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Type SDG-1T, -2T, -4T Static Ground Distance

CAUTION

Before putting relays into service, remove all blocking which may have been inserted for the purpose of securing the 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

Type SDG-1T, 2T and 4T relays are single zone ground distance relays used to detect faults on subtransmission or transmission lines. Table I shows the particular application intended for each relay and the components included.

The I_0 fault detector prevents potential circuit trouble from causing immediate trip. The frequency verifier should be utilized for all high speed trip applications to avoid tripping on line energization or other conditions that cause high frequency transients.

The phase-to-phase desensitizer is used to eliminate a possible overreach on two-line-to-ground faults. This circuit is needed for Zone1 applications. It is not needed for overreaching applications. The nature of the design is that the phase-to-phase desensitizer is removed from service on settings S = 2 or S = 3.

Table 1

Relay	I_0 Fault Det	Freq. Verifier	Phase-to-Phase Desensitizer (Note 1)	Application
SDG-1T	X	X	X	Zone-1 or Zone-2
SDG-2T	–	X	X	Zone-1 or Zone-2
SDG-4T	–	–	–	Blocking Carrier Start

Note 1: For time delayed trip disconnect 2Ø-G circuit. A switch is provided for this function in the SDG-1T.

The potential supply must be 4 wire Wye-grounded. The broken delta voltage connection is provided inside the relay.

Mutual compensation is not required with these relays. With an 85% Zone1 setting and an extreme zero-sequence mutual impedance, the relay will reliably reach ground faults on at least 70% of the protected line.

All three relays are equipped with normally open output contacts and ICS's for indicating trip coil current flow. In addition the SDG-4T has a normally-closed contact for "contact-opening-carrier start".

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.

1.1. Fundamentals of Distance Measurement On Ground Faults

The SDG-T type distance relay operates on both single and double line-to-ground faults. In either case, neglecting fault resistance, the faulted phase-to-ground voltages at the relay consists of the line drop:

V_{LG} = Faulted phase-to-ground relay voltage

$$= K_1 I_1 nZ_{1L} + K_2 I_2 nZ_{1L} + K_0 I_0 nZ_{0L} + I_{OE} nZ_{OM} \quad \text{Eq. (1)}$$

Where K_1, K_2, K_0 are current distribution factors for the pos., neg., and zero sequence networks, respectively.

I_1, I_2, I_0 are the pos., neg., and zero sequence currents ***in the fault***.

nZ_{1L}, nZ_{0L} are the pos. and zero sequence line impedances ***to the fault***.

I_{0E} is the adjacent line zero sequence current.

Z_{0M} zero sequence mutual impedance.

See Figure 16 for further definition of terms. For an A to ground fault Eq. (1) would be written in terms of the phase A quantities (ignoring mutual effect).

$$V_{AG} = K_1 I_{A1} nZ_{1L} + K_2 I_{A2} nZ_{1L} + K_0 I_0 nZ_{0L} \quad \text{Eq. (2)}$$

Eq. (2) also applies for an AB to ground fault or any other fault. Additional expressions apply for the phase B and C quantities.

A distance ground relay made to respond to single phase-to-ground faults will also respond in the same way to double line-to-ground faults. This is true except for the effect of ground resistance, R_G. The different nature of these effects can be sensed from Figure 17. In Figure 17 the ground current $3I_0$ flowing through R_G is essentially in phase with the total faulted phase current. This is so, since $I_{A1} = I_{A2} = I_0$. This is not true for a 2L-G fault. The current $3I_0$ is out of phase with K_1IA_1 and K_2IA_2 (also out of phase with K_1I_{B1} and K_2I_{B2}). As a result the drop across R_G produces an apparent reactance term to the distance relay, causing it to underreach on one phase and overreach on the other faulted phase. The SDG-1T and SDG-2T relays contain a desensitizer circuit to prevent overreach on 2L-G faults, by reducing the reach of the relay.

The restraint voltages V_{XN}, V_{YN}, V_{ZN} are obtained by the use of compensators with an impedance Z_C, set to match the desired positive sequence line impedance reach. Only positive and negative sequence voltages appear in Eq. (3) to (5).

$$V_{XN} = (V_{A1} + V_{A2}) - Z_C(K_A I_{A1} + K_2 I_{A2}) \quad \text{Eq. (3)}$$

$$V_{YN} = (V_{B1} + V_{B2}) - Z_C(K_1 I_{B1} + K_2 I_{B2}) \quad \text{Eq. (4)}$$

$$V_{ZN} = (V_{C1} + V_{C2}) - Z_C(K_L I_{C1} + K_2 I_{C2}) \quad \text{Eq. (5)}$$

The zero sequence voltage is filtered out by not grounding the neutral of the set of Y-connected auxiliary transformers (T_{A2}, T_{B2} and T_{C2}) which are used to feed the restraint portion of the magnitude comparison circuit. These same connections render the zero sequence current flowing in the phase compensators ineffective. So the restraint voltages duplicate the delta voltage conditions at the fault when the fault is Z_C ohms from the relay (i.e., at the balance point). Zero sequence quantities are not required to duplicate the system voltage triangle at the balance point since zero sequence voltages cancels out of the line to line voltages.

The operating voltage is:

$$V_{WO} = V_0 - \frac{Z_{0L}}{Z_{1L}} ¥ Z_C\left(K_0 I_0 + I_{0E}\frac{Z_{0M}}{Z_{0L}}\right) \quad \text{Eq. (6)}$$

Here V_0 is the relay zero sequence voltage: it is compensated by using a compensator impedance $(Z_{0L}/Z_{1L})\ Z_C$ representing the zero sequence line impedance to the desired balance point. For mutual coupled lines this compensator can be fed with not only the protected line current but also with a portion of the mutual current I_{0E} (See Figure 16). The operating voltage V_{WO} duplicates the system zero sequence voltage for fault at the balance point.

Since the faulted phase-to-ground voltage is zero at the fault (neglecting fault resistance), the operating and faulted phase restraint voltage will be equal for a balance point fault. This can be seen by manipulating the fault voltage expression, remembering that the relay compensated voltages are a replica of the fault-point voltages:

V_{LGF} = Faulted phase-to-ground voltage at the fault

$$= V_{1F} + V_{2F} + V_{0F} = 0 \qquad \text{Eq. (7)}$$

$$V_{1F} + V_{2F} = -V_{0F} \qquad \text{Eq. (8)}$$

$$\left|V_{1F} + V_{2F}\right| = \left|V_{0F}\right| \qquad \text{Eq. (9)}$$

Eq. (9) states that the magnitude of the sum of the pos. and neg. sequence voltage equals the magnitude of the zero sequence voltage at the fault. This holds regardless of how many phases are grounded. Eq. (9) is the keystone of the SDG system.

This balance point condition is shown in Figure 18 for an A-G fault. The bus voltages (V_{A1} + V_{A2}) and V_0 are shown along with the compensator voltages, which modify the bus voltages to produce restraint voltage V_{XN} and operating voltage V_{WO}.

For this condition V_{YN} and V_{ZN} are also produced but these will be larger in magnitude since these are derived from the sound phases. Since these voltages exceed V_{XN}, they are irrelevant.

In Figure 18 for a fault beyond the balance point, V_{XN} exceeds V_{WO}; the reverse is true for the fault within the balance point. Note that for all these faults in the trip direction that the phase compensation acts to reduce the bus positive and negative sequence voltages; whereas, the zero sequence compensation is added to V_0. The reverse is true for a fault behind the relay. For this reason the SDGT is inherently directional as long as relay is set for no more than 1.5 times the impedance of the protected line, when operating voltage exceeds unfaulted phase restraints.

One other aspect of Figure 18 bears amplification. Note for the fault within the balance point that the phase compensation is almost enough to reverse V_{XN} polarity. It is possible for such a reversal to occur, and it is possible if very little zero sequence flows for the phase compensation to overtake the operating voltage and restrain the relay. Thus, the relay may fail to see a close-in fault if the zero sequence current is quite small. Any time this extreme condition occurs the phase-distance relay will operate. The phase-distance relay will clear the fault when:

$$Z_1 > \frac{V_0 \S I_0}{K_1 + K_2 + pKo}$$

where Z_1 is positive sequence relay reach

V_0 = zero sequence bus voltage for close-in fault

I_0 = total zero sequence fault current for close-in fault

K_1, K_2, K_0 pos.-, neg.- and zero sequence current distribution factors for close-in fault

p = ratio of zero sequence to positive sequence line impedance

2. CONSTRUCTION AND OPERATION

The type SDGT relay consists of: four air gap transformers, three auto-transformers for reach adjustment, four phase-splitter transformers, one isolating transformer which couples the zero sequence network ac output to the static frequency verifier circuit, one zero sequence current-to-voltage transformer, four phase-splitter and rectifier networks, a double line-to-ground fault desensitizer, one voltage regulating Zener diode, a telephone relay for the output function and printed circuit assemblies. The indicator contactor switch provides trip indicator and seal-in for the telephone relay contact.

The large printed circuit assembly contains a magnitude comparator, frequency check circuit, and the zero sequence current detector.

2.1. Compensators (T_A, T_B, T_C, T_O)

The compensators (Figure 13), which are designated T_A, T_B, T_C, and T_O are two-winding air gap transformers. Each current winding has seven taps which terminate at the tap block. 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 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 have been precisely set at the factory. The clamps which hold the lamination 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 (R1, R2, R3, R4) and provides a means of adjusting the phase angle between primary current and the induced secondary voltage. The phase angle may be set for any value between 60° and 90° by adjusting this resistor. The factory setting is for a maximum sensitivity angle of 75° current lagging voltage.

A tertiary winding M has four taps which may be connected to directly modify the T setting by any value from -18 to +18 percent in steps of 3%. 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.

2.2. Auto-Transformer (T_{A1}, T_{B1}, T_{C1})

The auto-transformers T_{A1}, T_{B1}, T_{C1} have three taps on their main winding S which are numbered 1, 2 and 3 on the tap block.

The three secondary windings of the auto-transformers are connected in a “broken delta”, thus serving as a source of zero sequence voltage for the operating circuit. The primary to secondary turn ratio is 3 : 1, thus producing the proper zero sequence voltage magnitude as required by the theory of relay operation. Using S = 2 or S = 3 settings reduces zero sequence voltage in the same proportion as the line-to-neutral voltages.

The auto-transformer makes it possible to expand the basic range of T ohms by a multiplier of S.

2.3. Phase-Splitter Transformer (T_{A2}, T_{B2}, T_{C2}, T_{O2})

The phase-splitter transformer provides isolation between the ac analog network and the magnitude comparator circuitry located on the printed circuit board, and couples the restraint and operating outputs to the phase-splitter network. The tap connection on the secondary winding serves as part of the phase-splitting circuit that converts a single-phase input into a three-phase output, thus minimizing the ripple of the rectified output.

2.4. Isolating Transformer (I_O)

The isolating transformer I_O serves two purposes: First it isolates the ac circuit from the dc circuit, and second, it produces a secondary voltage in the presence of zero sequence current.

2.5. Isolating Transformer (T_{FV})

The isolating transformer T_{FV} serves two purposes: First, it isolates the ac circuit from the dc circuit and second, it steps up the clipped ac signal to make the frequency check circuit sensitive to low level input signals.

2.6. Double Line-to-Ground Fault Desensitizer

The double line-to-ground fault desensitizer consists of the three networks. Each network consists of a resistor and a minimum voltage network. In this network the largest restraint voltage is blocked by a combination of two restraining voltages. If any two restraining voltages become smaller than the third restraint voltage, transistors Q17 and Q18 are turned on to prevent Q1 transistor from turning on. When operating voltage becomes larger than the highest restraint the relay is allowed to trip.

2.6.1. For SDG-T

A two phase-to-ground switch is connected between pin 8 of the 2Ø-Gnd. Circuit board S-203C369G01 and the positive supply bus. This permits de-activation of the 2Ø-Gnd. circuit when desired by opening the switch.

The desensitizer effect is limited to S =1 setting only and is not effective on the S = 2 or S = 3 setting. If S = 2 or S = 3 setting is used for Zone1 the setting should be reduced to 75% of the protected line to avoid overreach on double line-to-ground faults. For SDG-2T unsolder pin 8 connection to disable the circuit.

2.7. Magnitude Comparator Circuit

The magnitude comparator circuit consists of a minimum voltage network of the voltage balance type in which operating current is caused to flow through a current detector whenever one of the phase restraint voltages becomes smaller than the operating voltage.

Resistors (R9, R10, R11), shown in Figure 5, provide a return path for the operating current.

The sharp turn-on characteristic is obtained by use of special voltage reference circuit that consists of R33, R34, R35 and TH2 (for temperature compensation). The TP2 potential derived from this reference circuit provides base drive for Q8 transistor that is prevented from turning on as long as Q2 is turned on by TP1 potential. Whenever operating voltage V_{WO} exceeds one of the restraint voltage (V_{XN}, V_{YN} or V_{ZN}) transistor Q1 is turned on lowering the TP1 potential below TP2 potential thus making it possible for Q8 to conduct, thus turning on Q9 and after time delay controlled by R45-C9 time constant (or R76-C9 for SDG-1T, -2T or R77-C9 for SDG-4T relays), producing an output.

2.8. Zero Sequence Current Detector (SDG-1T Only)

To prevent operation of the magnitude comparator during a blown potential fuse or unequal pole closing, a zero sequence current detector supervises the operation of the triggering network by preventing capacitor C10 in the triggering circuit from charging, keeping the input to D51 at low potential through the diode D59.

With no or very low zero sequence current Q12 transistor is conducting.

In the presence of the residual current a current derived negative voltage through transformer I_0 appears across resistor R60, turns transistor Q12 off and thus raising its collector close to the positive dc voltage supply level, blocking D59 from discharging the C10 capacitor allowing Q13 to operate.

2.9. Frequency Verification

During certain switching conditions, such as energization of a transmission line, residual currents and voltages may exist of higher frequencies than 60 hertz per second. The frequency verifier prevents relay operation when the operating voltage period is less than 5 ms. The frequency verification circuit consists of two functional parts: zero-crossing and timing circuit. The zero-crossing circuit consists of transistors Q3, Q4, Q5 and Q6. The zero-crossing circuit is used to allow operation in the presence of higher frequencies of small magnitude superimposed on a fundamental of 60 Hz. During the positive or negative half cycles of the operating voltage V_{WO}, Q3 or Q4 transistors are driven into saturation by the output of the T_{FV} transformer. Transistor Q5 conducts until capacitors C6 or C7 respectively are fully charged. While either capacitor is charging through R29, transistor Q5 drives transistor Q6 to discharge timing capacitor C9, thus starting the timing cycle with close to zero charge on the capacitor. The function of the timing capacitor is to delay the operation of the relay for 5 milliseconds. The delay is obtained by delaying the firing time of Z2 Zener diode. If a next zero-crossing should occur within the preset delay time, C9 capacitor is discharged again and the timing cycle is repeated. In case of presence of predominant higher frequencies (over 100-140 Hz), several zero-crossing pulses will occur within the preset time delay, thus keeping the C9 capacitor from charging up to the Zener firing voltage.

The transient blocking is accomplished through the operation of Q7 transistor that is driven by a short pulse formed through R46 and C8 capacitor to clear C9 capacitor of any charge before initiating 5 millisecond delay. Any tripping signal coming off Q9 transistor of a duration less than 5 milliseconds output circuit will not produce a relay output.

2.9.1. For SDG-1T and SDG-4T

The coil of the telephone relay is in series with the collector of transistor Q16 so that, when Q16 is turned on, the telephone relay is energized causing the contacts to close. A Zener diode is connected across the collector of Q16 to limit the inductive kick voltage appearing at the collector during the pickup and dropout of the telephone relay.

2.9.2. For SDG-2T

The coil of the telephone relay is in series with the collector of transistor Q14 so that, when Q14 is turned on, the telephone relay is energized causing the contacts to close. A silicon diode is connected across the coil of the telephone relay to limit the inductive kick voltage appearing at the collector during the pickup and dropout of the telephone relay.

2.10. Push-button Check Circuit

2.10.1. SDG-2T Only

For the SDG-2T relay the push-button check circuit is used for in-service operational check-out of the output relay is used on S = 1 setting. Depressing the push-button operates the overcurrent circuit. This action must be preceded by the opening of the relay trip circuit (red handle) and relay voltage to neutral switch 7. The opening of the voltage switch produces operating voltage conditions in the magnitude comparator that gates the thyristor switch. Operation of the relay switch is indicated by the lighting of the bulb built into the push-button.

3. CHARACTERISTICS

3.1. Distance Characteristics

Figure 14 shows the relay characteristic in the complex plane is $Z = nZ_{1L} + \frac{3R_G}{F}$ for single-line-to-ground faults where factor F = $K_1 + K_2 + pK_0$, where K_1, K_2, K_0 are positive, negative and zero sequence current distribution factors and p = ratio of zero sequence to positive sequence line impedance. Impedance nZ_{1L} is the positive sequence line impedance from the relay to the fault. The apparent impedance Z must fall within the characteristic shown in Figure 14 in order to operate. The R-X characteristic is a composite of three circles whose centers are A, B, and C in Figure 14a. The circle whose center is "A" is produced from the comparison of faulted phase restraint and operating voltage for a single-line-to-ground fault; whereas the "B" and "C" circles result from sound-phase restraint comparison with operating voltage. Note that part (a) of Figure 14 applies for the case of a low source impedance vs. line impedance; parts (b) and (c) represent increasing amounts of source impedance, or conversely shorter line lengths. The solid-line characteristic is based on current distribution factors for a balance point fault with all breakers closed. As the fault moves toward the relay these distribution factors increase, with the relay approaching the dashed-line characteristic. In the case of Figure 14c, the dashed-line characteristic is not shown, as it essentially coincides with the solid line characteristic. Regardless of system conditions, the relay reaches Z_C positive sequence ohms for a fault at the compensator angle. The fact that the circle diameter expands with increasing source impedance is beneficial, since this provides increased fault resistance accommodation for the shorter line applications. By this we mean that it takes a greater $\frac{3R_G}{K_1 + K_2 + pK_0}$ component to yield a Z phasor which is outside the operate zone. In Figure 14c only the faulted phase characteristic is shown, since the other two fall well out of the first quadrant.

One might conclude from Figure 14 that the relay is not directional since its characteristic includes the origin. ***This conclusion would be erroneous***, since the characteristic equations assume faults in the trip direction per Figure 14 and do not apply for reversed faults. ***The relay is directional***. In Figure 14 the second and third quadrants are essentially theoretical since a "negative resistance" is only possible due to out-of-phase infeed. The fourth quadrant is pertinent for series capacitor applications. So we are normally only interested in the first quadrant.

3.2. General Characteristics

Impedance settings in ohms reach can be made in steps of 3 percent. The maximum sensitivity angle, which is set for 75 degrees at the factory, may be set for any value from 60 degrees to 82 degrees. A change in the maximum sensitivity angle will produce a slight change in reach for any given setting of the relay. Referring to Figure 13, not that the compensator secondary voltage output V, is largest when V leads the primary current, I, by 90°. This 90° relationship is approached, if the compensator loading resistor 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_A, IT_B, or IT_C. 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, as shown in Figure 13. The tap markings are based upon a 75° compensator angle setting. If the resistors R1, R2, R3, and R4 are adjusted for some other maximum sensitivity angle the nominal reach is different than that indicated by the taps. The reach Z_θ, varies with the maximum sensitivity angle, θ, as follows:

$$Z_\theta = \frac{TS \sin\theta(1 + M)}{\sin 75°}$$

3.3. Tap Plate Markings

3.3.1. T_A, T_B, T_C (Positive Sequence)

For 1.0 - 31 Ohms range —	1.2, 1.5, 2.1, 3.0, 4.5, 6.3, 8.7
For 2. - 4.25 Ohms Range —	.23, .307, .383, .537, .69, .92, 1.23

3.3.2. T_O (Zero Sequence)

For 1.0 - 31 Ohms Range —	3.60, 4.5, 6.3, 9.0, 13.5, 18.9, 26.1
For .2 - 4.35 Ohms Range —	0.69, 0.92, 1.15, 1.61, 2.07, 2.76, 3.69

$$\frac{(S_A \text{ and } S_C)}{1 \quad 2 \quad 3}$$

$\pm$ Values between taps $\frac{(M_A, M_B, M_C, M_O)}{.03 \quad .09 \quad .06}$

3.4. Time Curves and Burden Data

3.4.1. Operating Time

The speed of operation is shown in Figure 10. The curves indicate the time in milliseconds required for the relay to provide an output for tripping after the occurrence of a fault at any point on a line within the relay setting.

Current Circuit Rating in Amperes
(All Ranges, All Settings)

Continuous — 10 Amperes
1 Second — 240 Amperes

3.4.2. Burden

The potential burden at 69 volts varies from a maximum of 1.4 volt-amperes at S = 1 setting to a minimum of 0.42 volt-amperes based on 69 volts line-to-neutral per phase. Current burden varies from a maximum of 4.5 volt-amperes at 5 amperes for a maximum T-setting to a minimum of 0.60 volt-amperes for a minimum T-setting. This burden applies to each phase and residual current circuit. Dc current burden is .07 amperes at all rated voltages in non-trip condition.

3.4.3. Trip Circuit Constants

1 Ampere I.C.S. — 0.1 Ohms dc Resistance

4. CALCULATIONS AND SELECTION OF SETTING

Relay reach is set on the tap plate. 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 a 60° maximum sensitivity angle, by adjusting R_1, R_2, R_3 and R_4 as per calibration procedure for Zone1 application only. Set Zone1 reach to be 85% of the line, if S = 1 is used; 75% if S = 2 or 3 are used. Do not change angle for pilot trip or Zone2, or Zone3 applications.

Assume a desired balance point which is 85% of the total length of the line. The general formulas for setting the ohms reach of the relay are:

$$Z_1 = Z_{1L}\frac{0.85R_C}{R_V} \; ; \; Z_0 = Z_{0L}\frac{0.85R_C}{R_V}$$

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

Z_0 = Zero sequence ohmic reach to be used for relay settings.

Z_1 = Positive sequence ohmic reach to be used for relay settings.

$Z_{1,\,0}$ = TS (1 + M) = the tap plate setting.

T = Compensator tap value.

S = Auto-transformer tap value.

θ = Maximum sensitivity angle setting of the relay.

±M = Compensator tertiary 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 raise the Z setting. The sign is negative when “R” is above “L” and acts to lower the “Z” setting).

Z_{1L} = Positive sequence ohms per phase of the total line section, referred to the primary.

Z_{0L} = Zero sequence ohms per phase of the total line section, referred to the primary.

R_C = Current transformer ratio.

R_V = Voltage transformer ratio.

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

Zone 1 Setting (SDG-1T and SDG-2T Relays)

1a. Establish the desired values of Z_1 and Z_0 as above (available from transmission line data) and desired maximum sensitivity angle θ°.

1b. Determine the desired tap plate value Z′ using the formula a:

$Z_1 = Z_{1\theta}\frac{Sin75°}{Sin\theta}$ and $Z_0 = Z_0\frac{Sin75°}{Sin\theta°}$

$\theta =$ Angle to which relay is recalibrated

Then, for factory calibration

$$\theta = 75°,\ Z_1 = Z_{1\theta} \text{ and } Z_0 = Z_{0\theta}$$

2. Now refer to Table II or IV giving preferred Zone1 settings for the SDGT relays. If the desired reach exceeds the relay range for S = 1, use S = 2 and Table III or V (set for 75% of line).

2a. Locate a table value for relay reach nearest to the desired Z_1 value (it will always be within 1.5% of the desired value.)

2b. From this table read off the “S”, “T” and “M” settings. The “M” column includes additional information for the “L” and “R” lead setting for the specified “M” value. If the desired settings cannot be found on this table proceed to Table III or V to find the desired setting in this case. The relay reach must now be reduced from 85 to 75 percent to avoid overreach on two phase-to-ground faults on high fault resistance faults.

2c. Recheck relay settings for Z_1 and Z_0 using equation:

$$Z = TS(1 + M)$$

For example, assume the desired reach,

$Z_{1\theta}$ is 7 ohms at 60° (step 1a) and $Z_{0\theta}$ is 21 ohms at 60°.

Next step is (1b). Making correction of maximum sensitivity angle of the relay to match the characteristic angle of the line (60°) that is different from factory setting of 75°, we find the relay tap setting.

Z_1=7 x 1.11 = 7.77 ohms

Z_0=21 x 1.11 = 23.31 ohms

This procedure is followed when R_1, R_2, R_3, R_4 settings are changed, otherwise follow alternative procedure below.

Step (2a). In Table IV we find 7.65 to be the nearest value to 7.77 ohms.

$100\,\text{¥}\,\frac{7.65}{7.77} = 98.8\%$ or 1.2% from the desired value.

For the Z_θ selection find the nearest value to 23.31 ohms using the same S setting as above. 23.0 ohms is the nearest value.

$100\,\text{¥}\,\frac{23.0}{23.31} = 98.8\%$ or 1.2% within the desired value.

Step (2b). From Table IV read off:

S = 1
T = 8.7 $\quad T_0$ = 26.1
M = -.12 $\quad M_0$ = -.12

The “R” lead should be connected over “L” lead, with “L” lead connected to “0” tap and “R” lead to tap “09”. (The sum of the values between L and R is 0.12).

Step (2c). Recheck Settings.

Z_1=TS (1±M) = 1 x 8.7 (.88) = 7.65 and

Z_0=1 x 26.1 (.88) = 23.0

$Z_1 = Z_{1\theta}\ \frac{\sin 60°}{\sin 75°}\ 7.65\,\text{¥}\,900 = 6.90$ ohms at 60°

$Z_0 = Z_0\ \frac{\sin 60°}{\sin 75°} = 23.0\,\text{¥}\,900 = 20.7$ ohms at 60°

Where balance point product of $3I_0Z_1$ <40 volts (where Z_1 is positive sequence relay setting and $3I_0$ is zero sequence current in the relay for L-G fault) disconnect the phase-to-phase desensitizer and set Zone1 as calculated.

4.1. Alternative Calculations and Settings

If it is desired to avoid recalibration of the relay maximum sensitivity setting, the following procedure should be followed.

Follow Step (1a) as above.

Change Step (1b) to compute desired reach according with equation:

$$Z = \frac{Z}{Cos(75 - \theta)}$$

Table 1I
.2 - 4.35 OHMS RELAY RANGE

POSITIVE SEQUENCE (Z_1) S = 1								ZERO SEQUENCE (Z_0) S = 1								M		CONNECT		
T	.230	.307	.383	.537	.69	.92	1.23	T_0	.69	.921	1.15	1.61	2.07	2.76	3.69	+M	–M	"L" LEAD TO TAP	"R" LEAD TO TAP	
	.272	.362	.452	.632	.815	1.09	1.45		.815	1.09	1.36	1.90	2.44	3.26	4.40	+.18		.06	0	
	.264	.352	.441	.617	.794	1.06	1.41		.794	1.06	1.32	1.85	2.38	3.18	4.25	+.15		.06	.03	"L" OVER "R"
	.258	.344	.430	.601	.772	1.03	1.38		.772	1.03	1.29	1.80	2.32	3.10	4.15	+.12		.09	0	
	.251	.335	.418	.585	.754	1.00	1.34		.754	1.00	1.25	1.76	2.26	3.00	4.04	+.09		.09	.03	
	.244	.325	.405	.570	.732	.975	1.30		.732	.975	1.22	1.71	2.20	2.92	3.92	+.06		.06	.09	
	.237	.316	.396	.555	.710	.950	1.27		.710	.950	1.18	1.66	2.13	2.84	3.80	+.03		.03	0	
	.230	.307	.383	.537	.69	.920	1.23		.69	.921	1.15	1.61	2.07	2.76	3.69	0	0	0	0	
	.223	.298	.370	.520	.670	.892	1.19		.670	.892	1.12	1.56	2.00	2.68	3.58		–.03	0	.03	"R" OVER "L"
	.216	.288	.360	.505	.650	.865	1.15		.650	.865	1.08	1.52	1.95	2.60	3.46		–.06	.09	.06	
	.209	.280	.348	.488	.627	.840	1.12		.627	.840	1.05	1.47	1.88	2.51	3.36		–.09	.03	.09	
	.202	.270	.336	.472	.607	.810	1.08		.607	.810	1.01	1.42	1.82	2.43	3.25		–.12	0	.09	
	1.95	.260	.324	.456	.587	.782	1.05		.587	.782	.980	1.37	1.76	2.35	3.14		–.15	.03	.06	
	.188	.252	.314	.440	.565	.755	1.01		.565	.755	.940	1.32	1.70	2.26	3.02		–.18	0	.06	

Table 1II
.2 - 4.35 OHM RELAY RANGE

POSITIVE SEQUENCE SETTINGS (Z_1)										ZERO SEQUENCE SETTINGS (Z_0)										M		CONNECT		
S = 2								S = 3		S = 2								S = 3				"L" LEAD TO TAP	"R" LEAD TO TAP	
T	.230	.307	.383	.537	.69	.92	1.23	.92	1.23	T_0	.69	.921	1.15	1.61	2.07	2.76	3.69	2.76	3.69	+M	–M			
	.544	.724	.905	1.26	1.63	2.17	2.90	3.26	4.40		1.63	2.17	2.72	3.80	4.90	6.50	8.70	9.80	12.1	+.18		.06	0	"L" OVER "R"
	.528	.704	.880	1.23	1.59	2.12	2.82	3.18	4.25		1.59	2.12	2.65	3.70	4.76	6.35	8.48	9.55	12.7	+.15		.06	.03	
	.516	.688	.860	1.20	1.55	2.06	2.76	3.10	4.15		1.55	2.06	2.58	3.60	4.65	6.20	8.25	9.30	12.4	+.12		.09	0	
	.502	.670	.835	1.17	1.51	2.00	2.68	3.00	4.04		1.51	2.00	2.50	3.50	4.52	6.00	8.05	9.05	12.1	+.09		.09	.03	
	.488	.650	.810	1.13	1.46	1.95	2.60	2.92	3.92		1.46	1.95	2.44	3.41	4.40	5.85	7.80	8.80	11.8	+.06		.06	.09	
	.474	.632	.790	1.10	1.42	1.90	2.53		3.80		1.42	1.90	2.37	3.32	4.26	5.70	7.60		11.4	+.03		.03	0	
	.460	.614	.766	1.07	1.38	1.84	2.46		3.69		1.38	1.84	2.30	3.22	4.14	5.52	7.38		11.1	0	0	0	0	
	.446	.596	.740	1.04	1.34	1.78	2.40		3.58		1.34	1.78	2.24	3.12	4.02	5.35	7.15		10.7		-.03	0	.03	"R" OVER "L"
	.432	.576	.716	1.01	1.30	1.73	2.32		3.46		1.30	1.73	2.16	3.02	3.90	5.16	6.94		10.4		-.06	.09	.06	
	.418	.560	.695	.975	1.25	1.67	2.24		3.36		1.25	1.67	2.09	2.94	3.78	5.00	6.70		10.1		-.09	.03	.09	
	.404	.540	.674	.940	1.21	1.62	2.17				1.21	1.62	2.02	2.83	3.66	4.85	6.50		9.8		-.12	0	.09	
	.390	.520	.650	.910	1.17	1.56	2.10				1.17	1.56	1.95	2.74	3.55	4.67	6.27		9.4		-.15	.03	.06	
	.376	.504	.625	.880	1.13	1.50	2.08				1.13	1.50	1.79	2.64	3.40	4.50	6.05		9.1		-.18	0	.06	

Table 1V
1.1 - 31 OHMS RELAY RANGE

	POSITIVE SEQUENCE (Z_1)							ZERO SEQUENCE (Z_0)								M		CONNECT		
T	S = 1							S = 1										"L" LEAD TO TAP	"R" LEAD TO TAP	
	1.2	1.5	2.1	3.0	4.5	6.3	8.7	T_0	3.6	4.5	6.3	9.0	13.5	18.9	26.1	+M	-M			
	1.42	1.77	2.48	3.54	5.3	7.43	10.2		4.25	5.30	7.45	10.6	15.9	22.2	30.8	+18		.06	.0	"L" OVER "R"
	1.38	1.73	2.42	3.45	5.17	7.25	10.0		4.15	5.17	7.25	10.4	15.5	21.7	30.0	+.15		.06	.03	
	1.34	1.68	2.36	3.36	5.04	7.05	9.75		4.05	5.04	7.05	10.1	15.1	21.2	29.3	+.12		.09	0	
	1.31	1.64	2.29	3.27	4.90	6.89	9.50		3.94	4.90	6.89	9.81	14.7	20.6	28.4	+.09		.09	.03	
	1.27	1.59	2.22	3.18	4.77	6.70	9.25		3.82	4.77	6.70	9.54	14.3	20.0	27.7	+.06		.06	.09	
	1.24	1.55	2.16	3.09	4.64	6.50	8.95		3.71	4.64	6.50	9.27	13.9	19.5	26.9	+.03		.03	0	
	1.20	1.5	2.10	3.00	4.50	6.30	8.70		3.6	4.0	6.30	9.0	13.5	18.9	26.1	0	0	0	0	
	1.16	1.45	2.04	2.91	4.36	6.10	8.45		3.50	4.36	6.10	8.73	13.1	18.3	25.2		-.03	0	.03	"R" OVER "L"
	1.13		1.97	2.82	4.23	5.90	8.15		3.38		5.90	8.46	12.7	17.7	24.5		-.06	.09	.06	
	1.09		1.91	2.73	4.10	5.74	7.90		3.27		5.74	8.19	12.3	17.2	23.7		-.09	.03	.09	
	1.06		1.85	2.64	3.96	5.55	7.65		3.16		5.55	7.92	11.9	16.6	23.0		.-12	0	.09	
	1.02		1.77	2.55	3.82	5.35			3.06		5.35	7.65	11.5	16.0			-.15	.03	.06	
	.99				3.69				2.95				11.1				-.18	0	.06	

Table 1
1.1 - 31 OHM RELAY RANGE

POSITIVE SEQUENCE SETTINGS (Z_1)										ZERO SEQUENCE SETTINGS (Z_0)										M		CONNECT		
S = 2								S = 3		S = 2								S = 3				"L" LEAD TO TAP	"R" LEAD TO TAP	
T	1.2	1.5	2.1	3.0	4.5	6.3	8.7	6.3	8.7	T_0	3.6	4.5	6.3	9.0	13.5	18.9	26.1	18.9	26.1	+M	-M			
	2.84	3.54	4.96	7.08	10.62	14.9	20.5	22.3	30.8		8.50	10.6	14.9	21.2	31.8	44.5	61.5	66.6	92.5	+.18		.06	0	"L" OVER 'R'
	2.76	3.46	4.84	6.90	10.35	14.5	20.0	21.6	30.0		8.30	10.34	14.5	20.7	31.0	43.5	60.0	65.1	90.0	+.15		.06	.03	
	2.68	3.36	4.72	6.72	10.08	14.1	19.5	21.2	29.3		8.10	10.08	14.1	20.2	30.2	42.4	58.5	63.6	87.5	+.12		.09	0	
	2.62	3.28	4.58	6.54	9.81	13.8	19.0		28.4		7.88	9.80	13.8	19.6	29.4	41.2	56.8		85.2	+.09		.09	.03	
	2.54	3.18	4.44	6.36	9.54	13.4	18.5		27.7		7.64	9.54	13.4	19.1	28.6	40.0	55.3		83.0	+.06		.06	.09	
	2.48	3.10	4.32	6.18	9.27	13.0	17.9		27.0		7.42	9.28	13.0	18.5	27.8	39.0	53.8		80.5	+.03		.03	0	
	2.4	3.0	4.20	6.0	9.0	12.6	17.4		26.1		7.20	9.0	12.6	18.0	27.0	37.8	52.2		78.3	0	0	0	0	
	2.32	2.90	4.08	5.82	8.73	12.2	16.9		25.2		7.00	8.72	12.2	17.5	26.2	36.6	50.5		75.8		-.03	0	.03	"R" OVER "L"
	2.26		3.95	5.64	8.46	11.8	16.3		24.5		6.76		11.8	16.9	25.4	35.4	49.0		73.5		-.06	.09	.06	
	2.18		3.82	5.46	8.19	11.5	15.8		23.7		6.54		11.5	16.4	24.6	34.4	47.5		71.0		-.09	.03	.09	
	2.12		3.70	5.28	7.92	11.1	15.3		23.0		6.32		11.1	15.8	23.8	32.2	45.8		68.8		-.12	0	.09	
	2.04		3.54	5.10	7.65	10.7			22.7		6.12		10.7	15.3	23.0	32.0					-.15	.03	.06	
	1.98				7.38										22.2						-.18	0	.06	

NOTE: Do not use equation to predict relay response for angles more than 15° away from θ.

Then $Z_1 = \dfrac{7}{Cos(75-60)} = \dfrac{7}{.965} = 7.25$

$$Z_0 = \frac{21}{Cos(75-60)} = \frac{21}{.965} = 21.75$$

Step 2a as above from Table IV you will find 7.25 value and 21.75 ohm-values as the exact values.

Step (2b) from Table IV read off:

$S = 1$
$T = 6.3 \quad T_0 = 18.9$
$M = +.15 \quad M_0 = +.15$

Step (2c) Recheck Settings.

$Z_1 = Z_1 \text{ Cos}(75° - \theta) = 7.25 \times .965 = 7$ ohms

$Z_0 = Z_0 \text{ Cos}(75° - \theta) = 21.75 \times .965 = 21$ ohms

4.1.1. Zone 2 and 3 Settings or Pilot Trip Applications

For Zone 2 and 3 or pilot trip settings use a procedure similar to alternative for Zone 1 described above. Tables II to V give the required settings. ***There is no need to recalibrate relay for difference in maximum torque angle when alternative procedure is used.***

NOTE: The S setting must be the same for both the positive and zero sequence reach.

4.2. Setting The Relay

The SDGT relays require settings for the four compensators (T_A, T_B, T_C and T_O), the three auto-transformer primaries (S_A,S_B and S_C), and the four compensator tertiaries (M_A, M_B, M_C, and M_O). All of these settings are made with taps on the tap plate, with relay deenergized.

4.2.1. Compensator (T_A, T_B, T_C, T_O and M_A, M_B, M_C, M_O)

Each set of compensator primary T_A, T_B, T_C, T_O, 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. A compensator tap setting is made by loosening the connector screw in the center. Before removing the screw open switches 12 through 19 to bypass the current around the relay. 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. Compensator secondary tap connections are made through two leads identified as L and R for each compensator. 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 connectors are held in place on the proper tap by 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 lead 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 through Table V to determine the desired "M" value. Neither lead connector should make electrical contact with more than one tap at a time.

4.2.2. 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 60° maximum sensitivity angle by adjusting the compensator loading resistors R_1, R_2, R_3, R_4. Refer to repair calibration under "Maximum Torque Angle Adjustment", when a change in maximum sensitivity angle is desired. For Zone 2 and 3 or pilot trip application no need to recalibrate relay.

In general, the change in maximum torque angle adjustment, if desired, can be avoided. In this case the tap plate setting of the relay is adjusted to compensate for difference in the maximum torque angle of the relay (75°) and the characteristic angle of the line θ according to the following equation: (In this case, follow procedure outlined under alternative calculations and settings).

$$Z_{1,0} = \frac{Z_{1,0}}{Cos(75° - \theta)}$$

Here $Z_{1,0}$ – Tap Plate Setting

$Z_{1,0}$ – Desired Ohmic Reach

4.2.3. Phase-to-Phase Desensitizer

When it is necessary to disconnect this circuit unsolder or cut terminal 8 to the 2Ø-G board (see Figure 24) for SDG-2T or open 2Ø-G switch for SDGT-1T.

5. 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 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 outline and drilling panel see Figure 12.

For detailed information on the FT case refer to IL 41-076.

5.1. External Connections

Figure 11 shows typical connection for single zone protection using and SDG relay. SPP capacitors are not required unless surge voltage may exceed 2500 volts.

5.2. Acceptance Test

Acceptance tests consist of:

1. A visual inspection
2. "Push-button" check (for SDG-2T only).
3. An electrical test to make certain that the relay measures the balance point impedance accurately.

Step 1. Visual Inspection

Give a visual check to the relay to make sure that there are no loose connections, broken resistors or broken wires.

.2-4.25 Ohm Relay	1.0-31.0 Ohm Relay
All T = 1.23 All T_0 = 3.69 All S = 1 All M = +.18	All T = 8.7 T_0 = 26.1 All S = 1 All M = +.18

Step 2. Push-button Check

For SDG-2T only open relay terminal 10 and 11.

Using the test connections of Figure 9. Connect the ac voltages as per test No. 1. No current connections are required. Connect the rated dc voltages as shown. Open circuit connections to terminal No. 7. Set V_{BN} = V_{CN} = 70 volts. Depress the white push-button. The push-button should light. If the push-button does not light, observe contact operation. If there is an operation but the lamp does not light this indicates a fault in the push-button circuit. If there is no fault indication proceed with the electrical test to isolate the fault in the push-button circuit or the relay.

Step 3. Electrical Tests

Distance Unit

Tripping is indicated by contact operation. Refer to Figure 9 for all test connections.

For .2-4.35 Ohm Relay

A. Use connections for Test No. 5 and set V_{AN} voltage = 20 volts. V_{BN} = V_{CN} = 70 volts. Set the phase shifter for 75˚ current lagging voltage.

   The relay current required to make the trip should be between 8.0 - 8.6 amp.

B. Use connections for Test No. 6 and set V_{BN} voltage = 20 volts. V_{AN} = V_{CN} = 70 volts. Set the phase shifter as above. The relay trip current should be 8.0-8.6 amps.

C. Use connections for Test No. 7 and set V_{CN} = 20 volts V_{AN} = V_{BN} = 70 volts. Set the phase shifter as above. The SDG relay trip current should be 8.0-8.6 amps.

For 1.0 - 31.0 Ohm Relay

A. Use connections for Test No. 5 and set V_{AN} = 60 volts and V_{BN} = V_{CN} = 70 volts in proper phase sequence. Set the phase shifter for 75˚ current lagging voltage. The relay trip current should be 3.35 - 3.65 amperes.

B. Use connections for Test No. 6 and set V_{BN} = 60 volts and $V_{AN} = V_{CN}$ = 70 volts. Set the phase shifter as above. The relay trip current should be 3.35 - 3.65 amperes.

C. Use connections for Test No. 7 and set V_{CN} = 60 volts and $V_{AN} = V_{BN}$ = 70 volts. Set the phase shifter as above. The relay trip current should be 3.35 - 3.65 amperes.

If the electrical response is outside the limits a more complete series of tests outlined in the section titled “Calibration” may be performed to determine which component is faulty or out of calibration.

If you desire to check relay response at some other settings use following equation for the trip value of current.

$$I = \frac{3V_{LN}}{(2+p)Z_1}, \text{ where } p = \frac{Z_0}{Z_1}$$

Z_0 = Zero sequence reach

Z_1 = Positive sequence reach (in above cases p = 3)

V_{LN} = desired fault voltage

WARNING

If testing requires trip current over 15 amps. over prolonged periods, it is recommended that a heavy short lead be connected from terminal 19 to the center tap of T_0 socket. Also connect a jumper lead from terminal 17 to terminal 1 on the large printed circuit board for SDG-1T relay. (Lower set of terminals rear view).

5.3. Maximum Torque Angle

Maximum torque angle check is optional. In general, this check is complicated for SDG-1T and SDG-2T relays by the presence of transient blocking circuit, and the two-phase-to-ground fault desensitizer circuit.

The presence of transient blocking circuit requires that check for maximum torque angle should be made going from non-tripping to tripping condition at each end of the tripping range of the relay under test.

Since the lab method of testing as used here presents artificial voltage conditions, under certain voltage and phase angle conditions two-phase-to-ground desensitizer will distort phase angle response; hence, it is required to disable the 2ϕ-G circuit for SDG-1T by opening the front switch OR connect a 10K resistor from the cathode of Z6 on the 2ϕ to Gnd to module to relay terminal 2 for SDG2-T relays.

To disable transient blocking circuit short out resistor R48 on large printed circuit board for SDG-1T and SDG-2T.

5.3.1. Phase A Check

Use connection No. 5. Relay tap settings should be the same as before. For all ranges set V_{AN} = 20 volts, V_{BN} -V_{CN} = 70 volts.

Set current for 1-30 ohm relay or 1.54 amp, and for .2-4.35 ohm relay for 11 amp. Set phase-shifter for 75° current lagging V_{AN} voltage. Turn phase-shifter toward 0°. After relays have dropped out, reverse phase-shifter rotation and note the angle (ϕ1) at which relay is fully tripped. Rotate the phase-shifter past the 75° until relay resets again. Then rotate phase-shifter back toward 75° until relay is fully tripped. Note the angle again (ϕ2).

Maximum torque angle is equal then to

$$\frac{\phi 1 + \phi 2}{2} = 75°(\pm 5°)$$

Any other T setting may be used, except use 130% current of the trip current at 75° angle.

5.3.2. Phase B Check

Use connection No. 6 Set V_{BN} = 20 volts. $V_{AN} = V_{CN}$ = 70 volts. Otherwise follow the same procedure as for Phase A.

5.3.3. Phase C Check

Use connection No. 7. Set V_{CN} = 20 volts, $V_{AN} = V_{BN}$ = 70 volts. Otherwise follow the same procedure as for Phase A. When completed remove jumper from R48 resistor.

5.4. Two-phase-to-ground Desensitizer Check

Use connection No. 5 except no current connection is required for this test.

5.5. AB – Combination

Set V_{CN} = 70 volts. V_{AN} = V_{BN} = 10 volts. Check dc voltage on small PC board located just behind R1-R4 potentiometers terminal “10” (positive) located behind R1 potentiometer (second from the bottom) and relay terminal “2”. It should measure 10 to 22 volts. Reset V_{AN} = V_{BN} 70 volts. Dc output should disappear.

5.5.1. BC – Combination

Same check as for AB except first set V_{AN} = 70 volts. V_{BN} = V_{CN} = 10 volts and then reset V_{BN} = V_{CN} = 70 volts.

5.5.2. CA – Combination

Same check as for AB except first set V_{AN} = 70 volts. V_{CN} = V_{AN} = 10 volts and then reset V_{CN} = V_{AN} = 70 volts.

5.6. Overcurrent Unit

Check operation of the overcurrent unit by using test connection No. 5 of Figure 9. Set V_{AN} = 0, V_{BN} = V_{CN} = 70 volts. The .2 - 4.35 ohm relay should operate at .75 - .83 amperes, and the 1 - 31.0 ohms relay should operate at .37 - .420 amperes. If not, check adjustment of R63 potentiometer.

5.7. Indicating Contactor Switch (ICS)

With the SDGT relay tripping, 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 or 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 0.07” 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.

6. ROUTINE MAINTENANCE

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

In-Service Test
(If Relay is Set for S = 1 Only)
(SDG-2T Only)

In-service testing is performed as follows:

1. Open relay trip circuit by opening red handle switch No. 11.
2. Open relay voltage terminal 7.
3. Press white push-button. Push-button light should light.

This test checks the operation of the magnitude comparator and output circuitry.

When push-button is used for direct breaker trip, depress push-button for short time only.

7. REPAIR CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. *Printed circuit boards styles and components are identified on Figures 5 to 8. Component location as per Figures 20 to 27.*

For easier access to the parts, the relay should be tested out of the case.

Use Figure 15 for Test Point Traces reference.

Part A Preliminary Settings

1. Remove the printed circuit board(s) (PCB) in the rear of the relay.
2. Set R_1, R_2, R_3, R_4 potentiometers fully counterclockwise for maximum resistance.
3. Set relay for S = 1, M = +18 (“L” lead over “R” lead), all T = 8.7, T_0 = 26.1 for the 1.0 - 31.0 ohm relays and for the .2 - 4.35 ohms relay all T = 1.23 T_0 = 3.69.

Part B Voltage Circuit Tests

1. Apply 3-phase balanced voltages as per test 1 of Figure 9 except no current is applied.
2. Set V_{AN} = V_{BN} = V_{CN} = 70 volts ac. Measure following ac voltages.

   From relay terminal 6 to S_A = 1 Tap 70 (±1) Volts.

   From relay terminal 6 to S_A = 2 Tap 140 (±2) volts.

From relay terminal 6 to S_A = 3 Tap 210 (±3) volts.

From relay terminal 6 to R_A lead 39.2 (±5) volts.

Repeat the same measurements for S_B, S_C, and R_B, R_C leads.

3. Disconnect R_0 lead from M_O = 0 Tap and measure the voltage from relay terminal "4" to the R_0 lead. It should be below 0.7 volts ac.

4. Apply rated dc voltage to the relay. Check the dc voltage across the lower set of plug-in terminals (rear view) "5" and "1" for the SDG-1T, -2T, and -4T relays. It should measure 20 (±2) volts.

Note: 250 V dc relay requires external resistor.

5. Plug in the lower and upper boards.

Part C Potentiometer Adjustments

CAUTION

All potentiometers are locked type and should be unlocked before adjustment and locked after adjustment is complete.

1. Set R5, R6, R7, R8 for maximum setting (counterclockwise).

2. If no scope is available, measure the voltages with a Rectox-type voltmeter across the specified terminals of the small upper terminal board located in the rear. All the following measurements are done on the small upper board. Terminal numbers refer to this board only. Use of scope is preferred.

■ **R5 Adjustment**

Measure the voltage across terminals 2 and 3. Adjust R5 until voltages across 4 and 2 and 4 and 3 are equal (±0.1 volt) to each other and are within 1.0 volt of voltage across 2 and 3. If oscilloscope is available, observe voltage across R9 and set R5 so that peaks on the 360 Hz ripple are in ascending order.

■ **R6 Adjustment**

Measure the voltage across terminals 6 and 8. Adjust R6 until voltages across terminals 7 and 6 and 7 and 8 are equal (±.1 volt) to each other and are within 1.0 volt of voltage across 6 and 8. If an oscilloscope is available observe voltage across R10 and set R6 so that peaks are in ascending order.

■ **R7 Adjustment**

Measure the voltage across terminals 17 and 18. Adjust R7 until voltages across terminals 15 and 18 and 15 and 17 are equal (±0.1 volt) to each other and are within 1.0 volt of voltages across 17 and 18. If oscilloscope is available observe voltage across R11 and set R7 so that peaks are in ascending order.

■ **R8 Adjustment**

Reduce V_{AN} to zero and measure the voltage across terminals 11 and 12. Adjust R8 until voltages across terminals 14 and 11 and 14 and 12 are equal (0.1 volt) to each other and are within 1.0 volt of voltage across 11 and 12. If oscilloscope is available observe voltage across R12 and set R8 so that the two valleys in the middle are equal.

Maximum Torque Angle Adjustment

Disconnect all R and L leads and jumper relay terminals 5 and 6.

■ **R1 Adjustment**

For the 1.0 - 31.0 ohm relay use the No. 1 test connection of Figure 9. Apply 5.08 amp ac current to the relay. Set V_{AN} 45 volts and $V_{BN} = V_{CN} = 0$ volts. Set the phase-shifter for 75° current lagging voltage.

For .20 - 4.35 ohm relay use the same procedure as above except set the current for 15.65 amp. and V_{AN} = 20 volts.

Insert an ac voltmeter of 0.3 volts range between R_A and L_A leads. Adjust R1 potentiometer for a minimum ("null" reading) and lock R1 in place. Vary current slightly to achieve lower "null" reading.

For other angles multiple current by:

$$K = \frac{\sin 75}{\sin \theta}$$

where θ = desired maximum torque angle, for θ = 60° K = 1.11.

■ R-2 Adjustment

Use No. 2 test connections of Figure 9. Set V_{BN} = 45 volts and V_{AN} = V_{BN} = 0 volts. Set I_B = 5.08 amps. 75° lagging V_{BN}. (Modify voltage and current settings for the .2 - 4.35 ohm relay as above). Measure the voltage between R_B and L_B leads. Adjust R2 potentiometer for a minimum (“null” reading” and lock R2 in place.

■ R3 Adjustment

Use No. 3 test connections of Figure 9. Set V_{CN} = 45 volts and V_{AN} = V_{BN} = 0 volts. I_C = 5.08 amp. 75° lagging V_{CN}. (Modify voltage and current for the .2 - 4.35 ohm relay as above).

Measure the voltage between R_C and L_C leads. Adjust R3 potentiometer for a minimum (“null” reading) and lock R3 in place.

■ R4 Adjustment

Remove jumper from relay terminals 5 and 6. Use the No. 4 test connections of Figure 7. Connect all “L” and “R” leads back to previous setting, except R_O lead. Set V_{CN} = 0 and V_{AN} = V_{BN} = 70 volts. Set I_C = 2.34 amp. 75° lagging V_{CN}. (For the .2 to 4.35 relay set V_{CN} = 0 and V_{BN} = V_{AN} = 45 volt. I_C = 9.9 amperes). Measure the voltage between R_0 and the lowest M0 tap marked “0”.

Adjust the R4 potentiometer for minimum voltage (“null” reading) and lock R4 in place.

Part D M Taps Check

Use a Rectox-Type Voltmeter.

Open all “R” and “L” leads.

For 1 - 30 ohm Relay

M_A Taps — Use test connection No. 1 of Figure 9. Pass 10 amp. current through the relay. The voltages should read as follows:.

1.5 (±0.2) volts between 0 tap and .03 tap.

6.0 (±0.6) volts between 0 tap and .09 tap

9.0 (±1.0) volts between0 tap and .06 tap

M_B Taps — Use test connection No. 2 and repeat above.

M_C Taps — Use test connection No. 3 and repeat above.

M_0 Taps — Use test connection No. 4 and repeat above.

For .2 - 4.35 ohm relay

NOTE: Provide a jumper from terminal 19 to center tap of the T_0 tap block for the SDG-1T relay.

M_A taps — Use connection No. 1 of Figure 9. Pass 20 amp. of current through relay. The voltages should read as follows:

.425 (±.05 volts) between “0” tap and “.03” tap

1.70 (±.1 volts) between “0” tap and “.09” tap

2.55 (±.1 volts) between “0” tap and “.06” tap

M_B Taps — Use test connection No. 2 and repeat above.

M_C Taps — Use test connection No. 3 and repeat above.

Part E — Overcurrent Detector (For SDG-1T)

1. Energize dc circuit with rated dc voltage.
2. Use test connection No. 5. Set V_{AN} = 0, V_{BN} = V_{CN} = 70 volts. Set current for 0.4 ampere for *1 - 30 ohm relays*, and for 0.8 ampere for *.2 - 4.35 ohm relays.*

Check relay output at test point 12 with voltameter or oscilloscope. There should be a continuous output of 18-22 volt level under conditions specified above. Adjust R63 potentiometer for specified pickup current. Dropout should occur at:

.38 to .3 amp for 1-30 ohm relays

.76 to .6 amp for .2-4.35 ohm relays

Part F — Magnitude Comparator Circuit Adjustment (large Printed Circuit Board) — All relays R33 Adjustment

Energize relay with dc only. Connect 10K resistor (±5%) between TP1 of the large PC board and relay terminal 2. Use scope to monitor TP9 and adjust R33 until a positive output is obtained at TP9 (17 - 23 volts).

Frequency Verifier Adjustment (For SDG-1T-2T)

Use oscilloscope to observe wave shape at test point TP11. Use test connection No. 5. Set V_{AN} = 0 V_{BN} = V_{CN} = 70 volts. Set current for 2.5 amps current lagging voltage by 75°. Adjust R76 until less than 1 volt signal of 5.0 to 5.3 ms duration is followed by a positive pulse (17-23 volts) of approximately 3 ms duration. See Test Point Wave Shape, Figure 15a.

Impedance Check

Start with 2.5 volts test. Use voltmeter for monitoring the relay output. The first short deflection is positive indication of meeting current limits. Then increase current slightly to see if full 18 volt dc output is obtained. There should be no drop in output to zero volts while current is increased. If the currents are outside the limits for 2.5 volt-test as outlined, proceed as follows:

Set V_{AN} = V_{BN} = V_{CN} = 70 volts as close to each other as possible. Use connection No. 5. No current is applied. Measure dc voltage across R9, R10, R11 resistors. Readjust potentiometers R5, R6, R7 until the voltages across R9, R10, R11 are as close to each other as possible. These voltages should be in 20-25 volts range. In most cases only slight adjustment of R5, R6, or R7 will be required. Then recheck pickup current for 2.5 volt test again. If the pickup currents are close together but outside the specified limits readjust R18 or R8 to move all pickup values up or down. Note that R5, R6, R7 are interacting. Therefore, recheck all three voltages after each adjustment. If difficulties in balancing at 2.5 volts persist, use 5 volts and double the limits. If it is desired to check relay response at some other settings use following equation for the trip value of current.

$$I = \frac{3V_{LN}}{(2+p)Z_1}, \text{ where } p = \frac{Z_0}{Z_1}$$

Z_0 = Zero sequence reach

Z_1 = Positive sequence reach (in above cases p = 3)

V_{LN} = Faulted Phase Voltage

7.1. 1 – 30 Ohm Relay

7.1.1. SDG-1T, SDG-2T, and SDG-4T Relays

Using previous relay tap settings, apply rated dc voltage and proceed as follows:

Part A: 2.5 VOLT TEST

Phase A

Use test connection No. 5. Set V_{AN} = 2.5 volts. V_{BN} = V_{CN} = 70 volts. Disable overcurrent unit by jumping terminals 1 & 17 on magnitude comparator module. Adjust R18 for proper pickup level. Pickup current I_A should be .140 - .155 amps, current lagging voltage V_{AN} by 75˚.

Phase B

Use test connection No. 6. Set V_{BN} = 2.5 volts. V_{AN} = V_{CN} = 70 volts. Pickup current I_B should be .140 - .155 amps, current lagging voltage V_{BN} by 75˚.

Phase C

Use test connection No. 7. Set V_{CN} = 10 volts. V_{AN} = V_{CN} = 70 volts. Pickup current I_C should be .140 - .155 amps, current lagging voltage V_{BN} by 75˚. Remove jumper from overcurrent unit and return all “S” connections to S=1.

Part B: 70 VOLTS TEST

Phase A

Use connections for Test No. 5 and set V_{AN} = V_{BN} = V_{CN} = 70 volts. Set phase-shifter for 75° current lagging voltage. The relay trip current should be 3.95 - 4.20 amperes, current lagging voltage V_{AN} by 75˚.

Phase B

Use connections for Test No. 6 and set V_{AN} = V_{BN} = V_{CN} = 70 volts, and set the phase-shifter as above. The relay trip current should be 3.95 - 4.20 amperes, lagging 75° V_{CN} voltage.

Phase C

Use test connections for Test No. 7 and set V_{AN} = V_{BN} = V_{CN} = 70 volts. Set the phase-shifter as above. The relay trip current should be 3.95 - 4.20 amperes, current lagging 75° voltage V_{CN} by 75˚

Part C: S = 3 TEST

Set S_A, S_B, S_C = 3. Set V_{BN} = V_{CN} = 70 volts. V_{AN} = 10 volts. Disable overcurrent unit again as for 2.5 volt test.

Phase A

Use test connection No. 5. Pickup Current I_A should be .190 -.218 amps, current lagging voltage V_{AN} by 75°.

Phase B

Use test connection No. 6. Set V_{BN} = 10 volts. V_{AN} = V_{CN} = 70 volts. Pickup current I_B should be .190 - .218 amps, current lagging voltage V_{BN} by 75˚.

Phase C

Use test connection No. 7. Set V_{CN} = 10 volts. V_{AN} = V_{CN} = 70 volts. Pickup current I_C should be .190 - .218 amps, current lagging voltage V_{CN} by 75˚. Remove jumper from overcurrent unit and return all “S” connections to S = 1.

7.2. .2 – 4.25 Ohm Relay

7.2.1. SDG-1T, SDG-2T, SDG-4T Relays

Using previous relay tap settings, apply rated dc voltage and proceed as follows.

Part A: 2.5 VOLT TEST

Phase A

Use test connection No. 5. Set V_{AN} - 2.5 volts. V_{BN} = V_{CN} = 70 volts. Disable overcurrent unit by jumping terminals 1 & 17 on magnitude comparator module. Adjust R18 for proper pickup level. Pickup current I_A should be 1.00 - 1.10 amps, current lagging voltage V_{AN} by 75˚.

Phase B

Use test connection No. 6. Set V_{BN} = 2.5 volts, V_{AN} = V_{BN} = 70 volts. Pickup current I_B should be 1.00 - 1.10 amps, current lagging voltage 75°.

Phase C

Use test connection No. 7. Set V_{CN} = 2.5 volts, V_{AN} = V_{BN} = 70 volts. Pickup current should be 1.00 - 1.10 amps, current lagging voltage V_{CN} by 75°. Remove jumper from overcurrent unit and return all “S” connections to S = 1.

If limits above are not met, see special note under “Impedance Test.”

Part B: 20 VOLT TEST

Phase A

Use test connection No. 5. Set V_{AN} = 20 volts. V_{BN} = V_{CN} = 70 volts. Set phase-shifter for 75° current lagging voltage. Pickup current I_A should be 8.05 - 8.55 amps, current lagging V_{AN} voltage by 75°.

Phase B

Set V_{BN} = 20 volts, V_{AN} = V_{CN} = 70 volts. Use test connection No. 6. Pickup current I_B should be 8.05 - 8.55 amp, current lagging V_{BN} voltage by 75°.

Phase C

Set V_{CN} = 20 volts, V_{AN} = V_{BN} = 70 volts. Use test connection No. 6. Pickup current I_C should be 8.05 - 8.55 amps, current lagging V_{CN} voltage by 75°.

Part C: S = 3 TEST

Set S_A = S_B = S_C = 3. Set V_{AN} = 10 volts. V_{BN} = V_{CN} = 70 volts.

Phase A

Use test connection No. 5. Pickup current I_A should be 1.35 - 1.43 amps, current lagging voltage V_{AN} by 75˚.

Phase B

Use test connection No. 6. Set V_{BN} = 10 volts, V_{AN} = V_{CN} = 70 volts. Pickup current I_B should be 1.35 - 1.43 amps, current lagging voltage V_{BN} by 75˚.

Phase C

Use test connection No. 7. Set V_{CN} = 10 volts, V_{AN} = V_{CN} = 70 volts. Pickup current I_C should be 1.35 - 1.43 amps, current lagging voltage V_{CN} by 75˚. Remove jumper from overcurrent unit and return all “S” connections to S = 1.

7.3. push-button Test

Use test connection No. 1. No current is required. Apply dc to the relay. Open circuit voltage connection to relay terminal No. 7. Set V_{BN} = V_{CN} = 70 volts. Depress white push-button and it should light.

7.3.1. Indicating Contactor Switch

With the relay tripped, pass sufficient dc current through the trip circuit to close the contacts of 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 setting being used for the 0.2-2.0 amperes 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.

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, and component style number given in the electrical parts list.

See detailed Internal Schematics for printed circuit styles and Reference Drawing list for component location details.

Figure	Description	Drawing
1	SDG-1T Relay without Case (Front View)	PHOTO
2	SDG-1T Relay without Case (Rear View)	PHOTO
3	SDG-2T Relay without Case (Front View)	PHOTO
4	SDG-2T Relay without Case (Rear View)	PHOTO
5	Detailed Internal Schematic of SDG-1T Relay with Parts List	6694D74
6	Internal Diagram of Type SDG-2T	719B766
7	Detailed Internal Schematic of SDG-2T Relay with Parts List	6694D77
8	SDG-4T Detailed Internal Schematic Relay with Parts List (Double Contact)	1339D60
9	Test Connections for SDGT Line	1495B95
10	Typical Operating Time Curves	9646A38
11	Distance Phase and Distance Ground Relaying (External Connections)	2396F25
12	Outline and Drilling Plan for SDGT Line Relays in an FT-42 Case	57D7905
13	Compensator Construction	849A034
14	Impedance Circles for the SDG Line Relays	837A14, 15, 16
15	Test Points for SDGT – Line of Relays	9646A39
15a	Test Points for SDGT – Line of Relays	9646A40
16	Definition of Terms	837A125
17	Fault Resistance	837A125
18	Relay Voltages for AG Faults at Selected Points	837A117
19	Impedance Curve for the SDGT Line of Relays	878A006
20	SDGT-1T Component Location of Magnitude Comparator Board	774B971
21	SDGT-2T Component Location of Magnitude Comparator Board	774B972
22	SDGT-4T Component Location	203C301
23	SDG-1T-2T-4T component Location of Phase Splitter Rectifier Board	716B095
24	SDG-1T and SDG-2T 2ϕ-Ground Board Parts Component Location	774B966
25	SDG-1T Capacitor – Restraint Filter Board – Parts Location	3507A85
26	SDG-2T Capacitor – Restraint Filter Board – Parts Location	3507A86

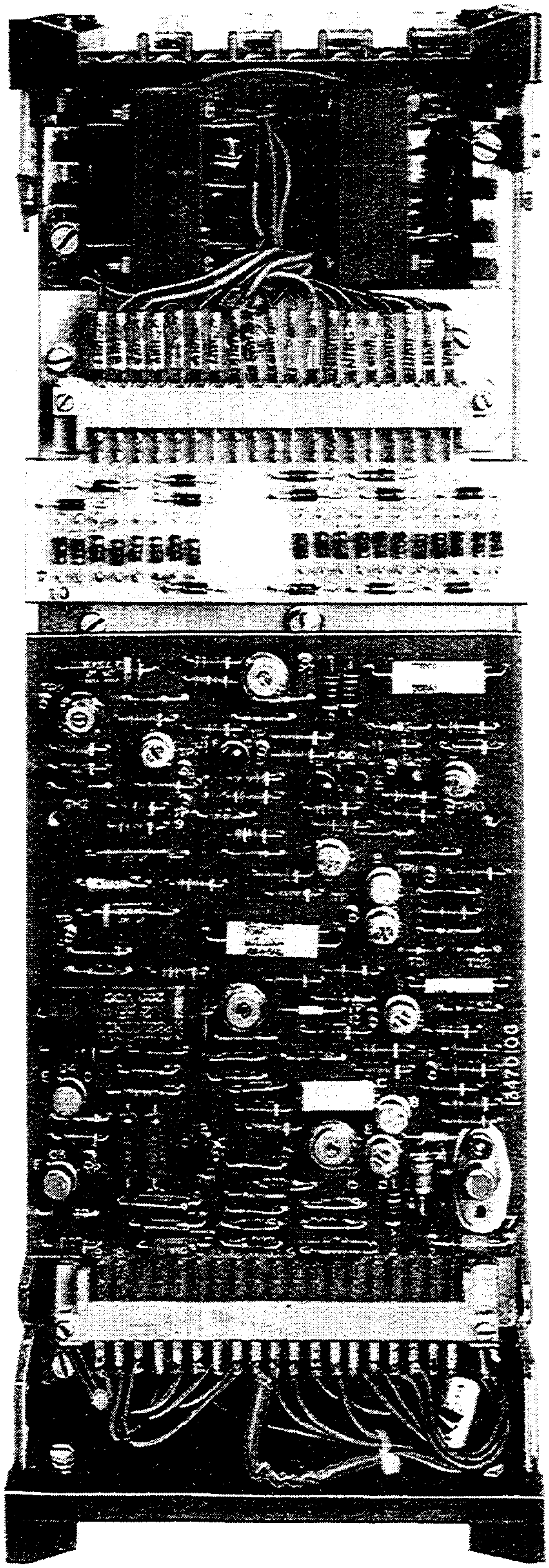
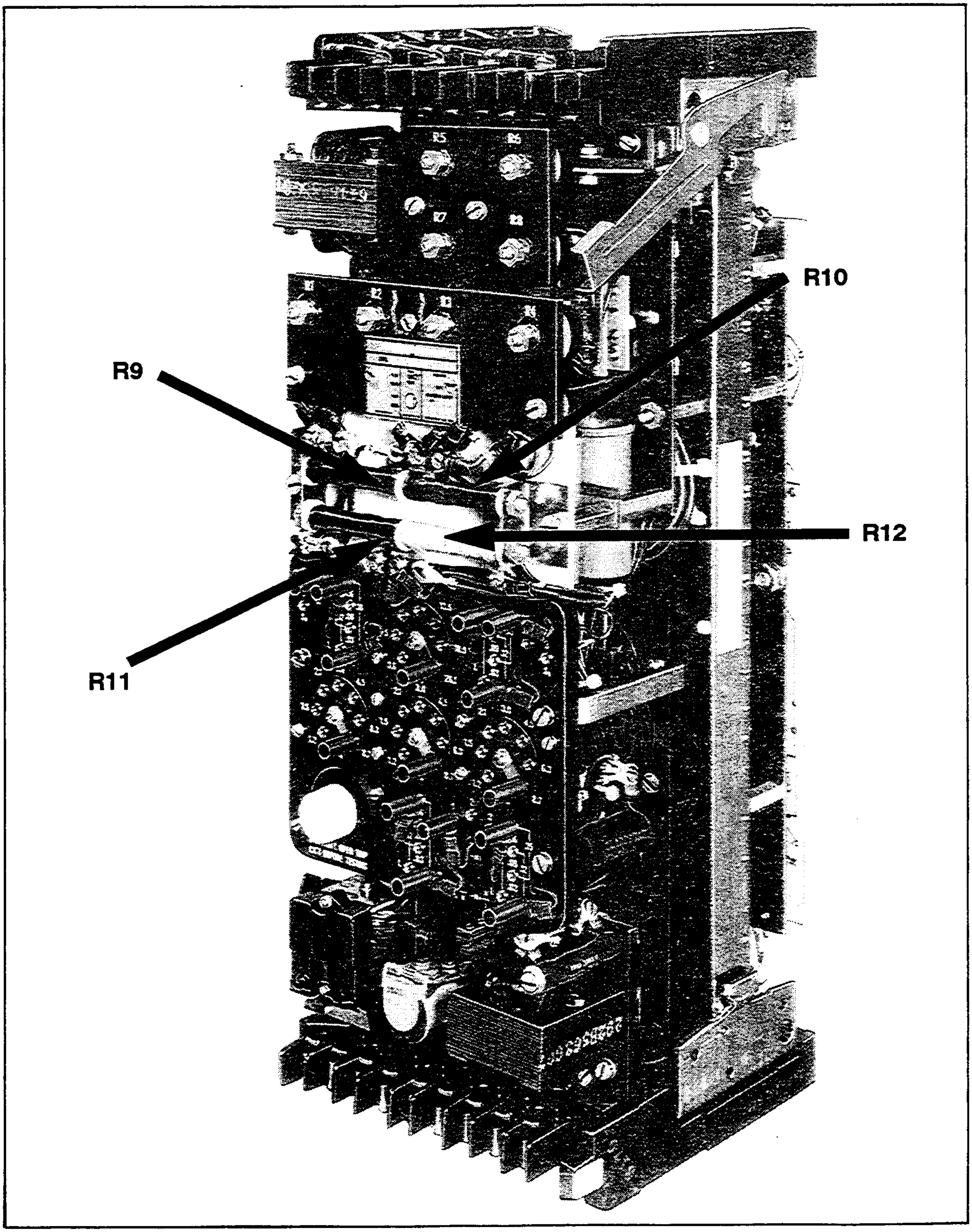


Fig. 2. Type SDG-1T Relay Without Case (Rear View)



✪ *Fig. 3. Type SDG-2T Relay Without Case (Front View)*

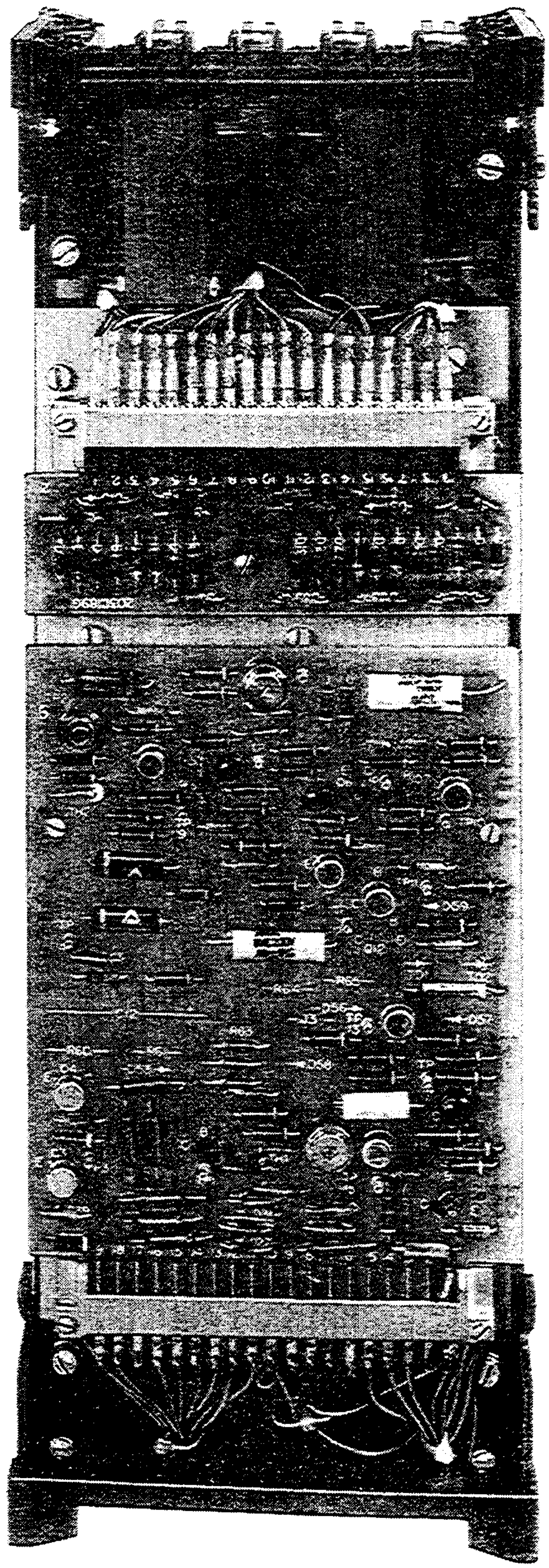
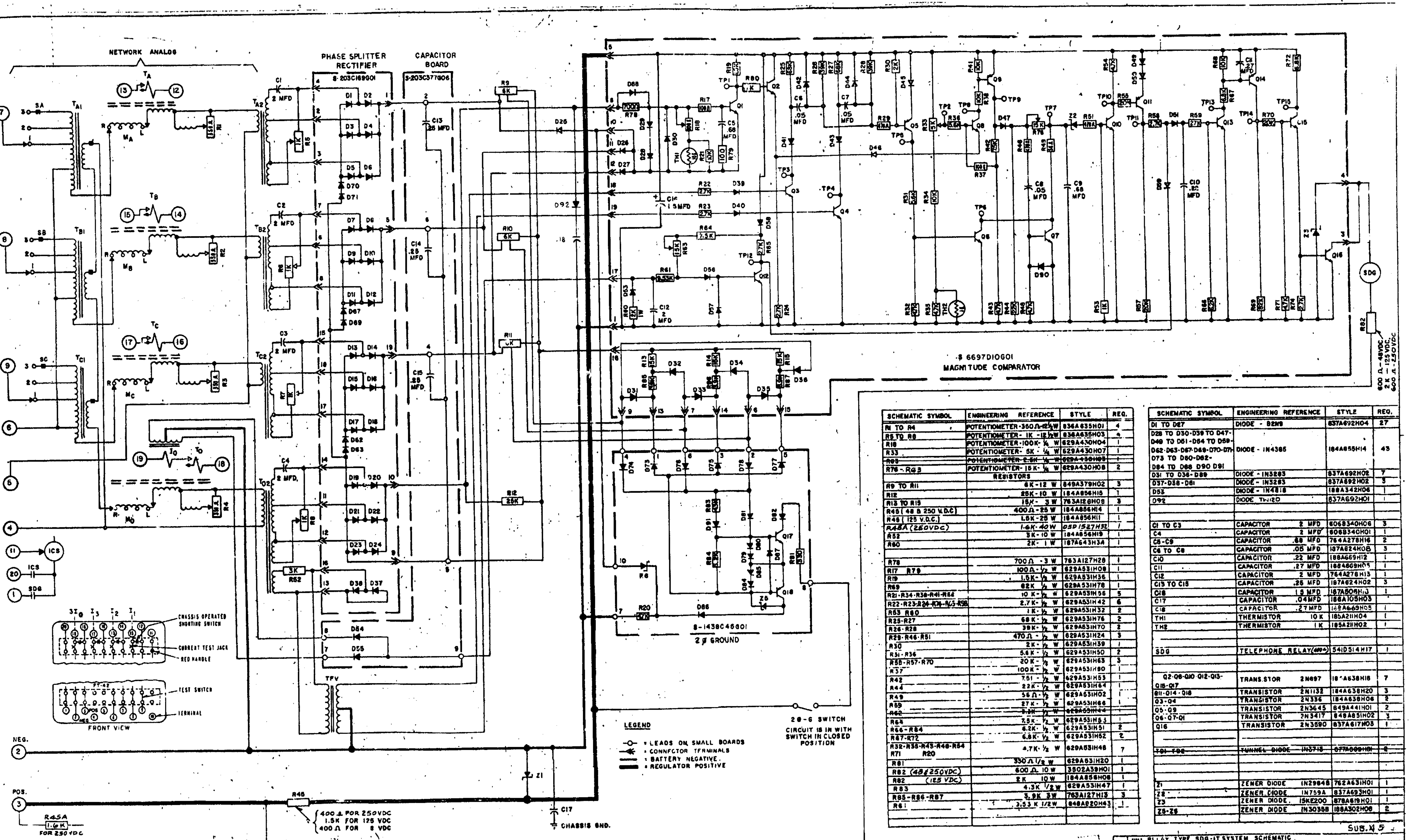


Fig. 4. Type SDG-2T Relay Without Case (Rear View)



SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
R1 TO R4	POTENTIOMETER-360Ω-12½W	836A635H01	4
R5 TO R8	POTENTIOMETER- 1K -12½W	836A635H03	4
R18	POTENTIOMETER-100K- ¼ W	629A430H04	1
R33	POTENTIOMETER- 5K - ¼ W	629A430H07	1
~~R63~~	~~POTENTIOMETER-2.5K- ¼ W~~	~~629A430H05~~	~~1~~
R76 - R63	POTENTIOMETER- 15K- ¼ W	629A430H08	2
	RESISTORS		
R9 TO R11	6K-12 W	849A379H02	3
R12	25K-10 W	184A856H16	1
R13 TO R15	15K- 3 W	763A126H08	3
R45 (48 & 250 V.D.C)	400Ω-25 W	184A856H14	1
R45 (125 V.D.C.)	1.5K-25 W	184A856H11	1
R45A (250VDC)	1.6K-40W	05P1527H32	1
R52	3K-10 W	184A856H19	1
R60	2K- 1 W	187A643H34	1
R78	700Ω -3 W	763A127H28	1
R17 R79	100Ω- ½ W	629A531H08	1
R19	1.5K- ½ W	629A531H36	1
R69	82K ½ W	629A531H78	1
R21-R34-R38-R41-R68	10 K- ½ W	629A531H56	5
R22-R23-~~R24-R74-R65~~-R58	2.7K- ½ W	629A531H42	6
R53 R80	1K- ½ W	629A531H32	2
R25-R27	68K- ½ W	629A531H76	2
R26-R28	39K- ½ W	629A531H70	2
R29-R46-R51	470Ω - ½ W	629A531H24	3
R30	2K- ½ W	629A531H39	1
R31-R36	5.6K - ½ W	629A531H50	2
R55-R57-R70	20K - ½ W	629A531H63	3
R37	100K - ½ W	629A531H80	1
R42	7.51 - ½ W	629A531H53	1
R44	22K- ½ W	629A531H64	1
R49	56Ω- ½ W	629A531H02	1
R59	27K- ½ W	629A531H66	1
~~R62~~	~~3.9K- ½ W~~	~~629A531H44~~	~~1~~
R64	7.5K- ½ W	629A531H53	1
R66-R84	6.2K- ½ W	629A531H51	2
R67-R72	6.8K- ½ W	629A531H52	2
R32-R35-R43-R48-R54 R71 R20	4.7K- ½ W	629A531H48	7
R81	330Ω ½ W	629A531H20	1
R82 (48 & 250VDC)	600Ω 10 W	3502A39H01	1
R82 (125 VDC)	2K 10 W	184A856H06	1
R83	4.3K ½ W	629A531H47	1
R85-R86-R87	3.9K 3W	763A127H13	3
R61	3.53 K 1/2 W	848A820H43	1

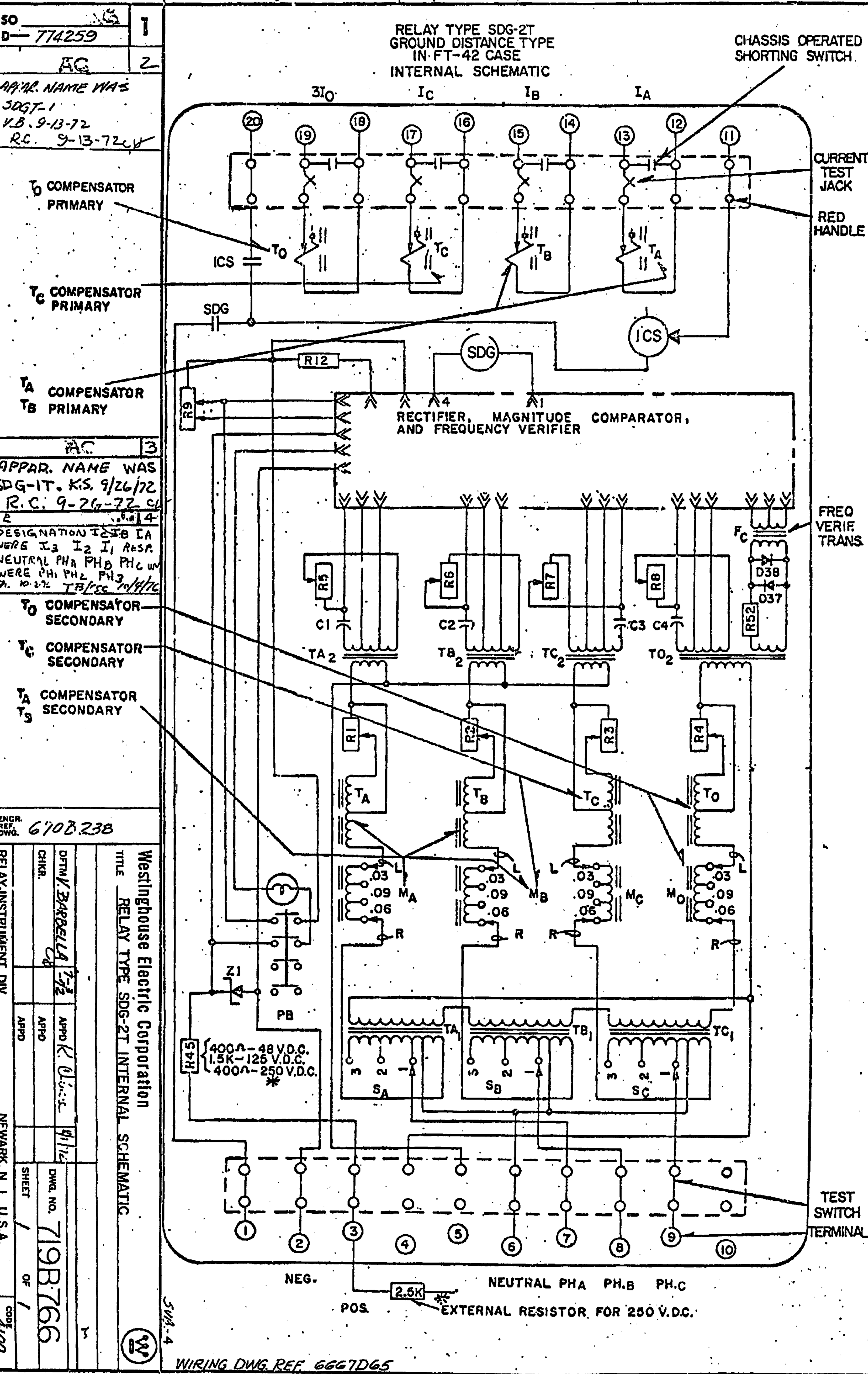
SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
D1 TO D27	DIODE - B2N9	837A692H04	27
D28 TO D30-D39 TO D47-D49 TO D51-D64 TO D59-D62-D63-D67-D69-D70-D71-D73 TO D80-D82-D84 TO D88 D90 D91	DIODE - 1N4385	184A855H14	43
D31 TO D36-D89	DIODE - 1N3283	837A692H02	7
D37-D38-D61	DIODE - 1N3283	837A692H02	3
D53	DIODE - 1N4818	188A342H06	1
D92	DIODE TW120	837A692H01	1
C1 TO C3	CAPACITOR 2 MFD	606B340H06	3
C4	CAPACITOR 2 MFD	606B340H01	1
C5-C9	CAPACITOR .68 MFD	764A278H16	2
C6 TO C8	CAPACITOR .05 MFD	187A624H08	3
C10	CAPACITOR .22 MFD	188A669H12	1
C11	CAPACITOR .27 MFD	188A669H05	1
C12	CAPACITOR 2 MFD	764A278H13	1
C13 TO C15	CAPACITOR .25 MFD	187A624H02	3
C16	CAPACITOR 1.5 MFD	187A506H13	1
C17	CAPACITOR .04MFD	186A105H03	
C18	CAPACITOR .27MFD	188A669H05	1
TH1	THERMISTOR 10 K	185A211H04	1
TH2	THERMISTOR 1 K	185A211H02	1
SDG	TELEPHONE RELAY(4004)	541D514H17	1
Q2-Q8-Q10-Q12-Q13-Q15-Q17	TRANSISTOR 2N697	184A638H18	7
Q11-Q14-Q18	TRANSISTOR 2N1132	184A638H20	3
Q3-Q4	TRANSISTOR 2N336	184A638H06	2
Q5-Q9	TRANSISTOR 2N3645	849A441H01	2
Q6-Q7-Q1	TRANSISTOR 2N3417	848A851H02	3
Q16	TRANSISTOR 2N3590	837A617H03	1
~~TD1-TD2~~	~~TUNNEL DIODE 1N3713~~	~~877A609H01~~	~~2~~
Z1	ZENER DIODE 1N2984B	762A631H01	1
Z2	ZENER DIODE 1N759A	837A693H01	1
Z3	ZENER DIODE. 15KE200	878A619H01	1
Z5-Z6	ZENER DIODE 1N3035B	188A302H06	2

SUB. 5

RELAY TYPE SDG-IT SYSTEM SCHEMATIC

FT-42

SO ... D— 774259		1
AC	APPAR. NAME WAS SDGT-1 V.B. 9-13-72 R.C. 9-13-72	2
AC	APPAR. NAME WAS SDG-1T. K.S. 9/26/72 R.C. 9-26-72	3
E	DESIGNATION I_C I_B I_A WERE I_3 I_2 I_1 RESP. NEUTRAL PHA PHB PHC WERE PH1 PH2 PH3 ... 10-3-76 TB/... 10/4/76	4



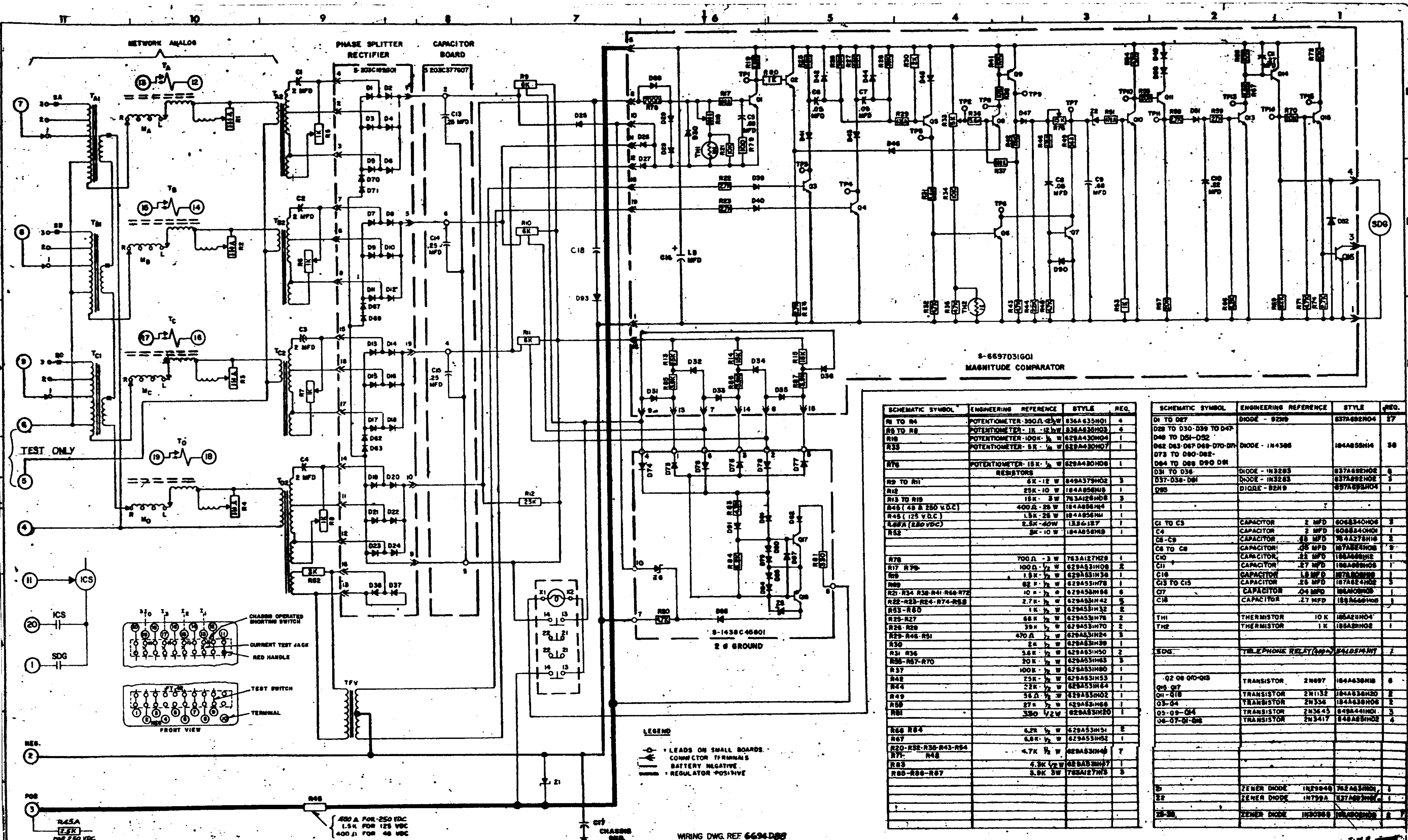
ENGR. REF. DWG. 670B238

Westinghouse Electric Corporation

TITLE RELAY TYPE SDG-2T INTERNAL SCHEMATIC

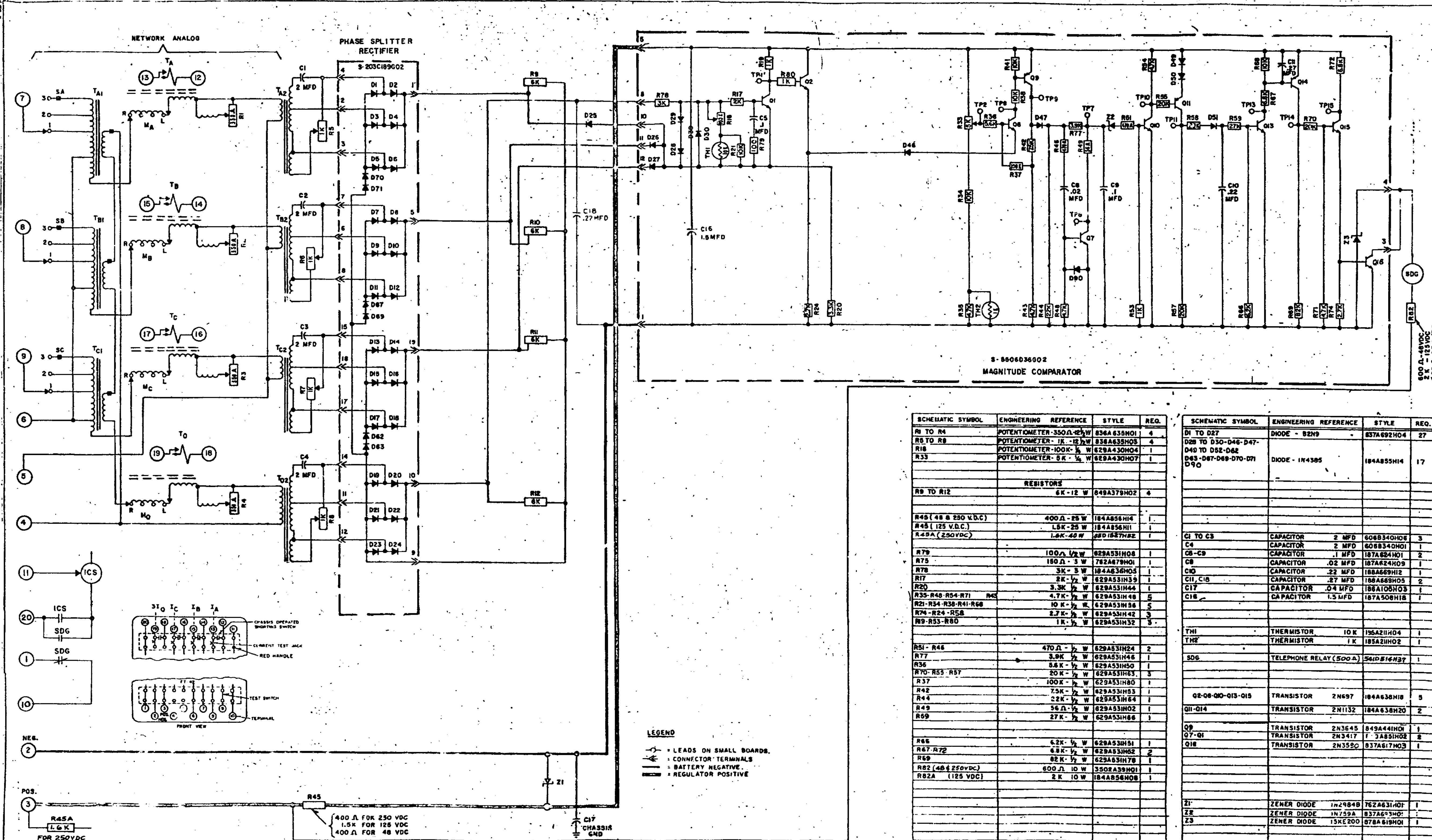
DFTM	V. BARBELLA 7-3-72
CHKR.	
APPD	K. Olive
APPD	
DWG. NO.	719B766
SHEET	1 OF 1
CODE	4100

RELAY-INSTRUMENT DIV. NEWARK N.J. U.S.A.



SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
R1 TO R4	POTENTIOMETER-350Ω-12½W	836A635H01	4
R5 TO R8	POTENTIOMETER - 1K - 12½W	836A635H03	4
R18	POTENTIOMETER-100K- ½ W	629A430H04	1
R33	POTENTIOMETER- 5K - ½ W	629A430H07	1
R76	POTENTIOMETER- 15K- ½ W	629A430H08	1
	RESISTORS		
R9 TO R11	6K - 12 W	849A379H02	3
R12	25K - 10 W	184A856H18	1
R13 TO R15	15K - 3 W	763A126H08	3
R45 (48 & 250 V.D.C)	400Ω - 25 W	184A856H14	1
R45 (125 V.D.C)	1.5K - 25 W	184A856H11	1
R45A (250 VDC)	2.5K - 40W	1336127	1
R52	3K - 10 W	184A856H19	1
R78	700Ω - 3 W	763A127H28	1
R17 R79	100Ω - ½ W	629A531H08	2
R19	1.5K - ½ W	629A531H36	1
R69	82 K - ½ W	629A531H78	1
R21-R34 R38-R41-R68-R72	10 K - ½ W	629A531H56	6
R22-R23-R24-R74-R58	2.7K - ½ W	629A531H42	5
R53-R80	1K - ½ W	629A531H32	2
R25-R27	68K ½ W	629A531H76	2
R26-R28	39K ½ W	629A531H70	2
R29-R46-R51	470 Ω ½ W	629A531H24	3
R30	2K ½ W	629A531H39	1
R31 R36	5.6K - ½ W	629A531H50	2
R56-R57-R70	20K - ½ W	629A531H63	3
R37	100K - ½ W	629A531H80	1
R42	25K - ½ W	629A531H53	1
R44	22K - ½ W	629A531H64	1
R49	56 Ω - ½ W	629A531H02	1
R59	27K ½ W	629A531H66	1
R81	330 ½ W	629A531H20	1
R66 R84	6.2K ½ W	629A531H51	2
R67	6.8K - ½ W	629A531H52	1
R20-R32-R35-R43-R54 R71- R48	4.7K ½ W	629A531H48	7
R83	4.3K ½ W	629A531H47	1
R85-R86-R87	3.9K 3W	763A127H13	3

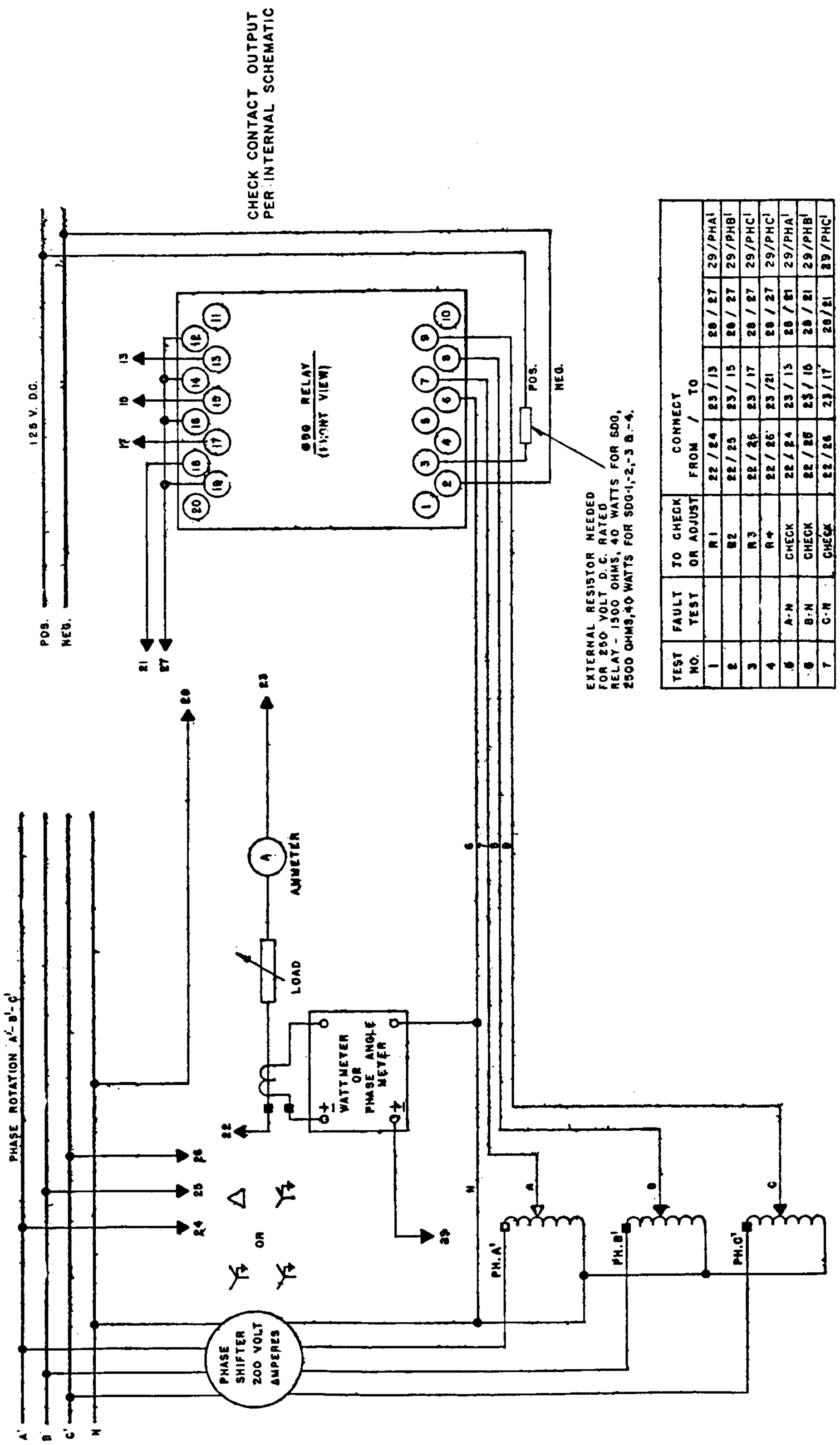
SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
D1 TO D27	DIODE - B2N9	837A692H04	27
D28 TO D30-D39 TO D47-D49 TO D51-D52 D62-D63-D67-D69-D70-D71-D73 TO D80-D82-D84 TO D88 D90 D91	DIODE - 1N4385	184A855H14	38
D31 TO D36	DIODE - 1N3283	837A692H02	6
D37-D38-D81	DIODE - 1N3283	837A692H02	3
D93	DIODE - B2N9	837A692H04	1
C1 TO C3	CAPACITOR 2 MFD	606B340H06	3
C4	CAPACITOR 2 MFD	606B340H01	1
C5-C9	CAPACITOR .68 MFD	764A278H16	2
C6 TO C8	CAPACITOR .05 MFD	187A624H08	3
C10	CAPACITOR .22 MFD	188A669H12	1
C11	CAPACITOR .27 MFD	188A669H08	1
C16	CAPACITOR 1.8 MFD	187A809H18	1
C13 TO C15	CAPACITOR .25 MFD	187A624H02	3
C17	CAPACITOR .04 MFD	186A108H05	1
C18	CAPACITOR .27 MFD	188A669H08	1
TH1	THERMISTOR 10 K	185A211H04	1
TH2	THERMISTOR 1 K	185A211H02	1
SDG	TELEPHONE RELAY (4104)	541D514H17	1
Q2 Q8 Q10-Q13 Q15 Q17	TRANSISTOR 2N697	184A638H18	6
Q11-Q18	TRANSISTOR 2N1132	184A638H20	2
Q3-Q4	TRANSISTOR 2N336	184A638H06	2
Q5-Q9-Q14	TRANSISTOR 2N3645	849A441H01	3
Q6-Q7-Q1-Q16	TRANSISTOR 2N3417	848A851H02	4
Z1	ZENER DIODE 1N2984B	762A631H01	1
Z2	ZENER DIODE 1N759A	837A693H01	1
Z3-Z4	ZENER DIODE 1N3036B	186A808H08	2



SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
R1 TO R4	POTENTIOMETER-350Ω-12½W	836A635H01	4
R5 TO R8	POTENTIOMETER- 1K -12½W	836A635H05	4
R18	POTENTIOMETER-100K- ¼ W	629A430H04	1
R33	POTENTIOMETER- 5K - ¼ W	629A430H07	1
	RESISTORS		
R9 TO R12	6K-12 W	849A379H02	4
R45 (48 & 250 V.D.C)	400Ω-25 W	184A856H14	1
R45 (125 V.D.C.)	1.5K-25 W	184A856H11	1
R45A (250VDC)	1.6K-40 W	85D1527H82	1
R79	100Ω ½W	629A531H08	1
R75	150Ω - 3 W	762A679H01	1
R78	3K- 3 W	184A636H05	1
R17	2K- ½ W	629A531H39	1
R20	3.3K ½ W	629A531H44	1
R35-R48-R54-R71 R43	4.7K- ½ W	629A531H48	5
R21-R34-R38-R41-R68	10 K- ½ W	629A531H56	5
R74-R24-R58	2.7K- ½ W	629A531H42	3
R19-R53-R80	1K- ½ W	629A531H32	3
R51- R46	470Ω - ½ W	629A531H24	2
R77	3.9K ½ W	629A531H46	1
R36	5.6K - ½ W	629A531H50	1
R70- R55 R57	20 K - ½ W	629A531H63	3
R37	100K - ½ W	629A531H80	1
R42	7.5K - ½ W	629A531H53	1
R44	22K - ½ W	629A531H64	1
R49	56Ω - ½ W	629A531H02	1
R69	27K - ½ W	629A531H66	1
R66	6.2K- ½ W	629A531H51	1
R67-R72	6.8K- ½ W	629A531H62	2
R69	82K- ½ W	629A531H78	1
R82 (48 & 250VDC)	600Ω 10 W	3502A39H01	1
R82A (125 VDC)	2 K 10 W	184A856H08	1

SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
D1 TO D27	DIODE - 82N9	837A692H04	27
D28 TO D30-D46-D47-D49 TO D52-D62 D63-D67-D69-D70-D71 D90	DIODE - 1N4385	184A855H14	17
C1 TO C3	CAPACITOR 2 MFD	606B340H06	3
C4	CAPACITOR 2 MFD	606B340H01	1
C8-C9	CAPACITOR .1 MFD	187A624H01	2
C8	CAPACITOR .02 MFD	187A624H09	1
C10	CAPACITOR .22 MFD	188A669H12	1
C11, C18	CAPACITOR .27 MFD	188A669H05	2
C17	CAPACITOR .04 MFD	186A105H03	1
C16	CAPACITOR 1.5 MFD	187A508H18	1
TH1	THERMISTOR 10 K	196A211H04	1
TH2	THERMISTOR 1 K	185A211H02	1
SDG	TELEPHONE RELAY (500A)	541D514H37	1
Q2-Q8-Q10-Q13-Q15	TRANSISTOR 2N697	184A638H18	5
Q11-Q14	TRANSISTOR 2N1132	184A638H20	2
Q9	TRANSISTOR 2N3645	849A441H01	1
Q7-Q1	TRANSISTOR 2N3417	[illegible]3A851H02	2
Q16	TRANSISTOR 2N3590	837A617H03	1
Z1	ZENER DIODE 1N2984B	762A631H01	1
Z2	ZENER DIODE 1N759A	837A693H0[illegible]	[illegible]
Z3	ZENER DIODE 15KE200	878A619H01	1

SUB 3



TEST NO.	FAULT TEST	TO CHECK OR ADJUST	CONNECT FROM / TO			
1		R1	22 / 24	23 / 13	28 / 27	29/PHA'
2		R2	22 / 25	23 / 15	28 / 27	29/PHB'
3		R3	22 / 26	23 / 17	28 / 27	29/PHC'
4		R4	22 / 25	23 / 21	28 / 27	29/PHC'
5	A-N	CHECK	22 / 24	23 / 13	28 / 21	29/PHA'
6	B-N	CHECK	22 / 25	23 / 15	28 / 21	29/PHB'
7	C-N	CHECK	22 / 26	23 / 17	28 / 21	29/PHC'

Fig. 9. Test Connections for SDGT Line

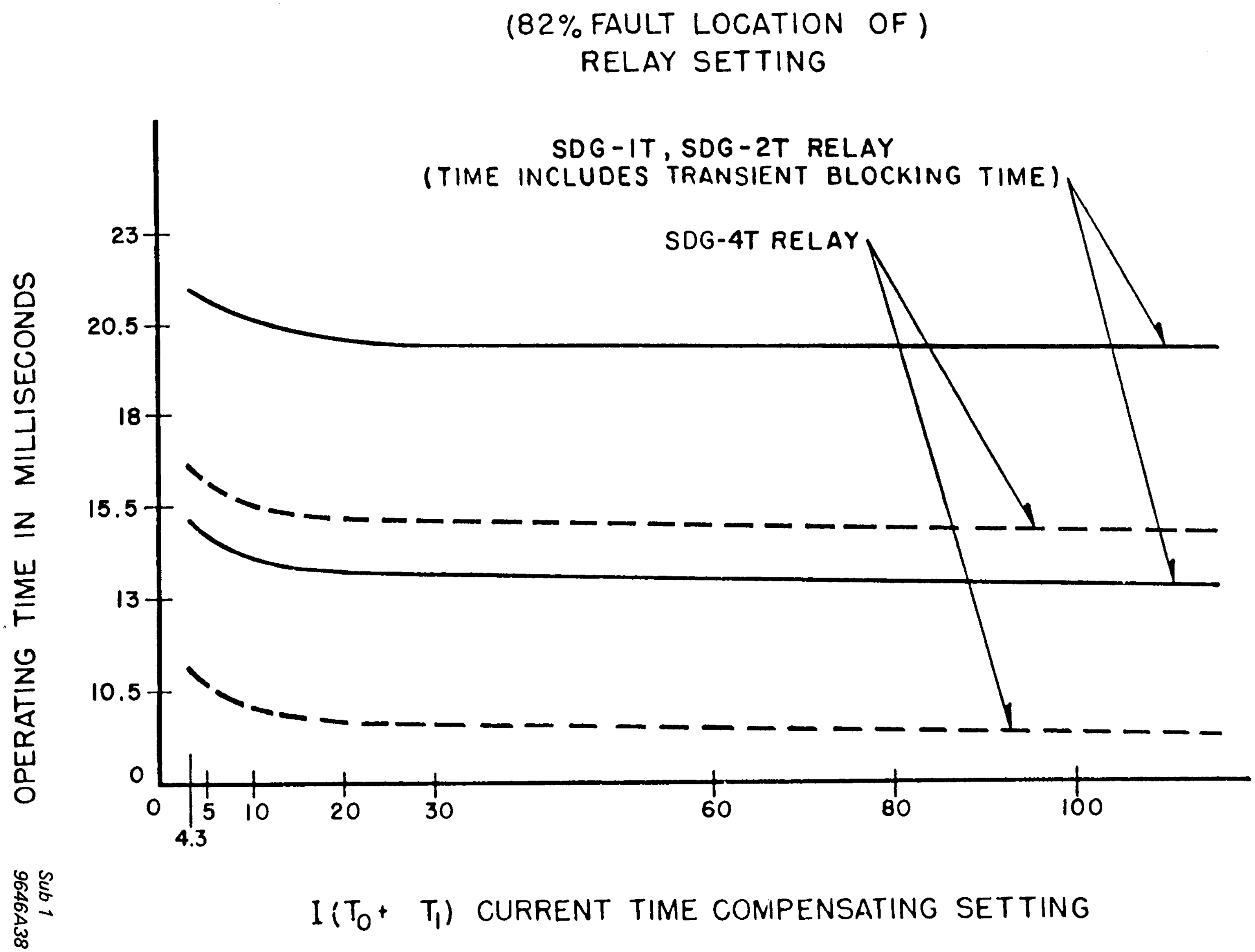
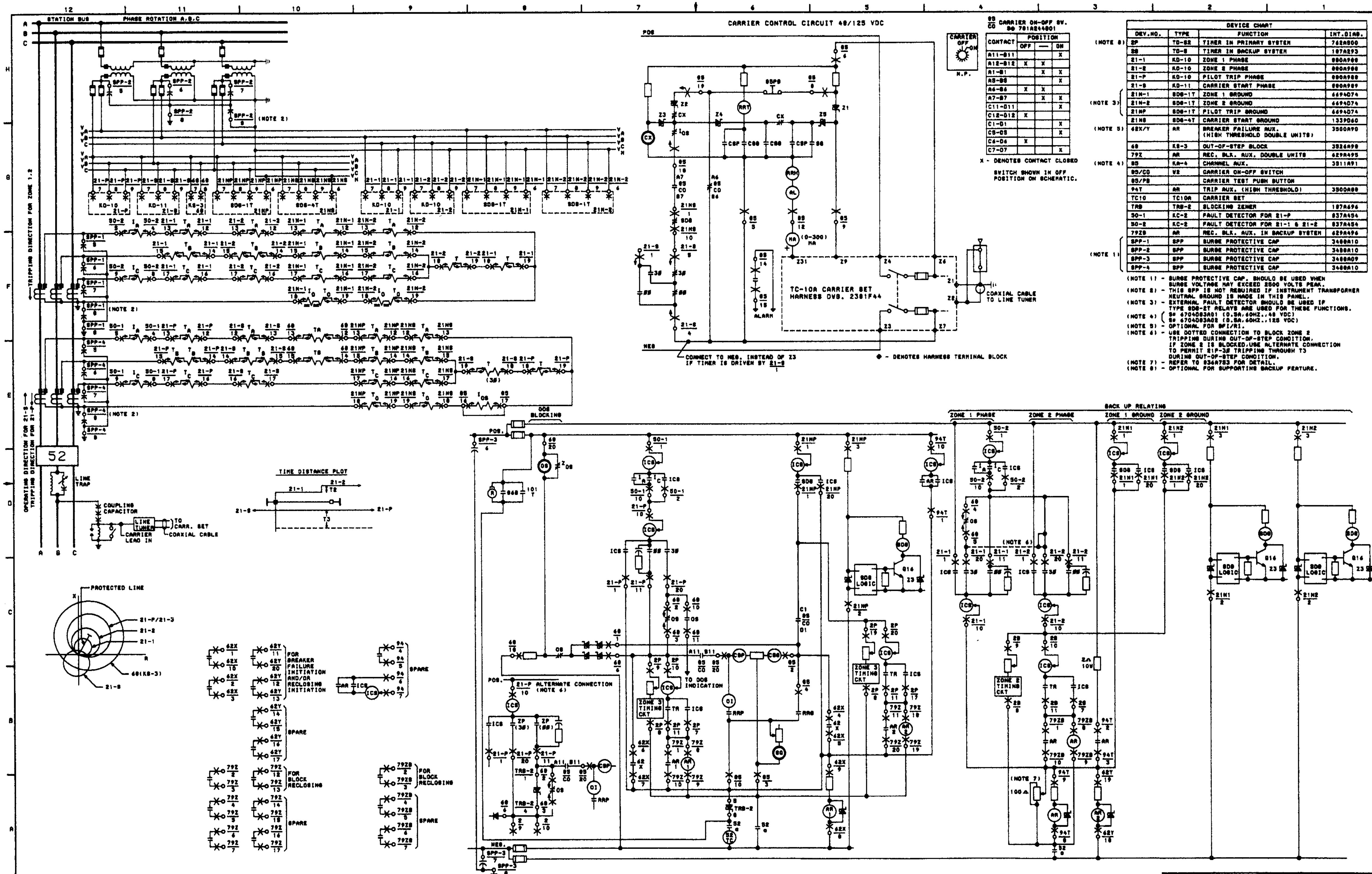


Fig. 10. Typical Operating Time Curves



85/CO CARRIER ON-OFF SW.
S# 701A244G01

CONTACT	POSITION OFF	POSITION —	POSITION ON
A11-B11			X
A12-B12	X	X	
A1-B1		X	X
A5-B5			X
A6-B6	X	X	
A7-B7		X	X
C11-D11			X
C12-D12	X		
C1-D1			X
C5-D5			X
C6-D6	X		
C7-D7			X

X - DENOTES CONTACT CLOSED

SWITCH SHOWN IN OFF POSITION ON SCHEMATIC.

DEVICE CHART				
	DEV.NO.	TYPE	FUNCTION	INT.DIAG.
(NOTE 8)	2P	TD-52	TIMER IN PRIMARY SYSTEM	762A800
	2S	TD-5	TIMER IN BACKUP SYSTEM	187A293
	21-1	KD-10	ZONE 1 PHASE	880A968
	21-2	KD-10	ZONE 2 PHASE	880A968
	21-P	KD-10	PILOT TRIP PHASE	880A968
	21-S	KD-11	CARRIER START PHASE	880A969
(NOTE 3)	21N-1	SDG-1T	ZONE 1 GROUND	6494D74
(NOTE 3)	21N-2	SDG-1T	ZONE 2 GROUND	6494D74
(NOTE 3)	21NP	SDG-1T	PILOT TRIP GROUND	6494D74
	21NS	SDG-4T	CARRIER START GROUND	1339D60
(NOTE 5)	62X/Y	AR	BREAKER FAILURE AUX. (HIGH THRESHOLD DOUBLE UNITS)	3500A90
	68	KS-3	OUT-OF-STEP BLOCK	3526A98
	79Z	AR	REC. BLK. AUX. DOUBLE UNITS	629A495
(NOTE 4)	85	KA-4	CHANNEL AUX.	3511A91
	85/CO	W2	CARRIER ON-OFF SWITCH	
	85/PB		CARRIER TEST PUSH BUTTON	
	94T	AR	TRIP AUX. (HIGH THRESHOLD)	3500A88
	TC10	TC10A	CARRIER SET	
	TRB	TRB-2	BLOCKING ZENER	187A696
	50-1	KC-2	FAULT DETECTOR FOR 21-P	837A454
	50-2	KC-2	FAULT DETECTOR FOR 21-1 & 21-2	837A454
	79ZB	AR	REC. BLK. AUX. IN BACKUP SYSTEM	629A496
(NOTE 1)	SPP-1	SPP	SURGE PROTECTIVE CAP	3488A10
(NOTE 1)	SPP-2	SPP	SURGE PROTECTIVE CAP	3488A10
(NOTE 1)	SPP-3	SPP	SURGE PROTECTIVE CAP	3488A09
(NOTE 1)	SPP-4	SPP	SURGE PROTECTIVE CAP	3488A10

(NOTE 1) - SURGE PROTECTIVE CAP. SHOULD BE USED WHEN SURGE VOLTAGE MAY EXCEED 2500 VOLTS PEAK.
(NOTE 2) - THIS SPP IS NOT REQUIRED IF INSTRUMENT TRANSFORMER NEUTRAL GROUND IS MADE IN THIS PANEL.
(NOTE 3) - EXTERNAL FAULT DETECTOR SHOULD BE USED IF TYPE SDG-2T RELAYS ARE USED FOR THESE FUNCTIONS.
(NOTE 4) S# 4704083A01 (0.5A,60HZ.,48 VDC)
S# 4704083A02 (0.5A,60HZ.,125 VDC)
(NOTE 5) - OPTIONAL FOR BFI/RI.
(NOTE 6) - USE DOTTED CONNECTION TO BLOCK ZONE 2 TRIPPING DURING OUT-OF-STEP CONDITION. IF ZONE 2 IS BLOCKED, USE ALTERNATE CONNECTION TO PERMIT 21P-3Ø TRIPPING THROUGH T3 DURING OUT-OF-STEP CONDITION.
(NOTE 7) - REFER TO 834A753 FOR DETAIL.
(NOTE 8) - OPTIONAL FOR SUPPORTING BACKUP FEATURE.

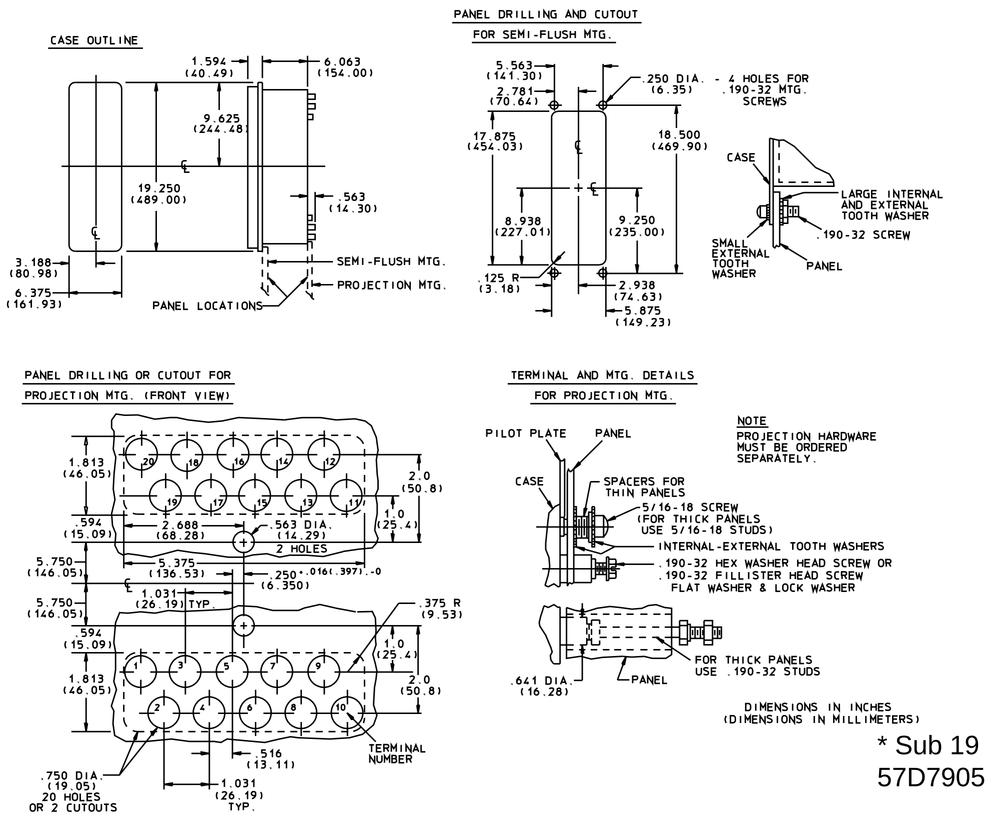


Figure 12. Outline and Drilling Plan for the SDGT Line Relays in an FT-42 Case

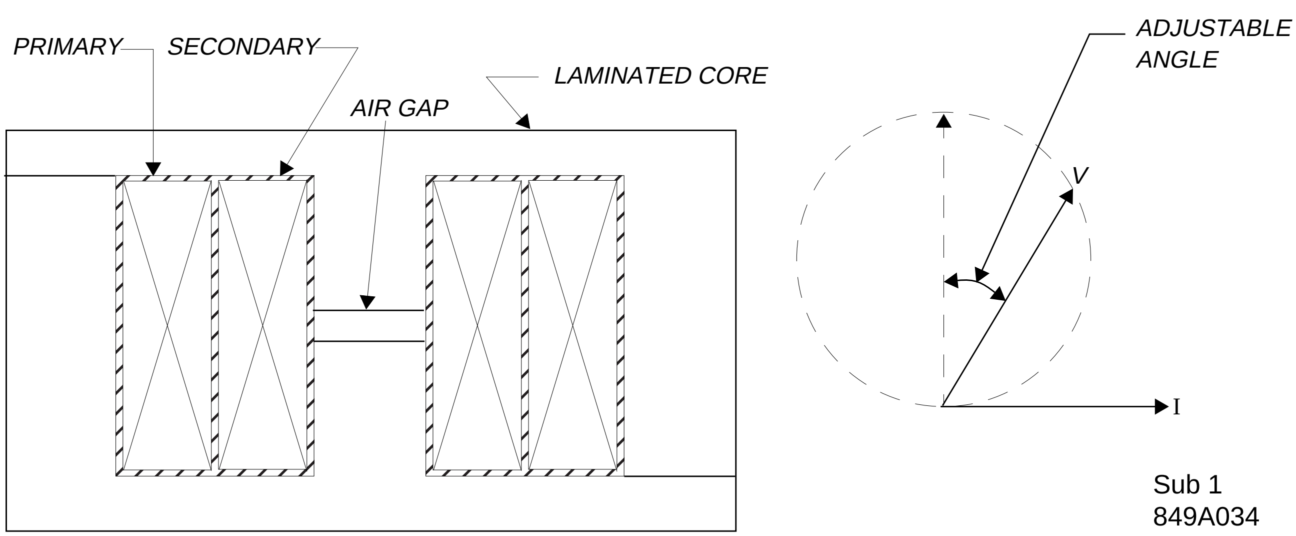
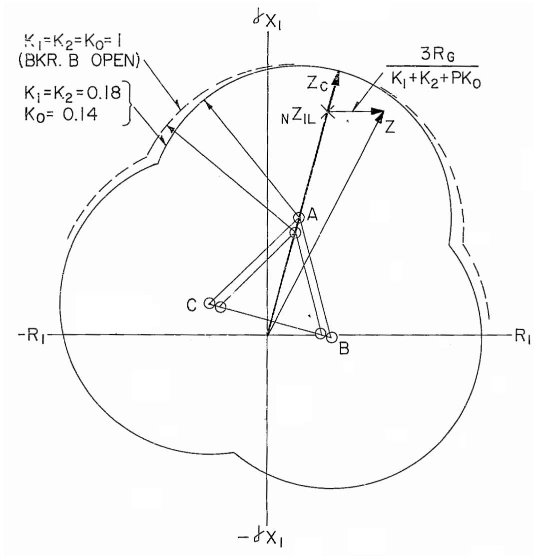
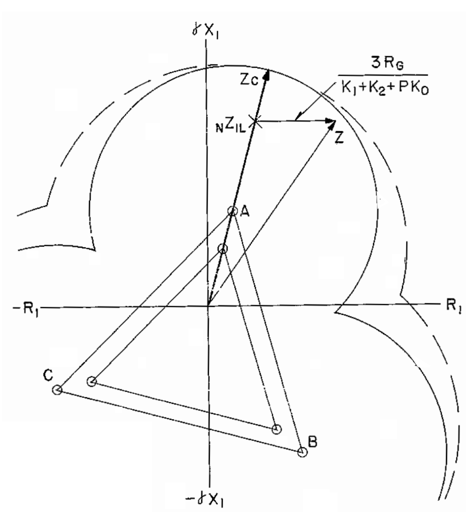


Figure 13. Compensator Construction

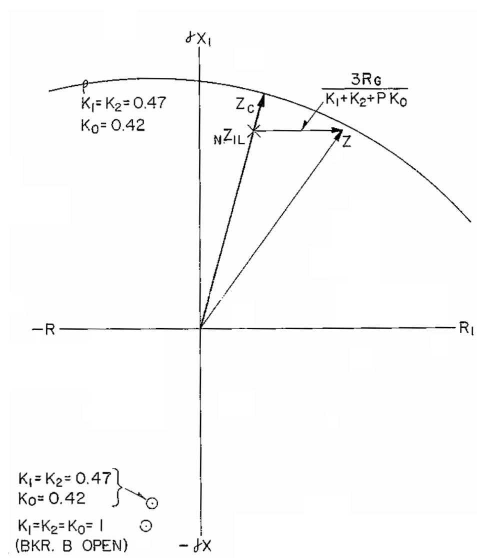


a) Long Line

(A)
837A116



b) Medium-Length Line



c) Short Line

(B)
837A114

(C)
837A115

Figure 14. Impedance Circles for the SDG Line Relays

SDGT – LINE (.2 TO 4.35Ω)

$S_{A, B, C} = 1$

$T_{A, B, C} = 1.23\Omega; \; T_O = 3.69\Omega$

TEST POINT TRACES

$M_{A, B, C, O} = +.18$

(D.C. NEG. REF.)

NO TRIP $V_{3\phi - G} = 70VAC$

$I_{3\phi - G} = 0$

TRIP $V_{A-G} = 2.5VAC;$

$V_{B, C-G} = 70VAC$

$I_{A-G} = 3AMP$

SDG-1T	EQUIVALENT TEST POINTS				
		SDG-2T		SDG-4T	
1	—	1	—	1	—
2	—	2	—	2	—
3	—	3	—	—	—
4	—	4	—	—	—
5	—	5	—	—	—
6	—	6	—	6	—
7	—	7	—	7	—
8	—	8	—	8	—
9	—	9	—	9	—
10	—	10	—	10 ❋	—
11	—	11	—	11 Δ	—
12	—	—	—	—	—
13	—	—	—	—	—
14	—	—	—	—	—
15	—	—	—	—	—

❋ = 0.7 - 7.6 Δ = 7.6 - 0.7

Sub 1
9646A39

Figure 15. Test Points for SDGT - Line of Relays

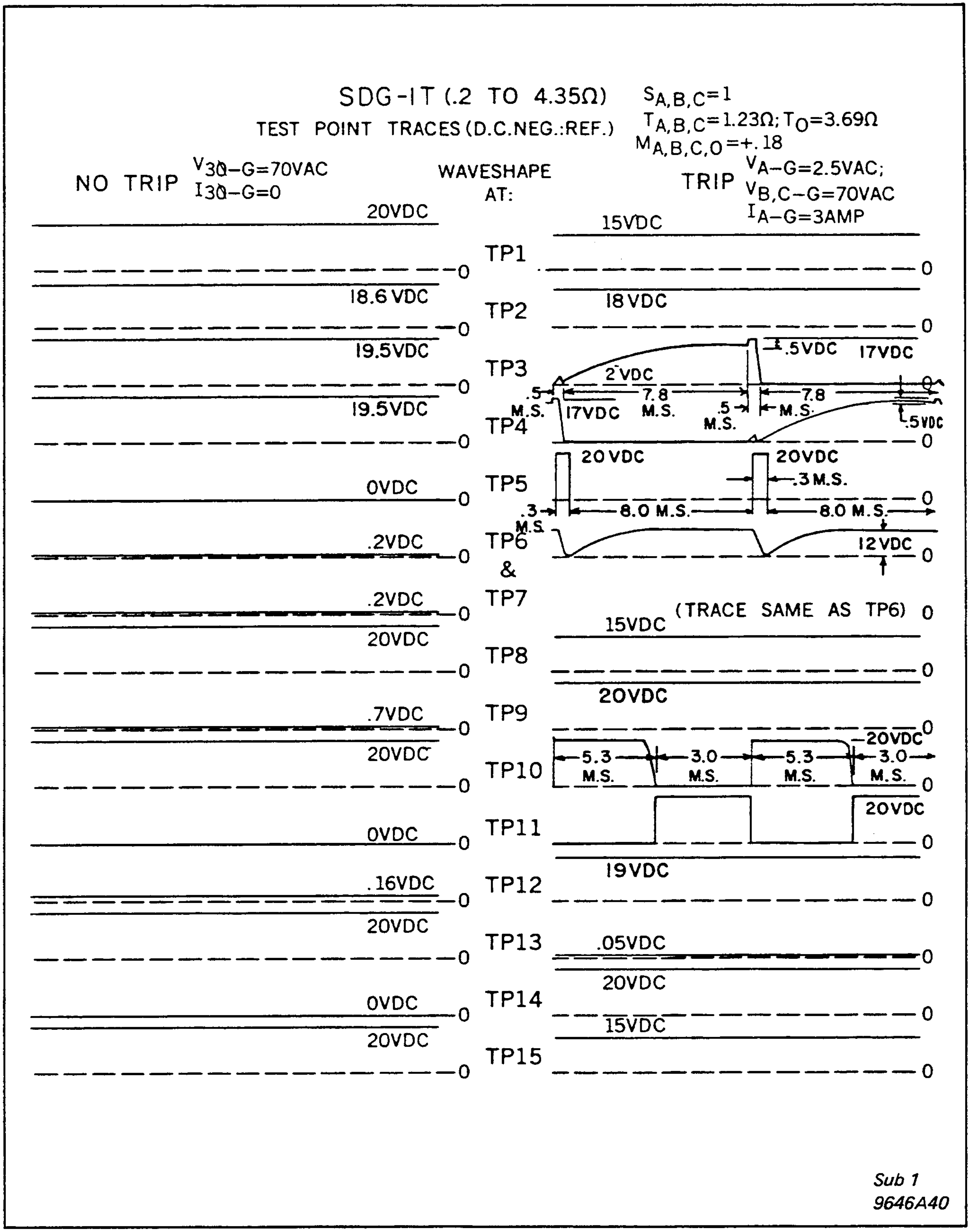


Fig. 15a. Test Points for SDGT – Line of Relays

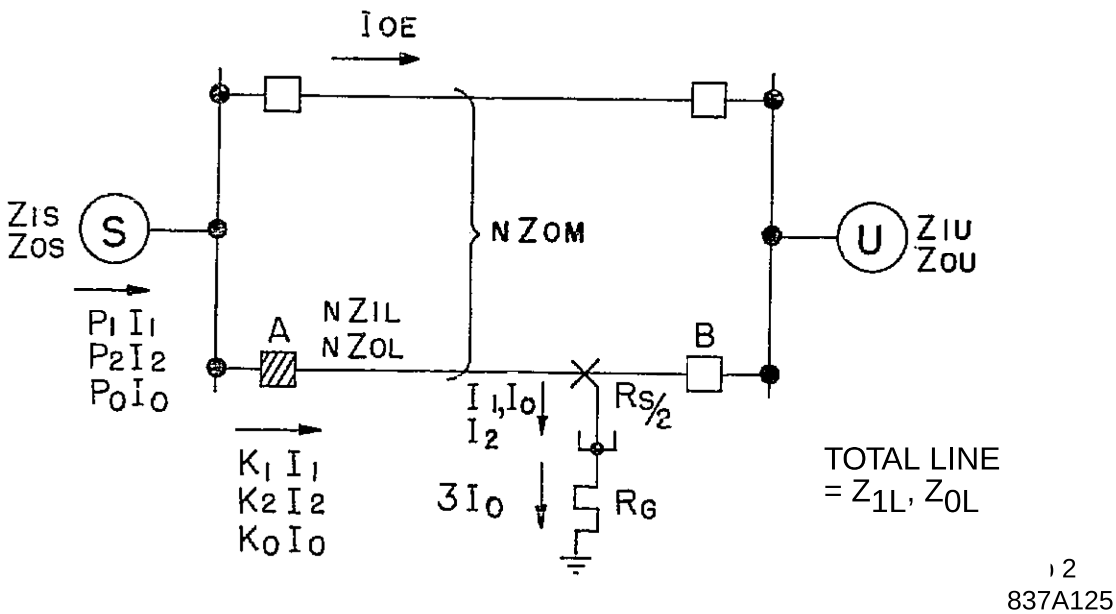


Figure 16. Definition of Terms

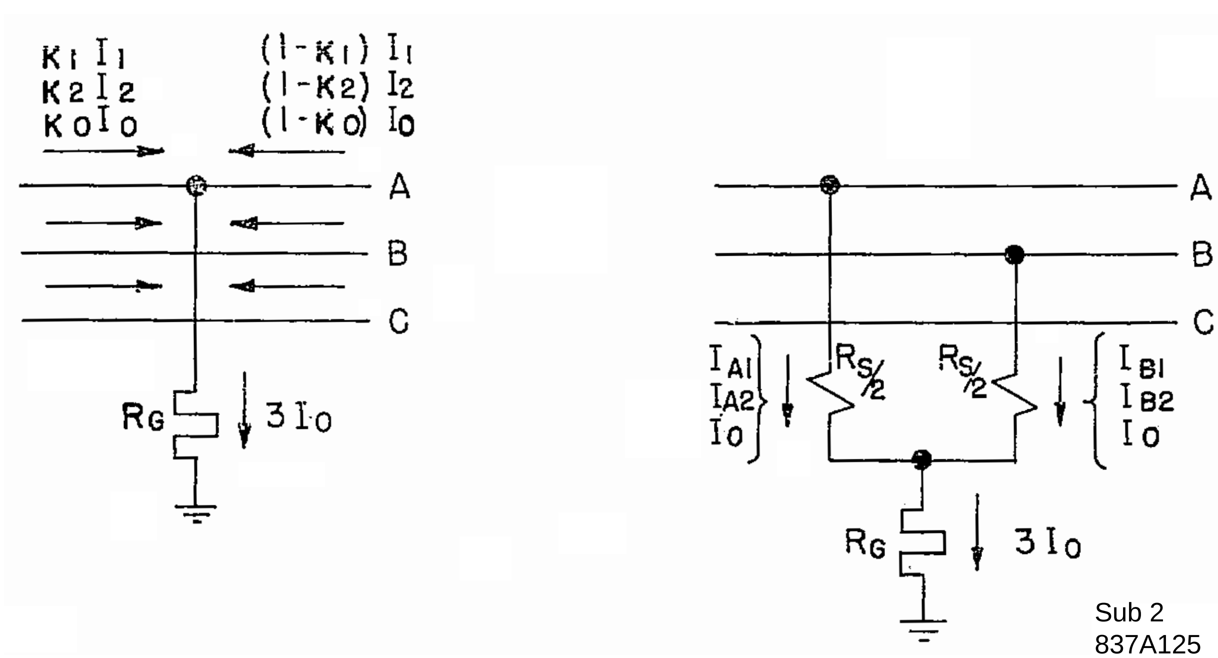
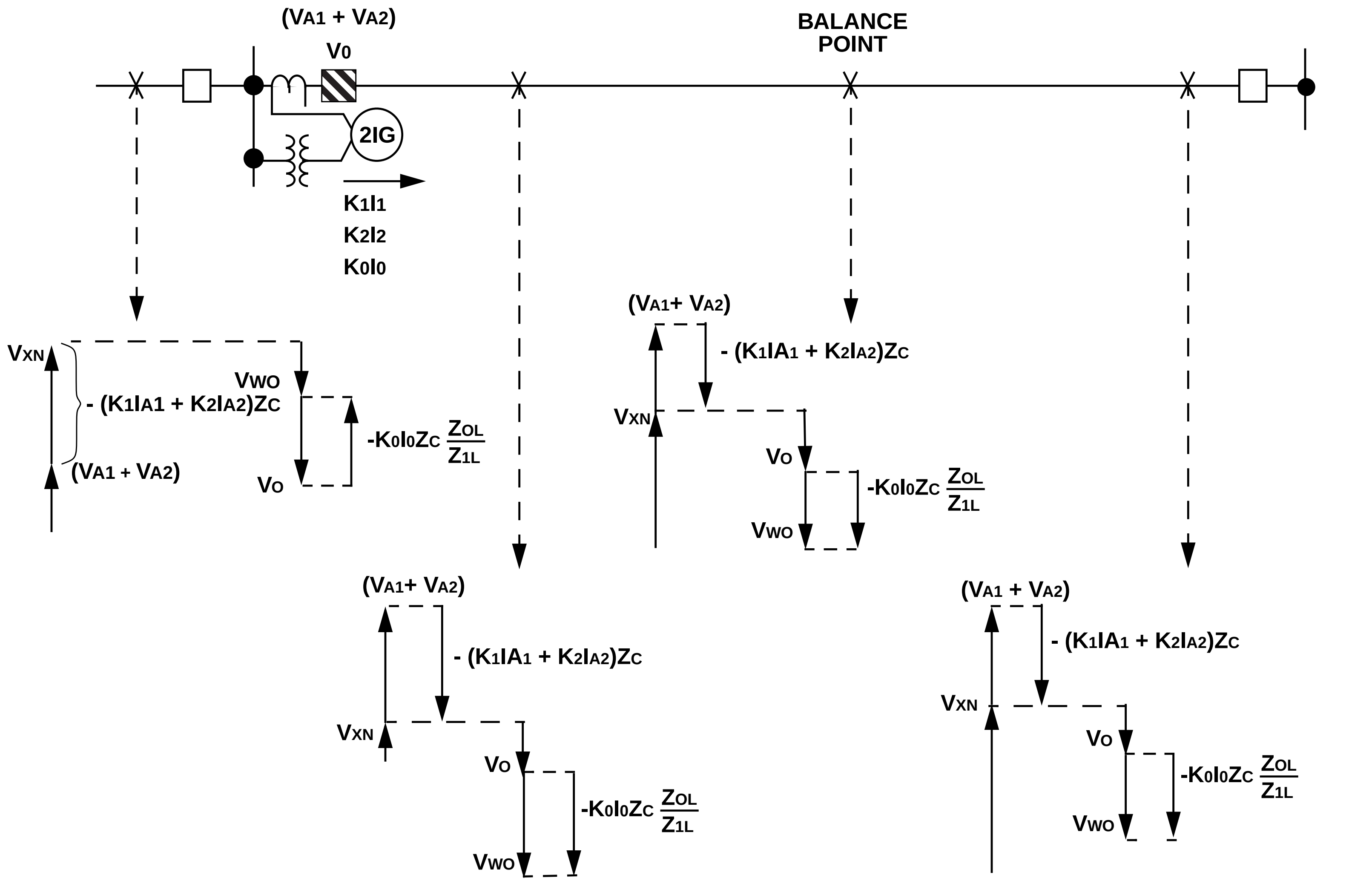


Figure 17. Fault Resistance



Sub 2
837A117

Figure 18. Relay Voltages for AG to Ground Faults at Selected Points

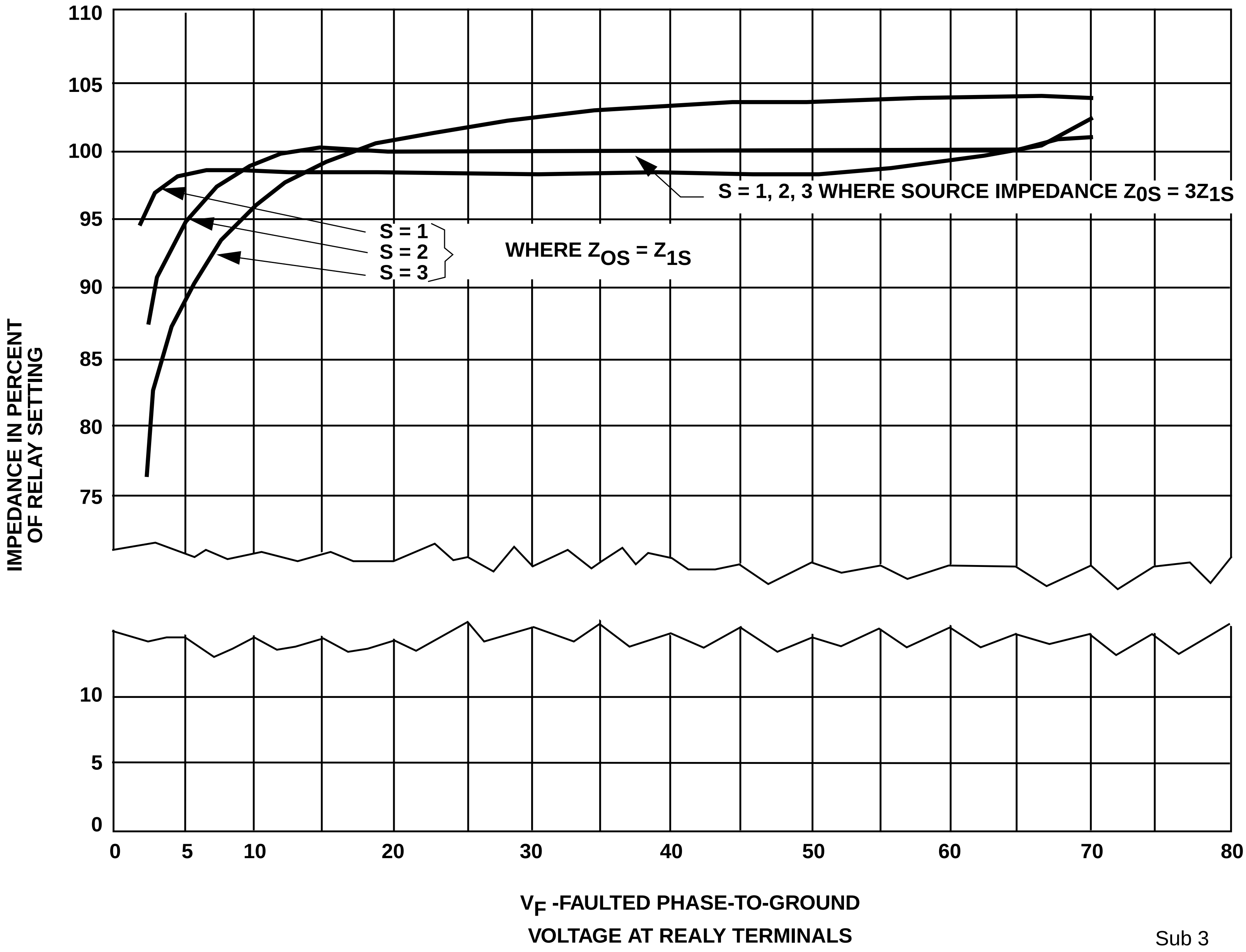
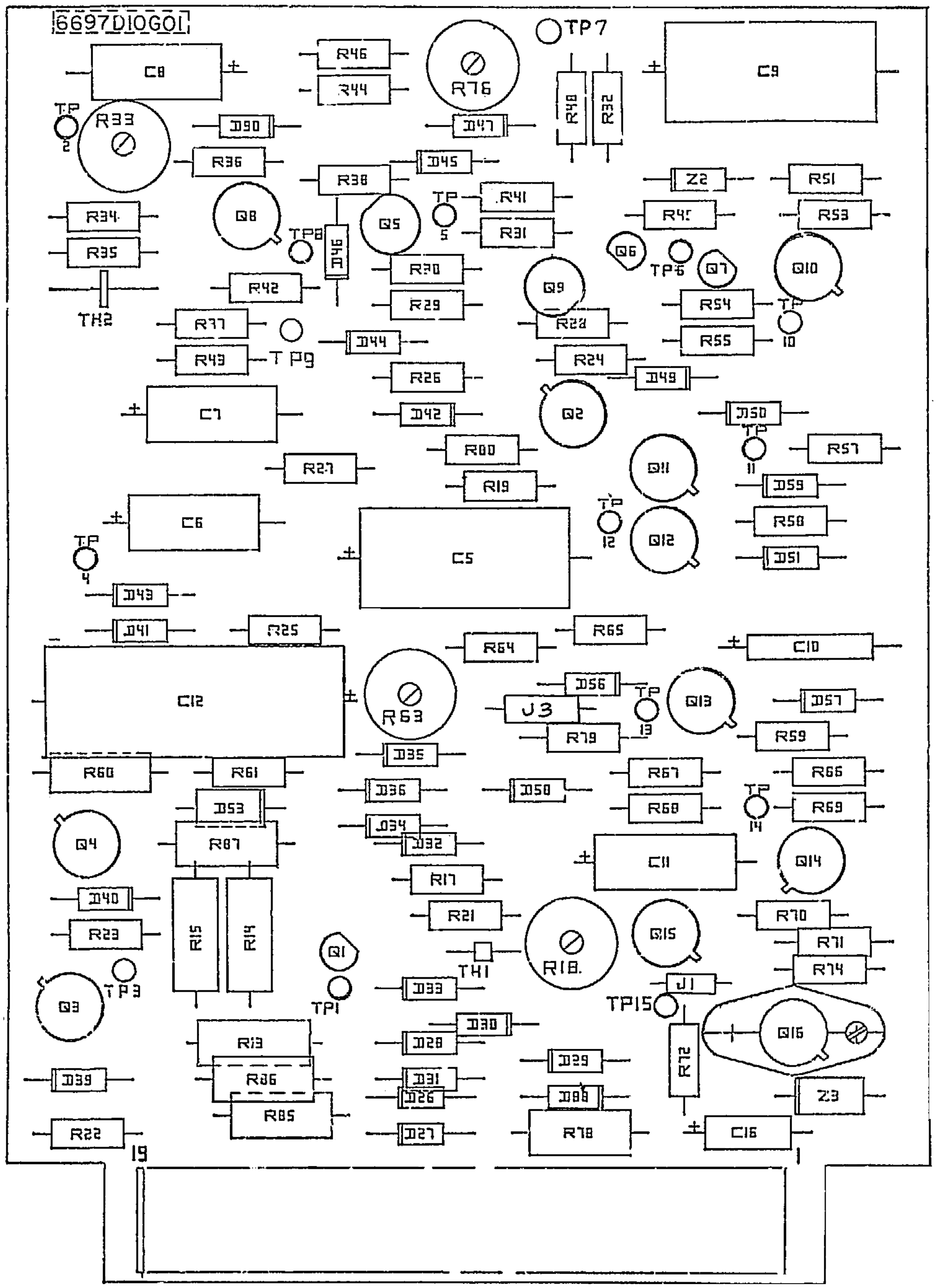


Figure 19. Impedance Curve for the SDGT Line of Relays



Sub 2
774B971

Figure 20. SDG-1T Component Location of Magnitude Comparator Board

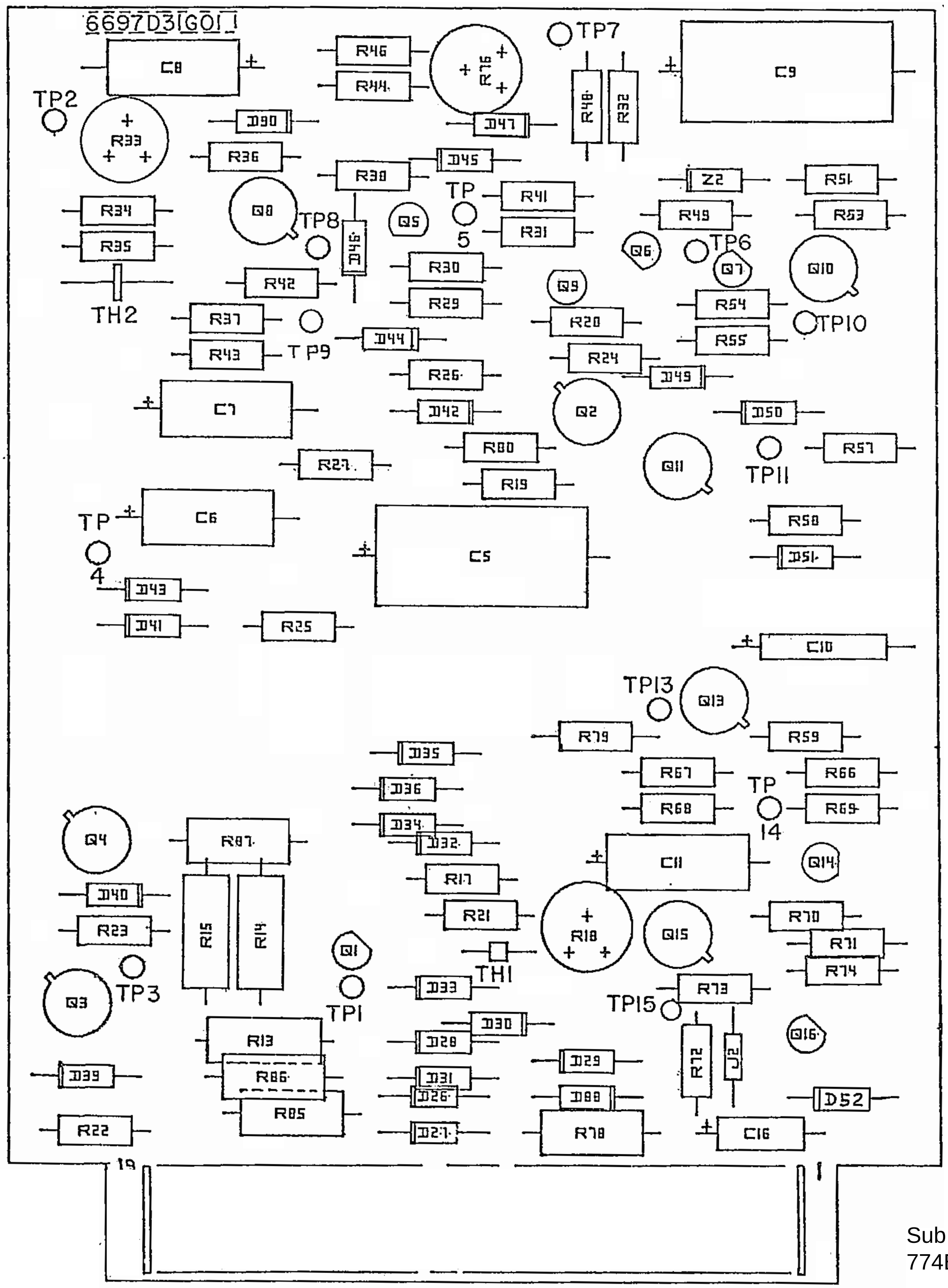


Figure 21. SDG-2T Component Location of Magnitude Comparator Board

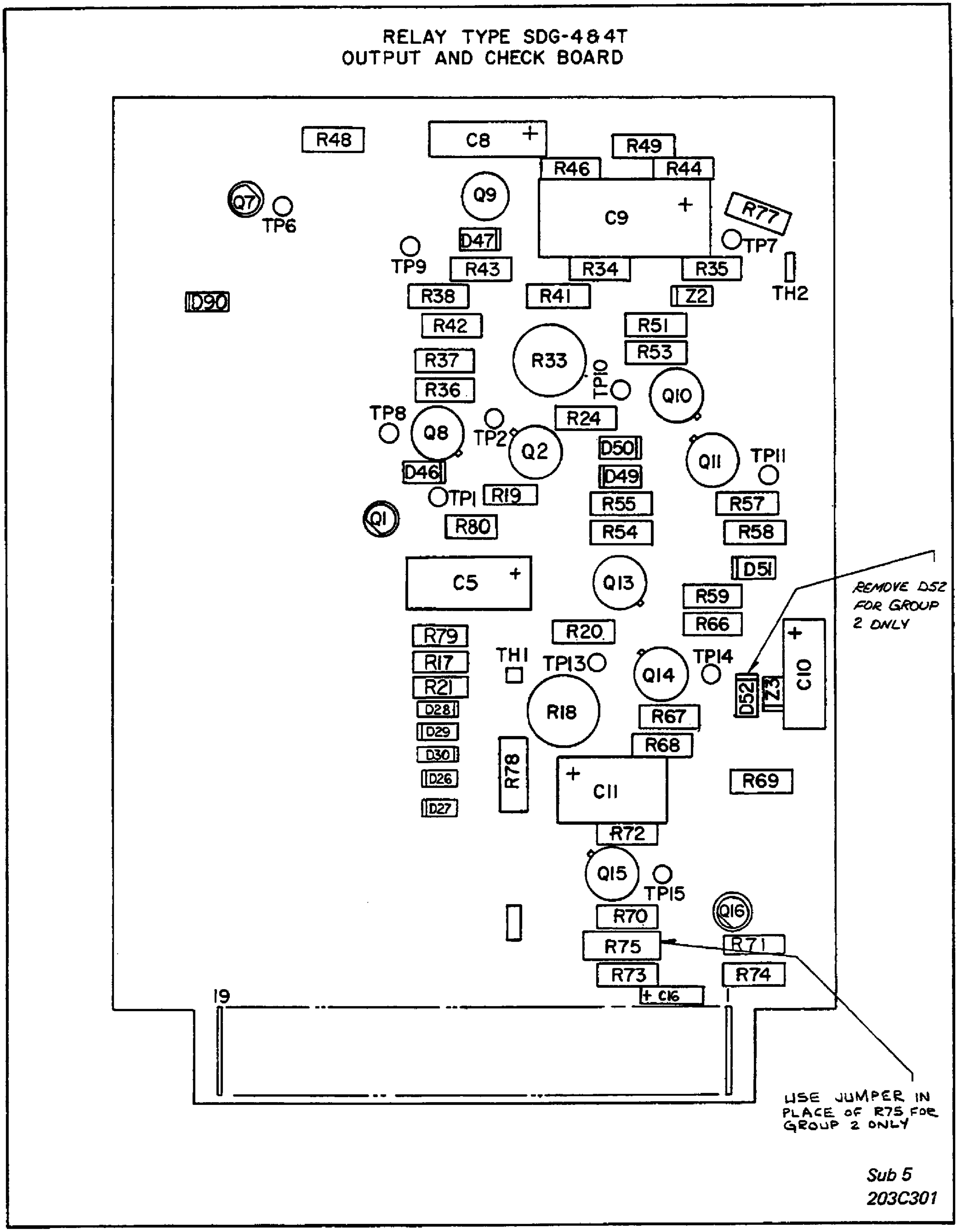
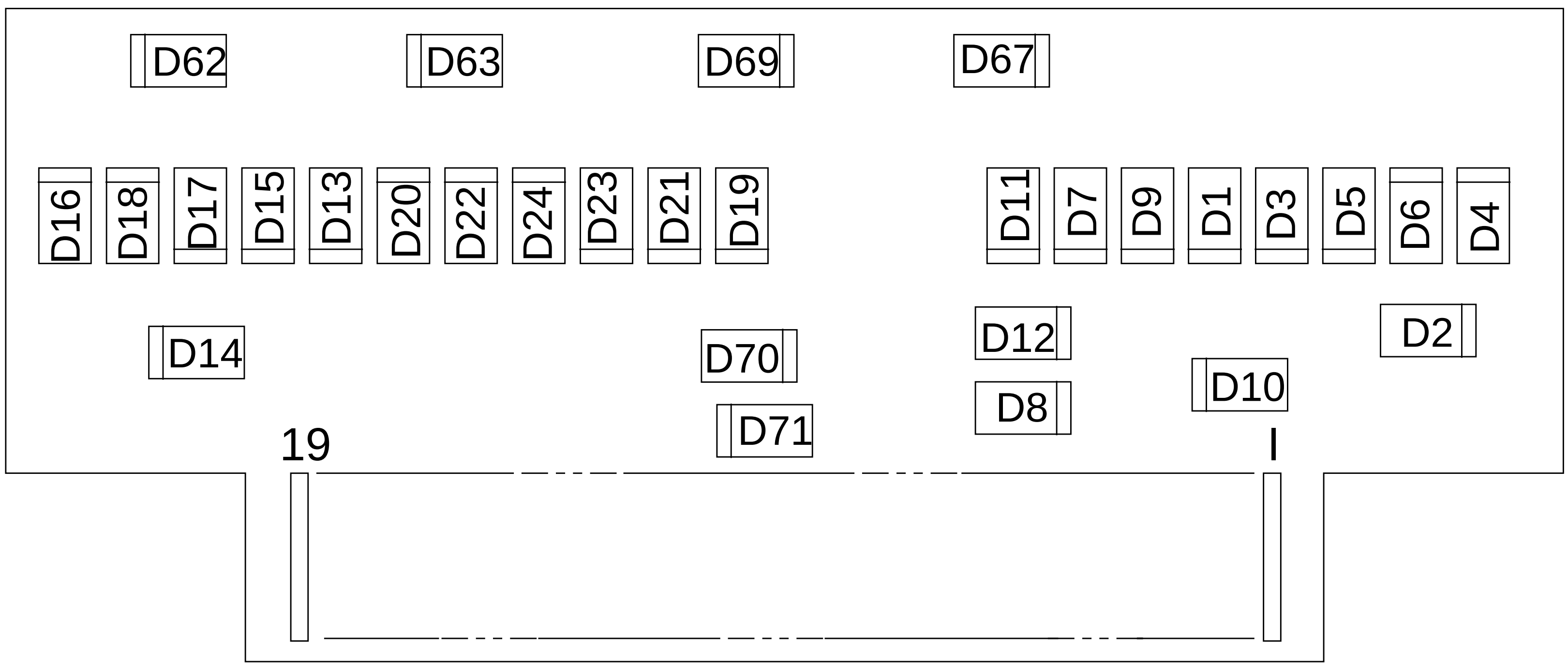
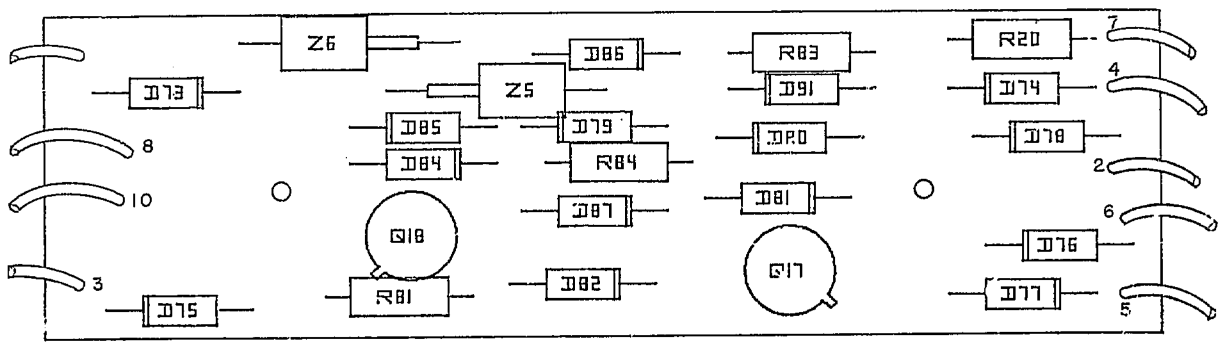


Fig. 22. SDG-4T Component Location



Sub 1
716B095

Figure 23. SDG-1T-2T-4T Component Location of Phase Splitter Rectifier Board



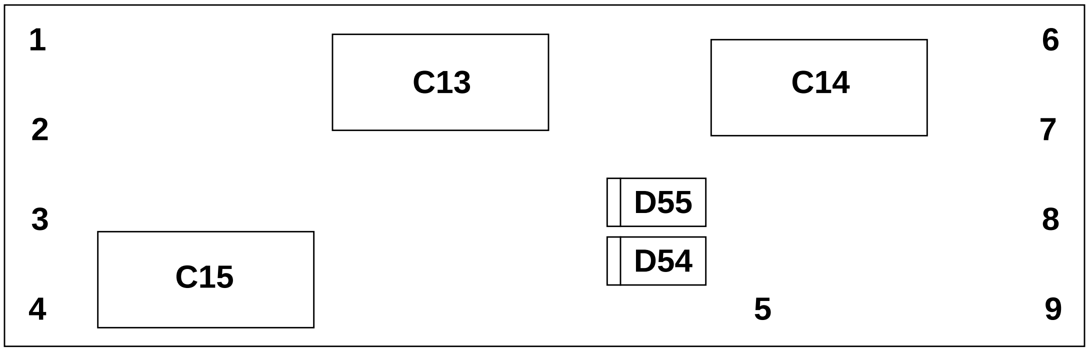
Ref. Dwg:

SYS. SCHEM. SDG-1T - 6694D74

SYS. SCHEM. SDG-2T - 6694D77

Sub 1
774B966

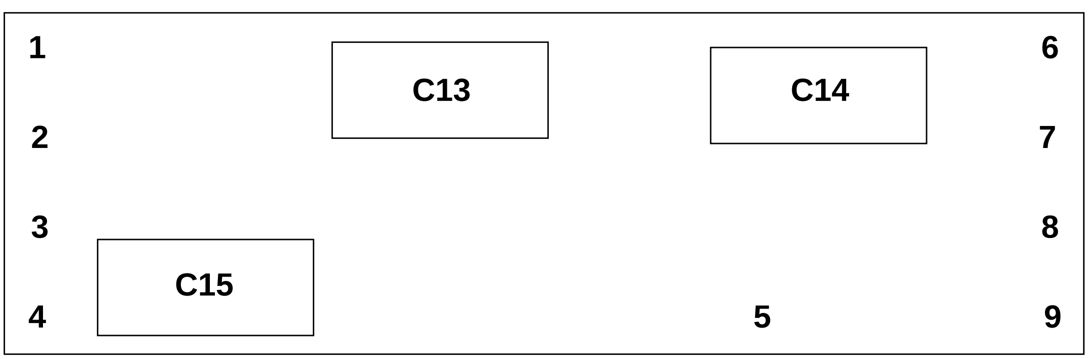
Figure 24. SDG-1T and SDG-2T 2ϕ-Ground Board Parts Location



REF. DWG.
CKT. BD. ASSY. 203C377G06
SYS. SCHEM. 6694D74

Sub 1
3507A85

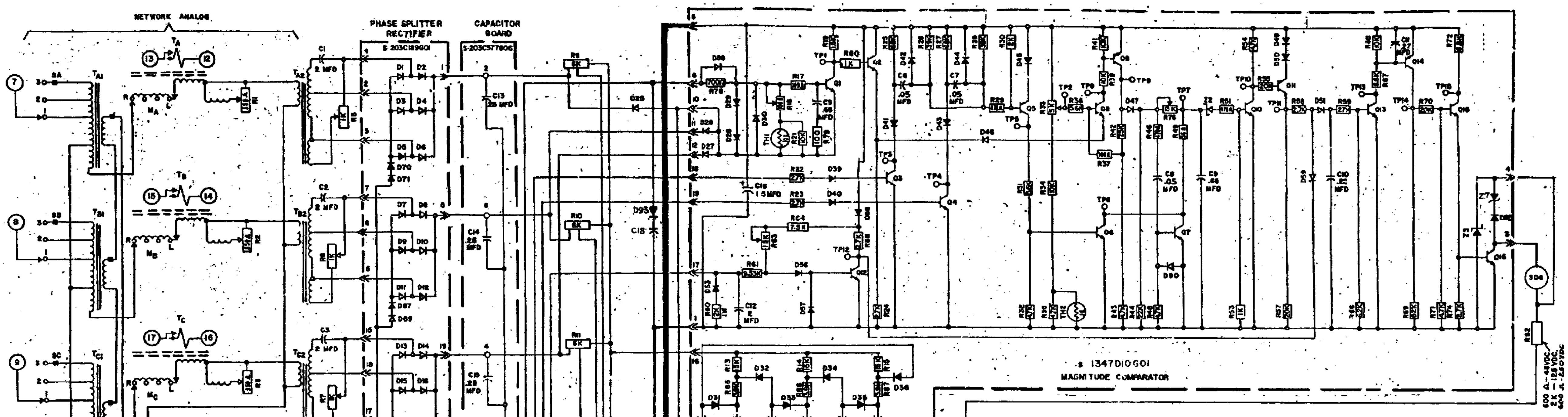
Figure 25. SDG-1T Capacitor – Restraint Filter Board – Parts Location

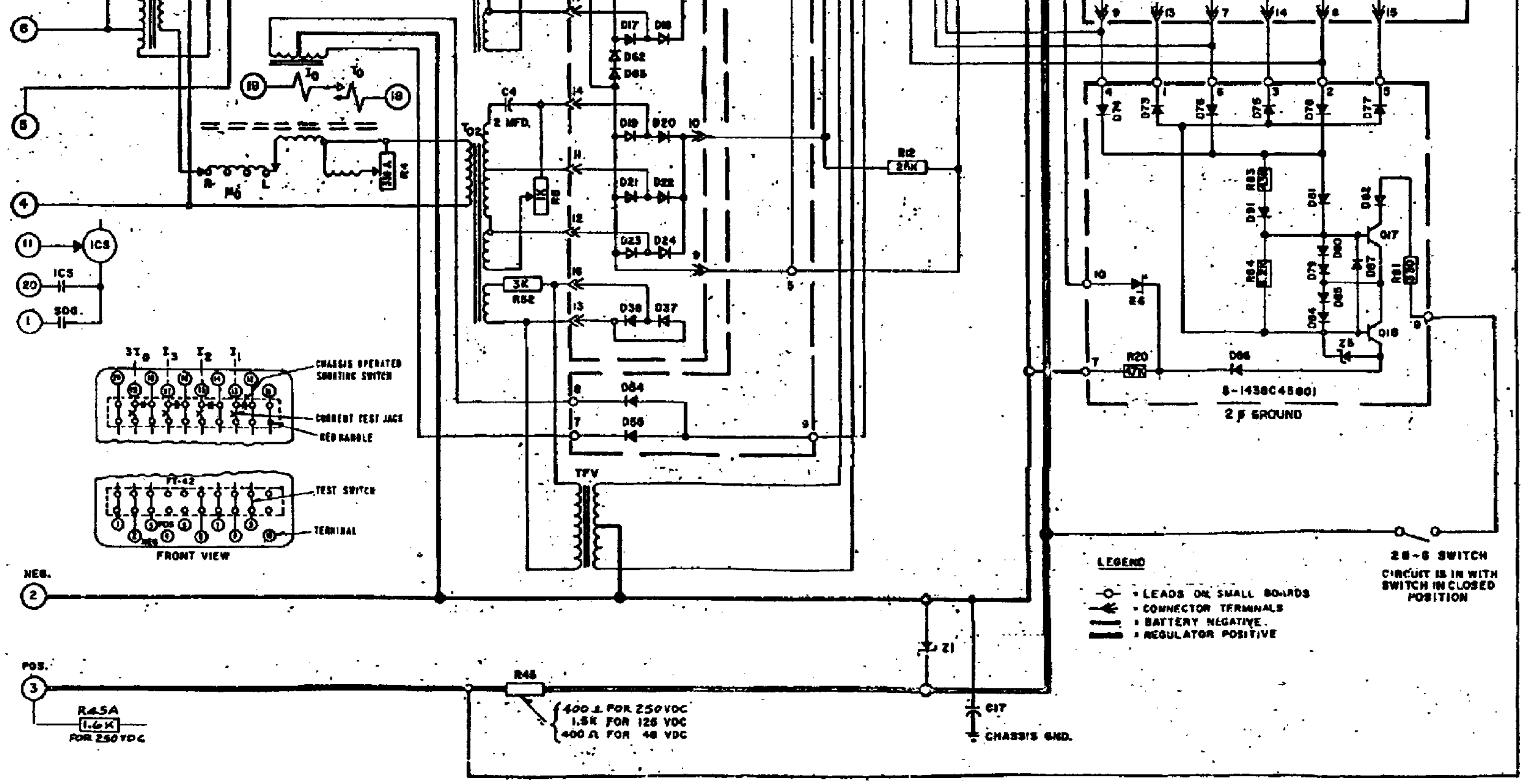


REF. DWG.
CKT. BD. ASSY. 203C377G07
SYS. SCHEM. 6694D77

Sub 1
3507A86

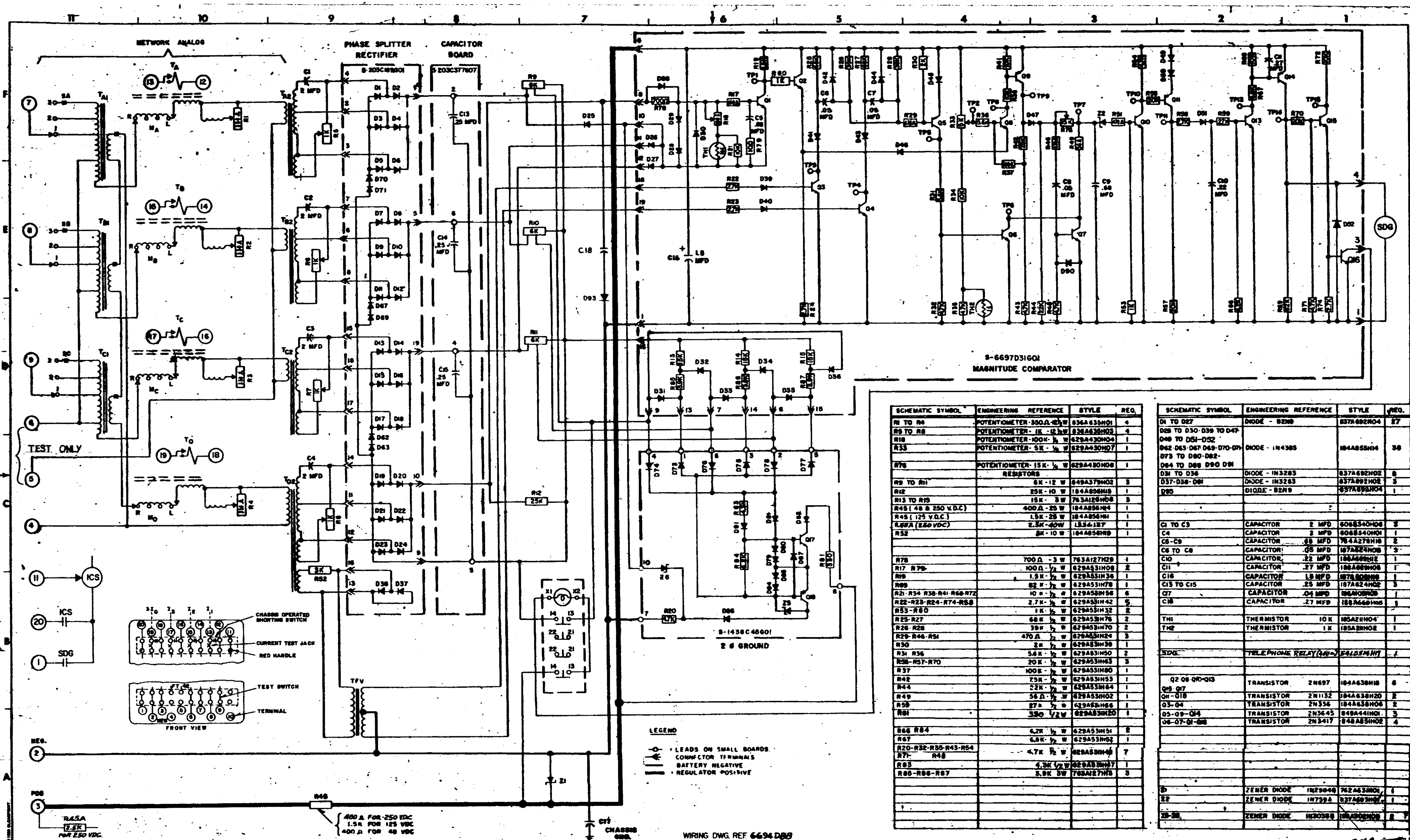
Figure 26. SDG-2T Capacitor – Restraint Filter Board – Parts Location





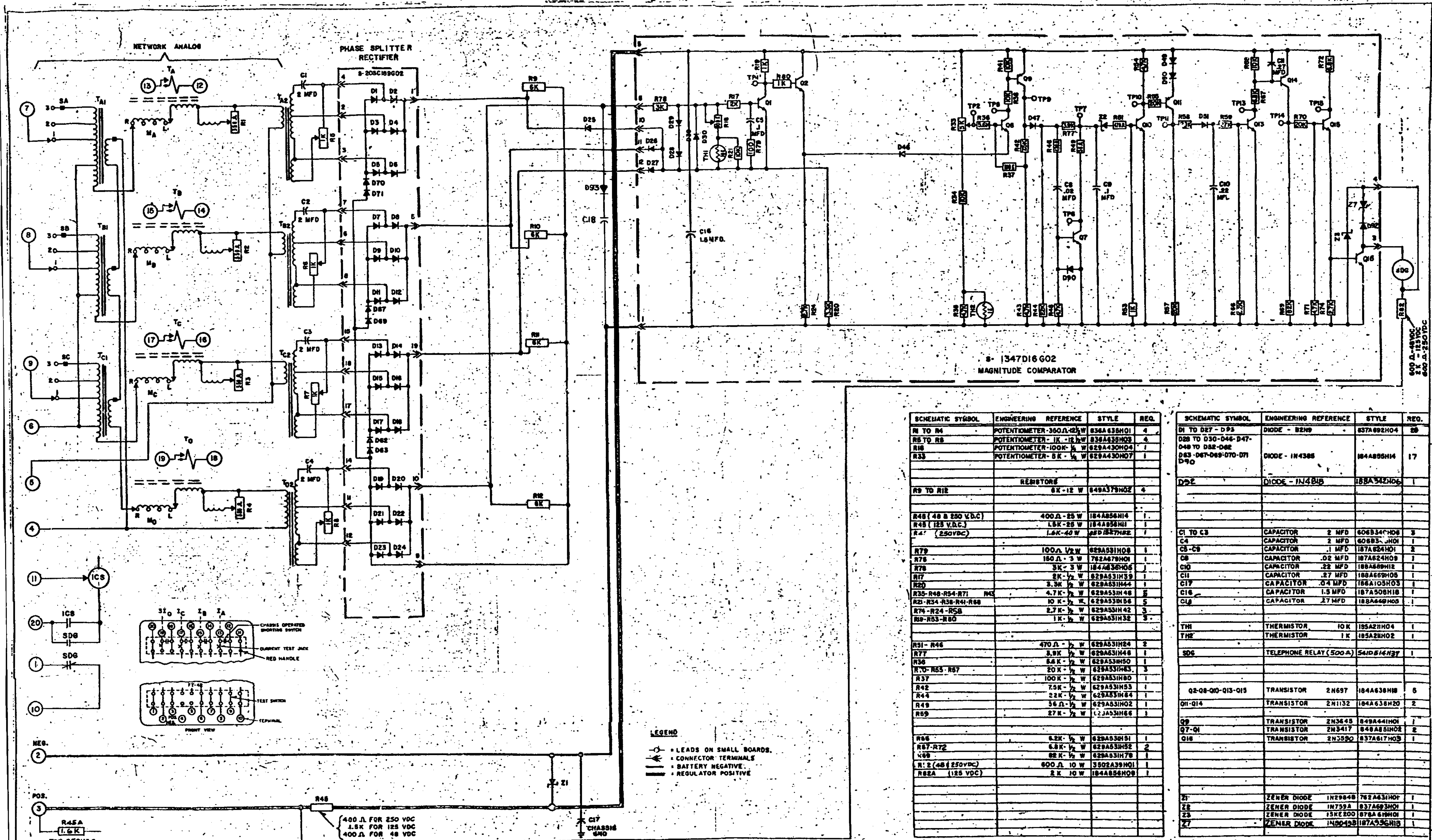
SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
R1 TO R4	POTENTIOMETER-350Ω-12½W	836A635H01	4
R5 TO R8	POTENTIOMETER- 1K -12½W	836A636H03	4
R18	POTENTIOMETER-100K- ¼ W	629A430H04	1
R33	POTENTIOMETER- 5K - ¼ W	629A430H07	1
~~R63~~	~~POTENTIOMETER-2.5K- ¼ W~~	~~629A430H05~~	~~1~~
R76 - R63	POTENTIOMETER- 15K- ¼ W	629A430H08	2
	RESISTORS		
R9 TO R11	6K - 12 W	849A379H02	3
R12	25K - 10 W	184A856H18	1
R13 TO R15	15K - 3 W	763A126H08	3
R45 (48 & 250 V.D.C)	400Ω - 25 W	184A856H14	1
R45 (125 V.D.C.)	1.5K - 25 W	184A856H11	1
R45A (250VDC)	1.6K- 40 W	05D1527H32	1
R	3K - 10 W	184A856H19	1
R60	2K - 1 W	187A643H34	1
R78	700Ω - 3 W	763A127H28	1
R17 R79	100Ω - ½ W	629A531H08	1
R19	1.5K - ½ W	629A531H36	1
R69	82K ½ W	629A531H78	1
R21-R34-R36-R41-R68	10 K - ½ W	629A531H56	5
R22-R23-R24-R04-R65-R58	2.7 K - ½ W	629A531H42	6
R53 R80	1 K - ½ W	629A531H32	2
R25-R27	68 K - ½ W	629A531H76	2
R26-R28	39 K - ½ W	629A531H70	2
R29-R46-R51	470 Ω - ½ W	629A531H24	3
R30	2 K - ½ W	629A531H39	1
R31 - R35	5.6 K - ½ W	629A531H50	2
R55-R57-R70	20 K - ½ W	629A531H63	3
R37	100K - ½ W	629A531H80	1
R42	7.5K - ½ W	629A531H53	1
R44	22K - ½ W	629A531H64	1
R49	56 Ω - ½ W	629A531H02	1
R59	27 K - ½ W	629A531H66	1
~~R50~~	~~3.3K - ½ W~~	~~629A531H44~~	~~1~~
R64	7.5K - ½ W	629A531H53	1
R66 - R84	6.2K - ½ W	629A531H51	2
R67-R72	6.8K - ½ W	629A531H52	2
R32-R35-R43-R48-R54 R71 R20	4.7K - ½ W	629A531H48	7
R81	330Ω ½ W	629A531H20	1
R82 (48 & 250VDC)	600 Ω 10 W	3502A39H01	1
R82 (125 VDC)	2 K 10 W	184A856H08	1
R83	4.3K ½ W	629A531H47	1
R85-R86-R87	3.9K 3W	763A127H13	3
R61	9.53 K 1/2W	848A820H43	1

SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
D1 TO D27 - D93	DIODE - S2N8	837A692H04	28
D28 TO D30-D39 TO D47-D49 TO D51-D64 TO D58-D62 D65-D67-D69-D70-D71-D73 TO D80-D82-D84 TO D88 D90 D91	DIODE - 1N4385	184A855H14	43
D31 TO D36-D89	DIODE - 1N3283	837A692H02	7
D37-D38-D81	DIODE - 1N3283	837A692H02	3
D53-D92	DIODE - 1N4818	188A342H06	2
C1 TO C3	CAPACITOR 2 MFD	606B340H06	3
C4	CAPACITOR 2 MFD	606B340H01	1
C5-C9	CAPACITOR .68 MFD	764A278H16	2
C6 TO C8	CAPACITOR .05 MFD	187A624H08	3
C10	CAPACITOR .22 MFD	188A669H12	1
C11	CAPACITOR .27 MFD	188A669H05	1
C12	CAPACITOR 2 MFD	764A278H13	1
C13 TO C15	CAPACITOR .25 MFD	187A624H02	3
C16	CAPACITOR 1.5 MFD	187A505H13	1
C17	CAPACITOR .04MFD	188A105H03	1
C18	CAPACITOR .27MFD	188A669H05	1
TH1	THERMISTOR 10 K	185A281H04	1
TH2	THERMISTOR 1 K	185A281H02	1
SDG	TELEPHONE RELAY(40#)	541D514H17	1
Q2-Q8-Q10-Q12-Q13-Q15-Q17	TRANSISTOR 2N697	184A638H18	7
Q11-Q14-Q18	TRANSISTOR 2N1132	184A638H20	3
Q3-Q4	TRANSISTOR 2N338	184A638H06	2
Q5-Q9	TRANSISTOR 2N3645	849A441H01	2
Q6-Q7-Q1	TRANSISTOR 2N3417	848A851H02	3
Q16	TRANSISTOR 2N3590	637A617H03	1
~~TD1-TD2~~	~~TUNNEL DIODE 1N3712~~	~~877A090H01~~	~~2~~
Z1	ZENER DIODE 1N2984B	762A631H01	1
Z2	ZENER DIODE 1N7594	837A693H01	1
Z3	ZENER DIODE 15KE200	878A619H01	1
Z5-Z6	ZENER DIODE 1N3038B	186A302H01	2
Z7	ZENER DIODE 1N3049B	151A926H13	1



SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
R1 TO R4	POTENTIOMETER-350Ω-12½W	836A635H01	4
R5 TO R8	POTENTIOMETER- 1K -12½W	836A636H03	4
R18	POTENTIOMETER-100K- ½ W	629A430H04	1
R33	POTENTIOMETER- 5K - ¼ W	629A430H07	1
R76	POTENTIOMETER- 15K- ¼ W	629A430H06	1
	RESISTORS		
R9 TO R11	6K - 12 W	849A379H02	3
R12	25K - 10 W	184A856H18	1
R13 TO R15	15K - 3 W	763A126H08	3
R45 (48 & 250 V.D.C)	400Ω - 25 W	184A856H14	1
R45 (125 V.D.C.)	1.5K - 25 W	184A856H11	1
R45A (250 VDC)	2.5K - 40W	1334127	1
R52	8K - 10 W	184A856H19	1
R78	700Ω - 3 W	763A127H28	1
R17 R79	100Ω - ½ W	629A531H08	2
R19	1.5K - ½ W	629A531H36	1
R89	82 K - ½ W	629A531H78	1
R21-R34 R38-R41-R68-R72	10 K - ½ W	629A531H56	6
R22-R23-R24-R74-R58	2.7K - ½ W	629A531H42	5
R53-R60	1K - ½ W	629A531H32	2
R25-R27	68K ½ W	629A531H76	2
R26-R28	39K ½ W	629A531H70	2
R29-R46-R51	470Ω ½ W	629A531H24	3
R30	2K ½ W	629A531H39	1
R31 R36	5.6K - ½ W	629A531H50	2
R56-R57-R70	20K - ½ W	629A531H63	3
R37	100K - ½ W	629A531H80	1
R42	7.5K - ½ W	629A531H53	1
R44	22K - ½ W	629A531H64	1
R49	56Ω - ½ W	629A531H02	1
R59	27K ½ W	629A531H66	1
R81	330 ½W	629A531H20	1
R66 R84	6.2K ½ W	629A531H51	2
R67	6.8K - ½ W	629A531H52	1
R20-R32-R35-R43-R54 R71- R48	4.7K ½ W	629A531H48	7
R83	4.3K ½W	629A531H47	1
R85-R86-R87	5.9K 3W	763A127H18	3

SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
D1 TO D27	DIODE - B2N9	837A692H04	27
D28 TO D30-D39 TO D47-D48 TO D51-D52 D62-D63-D67-D69-D70-D71-D73 TO D80-D82-D84 TO D88 D90 D91	DIODE - 1N4385	184A855H14	38
D31 TO D36	DIODE - 1N3283	837A692H02	6
D37-D38-D81	DIODE - 1N3283	837A692H02	3
D95	DIODE - B2N9	837A692H04	1
C1 TO C3	CAPACITOR 2 MFD	606B340H06	3
C4	CAPACITOR 2 MFD	606B340H01	1
C5-C9	CAPACITOR .68 MFD	764A278H16	2
C6 TO C8	CAPACITOR .05 MFD	187A624H08	3
C10	CAPACITOR .22 MFD	188A669H12	1
C11	CAPACITOR .27 MFD	188A669H05	1
C16	CAPACITOR L8 MFD	187A606H16	1
C13 TO C15	CAPACITOR .25 MFD	187A624H02	3
C17	CAPACITOR .04 MFD	186A105H08	1
C18	CAPACITOR .27 MFD	188A660H05	1
TH1	THERMISTOR 10 K	185A211H04	1
TH2	THERMISTOR 1 K	185A211H02	1
SDG	TELEPHONE RELAY (24Ω)	541D514H11	1
Q2-Q8-Q10-Q13 Q15-Q17	TRANSISTOR 2N697	184A638H18	6
Q11-Q18	TRANSISTOR 2N1132	184A638H20	2
Q3-Q4	TRANSISTOR 2N336	184A638H06	2
Q5-Q9-Q14	TRANSISTOR 2N3645	849A441H01	3
Q6-Q7-Q1-Q16	TRANSISTOR 2N3417	848A851H02	4
Z1	ZENER DIODE 1N2984B	762A631H01	1
Z2	ZENER DIODE 1N759A	837A693H01	1
Z3-Z6	ZENER DIODE 1N3035B	188A302H08	2



SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
R1 TO R4	POTENTIOMETER-350Ω-12½W	836A635H01	4
R5 TO R8	POTENTIOMETER- 1K -12½W	836A635H03	4
R16	POTENTIOMETER-100K- ¼ W	629A430H04	1
R33	POTENTIOMETER- 5K - ¼ W	629A430H07	1
	RESISTORS		
R9 TO R12	6K-12 W	849A379H02	4
R45 (48 & 250 V.D.C)	400Ω-25 W	184A856H14	1
R45 (125 V.D.C.)	1.5K-25 W	184A856H11	1
R45 (250VDC)	1.6K-40 W	85D1527H82	1
R79	100Ω ½W	629A531H08	1
R76	150Ω - 3 W	762A679H01	1
R78	3K - 3 W	184A636H05	1
R17	2K- ½ W	629A531H39	1
R20	3.3K ½ W	629A531H44	1
R35-R48-R54-R71 R43	4.7K- ½ W	629A531H48	5
R21-R34-R38-R41-R68	10 K- ½ W	629A531H56	5
R74-R24-R58	2.7K- ½ W	629A531H42	3
R19-R53-R80	1K- ½ W	629A531H32	3
R51- R46	470Ω - ½ W	629A531H24	2
R77	3.9K ½ W	629A531H46	1
R36	5.6K- ½ W	629A531H50	1
R50- R55 - R57	20 K - ½ W	629A531H63	3
R37	100K - ½ W	629A531H80	1
R42	7.5K - ½ W	629A531H53	1
R44	22K - ½ W	629A531H64	1
R49	36Ω - ½ W	629A531H02	1
R59	27K - ½ W	629A531H66	1
R66	6.2K- ½ W	629A531H51	1
R67-R72	6.8K- ½ W	629A531H52	2
R69	82 K- ½ W	629A531H78	1
R82 (48 & 250VDC)	600Ω 10 W	3502A39H01	1
R82A (125 VDC)	2 K 10 W	184A856H08	1

SCHEMATIC SYMBOL	ENGINEERING REFERENCE	STYLE	REQ.
D1 TO D27 - D93	DIODE - B2N9	837A692H04	28
D28 TO D30-D46-D47-D48 TO D52-D62 D63-D67-D69-D70-D71 D90	DIODE - 1N4385	184A855H14	17
D92	DIODE - 1N4818	188A342H06	1
C1 TO C3	CAPACITOR 2 MFD	606B540H06	3
C4	CAPACITOR 2 MFD	606B5[illegible]H01	1
C5-C9	CAPACITOR .1 MFD	187A624H01	2
C8	CAPACITOR .02 MFD	187A624H09	1
C10	CAPACITOR .22 MFD	188A669H12	1
C11	CAPACITOR .27 MFD	188A669H05	1
C17	CAPACITOR .04 MFD	186A105H03	1
C16	CAPACITOR 1.5 MFD	187A508H18	1
C18	CAPACITOR .27 MFD	188A669H05	1
TH1	THERMISTOR 10 K	185A211H04	1
TH2	THERMISTOR 1 K	185A211H02	1
SDG	TELEPHONE RELAY (500A)	541D514H37	1
Q2-Q8-Q10-Q13-Q15	TRANSISTOR 2N697	184A638H18	5
Q11-Q14	TRANSISTOR 2N1132	184A638H20	2
Q9	TRANSISTOR 2N3645	849A441H01	1
Q7-Q1	TRANSISTOR 2N3417	848A851H02	2
Q16	TRANSISTOR 2N3590	837A617H03	1
Z1	ZENER DIODE 1N2984B	762A631H01	1
Z2	ZENER DIODE 1N759A	837A693H01	1
Z3	ZENER DIODE 15KE200	878A619H01	1
Z7	ZENER DIODE 1N3049B	187A936H13	1

SUB. 12

RELAY TYPE SDG-4T SYSTEM SCHEMATIC
(WITH ONE FORM A & ONE FORM B CONTACT)