GEK-45451E

INSTRUCTIONS

STATIC DIFFERENTIAL RELAY

FOR

BUS PROTECTION

SBD11B

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CONTENTS

STATIC DIFFERENTIAL RELAY FOR BUS PROTECTION

TYPE SBD11B

DESCRIPTION

The type SBD11B is a single phase, high speed, high impedance static differential relay. It was specifically designed to provide bus differential protection, but it may also be used for differential protection of shunt reactors.

The SBD11B relay is provided with a target seal-in unit and comes mounted in a standard S2 size drawout case. Outline and panel drilling dimensions for the relay are shown in Figure 22. The internal connections for the relay are shown in Figure 13.

Three SBD11B relays plus one multi-contact lockout relay of the HEA type comprise a complete terminal of multi-phase and ground fault protection.

APPLICATION

The type SBD11B is a static high speed, high impedance, single phase relay that was specifically designed to provide differential protection for high and low voltage AC buses. However, because of its design and sensitivity, this relay may also be used for shunt reactor differential protection. While the normal bus scheme requires three SBD11B relays - one per phase - the number of relays required for the protection of shunt reactors depends on the scheme employed. The different schemes are discussed below.

Regardless of the scheme employed or the equipment to be protected, the following comments apply to the application of the SBD11B relay.

1. All of the CTs employed in the differential circuit should have negligible leakage reactance on the taps used. Most, if not all, modern multi-ratio bushing and column type CTs meet this requirement. All CTs wound on toroidally shaped cores meet this requirement if the windings (on the taps used) are completely distributed around the core. If the CTs to be employed do not meet this requirement, it may still be possible to apply the SBD11B relay provided the leakage reactance is known. In that case, the leakage reactance is added algebraically to the resistance of the fault CT circuit.

2. All of the CTs employed must be set on the same tap ratio. While a mixture of multi-ratio CTs may be used, it is essential that the taps used result in all of the CTs having the same ratio. Where CTs with taps set on other than the full winding are employed, it will be necessary to determine that the peak

voltage developed across the full winding due to auto transformer action does not exceed the insulation breakdown values for the connected equipment. This requires a very simple calculation using the equation derived in the section under **OPERATING PRINCIPLES** and repeated in the section under **CALCULATION OF SETTINGS.** Aside from this simple calculation, NO SPECIAL CALCULATIONS OR EQUIPMENT ARE REQUIRED WHEN MIXED RATIO CTs ARE USED.

3. In general, maximum sensitivity will be attained when the CTs are set on the highest available tap. Therefore, where all of the CTs are of the same ratio, the full winding should be utilized. Where all of the CTs are not of the same ratio, use the highest available tap setting that will permit all of the CTs to be set on the same ratio.

4. In general, dedicated CTs should be used with the SBD11B relays. However, it is possible to insert other devices in the CT circuits as long as their impedances are accurately known and added algebraically to the CT winding and cable resistance. Such applications will require higher pickup settings, and as a consequence will provide less sensitive protection. This should be evaluated before a decision is made to add other devices in the SBD11B circuits.

5. In order to ensure a proper relay setting, all cable and CT secondary winding resistances should be evaluated before a decision is made to add other devices in the SBD11B CT circuits.

6. If any of the CTs are protected by primary and/or secondary voltage-limiting devices such as vacuum gaps, additional considerations are necessary to ensure a reliable application. Some means must be incorporated to prevent this protective equipment from shorting the SBD11B. Such applications may be referred to the local General Electric Sales Office.

7. When the CT circuits of the bus differential zone are unbalanced, such as when circuit breakers are to be bypassed for maintenance purposes, it is recommended that studs 5 and 6 on each of the SBD11B relays in the circuit be shorted together and that the trip circuits be opened. This may be accomplished by the use of a differential cut-out switch or by removing the relay test plugs. It should be done prior to unbalancing the CT circuits in order to avoid any misoperation.

8. In general, it is desirable to minimize the fault CT loop resistance in order to minimize the voltage tap setting and so obtain maximum sensitivity. To this extent, the location of the differential junction point may be important. It is permissible to locate the junction point at the relay panel if the resultant setting for that location gives the desired sensitivity. If greater sensitivity is desired, it may be possible to obtain it by locating the junction point out in the switchyard. It may be desirable to do this in EHV outdoor installations where the distance between the breakers and the relay panel may be large.

9. The SBD11B relay is presently available in two models, differing only in the basic current sensitivities. One model has a sensitivity of 0.5/1.0 rms amperes, while the sensitivity of the other is 0.5/2.5 rms amperes. The relay having a sensitivity of 0.5/1.0 amperes should be used in those applications in which lightning arresters are not connected to the bus. For those applications in which lightning arresters will be connected to the bus, the relay having a sensitivity of 0.5/2.5 amperes should be used. The higher current setting (2.5 amperes) should be used if the arresters are already present; otherwise use the lower setting (0.5 amperes) until the arresters are connected.

10. A contact of the auxiliary lock-out relay, device 86, should be connected across studs 3 and 6 of the SBD11B relay to short out a portion of the input circuit after a trip output has been initiated. This will allow the relay to operate as a straight overcurrent function following device 86 operation and at the same time protect against exceeding the short-time rating of the SCRs. The relay may be used in any application where the total secondary current is not more than the current waveform of a fully offset fault, with 215 amperes rms symmetrical available, provided the auxiliary lockout relay has an operating time in the order of 16 milliseconds. The SBD relay acts as a straight overcurrent device once the lockout relay has operated, and may be used as part of a breaker failure backup scheme.

BUS PROTECTION

Three SBD11B relays applied on a per-phase basis, plus an auxiliary lockout relay, provide a complete terminal of bus protection for both multi-phase and single-line-to-ground faults. Typical external connections to the relays are shown in Figures 1 and 2. The connections are illustrated for a bus with three circuits, but the protection can easily be extended if more circuits are added to the bus. For additional circuits, it is only necessary to connect the CTs associated with the added circuits to the respective junction points and to connect contacts of the lockout relay in the respective trip circuits. The relay voltage tap setting is based on determining the maximum voltage that can be developed across the differential junction point during an external fault. Calculation of the maximum voltage is easily made and methods for doing so are given in the section under **CALCULATION OF SETTINGS**. A sample calculation for a bus differential scheme is also given in that section.

SHUNT REACTOR PROTECTION

Differential protection of shunt reactors may be provided by using only one SBD11B relay, or three SBD11B relays may be used in the application if desired. Typical AC external connection diagrams for these schemes are shown in Figures 3 and 4. The DC connections will be similar to those shown in Figure 2. Where only one relay is applied, protection will be provided for ground faults only. The scheme utilizing three SBD11B relays will provide protection for both multi-phase and line-o-ground faults. Calculations of the voltage tap setting are made using the same basic equation as used in any scheme employing the SBD11B relay. The procedures to follow in calculating the voltage tap setting for either scheme are provided in the section under **CALCULATION OF SETTINGS**.

OPERATING PRINCIPLES

The SBD11B differential relay is a high impedance device that operates from the instantaneous value of the CT secondary voltage to which the relay is connected. The diagram of Figure 1 illustrates typical external AC connections to the relay for use in a bus differential scheme. It can be noted from this diagram that a conventional differential connection is utilized; i.e. the CTs associated with all of the circuits off the bus are connected in wye and paralleled at one location on a per-phase basis. One SBD11B relay per phase is required to provide complete protection for the bus. The relay will operate to trip when the instantaneous voltage applied across studs 5 and 6 exceeds its voltage pickup setting and the fault current is greater than the basic sensitivity setting.

While the CTs need not be of the same ratio, it is required that they all be set on the same tap. Under these conditions, the voltage developed across the relay during normal system conditions will be very small. If the CTs all performed ideally and did not saturate, the same would be true for faults external to the zone of protection. However, CTs are not ideal and they do saturate.

If the protection scheme is to perform satisfactorily, then, it must not trip improperly for faults external to the zone of protection. For example, in Figure 5, which shows the connections for one phase only, the SBD11B must not operate for the external fault at F1. For this fault, the highest voltage that could possibly be developed at the relay would occur when the associated CT (CT3) saturated completely, and the others (CT1 and CT2) did not saturate at all. When a CT with a completely distributed toroidal winding (on the tap used) saturates completely, it produces no voltage and its impedance, as viewed from the secondary winding, is very nearly equal to the winding resistance. Thus, the highest peak voltage that can be developed across the SBD11B during an external fault will be equal to the voltage produced by the total secondary fault current flowing through the control cable resistance plus the winding resistance of the CT associated with the faulted feeder. In the case of the example of Figure 5, this is:

$$V_{peak} = (2)(\sqrt{2})(I_F)(R_S + 2R_L) \qquad (1)$$

where: I_F = RMS symmetrical value of fault current in the fault CT in secondary amperes

R_S = CT Secondary winding resistance plus any lead resistance (at highest expected operating temperature)

R_L = Cable resistance from junction point to CT (at highest expected operating temperature)

Equation (1) above yields the peak voltage developed at the relay for a completely offset wave of current having an rms symmetrical value of I_F secondary amperes. Because the SBD11B relay is calibrated in symmetrical rms volts, equation (2) below, which yields the rms value of the above voltage, is used in the section on **CALCULATION OF SETTINGS**.

$$V_R = I_F (R_S + 2R_L) \qquad (2)$$

CAUTION

If DC supply is removed, studs 5-6 should be shorted by pulling the connection plug. If this is not done, and if there is no backup protection, the SBD relay could be damaged due to continuous fault current flow through the SCRs of the SBD relay.

The pickup of the SBD11B must be set above the value of this rms voltage and above the rms value of the other voltages obtained in a similar manner on all the other circuits off the bus. Because the peak voltage is proportional to the fault current, the highest possible value of expected fault current in rms symmetrical amperes should be used in making the evaluation.

During internal faults on the bus, all of the CTs will be operating into the relatively high impedance of the SBD11B. Under these conditions, the maximum average voltage that can be produced will be limited to values as dictated by the CT secondary excitation characteristics. Examination of a typical CT secondary excitation characteristic will show that the average voltage levels off beyond the knee of the curve. However, the peak voltages that can be produced are not indicated on the standard excitation curve. The peak voltages will always be greater than indicated by the average, and will continue to increase in magnitude as the excitation is increased. Because these peak voltages will be much greater than the peak voltages experienced during external faults, and because the SBD relay operates as a function of the instantaneous voltage, the relay can be set to be selective between internal and external faults. An indication of the peak voltages that a CT can produce can easily be determined by a simple modification to the CT secondary excitation characteristic. The modification is shown by the lines CPB in Figure 7, which now define the excitation characteristics as a function of the peak voltages. Studies have shown that the peak voltages produced will be at least equal to or greater than those established by the modified characteristics. These characteristics are useful in determining the minimum internal fault for which the SBD11B relay will operate. The method for making the modifications, and their uses in determining the sensitivity, are given in the section under **CALCULATION OF SETTINGS.**

Figure 6 illustrates in simplified form the internal connections of the SBD11B relay. When an internal fault occurs, the peak voltage developed in the secondaries of the feeder CTs will appear across a resistor divider network in the relay via studs 5 and 6. A portion of this total voltage, depending on the tap selected in the resistor divider network, will appear across resistor R3, and hence across capacitor C and the silicon bilateral switch (SBS). Note that the SBS device exhibits high impedance in the "OFF" state and it will turn "ON" and conduct when its switching voltage is reached.

When the peak voltage developed across R3 exceeds the switching voltage of the SBS, it will conduct and allow capacitor C to discharge through the primary of the pulse transformer, T20. A pulse will be induced in the secondaries of T20, and depending on the polarity of the first half cycle of the applied voltage, SCR20 or SCR21 will be triggered to the "ON" condition. During subsequent half cycles, the SCRs will be triggered alternately until the associated lockout relay operates. When the SCRs fire, the CT circuits will be shorted and the total secondary fault current will flow through the SCR circuits and hence through the primary of current transformer T1. If the total secondary fault current, and hence the primary current of T1, is above the pickup level of the relay, an output will be provided via the output relay, A.

For convenience, the SBD11B relay voltage tap settings are calibrated in terms of rms symmetrical volts and all calculations for settings are made in terms of rms symmetrical quantities. The relay responds to the instantaneous value of applied voltage, and this maximum instantaneous value can be $2\sqrt{2}$ or 2.83 times V_T, the tap setting of the relay. As soon as the SBD operates, the shorting action of the SCR path reduces this voltage to a very low level. Thus the maximum peak voltage that can be produced in the differential circuit will be limited to the value as calculated in equation (3) below.

$$V_R = (2)\ (\sqrt{2})\ (V_T) = (2.83)(V_T) \qquad (3)$$

Where: V_R = maximum instantaneous voltage that can be developed in the differential circuit

V_T = SBD11B voltage tap setting in rms symmetrical volts

$(2)(\sqrt{2})$ = conversion of rms symmetrical volts to corresponding peak volts of a fully offset voltage wave.

Where CTs with taps set on other than the full winding are involved, the voltage developed across the full winding of these CTs can be greater than the differential circuit voltage as a result of autotransformer action. For example, consider the simple circuit of Figure 8. The voltage in the differential circuit, and consequently across CT1 and CT2, will be limited to V_R. But the voltage across the full winding of CT3 will be greater by the ratio of the total number of turns of the CT to the actual turns used.

$$V_F = \frac{N1}{N2} V_R = \frac{(2.83)(V_T)(N1)}{N2} \qquad (4)$$

where: V_F = voltage across the full winding

N1 = total number of CT secondary turns

N2 = number of CT secondary turns used, i.e. tap setting

The voltage across the full winding (V_F) should not exceed the insulation breakdown of the connected equipment. The value of the actual peak voltage that can be produced for any relay tap setting and mixed multi-ratio CT combination may be evaluated using equation (4) above.

RATINGS

VOLTAGE RANGE

The standard voltage range is 50 to 350 volts rms, 50/60 Hz. The taps are 50, 100, 150, 200, 250, 300 and 350.

VOLTAGE RATING

It is the nature of the application of this relay that voltage is not applied continuously. For calibration and test purposes (see ELECTRICAL TESTS in the **ACCEPTANCE TESTS** section) it may be of value to apply input voltage for times longer than the few milliseconds of voltage the relay would experience during an internal or external power system fault. For test and calibration purposes, the relay has been designed to withstand 75% of tap setting continuously. For voltages above this, see Figure 15.

FREQUENCY

The relay can be used on 50 or 60 Hz systems. It can be applied at frequencies down to 25 Hz if the AC current ratings are reduced by 10%.

AMBIENT TEMPERATURE

The relay is designed for operation in ambient air temperature from -20°C to +55°C.

DC SUPPLY

The relay is designed for operation on any of three DC voltages: 48, 125, or 250 volts. The voltage selecting link must be set to the correct voltage. Consult a General Electric Sales representative for any other DC voltage ranges.

AC CURRENT

The rms pickup current of the SBD relay can be set for either of two values and is selectable by a link at the front of the relay. There are two models available, with current sensitivity settings of 0.5/1.0 and 0.5/2.5 rms amperes.

Rating -	Continuous -	10 amperes rms
	1 second	- 160 amperes rms symmetrical
	5 cycles	- 480 amperes rms symmetrical
	2 cycles	- 215 amperes rms fully offset

Note: The current circuits can withstand 10 amperes continuously. However, the output telephone relay should not be energized for longer than 2 minutes.

HIGH POTENTIAL TESTING (INSULATION TESTING)

The relay will withstand 1500 volts for one minute applied between all studs tied together and the frame.

Note that all external connections to the surge ground stud (stud 4) must be removed before hipotting, to avoid damage to the surge protection capacitors.

OUTPUT CONTACTS

One set of output contacts is protected against heavy currents by the target and seal-in unit. The normally-open output contacts that are not protected by a target seal-in unit will make and carry 30 amperes for tripping duty and will make and carry 3 amperes continuously. The interrupting ratings are given in the following table.

The normally-open contact with a target seal-in unit will make and carry 30 amperes for tripping duty and will make and carry 3 amperes continuously. The interrupting ratings are given in the following table:

INTERRUPTING RATINGS

AC Volts	AMPS	
	Inductive**	Non-Inductive
115	0.75	2.0
230	0.5	1.5
DC Volts		
48	1.0	3.0
125	0.5	1.5
250	0.25	1.0

** The inductive rating is based on an L/R ratio of 0.1 second.

The continuous and short-time ratings of the seal-in unit are given in the table below.

CHARACTERISTICS OF SEAL-IN UNIT

	0.2	0.6	1.0	2.0	4.0
DC Resistance ± 10% (Ohms)	7	0.6	0.21	0.13	0.06
Minimum Operating (Amperes)	0.2	0.6	1.0	2.0	4.0
Carry Continuously (Amperes)	0.3	0.9	1.5	3	6
Carry 30 Amperes for (Seconds)	0.03	0.5	1.4	4	7
Carry 10 Amperes for (Seconds)	0.25	4	12	30	60
60 Hz Impedance (Ohms)	52	6	2.1	0.53	0.13
DC Dropout Amperes (Minimum)	0.05	0.15	0.25	0.5	1.0

CHARACTERISTICS

Operation of the SBD relay is initiated as a function of the instantaneous voltage developed across terminals 5 and 6 of the relay, but an output will not be produced unless the total secondary fault current that flows through the relay after the SCRs fire is greater than the pickup current setting; i.e. both voltage and current are required to produce an output. The voltage and current requirements needed to produce an output are determined by the voltage tap setting and the pickup current setting.

VOLTAGE TAP SETTING

The relay is provided with seven discrete taps in 50-volt steps over the range of 50-350 volts rms symmetrical. The SCRs will fire whenever the instantaneous value of the applied voltage is equal to twice the peak value ± 4% of an rms symmetrical voltage equal to the voltage tap setting; i.e.,

$$V_R = (2)(\sqrt{2})\,V_T \qquad (3)$$

where: V_R = instantaneous voltage needed to fire SCRs

V_T = voltage tap setting

Note that this voltage V_R is also equal to the peak voltage of a completely offset voltage wave having an rms symmetrical value equal to the voltage tap setting. In other words, the SCRs will fire whenever an rms symmetrical voltage greater than twice tap setting is applied, or whenever the corresponding peak voltage is exceeded on an instantaneous basis by an applied waveshape. When the SCRs fire, the relay will produce an output, provided the total secondary fault current that flows in the relay is greater than the pickup current setting.

PICKUP CURRENT

Pickup current is defined as the rms value of a symmetrical sinusoidal current that must flow in the primary of T1 (see internal connections, Figure 13) in order to provide a contact output. Two models of SBD relays are available with current pickup settings of 0.5/1.0 and 0.5/2.5 ± 10% rms amperes.

OPERATING TIMES

Typical operating times are shown in Figure 18. The dropout time is 15 milliseconds or less.

EFFECT OF TEMPERATURE

Voltage Tap Setting may vary an additional 2% over the operating temperature range. **Pickup Current** may vary an additional 20% over the operating temperature range.

BURDENS

DC BURDEN

The relay draws no power from the DC supply unless the output relay is picked up. The burden with the output relay picked up is 0.05 ampere or less at any rated voltage.

AC BURDEN

Tap Setting	Impedance (Ohms)		
50	935 @ -20°	or	880 - j320
100	1600 @ -37°	or	1280 - j960
150	2000 @ -48°	or	1340 - j1480
200	2200 @ -56°	or	1230 - j1830
250	2340 @ -62°	or	1100 - j2060
300	2400 @ -65°	or	1000 - j2200
350	2480 @ -69°	or	880 - j2300

CALCULATION OF SETTINGS

The SBD11B relay is set on the basis of the maximum possible voltage that can be produced in the differential circuit as the result of a fault external to the zone of protection. Determination of the maximum voltage for this condition is subject to simple calculations, hence the relay setting can be easily determined. The relay is tapped in seven discrete steps of 50 volts per step from 50 to 350 volts rms. Thus, it is first necessary to calculate the maximum voltage that can be produced in the differential circuit for an external fault, after which an appropriate tap can be selected. Next, if a mixture of multi-ratio CTs are involved in the application, or if the CTs are applied on taps other than the full winding, evaluate the application to determine that excessive voltages will not be produced across the full windings of these CTs. Finally, the minimum internal fault for which the relay will just operate is determined.

CALCULATION OF VOLTAGE TAP SETTING, V_T

The minimum acceptable voltage tap setting can be determined using the following equation:

$$V_T = 1.25\ (R_S + PR_L)\ \frac{I_F}{N} \qquad (6)$$

where: VT = minimum acceptable voltage tap setting. Since V_T in general will not come out exactly equal to one of the available taps, the next higher tap setting should be used; available voltage taps: 50V, 100V, 150V, 200V, 250V, 300V, or 350V rms

R_S = DC resistance of fault CT secondary windings and leads to housing terminal (at maximum expected operating temperature)

R_L = single conductor DC resistance of CT cable for one-way run from the differential junction point to the fault CT housing terminal (at maximum expected operating temperature)

P = one (1.0) for three-phase faults; two (2.0) for single phase-to-ground faults

I_F = maximum external fault current in fault CT in primary symmetrical rms amperes

N = CT ratio

1.25 = margin factor for safety

The following comments may be made with respect to the evaluation of equation (6).

1. The calculations need only be made for three phase and single phase-to-ground faults. If the results yield a satisfactory application, the application will also be satisfactory for other multi-phase faults.

2. For single phase-to-ground faults, the differential circuit is such that the CT secondary fault current will flow through both of the fault CT cables; thus the

multiplier P must be set equal to two. On the other hand, the CT secondary currents during balanced three-phase faults result in 0 current in the return cable; thus only the one-way cable resistance is involved, and P is set equal to one.

3. If the single phase-to-ground fault current at a given location is greater than or equal to the three-phase fault current, the calculations need only be made for single phase-to-ground faults.

4. The resistance of the CTs and connecting cables will increase with increasing temperature; therefore, if adequate margin is to be maintained at all times, equation (6) should be evaluated using resistance values corresponding to the maximum expected operating temperature.

The methods to be used in calculating the voltage tap setting using equation (6) will to some extent be dependent on the type of application. The following comments are made with respect to the different areas in which the SBD11B relay may be applied.

1. Bus Protection - Two methods will be outlined for evaluating equation (6) in order to determine an appropriate relay voltage tap setting.

   The first method offers a simplified conservative approach to the problem and requires that equation (6) be evaluated only once. With this method, it is assumed that a single phase-to-ground fault with a current magnitude equal to the maximum interrupting rating of the breaker occurs on the feeder associated with the CT having the longest cable run from the differential junction point. Under these assumptions, the effect of the fault current, I_F, is maximized, and so is the effect of cable resistance, because the highest value of resistance is used and P is set equal to 2. Thus, the highest possible value of V_T will be obtained.

   The second method offers an exact approach but requires that equation (6) be evaluated a number of times in order to obtain the maximum V_T. With this method, calculations must be made for the maximum single phase-to-ground fault and the maximum three-phase fault just off each of the n feeders on the bus. Therefore, equation (6) must be evaluated 2n times, using the associated value of cable resistance and P = 1 or P = 2, as required.

   In general, Method II will produce a lower voltage tap setting than Method I, but Method I is simpler to utilize. The user should begin with Method I. If the voltage tap setting resulting from the use of this method results in adequate sensitivity, a unique advantage is realized since the setting does not require recalculation following future changes in the power system configuration that result in higher fault current magnitudes. If the sensitivity resulting from the use of Method I does not prove adequate, then Method II should be used.

   Each of the methods are outlined below:

   Method I (Simplified Conservative Approach):

   a. Use the maximum interrupting rating of the circuit breaker as the maximum external single phase-to-ground symmetrical fault current (I_F).

b. R_L is based on the distance from the differential junction point to the most distant CT.

c. Calculate V_T substituting the values of current and resistance from a and b and set P = 2.

d. Select the highest available voltage tap (V_T) that just accommodates the voltage calculated in c above.

Method II (Exact Approach):

a. Determine the maximum three-phase and single phase-to-ground fault currents for faults just off each of the n breakers on the bus.

b. R_L is the one-way DC resistance of the cable from the associated CT to the differential junction point.

c. For each breaker in turn, calculate V_T separately, utilizing the associated maximum external three-phase symmetrical fault current in the fault CT, with P = 1 and the maximum external single phase-to-ground symmetrical fault current in the fault CT, with P = 2.

d. Use the highest of the 2n values of V_T so obtained, and select the next higher available tap setting that accommodates this value.

2. Shunt Reactor Protection - Depending on the type of protection required, shunt reactors may be protected by the SBD11B relay in one of two ways. See Figures 3 and 4. Since the shunt reactors contribute no current to an external fault, equation (6) should be evaluated using the highest magnitude of current that can possibly flow in the reactor under any system condition, exclusive of a fault in the reactor. If the differential junction point is located near the reactors, the resistance of the CT connecting cables can probably be ignored, and equation (6) need only be evaluated using the CT resistance and the maximum expected current. If the cable resistance cannot be ignored, use the maximum expected reactor current and P = 2. After a value of V_T has been calculated, select the next higher available voltage tap that just accommodates this voltage.

APPLICATIONS WITH MIXED MULTI-RATIO CT'S

Where CTs are to be used on other than their full windings, the application should be evaluated after a voltage tap has been selected, to determine that excessive voltages are not developed across the full windings of these CTs as a result of autotransformer action. It is desirable to limit the peak value of the voltage to less than the insulation breakdown of the connected equipment. It has been shown in the section under **OPERATING PRINCIPLES** that the peak voltage across the full winding can be calculated as follows:

$$V_F = \frac{(2.83)(V_T)(N1)}{N2} \qquad (4)$$

where: V_T = SBD11B relay voltage tap setting

N1 = Number of turns in full CT winding

N2 = Number of turns in CT tap used

2.83 = $2\sqrt{2}$ (peak value of fully offset wave)

V_F = Peak voltage across full winding

See Figure 8 for an illustration of the above terms. If V_F is less than the insulation breakdown, and if the current rating of the CT is not exceeded, the application is permissible. Equation (4) should be evaluated for the CT having the highest N1/N2 ratio. If the condition of equation (4) is met for this CT, then it will also be met for the remaining CTs.

MINIMUM FAULT TO TRIP

After the voltage tap setting has been established for an application, a check should be made to determine the minimum internal fault current that will just cause the relay to operate. The following expression can be used to determine the minimum internal fault current required for a particular tap setting:

$$I_{min.} = \sum_{X=1}^{n} (I)_X + I_R \quad n \qquad (7)$$

Where: $I_{min.}$ = Minimum rms symmetrical internal fault current required to operate the SBD11B relay

n = Number of CTs (number of circuits)

I = Secondary excitation current of individual CT at a voltage equal to $2\sqrt{2} \times V_T$

I_R = Current in the SBD11B at pickup setting

N = CT ratio on tap used

The excitation currents $(I)_1$, $(I)_2$,....$(I)_n$ will be a function of the peak voltages that can be produced in the secondaries of the respective CTs. It is possible to determine the currents with the aid of the secondary excitation characteristic for the respective CT, but it is first necessary to modify the characteristics so that they are plotted as a function of the peak voltages that can be produced. The modifications are easily made; the procedure for doing so is as follows:

1. Determine the knee point coordinates of the standard excitation curve (E_S and I_e). These points will be indicated on the given characteristic, or they can be found graphically by determining the point where a 45^o line is tangent to the knee of the excitation curve.

2. Calculate and plot the following point on the same sheet with the excitation curve.

$$V = (7)(E_S) \qquad (8)$$
$$I = (5)(I_e)$$

3. Draw a line having a slope of 1/2 through the point (V,I) calculated and plotted in 2. above. A slope of 1/2 corresponds to one log cycle on the vertical axis (voltage) and two log cycles on the horizontal axis (current). See line A-B in Figure 7.

4. Extend the lower part of the excitation curve in a straight line until it intersects the line A-B drawn in 3. above. See line C-D in Figure 7.

The curve (CPB) so formed by these two lines now represents the modified excitation characteristics as a function of the peak voltages that can be produced. After the curve has been drawn, calculate the following corresponding excitation current I.

$$V_S = 2(\sqrt{2})(V_T) \qquad (9)$$

Where V_S = Voltage coordinate for determining I

V_T = Voltage tap setting on SBD relay

Note that the first term in equation (7) reduces to nI if all the CTs have the same characteristics.

The second term in equation (7) represents the current (I_R) drawn by the relay just at the operating point. It can be calculated as follows:

$$I_R = \frac{(2)(V_T)}{2500} \qquad (10)$$

SAMPLE CALCULATION

The various steps for determining the setting of the SBD11B relay in a typical bus application will be demonstrated with the aid of a worked example. Assume the protected zone includes five breakers, all rated at 69kV, 1500mva, 1200 amperes, with a maximum interrupting rating of 12,500 amperes. The excitation curve for the 1200/5 bushing CTs in these breakers is shown in Figure 7.

The 0.5 ampere sensitivity setting will be used. The voltage tap setting will be determined by using Method I as described in the preceding section. The value of R_S from Figure 7 is (0.0019)(240)+2(0.0347) = 0.524 ohms. It is assumed that this resistance corresponds to the maximum expected operating temperature. It is further assumed that the longest CT cable run is 442 feet and that number 10 copper wire is used. The one-way cable resistance at 25°C is 0.450 ohms. The resistance value of wire at 25°C or at any temperature T1 may be corrected to any temperature T2 by means of the following equation.

$$R_{T2} = [1 = \rho_1\ (T2-T1)]R_{T1}$$

Where: R_{T2} = Resistance in ohms at T2, °C

R_{T1} = Resistance in ohms at T1, °C

ρ_1 = Temperature coefficient of resistance at T1

For standard annealed copper, $\rho_1 = 0.00385$ at $T1 = 25^oC$. If the maximum expected operating temperature is assumed to be 50^oC, then

$$R_L = [1 + 0.00385(50-25)]0.450$$
$$= (1.096)(0.450) = 0.493 \text{ ohms}$$

Substituting the various quantities in equation (6) yields:

$$V_T = 1.25\ [0.524 + 2(0.493)]\frac{12500}{240}$$
$$= 98.31 \text{ volts}$$

Since V_T = 98.31 volts is not exactly equal to one of the available taps, select the next higher available tap, which is 100 volts.

$$V_T = 100 \text{ volts}$$

Since the CTs are all used on the full winding, there is no need to check that excessive voltages will be produced in the CT circuits.

Now that a tap has been selected, the sensitivity may be calculated following the procedure outlined in the section under MINIMUM FAULT TO TRIP.

From Figure 7, the knee point coordinates, E_S and I_e, are 290 volts and 0.06 ampere. From equation (8):

$$V = (7)(E_S) = (7)(290) = 203 \text{ volts}$$
$$I = (5)(I_e) = (5)(0.06) = 0.30 \text{ ampere}$$

Plot this point (V,I) on the graph of Figure 7 and draw the lines A-B and C-D. This gives the modified secondary excitation characteristics. Calculate the voltage V_S using equation (9):

$$V_S = (2)(\sqrt{2})V_T = 283 \text{ volts}$$

From the modified curve, the current I_e corresponding to V_S = 283 volts is 0.05 ampere.

The relay current from equation (10) is:

$$I_R = \frac{(2)(V_T)}{2500} = \frac{(2)(100)}{2500} = 0.08 \text{ ampere}$$

The sensitivity of the relay, or the minimum fault to trip from equation (7) is:

$$I_{min.} = [(5)(0.05) + 0.08](240)$$
$$= 80 \text{ amperes}$$

With the relay set at 0.5 ampere, 120 amperes of primary current are required to produce 0.5 ampere secondary from the 1200/5 CTs. Since the calculated value is less than 120 amperes, the sensitivity will be 120 amperes. If a higher minimum basic current sensitivity is used on the relay, the minimum current required for pickup will be correspondingly higher.

CONSTRUCTION

The Type SBD relays are assembled in the small size double-ended (S2) drawout case with studs at both ends in the rear of the case for external connections. The electrical connections between the relay and the case studs are through stationary molded inner and outer blocks, between which nests a removable connecting plug. The outer blocks have the terminals for the internal connections.

Every circuit in the drawout case has an auxiliary brush, as shown in Figure 9, to provide adequate overlap when the connecting plug is withdrawn or inserted. Some circuits are equipped with shorting bars (see internal connections in Figure 13), and on those circuits it is especially important that the auxiliary brush make contact as indicated in Figure 9 with adequate pressure to prevent the opening of the important interlocking circuits.

The relay mechanism is mounted in a steel framework called the cradle, and is a complete unit with all leads terminated at the inner blocks. This cradle is held firmly in the case with a latch at both top and bottom and by a guide pin at the back of the case. The connecting plug, besides making the electrical connections between the respective blocks of the cradle and case, also locks the latch in place. The cover, which is drawn to the case by thumbscrews, holds the connecting plugs in place. The target reset mechanism is a part of the cover assembly.

The relay case is suitable for either semiflush or surface mounting on all panels up to two inches thick, and appropriate hardware is available. However, panel thickness must be indicated on the relay order to ensure that proper hardware will be included. Outline and panel drilling are shown in Figure 22.

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

RECEIVING, HANDLING AND STORAGE

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

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

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

ACCEPTANCE TESTS

VISUAL INSPECTION

When the relay is received, check the nameplate stamping to ensure that the model number and rating of the relay received agree with the requisition.

Remove the relay from its case and check that there are no broken or cracked molded parts or other signs of physical damage, and that all screws are tight.

MECHANICAL INSPECTION

Case and Cradle Blocks

Check that the fingers on the cradle and the case agree with the internal connection diagram. Each cradle finger should be flush or project above the between-finger barriers. Check that there is a coil spring under each finger. The case fingers, if not held down by a shorting bar, should come within 1/16 inch of touching a straight-edge bridging the case block from side to side. If the finger is held down by a shorting bar, opening the electrical circuit between the finger and the shorting bar should require at least one pound (450 grms.) of force. See Figure 9. Check that each auxiliary brush extends above the between-finger barrier.

Telephone Relay Unit (R_T)

Operate the telephone relay unit manually by pushing on the armature. Check that the movement is free of binding or roughness. Check that the normally-closed stationary contacts follow the moving contacts before they open. The normally-closed contact at the top of the stack should open last. All contacts, when in the open position, should have 0.015 inch or more gap. The normally-open contacts should have at least 0.005 inch travel after closing. This can be checked by putting a 0.005 inch shim between the armature and the pole piece, closing the armature by hand, and checking that each normally-open contact still closes. As the normally-closed contacts cannot be tested using a shim, they may be checked by measuring the force applied to the stationary contact which is required to open the contact. This should be at least 10 grams.

Target Seal-in Unit

Pick up the armature by hand. The orange target should appear. When the armature is released, the target should remain in view. Push in on the reset arm. The target should drop from view.

Hold the armature up by hand. The target should not be at the end of its travel. Verify this by reaching in one of the windows of the target with a sharp instrument such as a scribe or knife and pushing upward. The target should move definitely upward (at least 1/64 inch). Release the armature; the target should fall visibly downward (at least 0.010 inch) before the target is caught by the latch.

ELECTRICAL TESTS

CAUTION

Remove ALL power from the relay before removing or inserting any of the printed circuit cards. Failure to observe this caution may result in damage to and/or misoperation of the relay.

Drawout Relays, General

Since all drawout relays in service operate in their cases, it is recommended that they be tested in their cases or an equivalent steel case. In this way any magnetic effects of the enclosure will be accurately duplicated during testing. A relay may be tested without removing it from the panel by using a 12XLA13A test plug. This plug makes connections only with the relay and does not disturb any shorting bars in the case. Of course, the 12XLA12A test plug may also be used. Although this test plug allows greater testing flexibility, it also requires CT shorting jumpers and the exercise of greater care, since connections are made to both the relay and the external circuitry.

Power Requirements, General

All alternating current operated devices are affected by frequency. Since non-sinusoidal waveforms can be analyzed as a fundamental frequency plus harmonics of the fundamental frequency, it follows that alternating current devices (relays) will be affected by the applied waveform.

Therefore, in order to properly test alternating current relays it is essential to use a sine wave of current and/or voltage. The purity of the sine wave (i.e., its freedom from harmonics) cannot be expressed as a finite number for any particular relay; however, any relay using tuned circuits, RL or RC networks, or saturating electromagnets (such as time overcurrent relays), would be essentially affected by non-sinusoidal waveforms.

Similarly, relays requiring DC control power should be tested using DC and not full wave rectified power. Unless the rectified supply is well filtered, many relays will not operate properly due to the dips in the rectified power. Zener diodes, for example, can turn off during these dips. As a general rule, the DC source should not contain more than 5% ripple.

CAUTION

When performing the following electrical tests it is very important to adhere to the length of time that voltage and/or current is applied to the relay. The SBD relay is designed to perform satisfactorily during in-service operation when applied per the APPLICATION section and within the limits called for in the RATINGS section. The relay is <u>not</u> rated for continuous operation, with some of the voltages and currents applied, when performing all the following electrical tests.

Voltage Pickup

Set the SBD relay to the 50 volt tap setting (which is the equivalent of 100 volts rms symmetrical pickup as tested) located on the front of the relay, and connect the relay per the test diagram in Figure 11.

CAUTION

Do not apply voltage to the SBD relay for longer than 10 seconds and do not re-apply voltage more often than once every 2 minutes.

With S2 open and S1 closed, pre-set the voltage as read on the AC voltmeter for 95 volts. Open S1, then close S2, in that order. The relay is now ready to be tested. Close S1 and increase the voltage until the SCRs fire, as indicated by a drop in the voltmeter reading and an indication in the ammeter reading. The voltage reached prior to the voltmeter drop is the pickup voltage. If necessary, adjust the rheostat located on the front of the relay to obtain 100 ± 4 volts pickup.

Tap Voltage Test

This test is to check the calibration of the 100, 150, 200, 250, 300, and 350 volt tap settings, which are obtained by a movable lead, on a tap block located in the front of the SBD relay. Tap settings are a function of a voltage divider circuit consisting of precision resistors mounted on the printed circuit card.

Connect the relay per Figure 12. Set the relay to the tap setting that is to be tested. Apply 10% of tap voltage to the relay, as read on the AC voltmeter connected between terminals 5 and 6. The AC voltmeter connected between terminals 16 and 5 should read 5 volts ± 2%. (The voltmeter should have an input impedance of at least 5000 ohms/volt for this test.)

Pickup Current and Output Test

Set the relay to the minimum voltage tap setting. Set the pickup current link located on the front of the SBD relay to the desired current pickup setting. Connect the relay per the test diagram shown in Figure 16. Increase the current until the telephone relay (RT) operates and the lamp lights. This is the actual pickup current, and must be within 10% of the current pickup setting (either 0.5 or 1.0).

Full Voltage Test (Optional)

The previous tests are sufficient to verify the proper operation and calibration of the SBD relay.

CAUTION

The full voltage test, because of the high power requirements and the potential danger due to high voltages, with the possibility of damage to the SBD relay due to improper test procedure, is an optional test and left to the discretion of the user.

This test applies full voltage, current and power to the relay in order to duplicate conditions during a fault.

This optional test requires a source of adjustable AC voltage, with an excellent waveform, capable of providing more than twice the voltage of the tap to be tested, and enough current availability for pickup, determined by the pickup sensitivity setting. An HEA type lockout relay is required, with a coil rated for the DC control voltage of the SBD relay and having an operating time of approximately 16 milliseconds, and capable of interrupting the test voltage and current. The auxiliary relay shown in Figure 17 with two normally-closed contacts must open its contacts not more than 100 milliseconds after being energized.

When a voltage greater than twice the tap setting is applied, and enough current flows in the relay, the SBD will provide a contact closure, picking up the HEA, which will remove the AC source from the SBD relay. The auxiliary relay shown in Figure 17 provides the removal of the AC voltage should a malfunction occur. Note that, even though the applied voltage exceeds the voltage tap setting, if the required pickup current does not flow, the SBD relay will not operate and consequently the auxiliary relay will operate, protecting the SBD relay, and indicate a malfunction.

Observe the relay's short time ratings when performing this test. An oscilloscope or high speed oscillograph may be used to observe the operation of the relay.

OBSERVE ALL SAFETY PRECAUTIONS when performing the full voltage test. Carefully connect the SBD relay as shown in the test diagram of Figure 17. With S2 open and S1 closed, set the voltage, as read on the rms voltmeter, greater than two times the tap setting selected to be tested. Open S1 and close S2, in that order. The relay is now ready to be tested. Note that R (current limiting resistor) in Figure 17 is to be selected, to limit the current in SBD relay to two times the pickup current. Apply rated DC control voltage, then close S1. The SBD relay should operate, and the full voltage test will duplicate fault conditions.

High Potential Testing (Insulation Testing)

CAUTION

When high-potential testing this relay, the surge ground connection to stud 4 must be removed and all studs shorted together to avoid damage to the surge capacitors in the relay.

INSTALLATION PROCEDURE

LOCATION AND MOUNTING

The relay should be mounted on a vertical surface in a location reasonably free from excessive heat, moisture, dust and vibration. The relay case may be grounded, if desired, using at least #12 B&S gage copper wire. The outline and panel drilling diagram for the Type SBD relays is shown in Figure 22.

CONNECTIONS

The internal connection diagram for the Type SBD is shown in Figure 13. The external connection diagrams are shown in Figures 1 through 4.

Stud 4, the relay surge ground, should be connected to the station ground bus, using the shortest and most direct route.

The voltage tap plug and the current tap plug should be moved to the desired settings.

TARGET/SEAL-IN UNIT

Set the target/seal-in unit tap screw in the desired position. The contact adjustment will not be disturbed if a screw is first transferred from the left contact to the desired tap position on the right contact, and the screw in the undesired tap is then removed and transferred to the left contact.

HIPOT

See High Potential Testing section under **ACCEPTANCE TESTS.**

PERIODIC CHECKS AND ROUTINE MAINTENANCE

In view of the vital role of protective relays in the operation of a power system, it is important that a periodic test program be followed. The interval between periodic checks will vary depending upon environment, type of relay and the user's experience with periodic testing. Until the user has accumulated enough experience to select the test interval best suited to his individual requirements, it is suggested that the points listed under ACCEPTANCE TESTS be checked at an interval of from one to two years.

CONTACT CLEANING

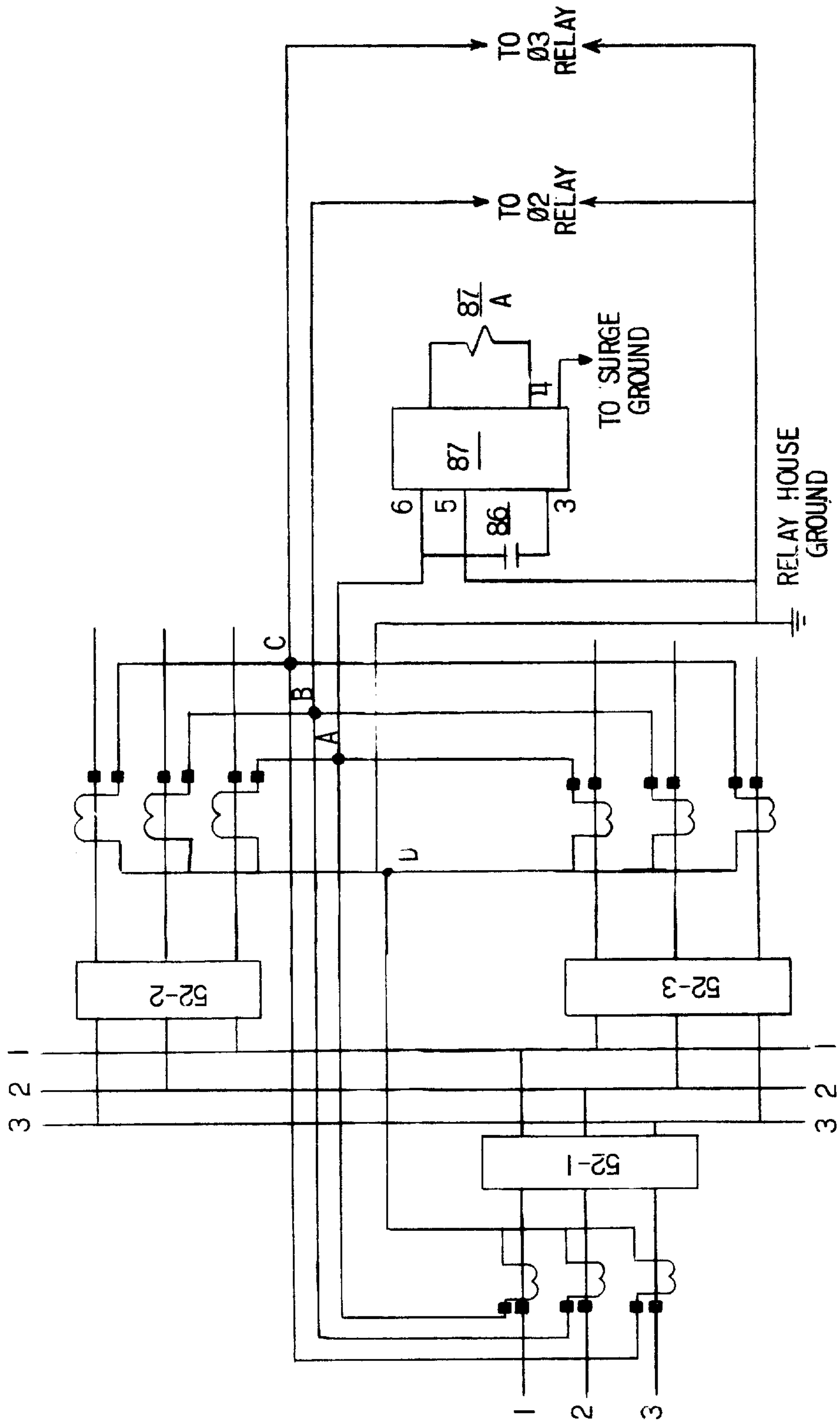
For cleaning relay contacts, a flexible burnishing tool should be used. This is a flexible strip of metal with an etch-roughened surface, which in effect resembles a superfine file. The polishing action of this file is so delicate that no scratches are left on the contacts, yet it cleans off any corrosion thoroughly and rapidly. The flexibility of the tool ensures the cleaning of the actual points of contact. Relay contacts should never be cleaned with knives, files, or abrasive paper or cloth.

RENEWAL PARTS

Sufficient quantities of renewal parts should be kept in stock for the prompt replacement of any that are worn, broken or damaged.

When ordering renewal parts, address the nearest Sales Office of the General Electric Company. Specify the name of the part wanted, quantity required, and complete nameplate data, including the serial number, of the relay for which the part is required.

Since the last edition, changes have been made on pages 7 and 8 in the **OPERATING PRINCIPLES** section, on p.9 in the VOLTAGE RATING paragraph, in the CONNECTIONS section on p.23, and in Figure 22.



LEGEND

DEVICE NO.	DEVICE TYPE	ELEM.	DESCRIPTION
87	SBD11A		SINGLE PHASE HIGH IMPEDANCE DIFFERENTIAL RELAY
		A	OUTPUT TELEPHONE RELAY
		TSI	TARGET AND SEAL-IN UNIT
86	HEA		LOCKOUT RELAY

Figure 1 (0246A6980-2) External AC Connections to SBD11B Relay for Bus Protection

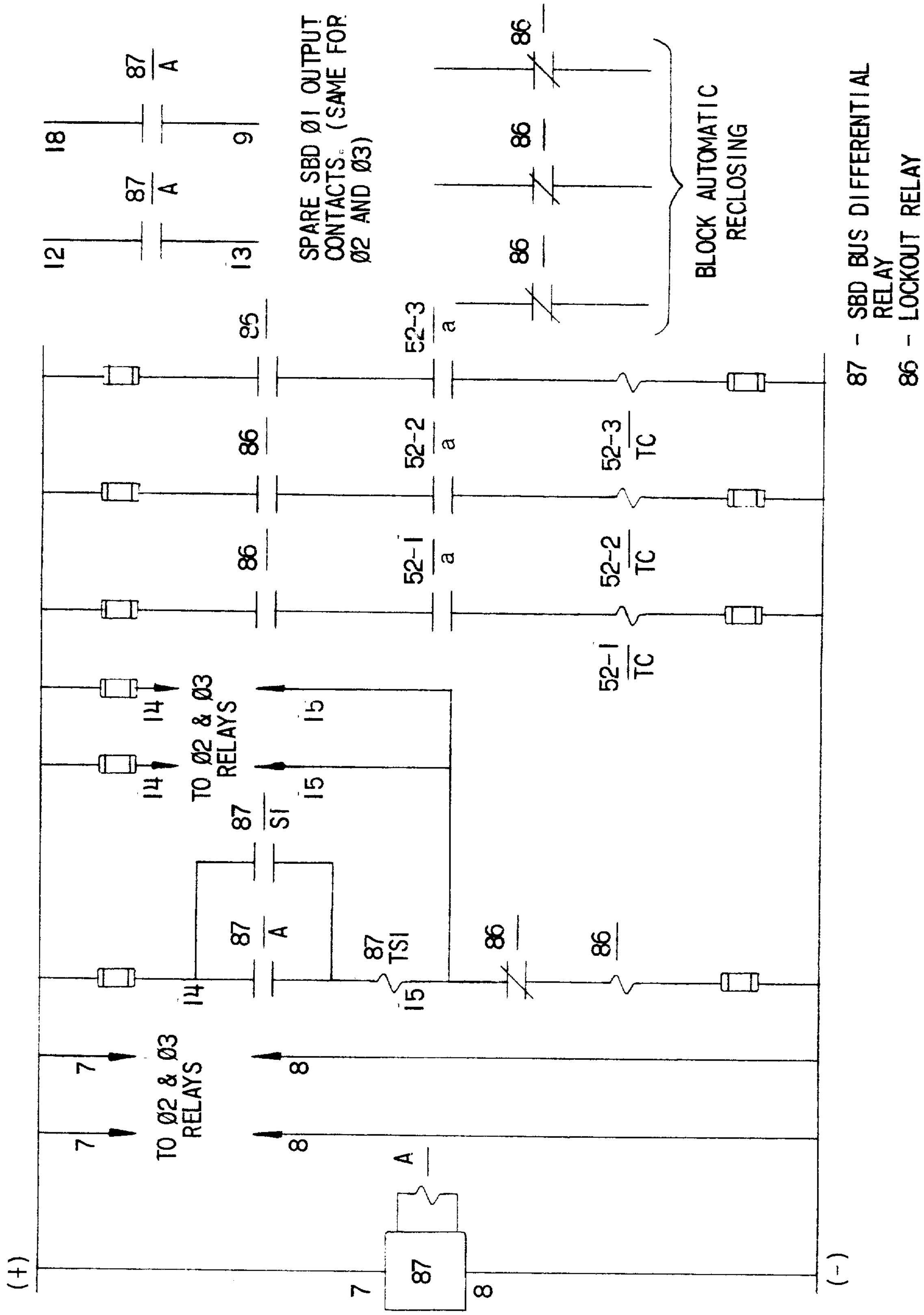


Figure 2 (0246A6979-2) External DC Connections to SBD11B Relay for Bus Protection

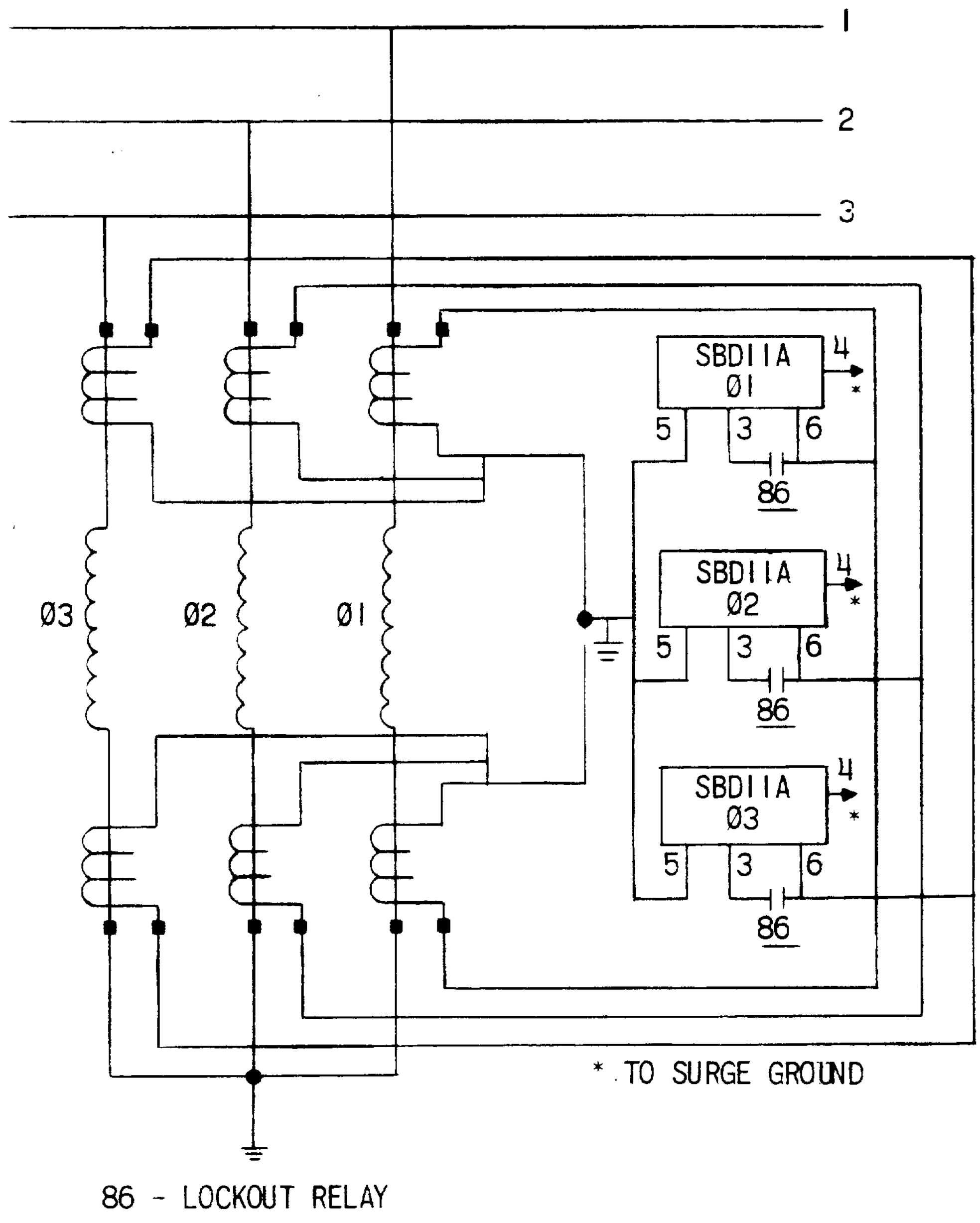


Figure 3 (0246A6981-2) External AC Connections to SBD11B for Shunt Reactor Protection for Multi-Phase and Line-to-Ground Faults

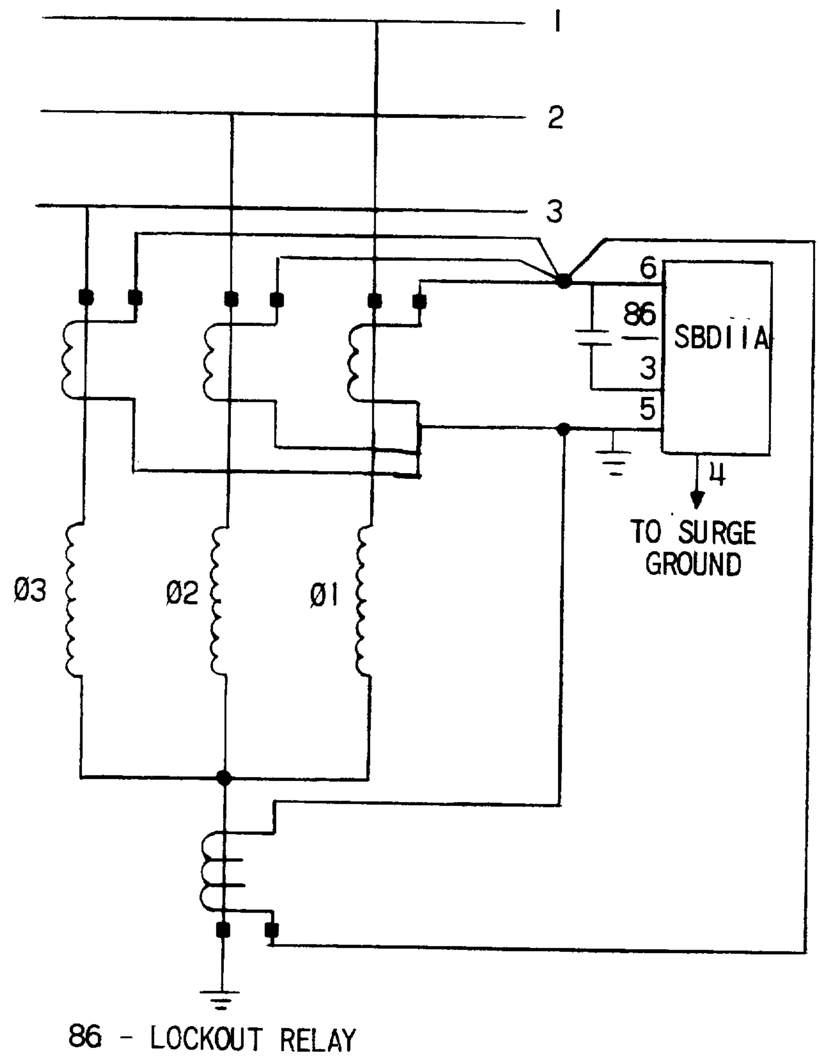
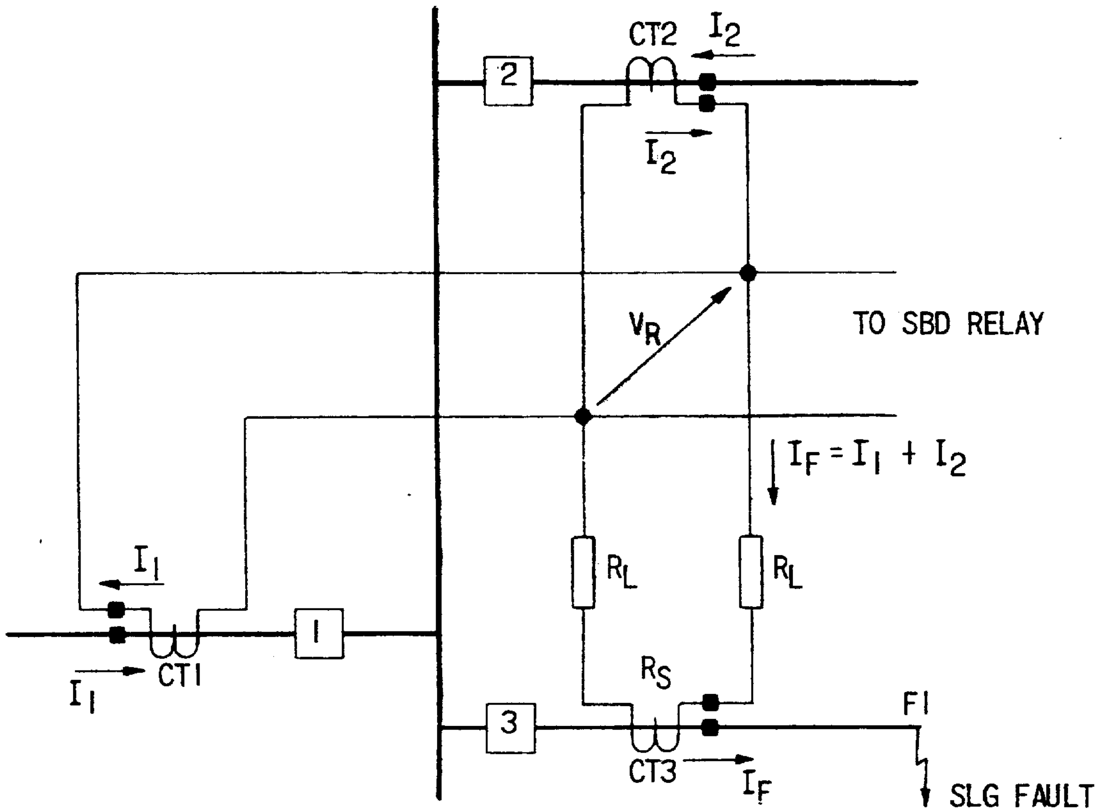


Figure 4 (0246A6982-2) External AC Connections to SBD11B Relay for Shunt Reactor Protection for Ground Faults



NOTE: CT3 ASSUMED TO BE COMPLETELY SATURATED

R_S CT SECONDARY WINDING RESISTANCE PLUS ANY LEAD RESISTANCE (AT HIGHEST EXPECTED OPERATING TEMPERATURE)

R_L CABLE RESISTANCE FROM JUNCTION POINT TO CT (AT HIGHEST EXPECTED OPERATING TEMPERATURE)

I_F RMS VALUE OF THE CURRENT IN THE PRIMARY OF CT3 DIVIDED BY THE SECONDARY TURNS.

V_R VOLTAGE ACROSS SBD

Figure 5 (0246A6976-0) Simplified Circuit Illustrating Effect of Single Line-to-Ground Fault at Location F1

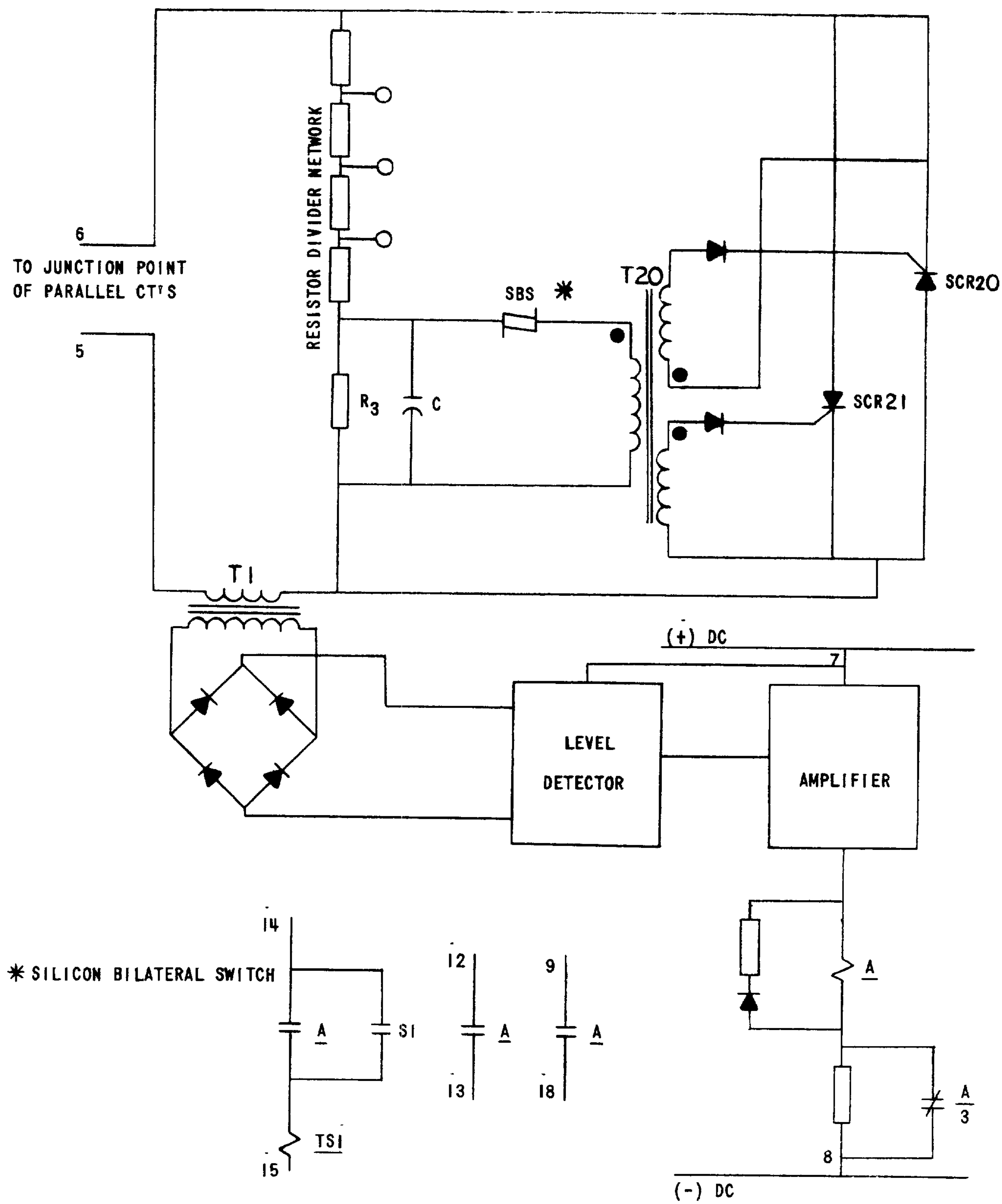


Figure 6 (0246A6977-3) Simplified Internal Connection Diagram for SBD11B Relay

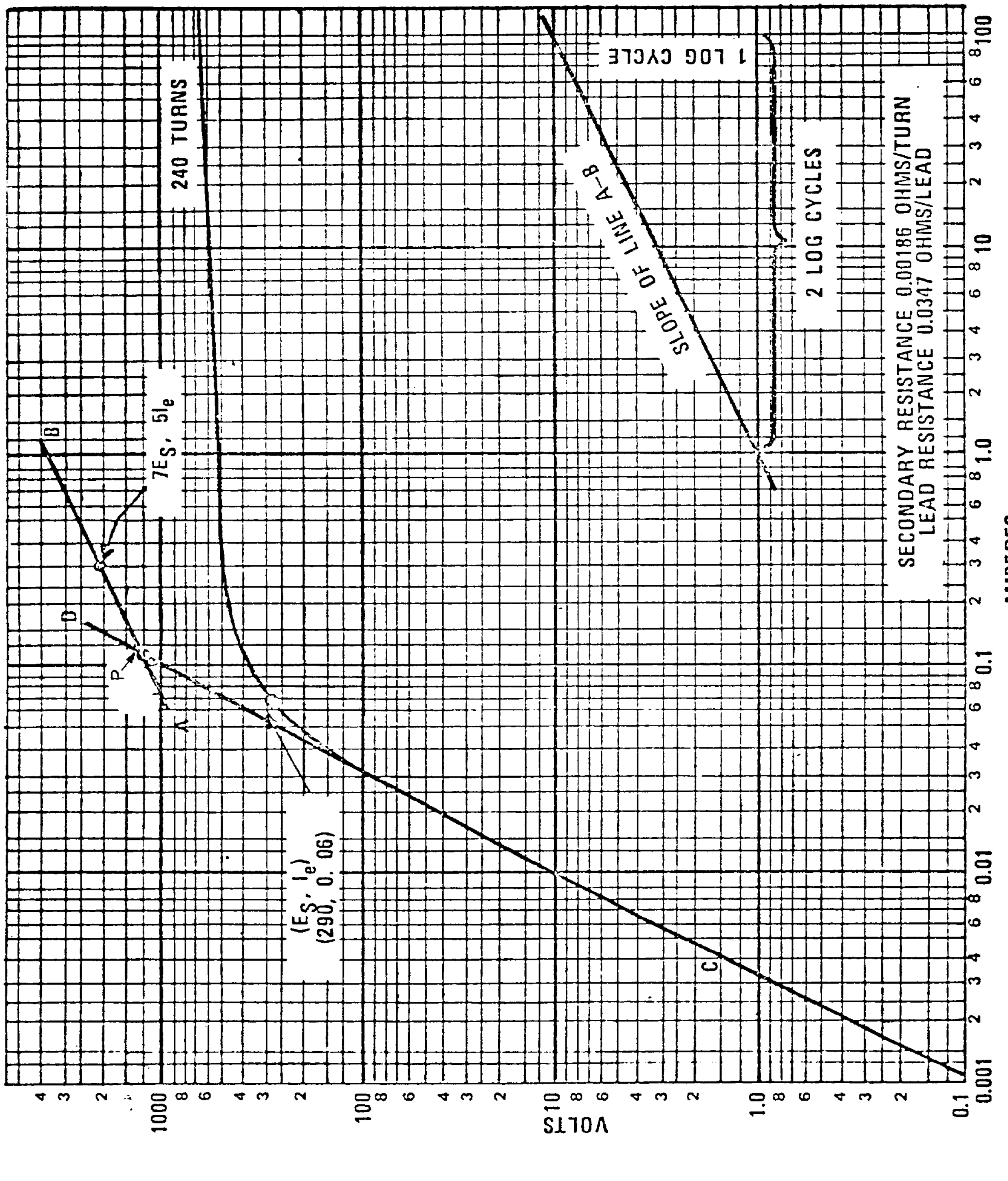
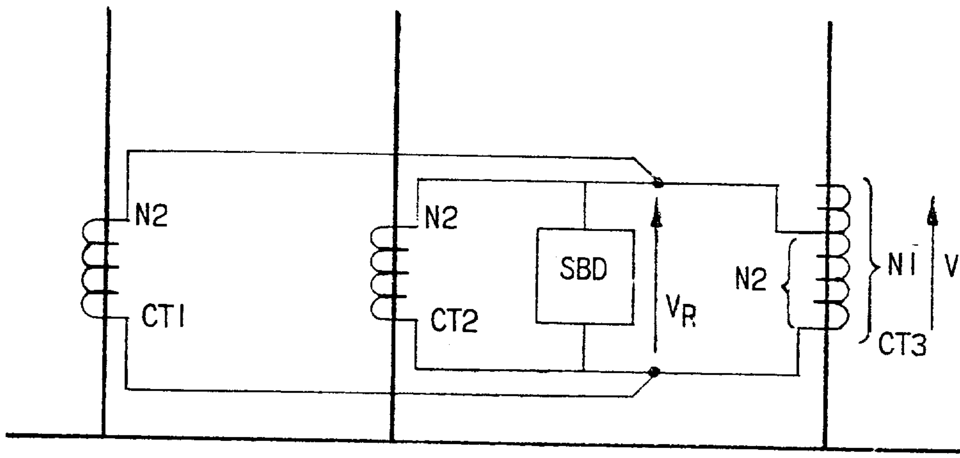


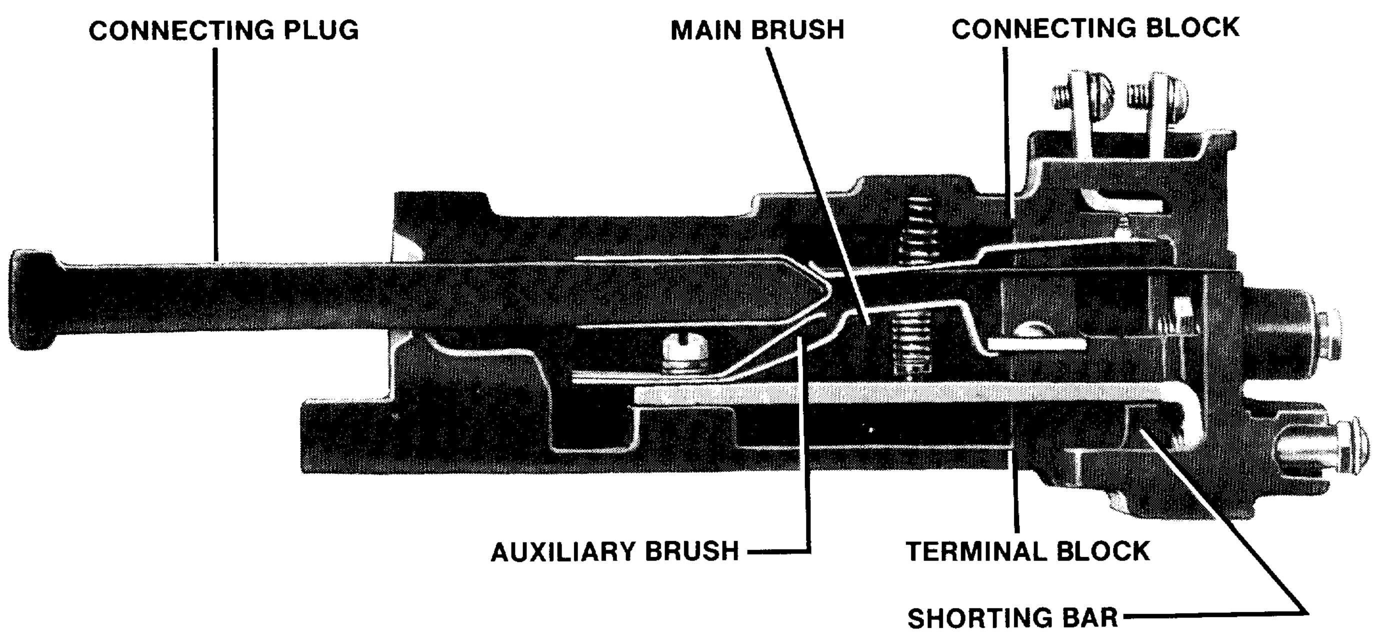
Figure 7 (0246A7082-3) Typical Secondary Excitation for 1200/5 Bushing Current Transformer



$$V_F = \frac{N1}{N2} V_R$$

V_F = VOLTAGE DEVELOPED ACROSS FULL WINDING
V_R = MAXIMUM INSTANTANEOUS VOLTAGE
N1 = TOTAL NUMBER OF CT TURNS
N2 = NUMBER OF CT TURNS USED (TAP SETTING)

Figure 8 (0246A6978-2) Voltage Appearing Across Full Winding of a CT Used on Tap Other than Full Winding



NOTE: AFTER ENGAGING AUXILIARY BRUSH CONNECTING PLUG TRAVELS ¼ INCH BEFORE ENGAGING THE MAIN BRUSH ON THE TERMINAL BLOCK.

Figure 9 (8025039) Cross Section of Drawout Case Showing Position of Auxiliary Brush and Shorting Bar

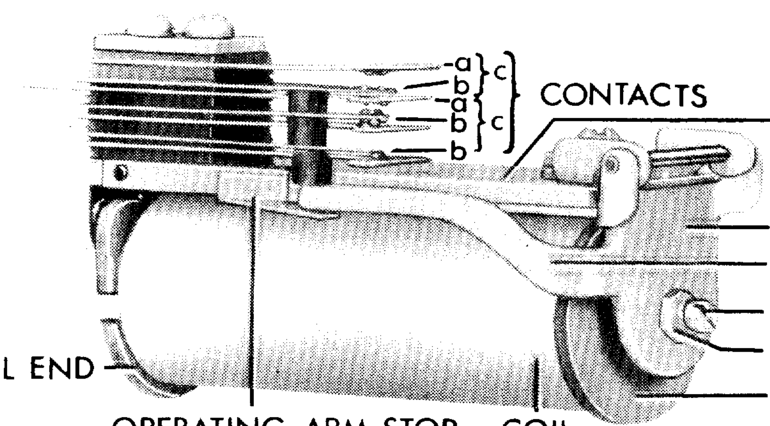


Figure 10 (8012106) Typical Telephone-Type Relay Unit

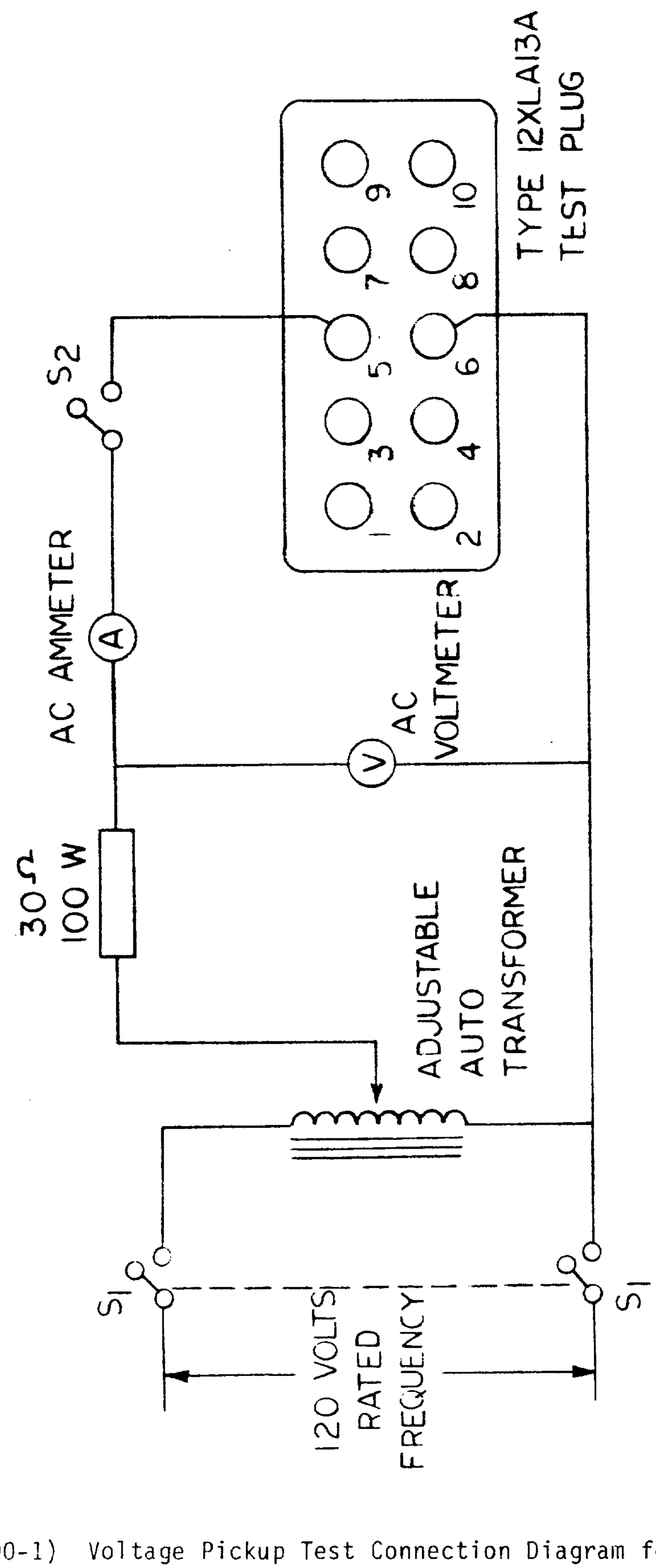


Figure 11 (0246A6990-1) Voltage Pickup Test Connection Diagram for the SBD11B Relay

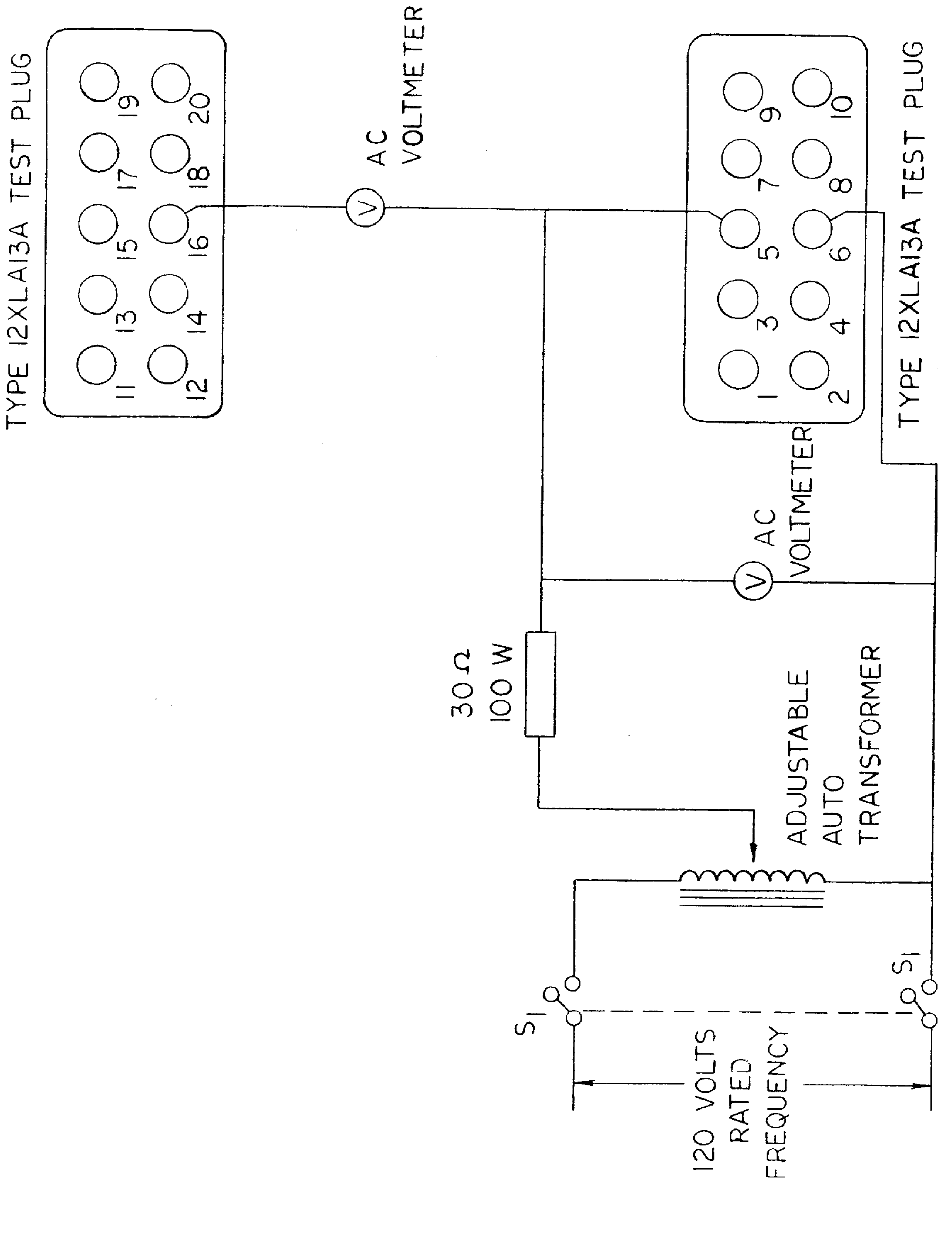


Figure 12 (0257A3208-0) Tap Voltage Test Connection Diagram for the SBD11B Relay

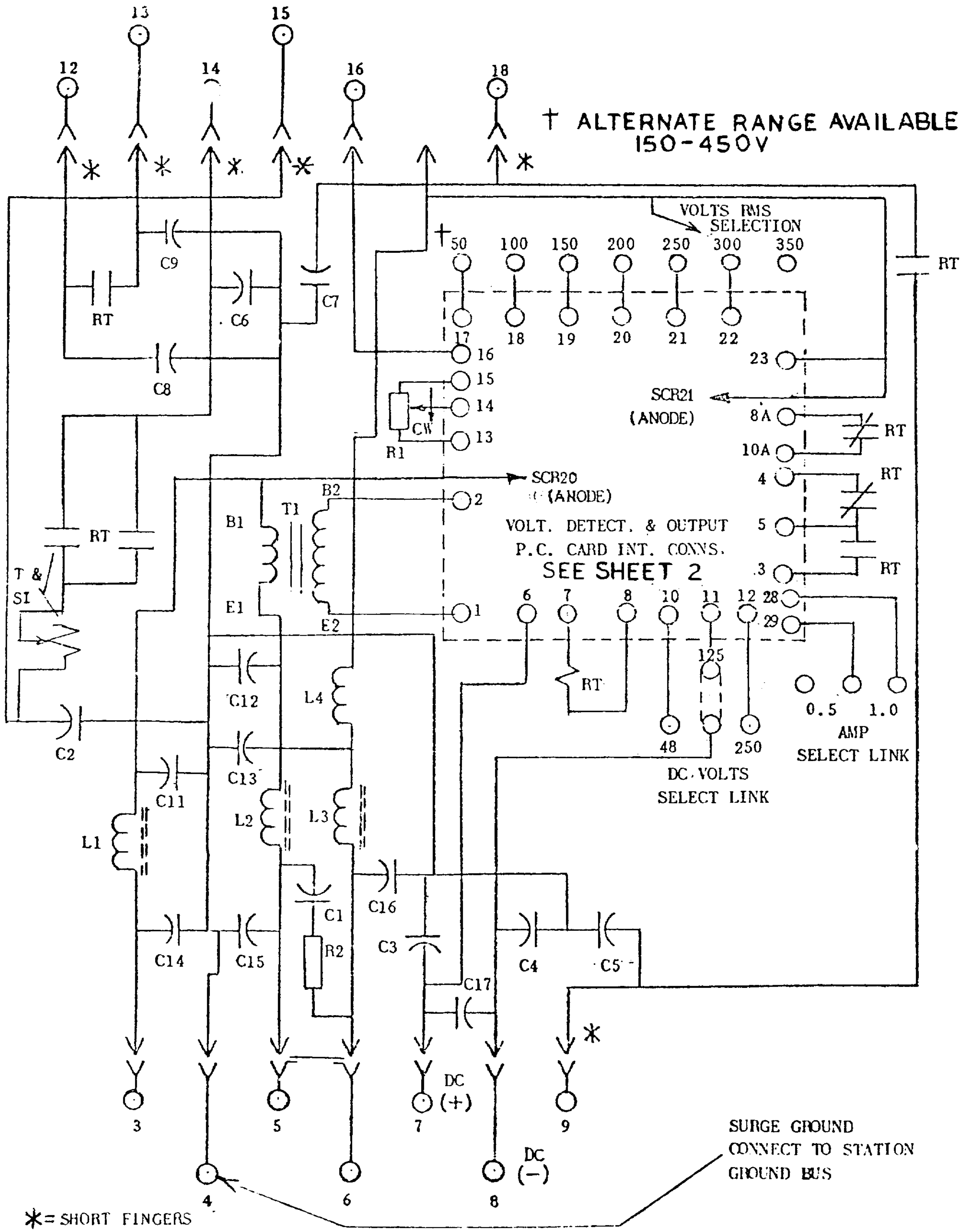
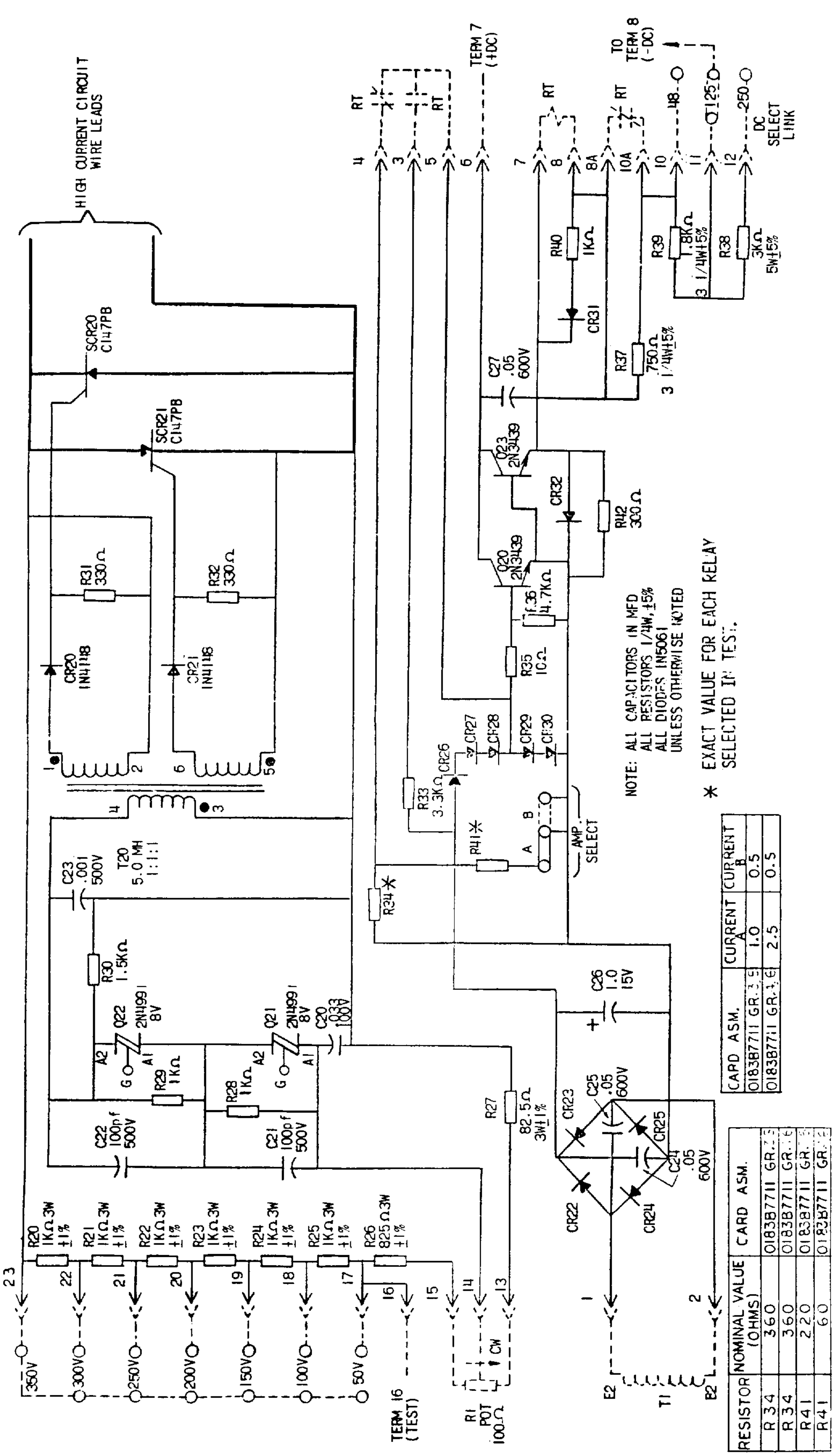


Figure 13A (0257A9612 Sh.1 [11]) Internal Connections Diagram for The Type SBD11B Relay

MODEL	FORM
12SBD11B	1 THRU 4
VOLTS AC	100
FREQUENCY	50/60 HZ
COMPONENT VALUES	
R1	100 Ω 12.5W
R2	24 Ω 2W
RT RELAY COIL	300 Ω
C2, C3, C4, C5, C6, C7, C8, C9, C17	.05uf 600V
C11, C12, C13, C14, C15, C16	.025uf 1.2KV
C1	1.0uf - 1KV

P.C. CARD INTERNAL CONNS.	
GROUP	DRAWING
1,2,3,	0108B8932
4	0183B4471

Figure 13B (0257A9612 Sh.2 [2]) Internal Connections Diagram for The Type SBD11B Relay



CARD ASM.	CURRENT A	CURRENT B
0183B7711 GR.[illegible]	1.0	0.5
0183B7711 GR.[illegible]	2.5	0.5

RESISTOR	NOMINAL VALUE (OHMS)	CARD ASM.
R34	360	0183B7711 GR.[illegible]
R34	360	0183B7711 GR.[illegible]
R41	220	0183B7711 GR.[illegible]
R41	60	0183B7711 GR.[illegible]

Figure 14 (0108B8932 [2]) Internal Connections Diagram for the Printed Circuit Board

Indicates revision

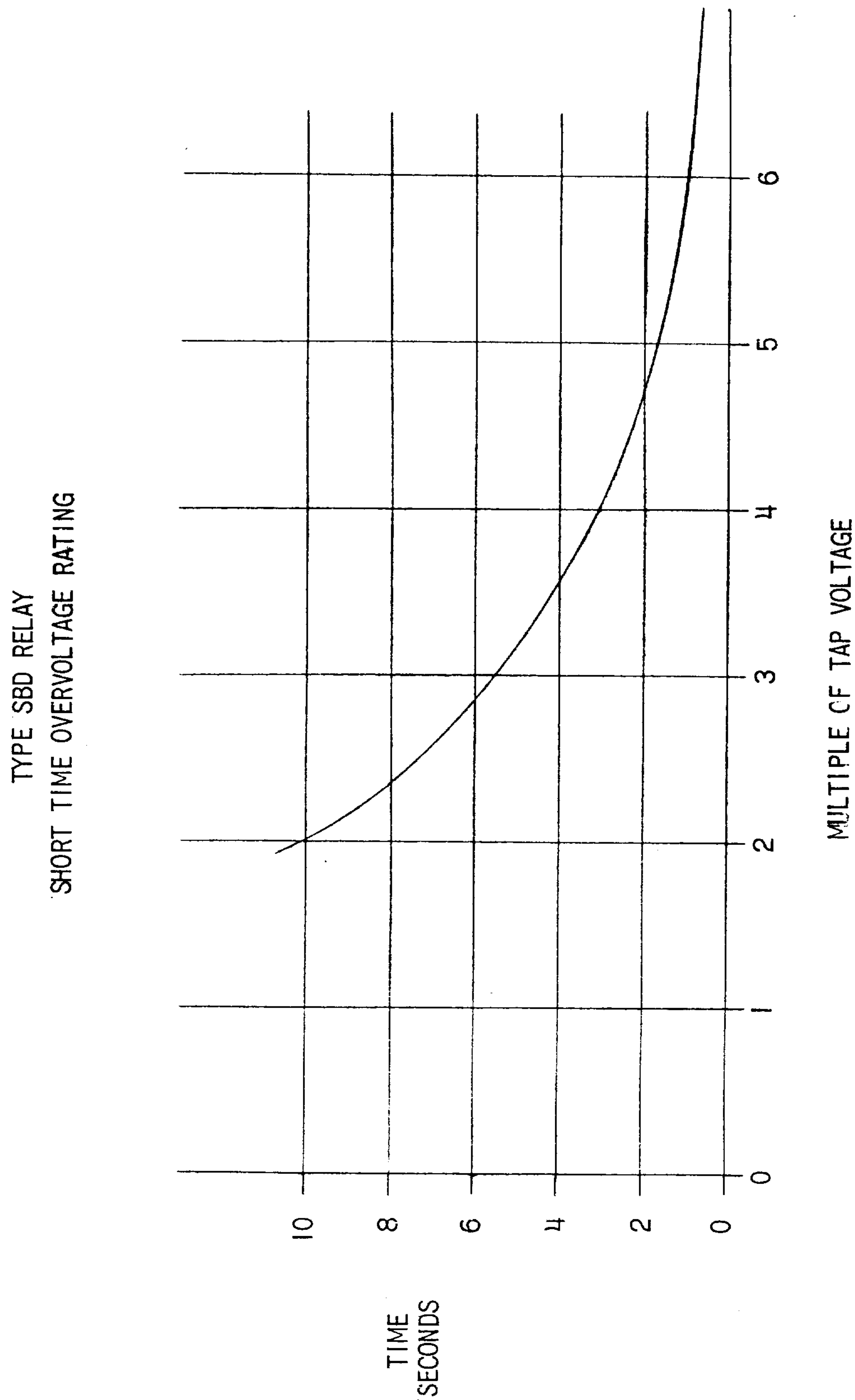


Figure 15 (0246A7091-0) Short-Time Rating Graph for the SBD11B Relay

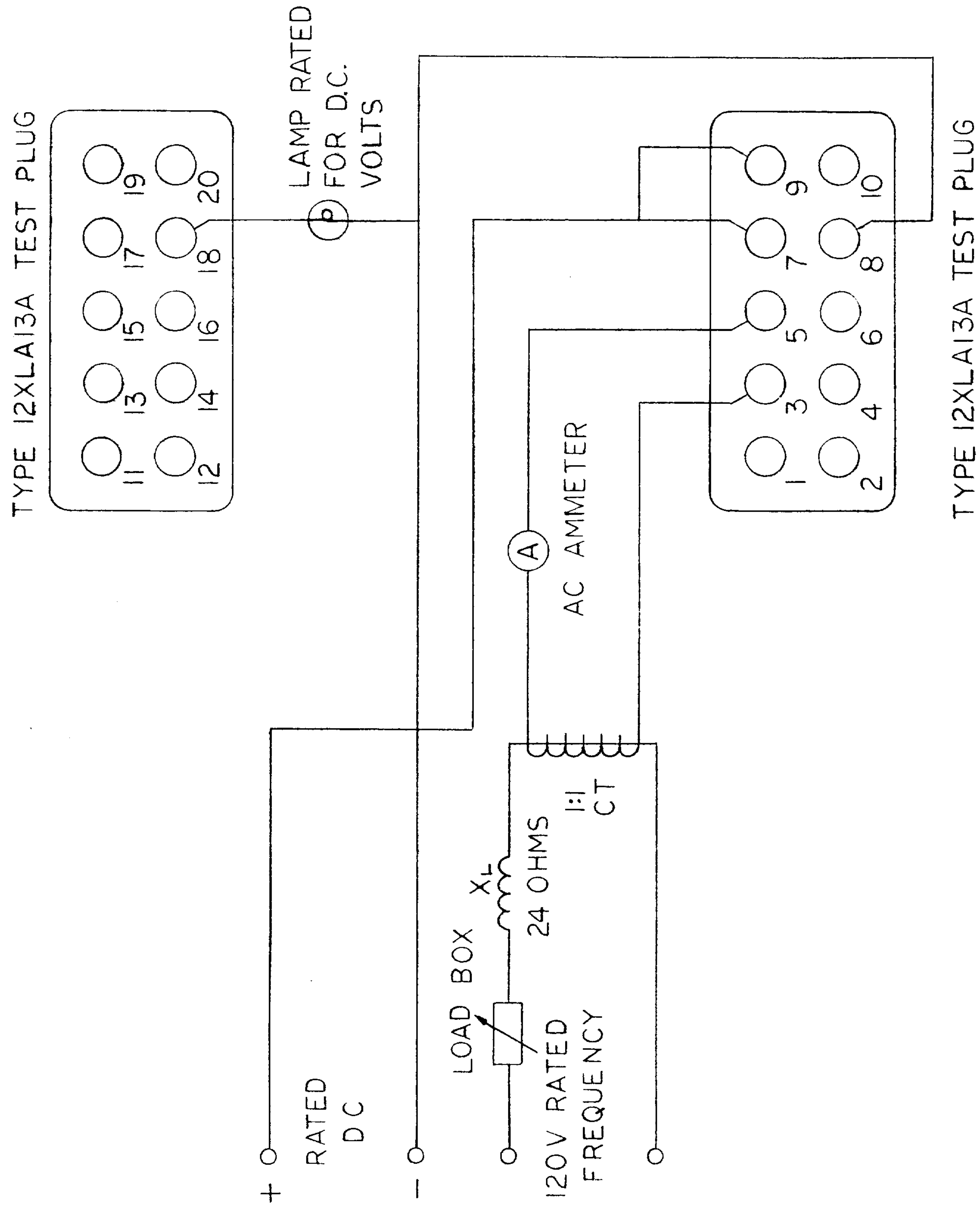


Figure 16 (0257A3207-1) Pickup Current Test Connections for the SBD11B Relay

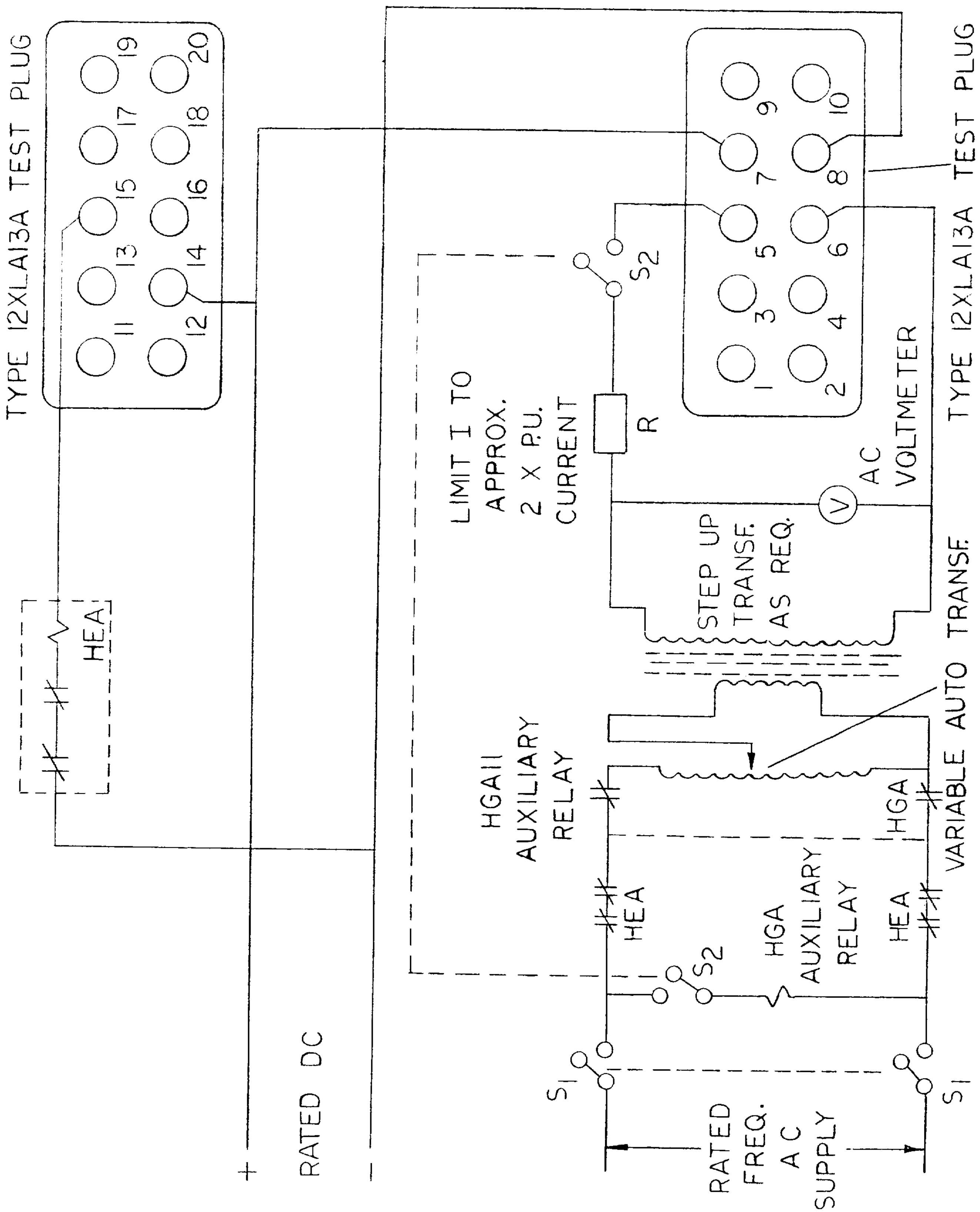


Figure 17 (0246A6991-2) Full Voltage Test Connection Diagram for the SBD11B Relay

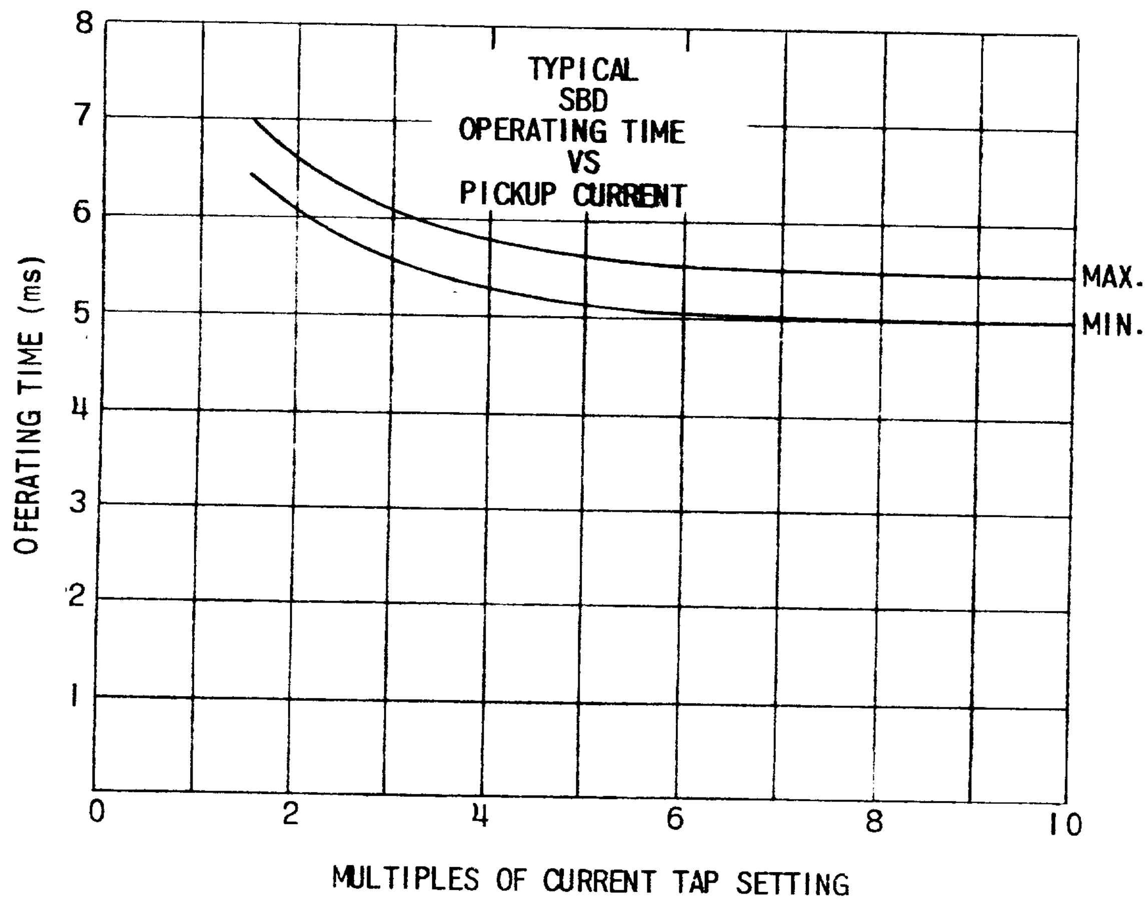


Figure 18 (0208A8696-0) Typical SBD11B Operating Times

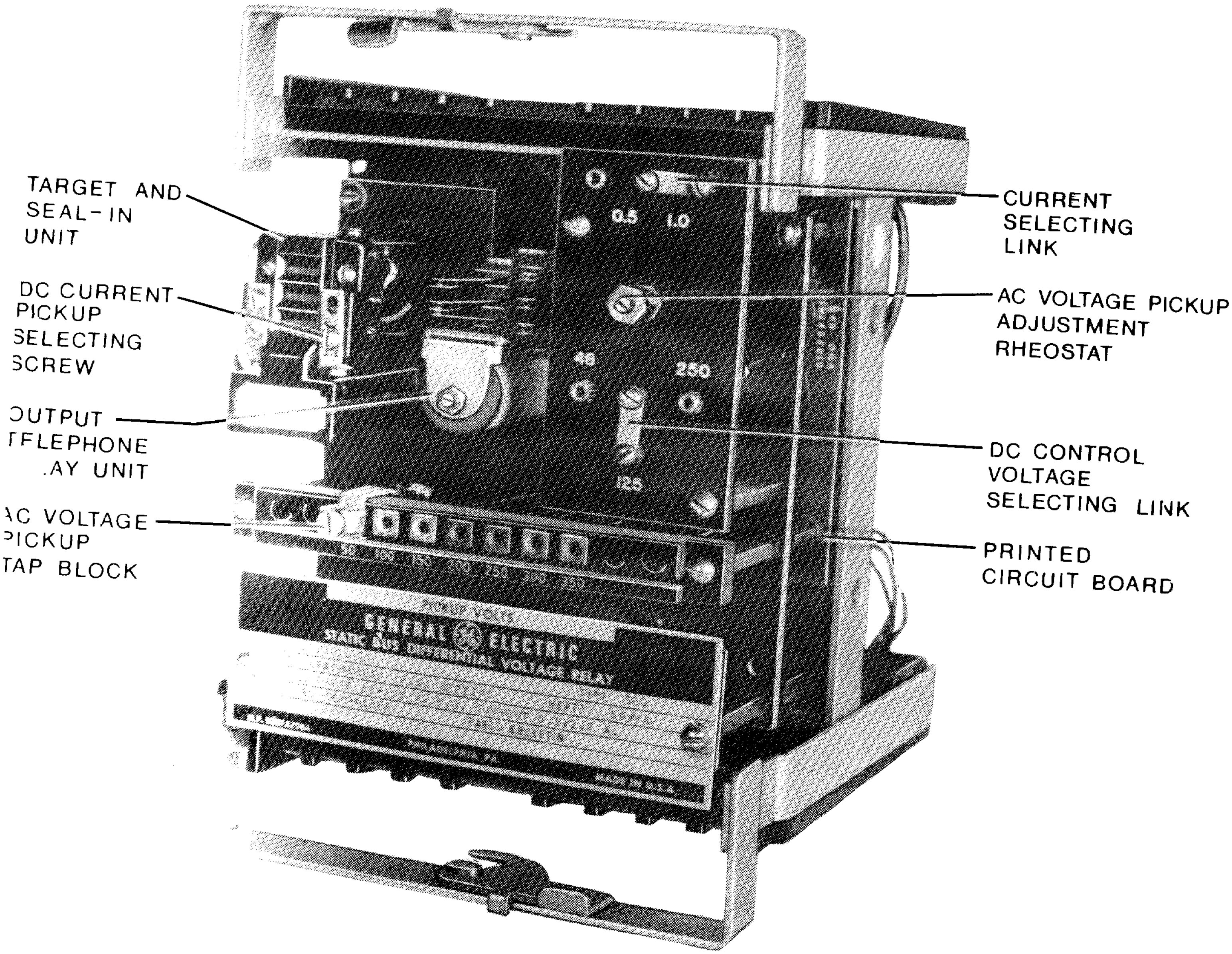


Figure 19 (8042393) Type SBD11B Relay Out of Case, 3/4 Front View

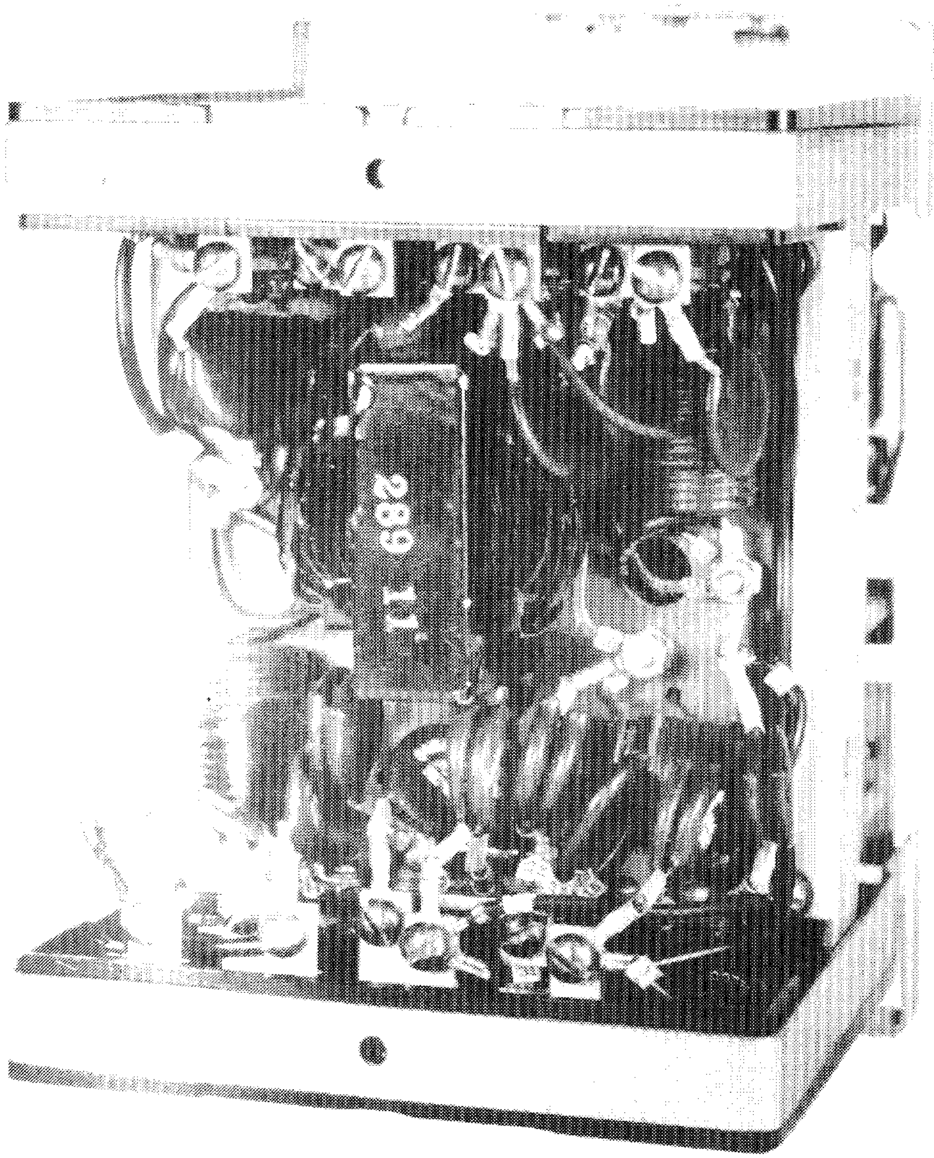


Figure 20 (8042391) Type SBD11B Relay Out of Case, Back View

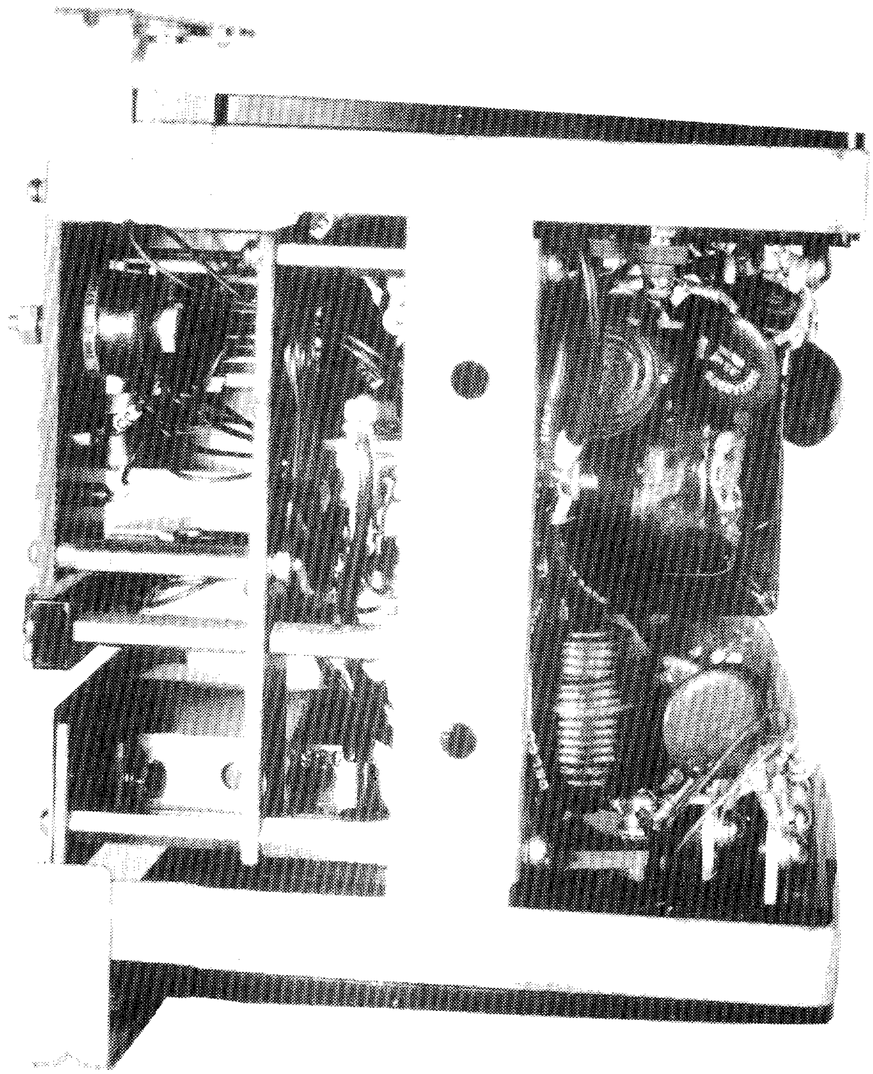


Figure 21 (8042390) Type SBD11B Relay Out of Case, Left Side View

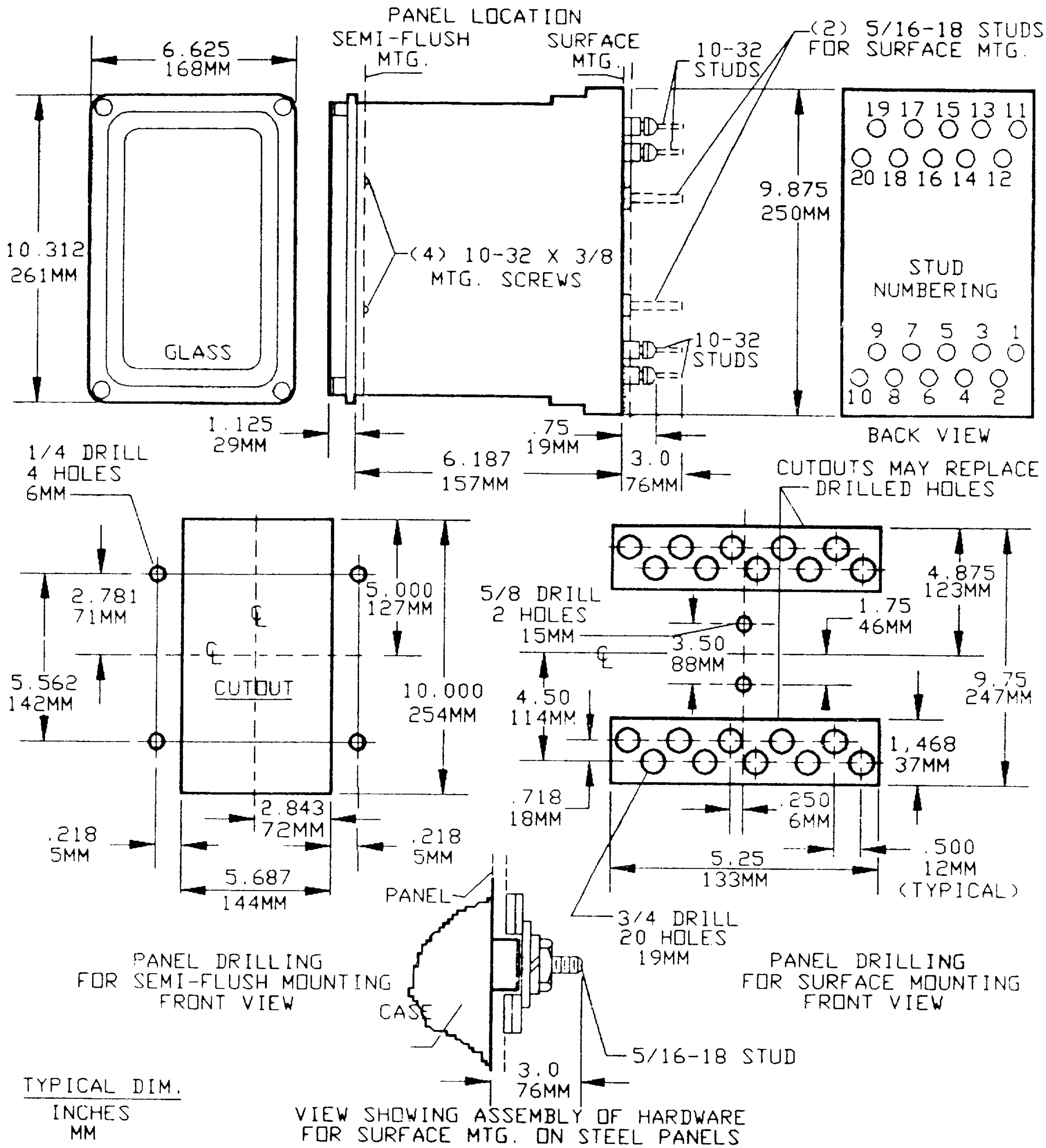


Figure 22 (6209272-7) Outline and Panel Drilling Dimensions for the S2 Size Case

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