	.978	1.31	1.96	2.62	–	3.92		-.06	.09	.06	
	.252	–	.42	–	.758	1.01	1.35	2.02	2.7	3.03	4.05		-.09	.03	.09	
	–	–	.435.	–	–	–	1.4	–	2.8	–	4.19		-.12	0	.09	
	–	–	–	–	–	–	1.45	–	2.89	–	4.35		-.15	.03	.06	
	–	–	–	–	–	–	1.5	–	3.0	–	4.5		-.18	0	.06	

TABLE IV

Relay Setting for .73-21 Ohm Range Relay

	"S" = 1							"S" = 2		"S" = 3		"M"		LEAD CONNECTIONS		
T =	.87	1.16	1.45	2.03	2.9	4.06	5.8	4.06	5.8	4.06	5.8	+M	-M	"L" LEAD	"R" LEAD	
	.737	.98	1.23	1.72	2.46	3.44	4.92	–	9.85	–	14.7	+.18		.06	0	
	.755	1.01	1.26	1.76	2.52	3.53	5.04	–	10.1	–	15.1	+.15		.06	.03	
	.775	1.03	1.29	1.81	2.59	3.63	5.18	7.26	10.3	–	15.5	+.12		.09	0	
	.800	1.01	1.33	1.86	2.66	3.73	5.32	7.44	10.6	–	15.9	+.09		.09	.03	"L" Over "R"
	.820	1.09	1.37	1.91	2.74	3.83	5.48	7.65	10.9	–	16.4	+.06		.06	.09	
	.845	1.12	1.41	1.97	2.81	3.94	5.64	7.88	11.3	–	16.9	+.03		.03	0	
	.870	1.16	1.45	2.03	2.9	4.06	5.8	8.12	11.6	–	17.4	0	0	0	0	
	.897	1.20	1.49	2.09	2.99	4.18	5.98	8.36	11.9	–	18.0		-.03	0	.03	
	.925	–	1.54	2.16	3.09	4.32	6.18	8.65	12.3	–	18.6		-.06	.09	.06	
	.955	–	1.59	2.23	3.19	4.47	6.38	8.93	12.7	–	19.2		-.09	.03	.09	"R" Over "L"
	–	–	1.65	2.31	3.29	4.62	6.60	9.13	13.2	–	19.8		-.12	0	.09	
	–	–	1.71	2.39	3.41	4.77	6.82	9.55	13.7	–	20.5		-.15	.03	.06	
	–	–	–	–	–	–	7.08	–	14.1	14.3	21.3		-.18	0	.06	

TABLE V

Relay Setting for 1.1-31.8 Ohm Range Relay

	"S" = 1							"S" = 2		"S" = 3		"M"		LEAD CONNECTIONS		
T =	1.31	1.74	2.18	3.05	4.35	6.1	8.7	6.1	8.7	6.1	8.7	+M	-M	"L" LEAD	"R" LEAD	
	1.11	1.47	1.85	2.58	3.68	5.16	7.37	–	14.71	–	22.1	+.18		.06	0	**"L" Over "R"**
	1.14	1.51	1.89	2.65	3.78	5.30	7.56	–	15.11	–	22.7	+.15		.06	.03	
	1.17	1.55	1.95	2.72	3.88	5.45	7.76	10.9	15.5	–	23.3	+.12		.09	0	
	1.20	1.6	2.00	2.8	3.99	5.6	7.98	11.2	16.0	–	23.9	+.09		.09	.03	
	1.23	1.64	2.06	2.87	4.10	5.75	8.20	11.5	16.4	–	24.6	+.06		.06	.09	
	1.27	1.69	2.12	2.96	4.22	5.92	8.45	11.8	16.9	–	25.3	+.03		.03	0	
	1.31	1.74	2.18	3.05	4.35	6.1	8.7	12.2	17.4	–	26.1	0	0	0	0	
	1.35	1.79	2.25	3.14	4.49	6.29	8.96	12.6	17.9	–	26.9		-.03	0	.03	**"R" Over "L"**
	1.39		2.32	3.24	4.62	6.49	9.25	13.0	18.5	–	27.8		-.06	.09	.06	
	1.44	–	2.4	3.35	4.78	6.70	9.55	13.4	19.1	–	28.7		-.09	.03	.09	
		–	2.48	3.46	4.94	6.93	9.88	13.9	19.8	–	29.7		-.12	0	.09	
	–	–	2.56	3.59	5.11	7.17	10.2	14.3	20.5	2.15	3.14		-.15	.03	.06	
	–		–	–	–	–	10.6	–	21.2	–	31.8		-.18	0	.06	

TABLE VI

Test Voltage = 30 V_{L-L}
M Setting = +.15
S Setting = 1

Range	Setting T	Setting Ohms	Test No.	Unit	Amperes to Trip At 75° Lag
.1-3.45 Ohms	.944	.821	5,6,7 5	Ø-Ø 3Ø	(100% Z-94.7%Z) 18.0-19.0 Amps
.2-4.5 Ohms	1.23	1.07	5,6,7 5	Ø-Ø 3Ø	(100% Z-94.7%Z) 13.8-14.8 Amps
.73-21 Ohms	5.8	5.05	5,6,7 5	Ø-Ø 3Ø	(101% Z-94.5%Z) 2.95-3.15 Amps
1.1-31.8 Ohms	8.7	7.57	5,6,7 5	Ø-Ø 3Ø	(100% Z-94.5%Z) 1.94-2.1 Amps

If the electrical response is outside the limits, a more complete series of tests outlined in Section 7.3 titled **"REPAIR CALIBRATION"** may be performed to determine which component is faulty or out of calibration.

Indicating Contactor Switch

With either of the distance units tripped, pass sufficient dc current through the trip circuit to close the contact of the ICS. This value of current should be not less than 1.0 ampere nor greater than 1.2 amperes for the 1 ampere ICS. The current should not be greater than the particular ICS tap setting being used for the 0.2-2.0 ampere ICS. The operation indicator target should drop freely.

The contact gap should be approximately 0.047" for the 0.2/2.0 ampere unit and 0.070" for the 1.0 ampere unit between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

7.2 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, connect together terminals 2 and 3 to avoid destroying components in the static network.

7.2.1 Distance Units

Use connections for Test #5, #6, and #7 of Figure 14 to check the reach of the relay. Note that the impedance measured by the 3-phase unit in Tests #5, #6, and #7 is:

$$Z_R = \frac{V_{L-L}}{2\, I_L}$$

where V_{L-L} is the phase-to-phase voltage, and I_L is the phase current. When in service and receiving three phase currents, the 3-phase unit response is:

$$Z_R = \frac{V_{L-L}}{\sqrt{3}\, I_L}$$

7.3 REPAIR CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed.

Connect the relay for testing as shown in Figure 14. The four-pole double-throw switch shown in the test circuit selects the type of voltage condition, for a phase-to-phase or a three-phase fault, that will be applied to the relay voltage terminals. The rotary switch switches the fault voltage to various terminals and thereby simulates any combination of phase-to-phase faults without the tester having to change connections or readjust the phase shifter and variable auto-transformers.

7.3.1 Auto-Transformer Check

Auto-transformers may be checked for turns ratio and polarity by using the No. 2 Test connections of Figure 14, and the procedure outlined below.

a. Set S_A and S_C on tap number 3. Set the "R" leads of M_A and M_C on 0.0 and disconnect all the "L" leads. Adjust the voltages V_{1F2F} and V_{2F3F} for 90 volts. Measure the voltage from terminals 8 to the #1 tap of S_A. It should be 30 volts. From 8 to the #2 tap of S_A should be 60 volts. The voltage should read 30 volts from 8 to S_C = 1 and 60 volts from 8 to S_C = 2.

b. Set S_A and S_C on 1 and adjust V_{1F2F} and V_{2F3F} for 100 volts. Measure the voltage drop from terminal 8 to each of the M_A taps. This voltage should be equal to 100 (1+ the sum of values between R and the tap being measured). Example: 100 (1 + .03 + .09) = 112 volts.

Check the taps of M_C in the same manner. Transformers that have an output different from nominal by more than 1.0 volt probably have been damaged and should be replaced.

7.3.2 Distance Unit Calibration

Check to see that the taps on front of the tap block are set as follows:

T_A, T_B (twice and T_C: Set on the highest tap value. (.944, 1.23, 5.8, or 8.7)

S_A and S_C: Set on 1.

"R" for M_A and M_C: disconnected

"L" for M_A and M_C: set for .06 (top position)

7.3.3 Maximum Sensitivity Angle Adjustment Phase-to-Phase Unit

a. Connect the relay for a 1-2 fault as indicated for Test #5. Connect a high-resistance voltmeter (2000 ohms/volt) between the "R" lead and the .03 tap position of M_A, and adjust voltage V_{1F2F} for 30 volts.

b. Pass the current called for in Table VII for 30 volts through T_{AB} compensator with the phase shifter set for the desired maximum sensitivity angle. Adjust potentiometer R2A for a null, or minimum reading, on the voltmeter.

c. Swing the phase shifter and adjust R2A slightly to obtain a minimum reading on the voltmeter when the phase-angle reading is at the desired maximum sensitivity angle. This adjusts the T_{AB} compensator angle.

d. Connect the relay for Test #6. Connect the voltmeter between the "R" lead and the .03 position of M_C, and repeat steps 6 and 7 above except adjust R2C to set the T_{CB} compensator angle.

e. The compensator output can be checked by connecting the voltmeter between the "L" lead of M_C and top terminal of resistor RC. With 5 amperes through the compensator, the voltage should be as measured above in step d.

f. The compensator output can be checked by connecting the voltmeter between the "L" lead of M_A and top terminal of resistor RA. Pass 5 amperes through the compensator. The secondary voltage should be:

V_S = 10.35 T Sin $\theta \pm 1.5\%$

where

θ = the desired maximum sensitivity angle

T = compensator tap setting

10.35 = a design constant = $\frac{10}{\sin 75°}$

1.5% = the allowable variation from nominal

		V_S VOLTS FOR GIVEN "T" SETTINGS		
Ø	V_S	T = 1.23	T = 5.8	T = 8.7
75°	10T	12.3	58	87
60°	8.96T	11.0	52	78

7.3.4 Circuit Calibration

a. Connect "R" for M_A and M_C on ".03" and "L" for M_A and M_C in the top position so that there is .15 between L and R. Connect terminals 7 and 9 together, apply 120Vac between terminals 8 and 9, and adjust R_{MC} until the Ø-Ø unit just trips.

b. Connect the relay as listed in Table VII. The phase-to-phase unit should trip within the current limits listed for the given test voltages. Check the 5.0 volt level first, and adjust R_{MC} further, if necessary, to make the current trip level or Test #7 fall between the trip levels for Test numbers 5 and 6.

To determine the limits of current when θ is not equal to 75°, multiply the nominal values tabulated above by the ratio:

$$\frac{\sin 75°}{\sin \theta}$$

7.3.5 Maximum Sensitivity Angle Check

Use the 30 volt condition in Table VII, except use 20 volts for short reach voltage. Supply the current necessary to fully trip at the 45° angle and swing the phase shifter to determine the two angles, θ_1 and θ_2, at which the unit just trips.

The maximum sensitivity angle, θ, is $\frac{\theta_1 + \theta_2}{2}$

This value should not be more than 5° different from the setting made in steps 5 to 9. The phase-

TABLE VII

Amperes To Trip for θ = 75°									
Test	Volts	.1-3.45 Range		.2-4.5 Range		.73-21 Range		1.1-31.8 Range	
No.	V1F2F	Imin	Imax	Imin	Imax	Imin	Imax	Imin	Imax
5,6,7	5.0	3.05	3.45	2.34	2.55	0.50	0.54	0.33	0.36
	30.0	18.0	19.0	14.0	14.8	2.95	3.15	1.98	2.1
	70.0			32.7	33.4	6.9	7.1	4.62	4.72

to-phase unit testing is complete. True maximum sensitivity angle is the angle adjusted by null method.

7.3.6 Maximum Sensitivity Angle Adjustment

Three-Phase Unit

a. Connect the relay for a 1-2 fault as indicated for Test #5. Apply 30 V_{L-L} between relay terminals 7 and 8. Supply 103% of the current necessary to trip the three-phase unit, and swing the phase shifter to determine the two angles, θ_1 and θ_2, at which the unit just trips. The maximum sensitivity angle, θ, is $\frac{\theta_1 + \theta_2}{2}$

The maximum sensitivity angle can be set by adjusting potentiometer RS. The angle for the three-phase unit should be the same as for the phase-to-phase unit as determined with Test #5 in part 7.3.5.

b. Set the phase shifter for the maximum sensitivity angle. Using only Test #5 connections, the three-phase unit should trip within the same limits as listed for the phase-to-phase unit.

c. The three-phase unit testing is complete.

8. 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.

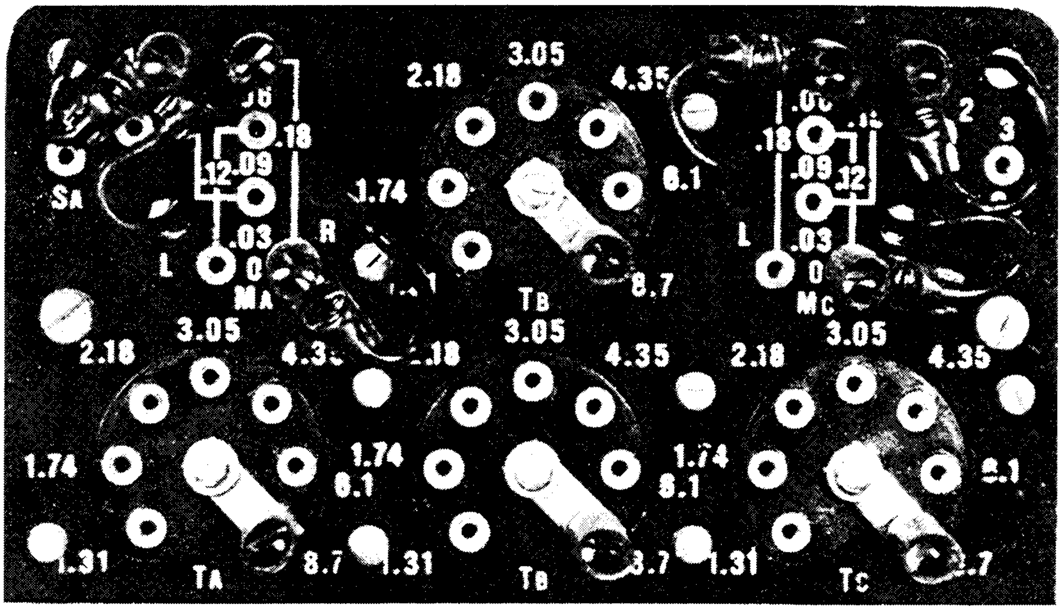
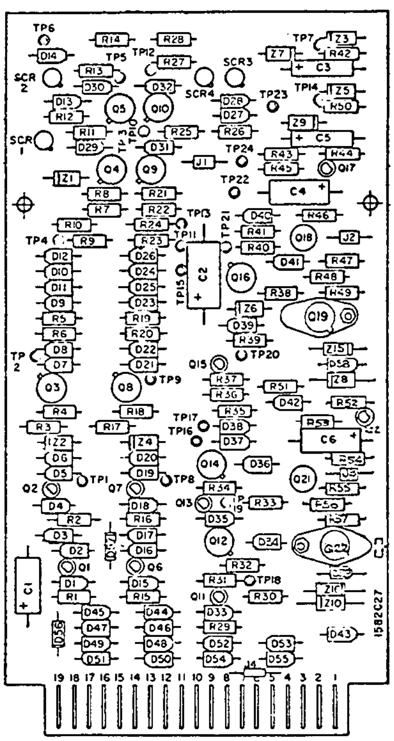


Fig. 2. Tap Plate of 30 Ohm Relay



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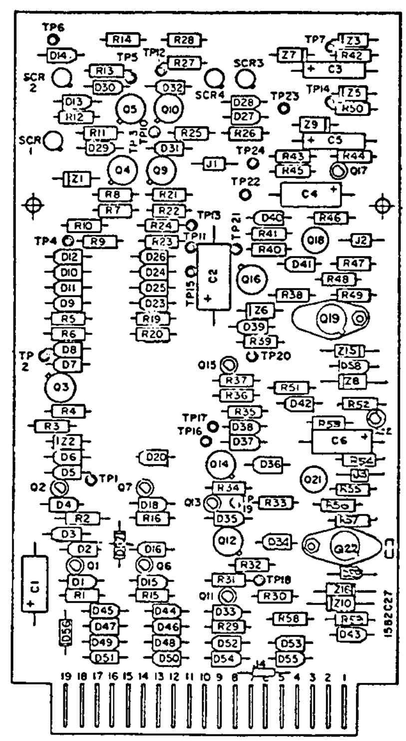
● *Fig. 3. Printed Circuit Component Location for Type SKD-T Relay*



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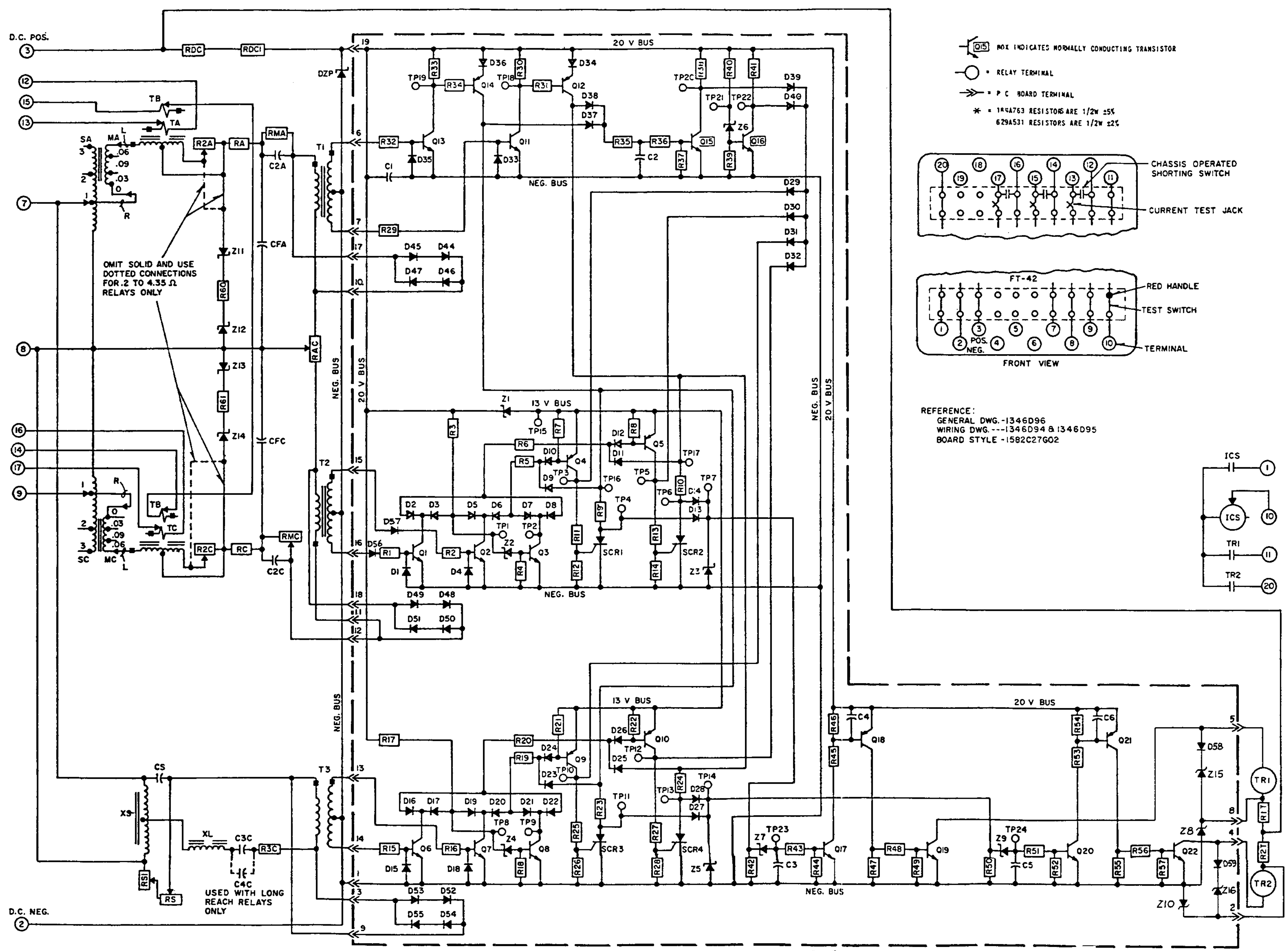
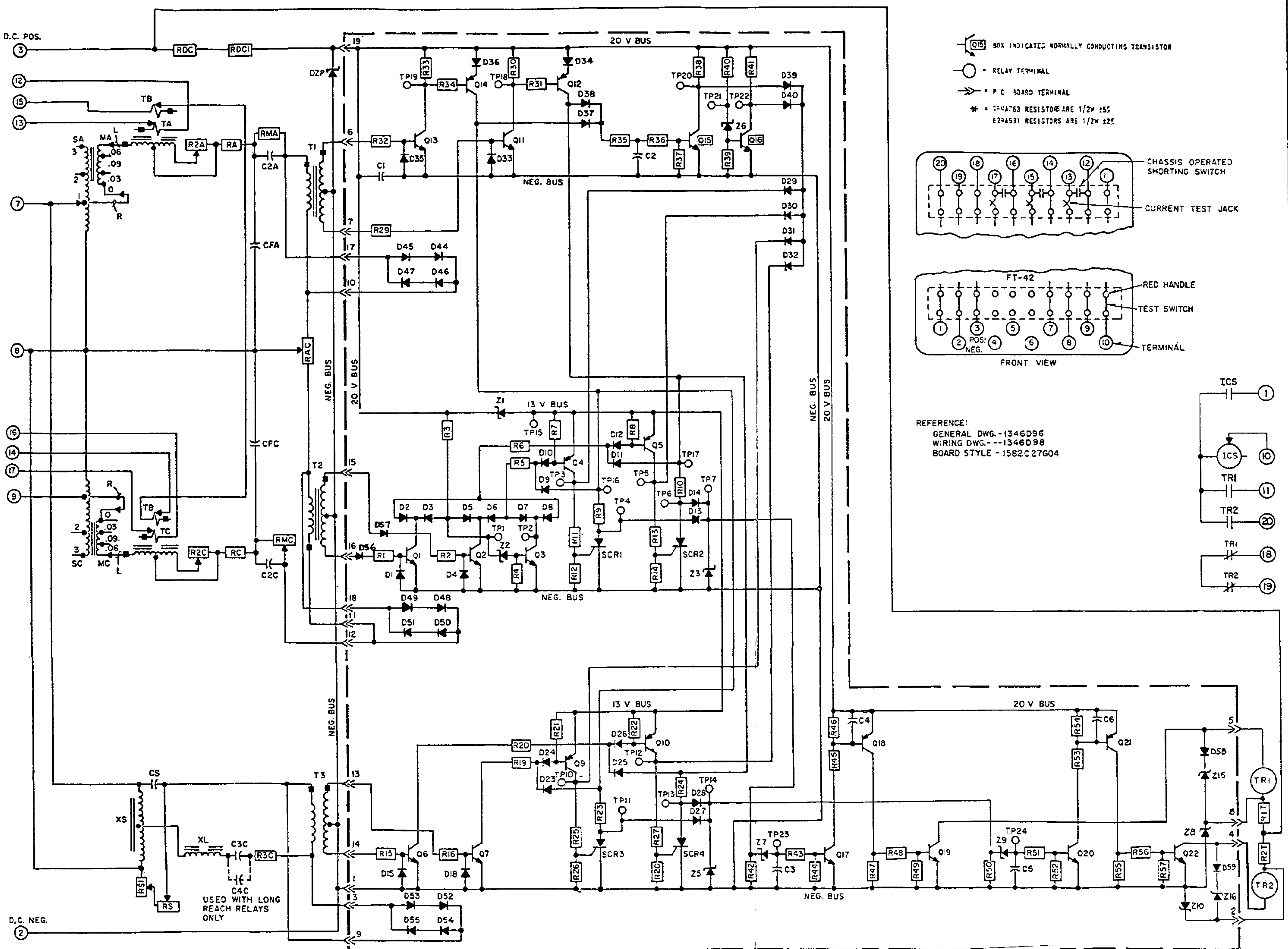
● *Fig. 4. Printed Circuit Component Location for Type SKD-IT Relay*



CAPACITOR	STYLE	REQ	REF.	
C2A-C2C	14C9400H12	2	1.8 MFD	
C3C	1724191	1	0 3 MFD	
C4C	1725974	1	0.3 MFD	
CFA-CFC	1876999	2	1 MFD	
CS	1723408	1	.45 MFD	
C1	187A508H10	1	18 MFD	
C2	187A624H02	1	.25 MFD	
C3-C5 (For .75-20 & 1-31 Ω Relays)	183A669H01	2	.47 MFD	
C4-C6	188A669H05	2	.27 MFD	
C3-C5 (FOR .2-4.35 RELAYS ONLY)	187A624H10	2	.015 MFD	
RESISTORS *				
RA-RC-RMA	1201004	3	1.8K-25W	
R3C	1202954	1	3K-25W	
RS1	185A925H05	1	10K-10W	
RAC	1955270	1	3,55K-25W	
RDC-RDC1	1202586	2	200Ω-25 W	48V
RDC-RDC1	1267285	2	750Ω-25 W	125V
R1T-R2T	1267297	2	2.24K 25W	125V
R1-2-15-16-29-32-35-36	184A763H75	8	100K	
R3-17	184A763H63	2	33K	
R4-18	184A763H59	2	22K	
R5-6-7-8-19-20-21-22-31-34	184A763H49	10	8.2K	
R1T-R2T	1267283	2	600 Ω 25W	48 V
R11-13-25-27	629A531H42	4	2,7K	
R9-10-11-12-23-24-26-28-41-14	184A763H37	9	2.7K	
R30-33	184A763H99	2	1MEG	
R40	184A763H57	1	18K	
R37-39	184A763H61	2	27K	
R38	184A763H45	1	5.6K	
R42-R50	184A763H69	2	56K	
R43-51-	629A531H63	2	20K	
R44-46-49-52-54-57-48-56	629A531H56	8	10K	
R45-53	629A531H52	2	6.8K	
R47-55	629A531H78	2	82K	
R60-61	763A129H03	2	500-Ω 5 W	
POTENTIOMETER				
R2A-R2C	836A635H03	2	1K 12 1/2W	
RMC	836A635H04	1	2.5K 12 1/2W	
RS	836A635H05	1	5K 12 1/2W	
TRANSISTOR				
Q1-2-6-7-11-13-15	848A851H01	7	2N3391	
Q3-8-16	184A639H18	3	2N697	
Q4-5-9-10-12-14	184A638H20	6	2N1132	
Q18-21	849A441H01	2	2N3645	
Q17-20	848A851H02	2	2N3417	
Q19-22	837A617H03	2	2N3590	
ZENER DIODES				
DZP	762A631H01	1	1N2984B	20V 5%
Z1-7-9	186A797H12	3	1N752A	5.6V 5%
Z2 TO Z6	186A797H01	5	1N758	10V 5%
Z8-Z10-Z15-Z16	187A936H13	4	1N3049B	160V
Z11 TO Z14	184A854H08	4	1N2846A	200V 10%
SCR				
SCR1 TO SCR4	185A517H05	4	2N884	
REACTOR				
XL	606B544G02	1		
XS	407C121G12	1		
TRANSFORMER				
T1 - T2	292B563G05	2		
T3	292B563G05	1		
SA MA - SC MC	407C121G11	2		
COMP & TOC ASSY				
TA-TB-TC	410C216G05	1	.2-4.35	
TA-TB-TC	410C216G03	1	.75-20	
TA-TB-TC	410C216G04	1	1.1-31	
TELEPHONE RELAY				
TR1 - TR2	541D514H17	2		
INDICATING CONTACTOR SWITCH	288B752G38	1		
DIODES				
D1 TO D40-44 TO 55-58-59	188A342H06	54	1N4818	
D56-D57	837A692H03	2	1N645A	

Fig. 5. Detailed Internal Schematic of SKD-T Relay.



CAPACITOR	STYLE	REQ	REF.	
C2A-C2C	14C9400H12	2	1.8 MFD	
C3C	1724191	1	0.3 MFD	
C4C	1725974	1	0.3 MFD	
CFA-CFC	1876999	2	1 MFD	
CS	1723408	1	45 MFD	
C1	187A508H10	1	18 MFD	
C2	187A624H02	1	.25 MFD	
C3-C5(FOR .75-20 & 1.1-31 Ω RELAYS)	188A669H01	2	.47 MFD	
C4-C6	188A669H05	2	.27 MFD	
C3-C5(FOR .2-4.35 Ω RELAYS ONLY)	187A624H10	2	.015 MFD	
RESISTORS *				
RA-RC-RMA	1201004	3	1.3K-25W	
R3C	1202954	1	3K-25W	
RS1	185A925H05	1	10K-10W	
RAC	1955270	1	3 55K-25W	
RDC-RDC1	1202586	2	200Ω - 25W	48V
RDC-RDC1	1267285	2	750Ω - 25W	125V
R1T-R2T	1267297	2	224K 25W	125V
R1-2-15-16-29-32-35-36	184A763H75	8	100K	
R3	184A763H63	1	33K	
R4	184A763H59	1	22K	
R5-6-7-8-19-20-21-22-31-34	184A763H49	10	8.2K	
R1T-R2T	1267283	2	600Ω 25W	48V
R11-13-25-27	629A531H42	4	2.7K	
R9-10-12-23-24-26-28-41-14	184A763H37	9	2.7K	
R30-33	184A763H99	2	1MEG	
R40	184A763H57	1	18K	
R37-39	184A763H61	2	27K	
R38	184A763H45	1	5.6K	
R42-R50	184A763H69	2	56K	
R43- -51-	629A531H63	2	20K	
R44-46-49-52-54-57-48-56	629A531H56	8	10K	
R45-53	629A531H52	2	6.8K	
R47-55	629A531H78	2	82K	
R60-61	763A129H03	2	500 Ω 5 W	
POTENTIOMETER				
R2A-R2C	836A635H03	2	1K 12 1/2W	
RMC	836A635H04	1	2.5K 12 1/2W	
RS	836A635H05	1	5K 12 1/2W	
TRANSISTOR				
Q1-2-6-7-11 13-15	848A851H01	7	2N3391	
Q3-	184A638H18	1	2N697	
Q4-5-9-10-12-14	184A638H20	6	2N1132	
Q18-21	849A441H01	2	2N3645	
Q17-20	848A851H02	2	2N3417	
Q19-22	837A617H03	2	2N3590	
ZENER DIODES				
DZP	762A631H01	1	1N2984B	20V 5%
Z1-7-9	186A797H12	3	1N752A	5.6V 5%
Z2	186A797H01	1	1N758	10V 5%
Z8-Z10-Z15-Z16	187A936H13	4	1N3049B	160V
Z11 TO Z14	184A854H08	4	1N2846A	200V 10%
SCR				
SCR1 TO SCR4	185A517H05	4	2N884	
REACTOR				
XL	606B544G02	1		
XS	407C121G12	1		
TRANSFORMER				
T1 - T2	292B563G05	2		
T3	292B563G05	1		
SA MA - SC MC	407C121G11	2		
COMP & SDC ASSY				
TA-TB-TC	410C216G05	1	2-4 35	
TA-TB-TC	410C216G03	1	75-20	
TA-TB-TC	410C216G04	1	1.1-31	
TELEPHONE RELAY				
TR1 - TR2	541D514H37	2		
INDICATING CONTACTOR SWITCH	288B752G38	1		
DIODES				
D1 TO 15-18-23 TO 40-44 TO 55-58-59	188A342H06	48	1N4818	
D56-57	837A692H03	2	1N645A	

Fig. 6. Detailed Internal Schematic of SKD-IT Relay.

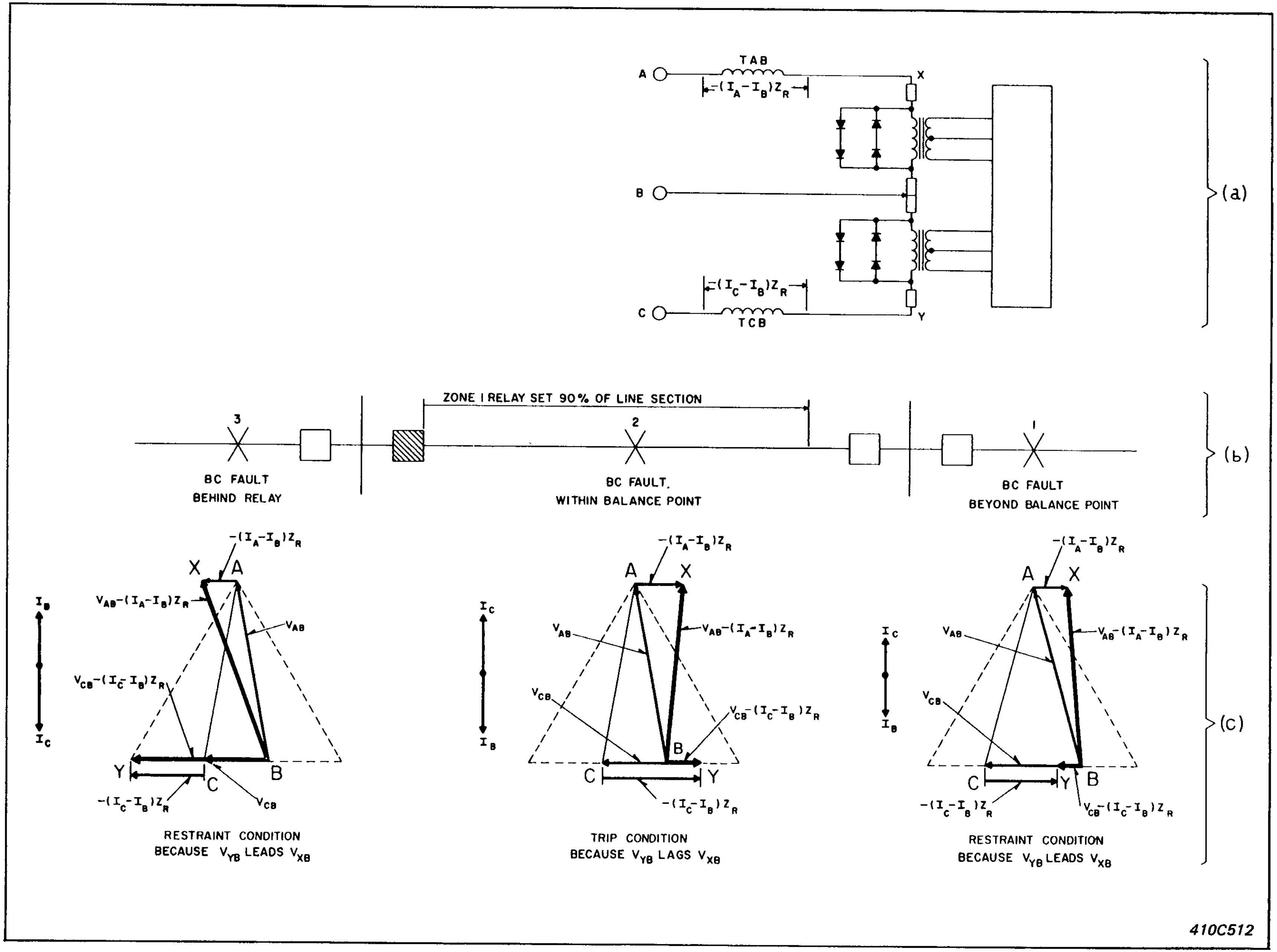


Fig. 7. Voltage and Current Conditions for the Phase-to-Phase Unit.

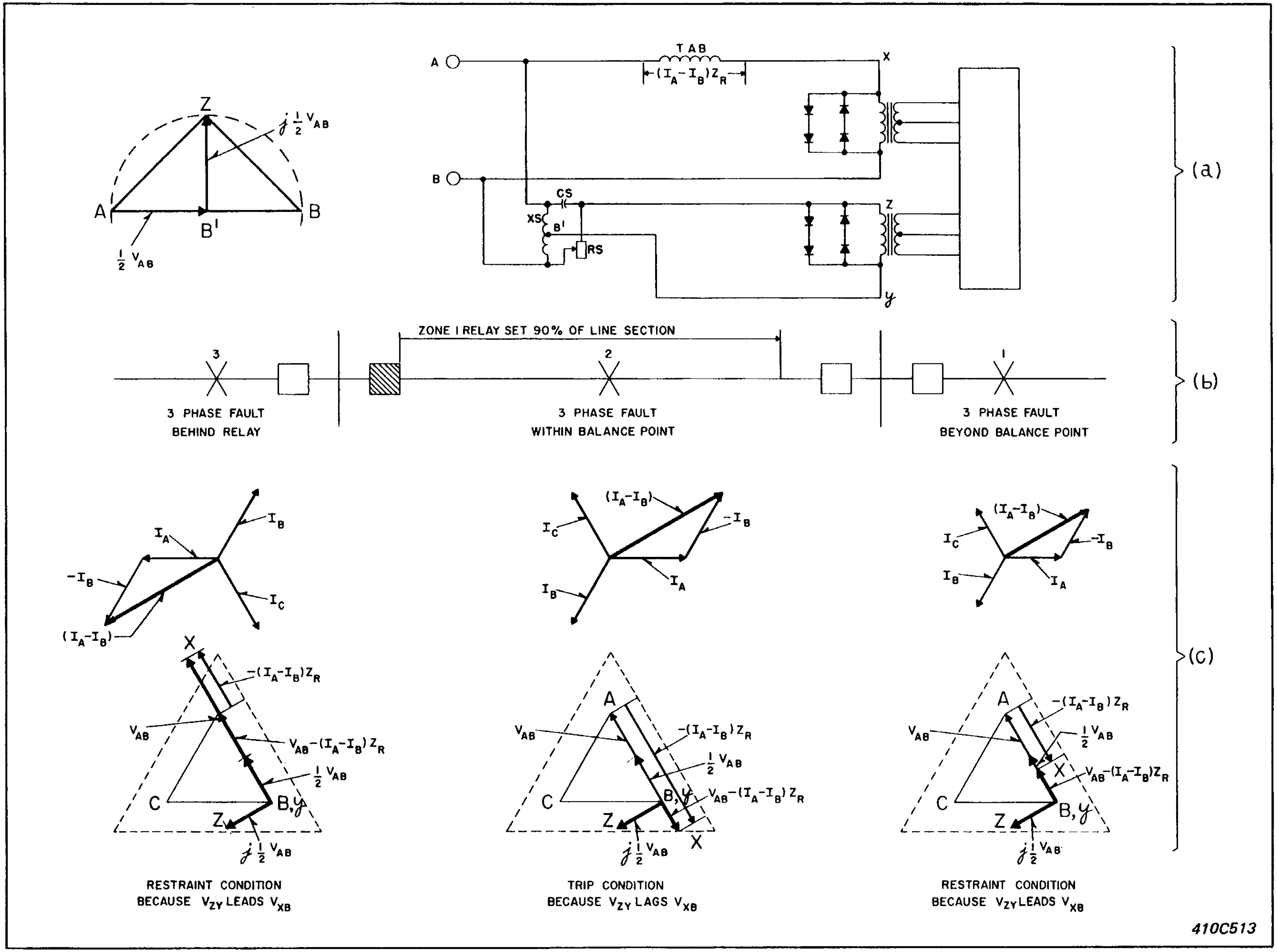


Fig. 8. Voltage and Current Conditions for the Three-Phase Unit.

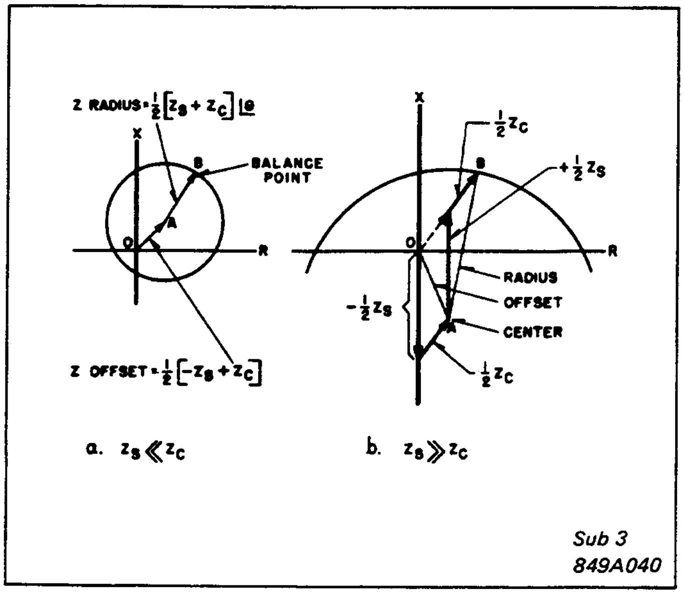


Fig. 9. Impedance Circles for Phase-to-Phase Unit in Types SKD-T and SKD-IT

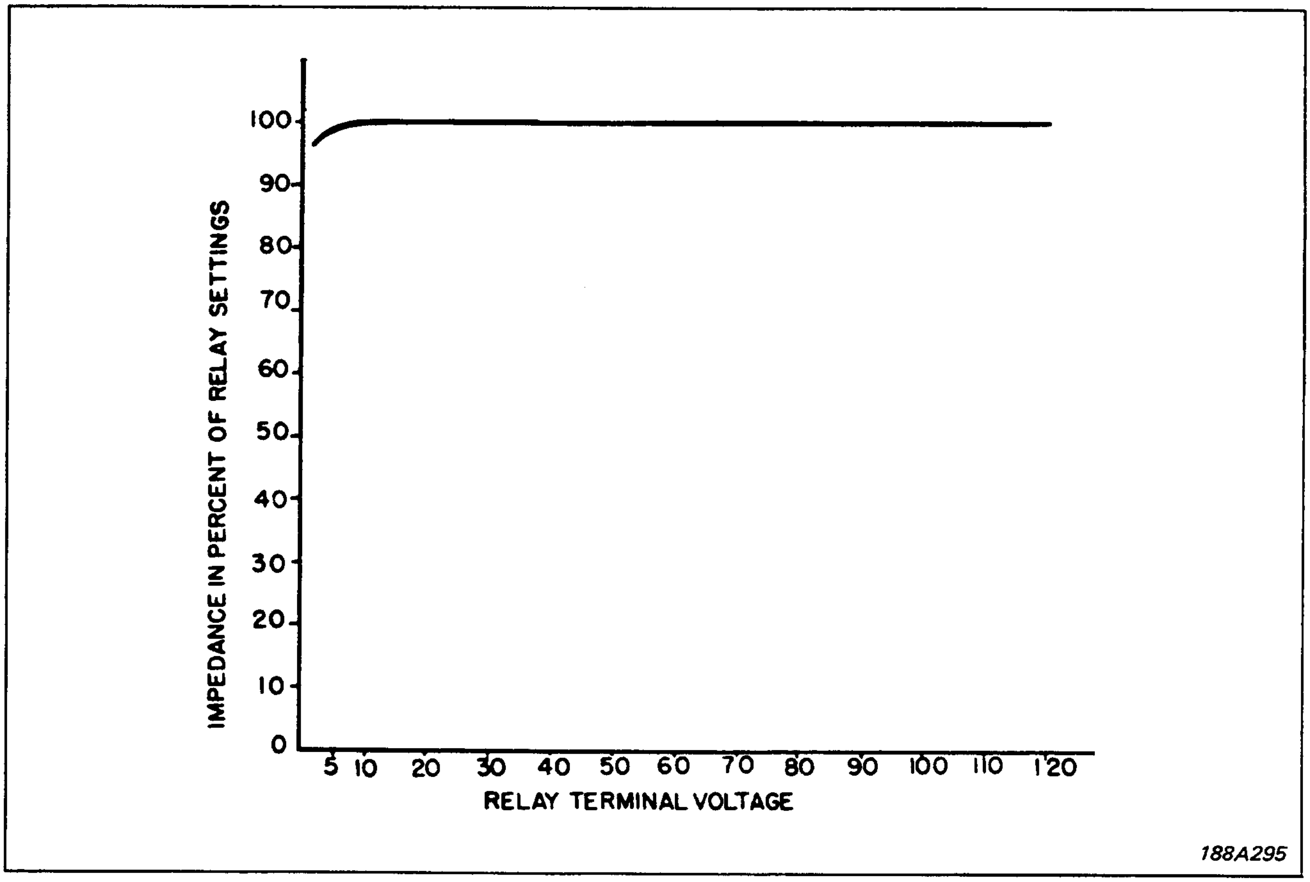


Fig. 10. Impedance Curves for Types SKD-T and SKD-IT Relays.

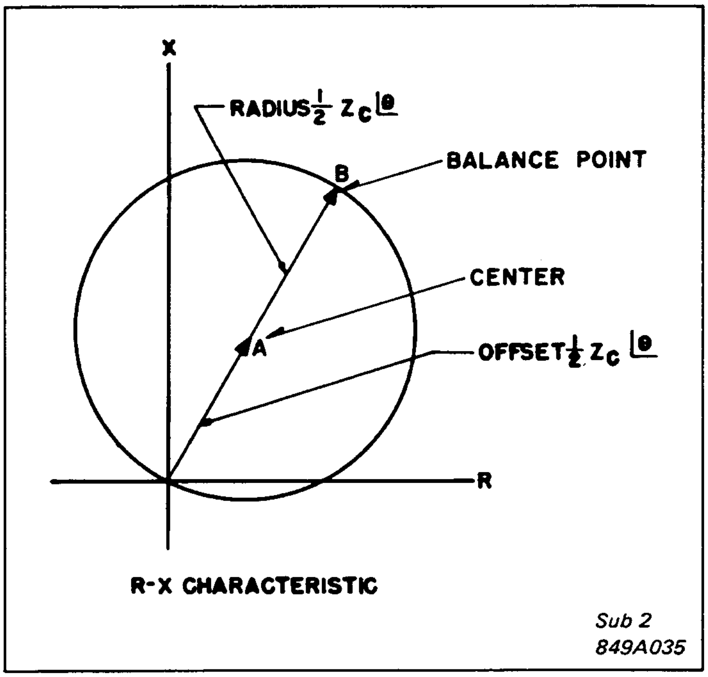


Fig. 11. Impedance Circle for Three-Phase Unit in Types SKD-T and SKD-IT Relays.

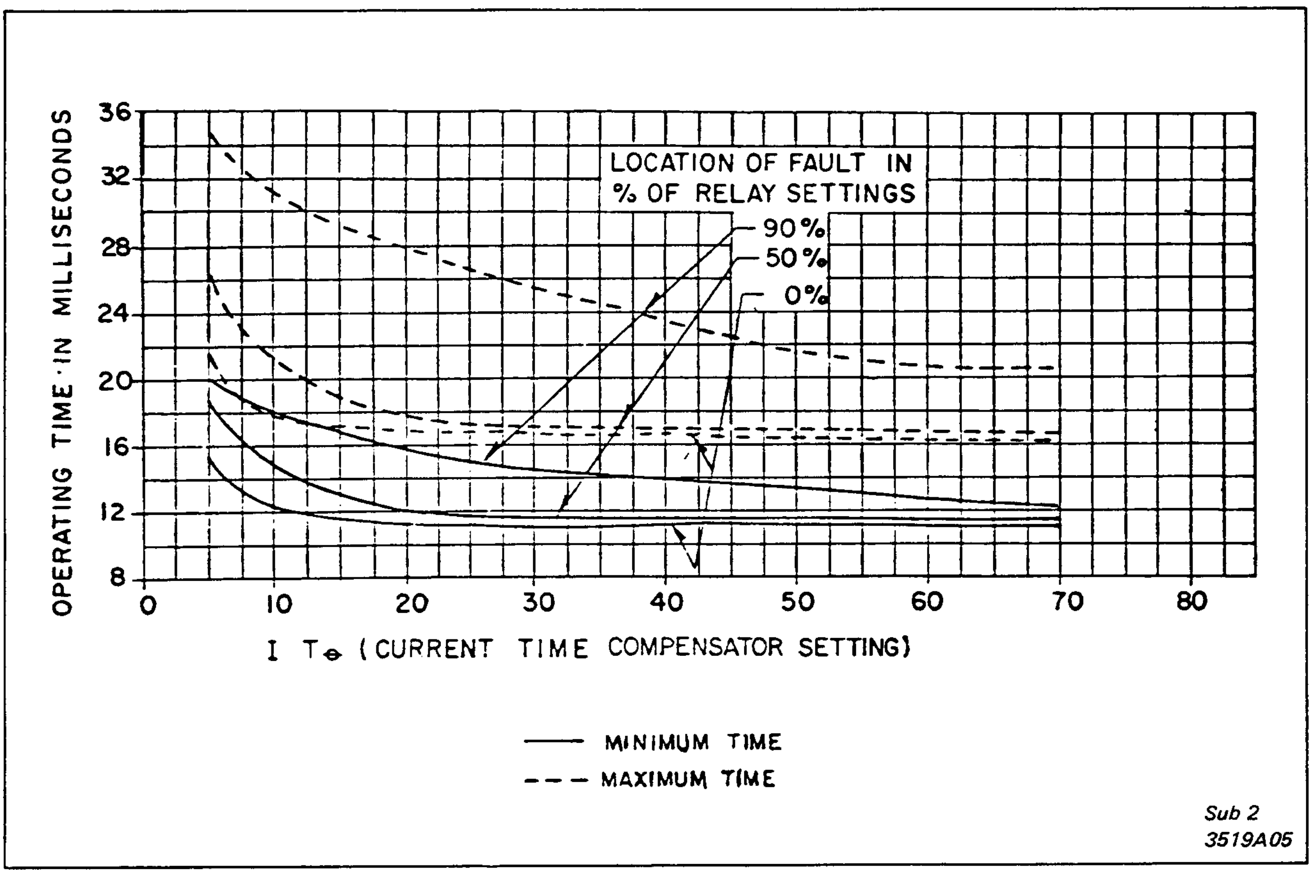
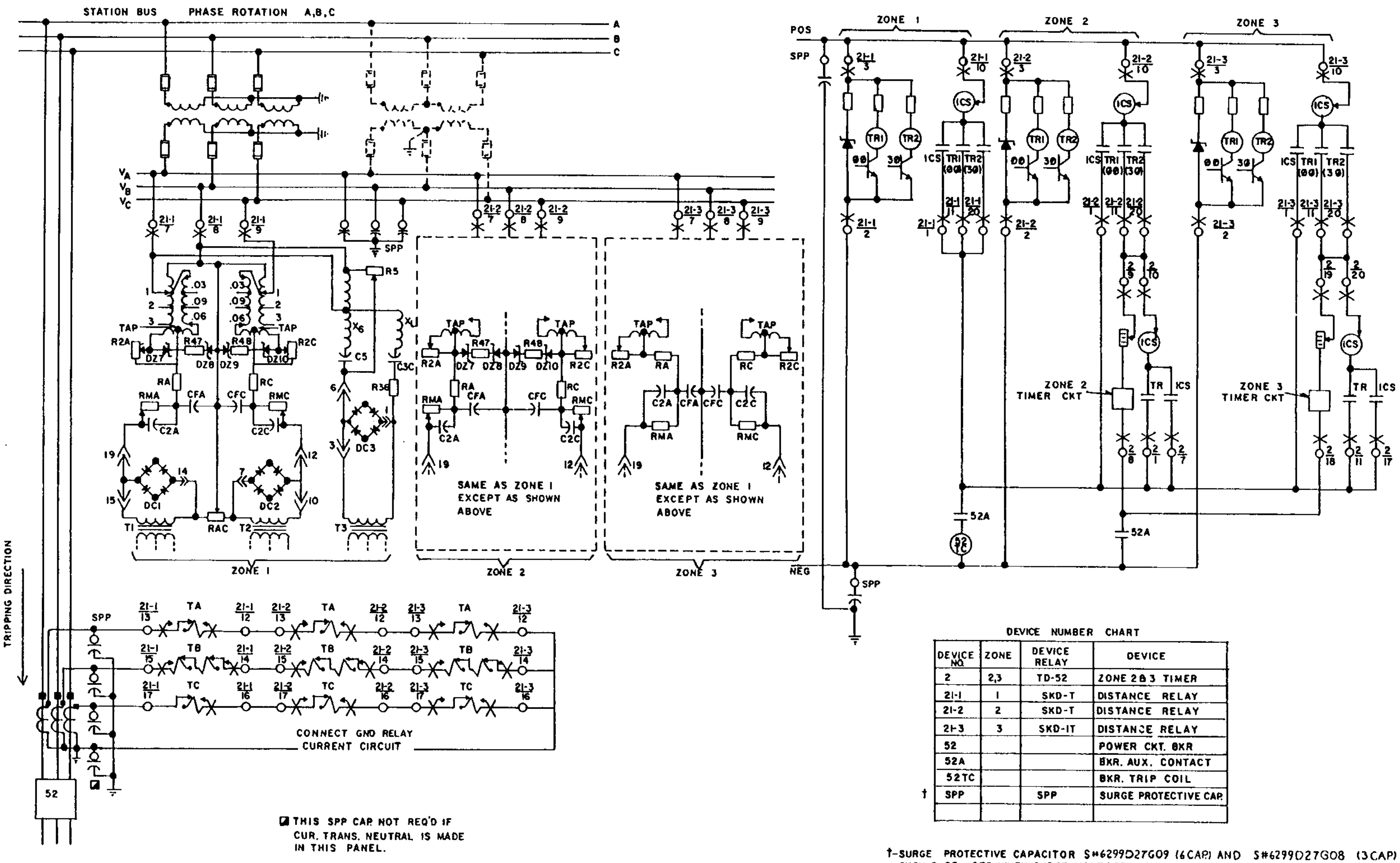


Fig. 12. Typical Operating Time Curves for SKD-T and SKD-IT Relays. Normal Voltage Before the Fault is 120 Volts.



DEVICE NUMBER CHART

DEVICE NO.	ZONE	DEVICE RELAY	DEVICE
2	2,3	TD-52	ZONE 2 & 3 TIMER
21-1	1	SKD-T	DISTANCE RELAY
21-2	2	SKD-T	DISTANCE RELAY
21-3	3	SKD-IT	DISTANCE RELAY
52			POWER CKT. BKR
52A			BKR. AUX. CONTACT
52TC			BKR. TRIP COIL
† SPP		SPP	SURGE PROTECTIVE CAP.

◪ THIS SPP CAP. NOT REQ'D IF CUR. TRANS. NEUTRAL IS MADE IN THIS PANEL.

†-SURGE PROTECTIVE CAPACITOR S#6299D27G09 (6CAP) AND S#6299D27G08 (3CAP) SHOULD BE USED WHEN SURGE VOLTAGE MAY EXCEED 2500 VOLTS PEAK.

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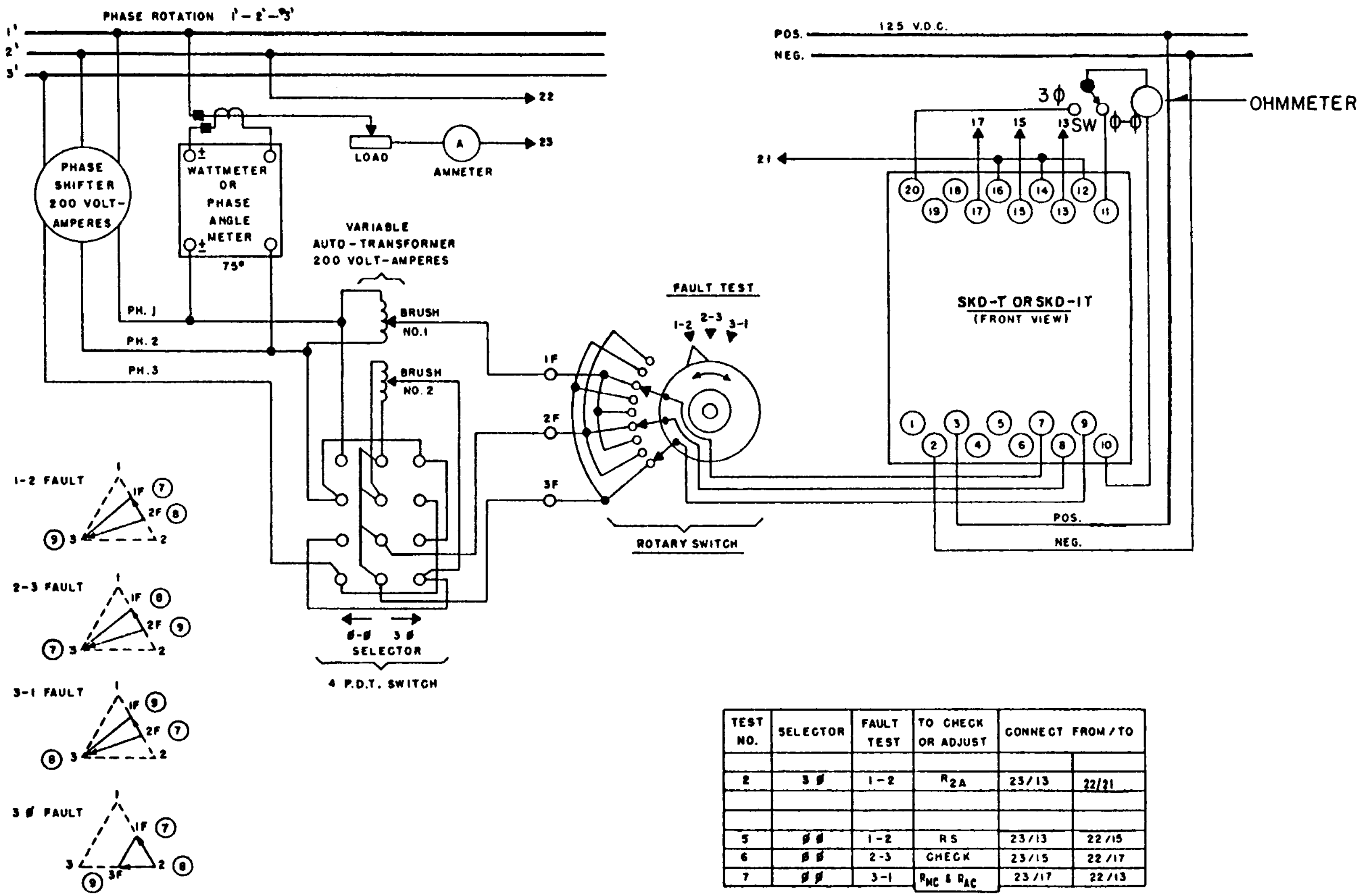
Fig. 13. External Schematic of Types SKD-T and SKD-IT Relays.



TEST NO.	SELECTOR	FAULT TEST	TO CHECK OR ADJUST	CONNECT FROM / TO	
2	3 ø	1 - 2	R_{2A}	23/13	22/21
5	ø ø	1 - 2	RS	23/13	22/15
6	ø ø	2 - 3	CHECK	23/15	22/17
7	ø ø	3 - 1	R_{MC} & R_{AC}	23/17	22/13

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● *Fig. 14. Test Connections for Types SKD-T and SKD-IT Relays.*

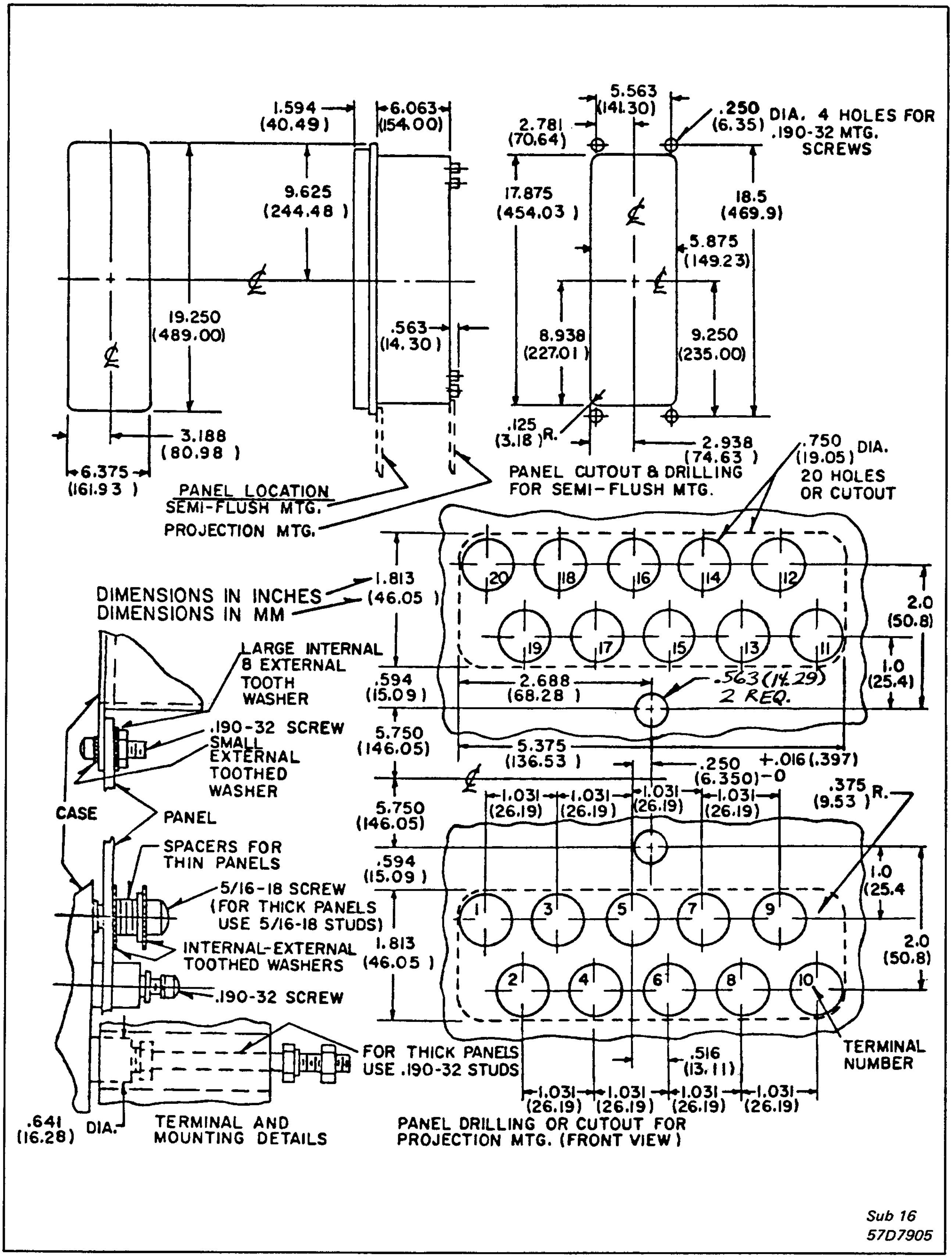

Fig. 15. Outline and Drilling Plan for Types SKD-T and SKD-IT Relays in Type FT-42 Case.