![ABB]

Type SA-1
Generator Differential Relay
Class 1E Application

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(|) Denotes Change Since Previous Issue

⚠ CAUTION

Before putting relays into service, operate the relay to check the electrical connections. Close red handle switch last when placing relay in service. Open red handle switch first when removing relay from service.

1.0   APPLICATION

These relays have been specially designed and tested to establish their suitability for Class 1E applications in accordance with the ABB relay program for Class 1E Qualification Testing as detailed in the ABB bulletin STR-1.

"Class 1E" is the safety classification of the electric equipment and systems in nuclear power generating stations that are essential to emergency shutdown of the reactor, containment isolation, cooling of the reactor, and heat removal from the containment and reactor, or otherwise are essential in preventing significant release of radioactive material to the environment.

The SA-1 relay is a three-phase high-speed relay used for differential protection of ac generator and motors. With proper selection of current transformers, the relay is unaffected by dc transients associated with asymmetrical through short circuit conditions.

Current transformer burden in ohms should not exceed $(N_P V_{CL})/133$; further, the burden factor BF, should not differ by more than a 2 to 1 ratio between the two sets of ct's. The above terms are defined as:

N_P =   the proportion of the total number of ct turns in use (per unit)

V_{CL} =   current transformer relaying accuracy class voltage

BF = $\dfrac{1000R_B}{N_P V_{CL}}$

R_B =   resistance of the burden, excluding ct winding resistance

For example, if the 400/5 tap of a 600/5 multi-ratio ct is used, N_P = 400/600 = 0.67. If this ct has a C200 rating, V_{CL} = 200, and the burden should not exceed:

$$\frac{N_P V_{CL}}{133} = \frac{0.67 \times 200}{133} = 1.0 \text{ ohm}$$

Assuming a resistance burden of R_B = 0.5 ohms, the burden factor, BF is:

$$BF = \frac{1000R_B}{N_P V_{CL}} = \frac{1000 \times 0.5}{0.67 \times 200} = 3.8$$

The other set of ct's may then have a burden factor as high as 2 x 3.8 = 7.6, or as low as 1/2 x 3.8 = 1.9.

If the other set of ct's also has a burden of 0.5 ohms, a C100, C200, or C400 rating would be satisfactory since the burden factors are 7.6, 3.8 and 1.9 respectively.

In the usual application, the 2 to 1 criteria can be ignored if the maximum R_B is 0.5 ohm or less.

In calculating the burden, use the one-way lead burden between the relay and the ct.

2.0 CONSTRUCTION

The type SA-1 relay consists of:

- Restraint Circuit
- Sensing Circuit
- Trip Circuit
- Surge Protection Circuit
- Operating Circuit
- Amplifier Circuit
- Indicating Circuit
- External Reactors

The principal parts of the relay and their location are shown in Figures 1 through 4 (page 5 thru page 9) and Figure 14 (page 16).

2.1 RESTRAINT CIRCUIT

The restraint circuit of each phase consists of a center-tapped transformer, a resistor, and a full-wave rectifier bridge. The outputs of all the rectifiers are connected in parallel. The parallel connection of rectifiers is a maximum voltage network. Hence, the voltage applied to the filter circuit is proportional to the phase current with the largest magnitude.

2.2 OPERATING CIRCUIT

The operating circuit consists of a transformer, a resistor, and a full wave rectifier bridge. The outputs of all the rectifiers are connected in parallel. This parallel connection of rectifiers is a maximum voltage network. Hence, the voltage applied to the filter circuit is proportional to the differential current with the largest magnitude.

2.3 SENSING CIRCUIT

The sensing circuit is connected to the output of the restraint filter circuit, the operating filter circuit and the input to the amplifier circuit.

2.4 AMPLIFIER CIRCUIT

The amplifier circuit consists of a two-transistor amplifier which controls the operation of a relaxation oscillator.

The amplifier circuit is connected to the sensing circuit such that it receives the difference in output of the restraint filter and the operating filter. Thus, the polarity of the input voltage to the amplifier depends upon the relative magnitude of the voltages appearing on the restraint and operating filters. When the voltage output of the operating filter is greater than the output voltage of the restraint filter, a voltage of a certain polarity appears across the input of the amplifier. To trigger the amplifier requires that the output voltage of the operating filter be greater than the output voltage of the restraint filter.

2.5 TRIP CIRCUIT

The trip circuit consists of a thyristor which has an anode, cathode, and a gate. The anode of the thyristor is connected to the positive side of the dc supply and the cathode of the thyristor is connected to the negative side of the dc supply through the trip coil of a breaker. The gate of the thyristor is connected to the output of the amplifier circuit through a pulse transformer.

With no gate current flowing, the thyristor acts as an open circuit to the breaker trip coil. When a gate current is applied to the thyristor, the thyristor connects the breaker trip coil to the dc supply.

2.6 INDICATING CIRCUIT

The indicating circuit is triggered by a signal from the amplifier of the relay. Under normal or non-fault conditions, the indicating circuit is turned off. When a fault is applied to the relay, the amplifier will conduct to cause a signal to flow into the indicator circuit. When the indicator circuit is triggered, the lamp will turn on. This lamp will remain lit until the indicator circuit is interrupted by resetting the micro-switch.

2.7 SURGE PROTECTION CIRCUIT

The surge protection circuit consists of two capacitors (C10 and C11) and a RC network which is connected across the anode and cathode of the tripping thyristor to prevent the SCR from firing by a surge voltage on the dc supply.

2.8 EXTERNAL REACTORS

Three reactors are mounted on a metal plate with a separate terminal strip. The reactors are of the saturable type.

3.0 OPERATION

The type SA-1 relay is connected to the protected apparatus as shown in Figure 5 (page 10). On external faults, current flows through the primary winding of the restraint transformers to induce a voltage on the restraint side of the sensing circuit. If the two sets of main current transformers have different performances, some current will flow out of the mid-tap of the restraint transformers to the operating transformers. This will produce a voltage on the operating side of the sensing circuit. With the relay correctly applied, sufficient restraint voltage will exist to prevent the operating voltage from triggering the amplifier.

The percentage slope characteristic of the relay limits the operating voltage on heavy external faults where the performance of the two sets of current transformers may be quite different.

On internal faults, the operating coil current is the difference of the current flowing in each of the windings of the restraint transformer and sufficient operating voltage is available to overcome the restraint voltage.

4.0   CHARACTERISTICS

The percentage slope curves are shown in Figures 8 and 9 (page 12 and page 13). It will be observed that the relay operates at 5% unbalance at 5 amperes restraint (Figure 8, page 12) to provide high sensitivity for internal faults up to full load conditions. At 60 amperes restraint, the operating current required to trip the relay is 30 amperes or 50% unbalance (Figure 9, page 13). Thus, when 60 amperes through fault current is flowing, the output of the main current transformers may vary considerably without causing incorrect operation.

The minimum pickup of the relay is 0.14 amperes.

The time curve of the relay is shown in Figure 10 (page 14).

The frequency response characteristic of the Type SA-1 relay is shown in Figure 11 (page 15).

5.0   ENERGY REQUIREMENTS

5.1   EACH RESTRAINT CIRCUIT

Burden at 5 amperes is 0.25 VA
Continuous rating 20 amperes
1 second rating 300 amperes

5.2   OPERATING CIRCUIT

The burden imposed by the operating circuit on each current transformer is variable because of the saturating transformer. At 0.5 amperes, it is 1.48 ohms, and at 60 amperes, it is 0.47 ohms.

Note that the neutral reactors are in series with the operating coil circuit. They also have a saturating characteristic, with a maximum impedance of roughly 80 ohms.

Continuous rating 10 amperes
1 second rating 200 amperes

5.3   AMPLIFIER

The dc burden on the station battery is:

Volts	Milliamperes	Watts
125 dc	55	6.9
48 dc	60	2.9

6.0   SETTINGS

There are no taps on either transformer and, consequently, there are no settings to be made. The 48/125 Vdc relays are normally shipped for 125 volts. For 48 Vdc applications use the mid tap on the resistor mounted at the top of the relay. The red dot on the resistor is the common point – DO NOT REMOVE.

7.0   INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from moisture. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting.

Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws.

The external reactor assembly should be mounted and wired per "Interwiring Connection Drawing", Figure 7 (page 11).

For detailed FT case information, refer to Instruction Leaflet 41-076.

8.0   ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer.

8.1   ROUTINE TEST

The following check is recommended to insure that the relay is in proper working order. All checks can best be performed by connecting the relay per the test circuit of Figure 12 (page 15). Due to high impedance of the external reactor, prior to saturation, the test circuit of Figure 12 should be used to test the relay only. The reactors can be checked by applying

0.2 amperes 60 hertz and reading the voltage drop across the reactor with a high impedance true rms reading voltmeter. The voltage drop will be between 20 and 26 V (true rms). For 0.4 amperes input, the reading should be between 24 and 31 volts (true rms).

1. **Minimum Trip Current** with I_R set at zero amperes, apply $0.14 \pm 5\%$ amperes operating current to each operating circuit of the relay. The relay should operate and the indicator lamp should light.

2. **Differential Characteristic**

   a) Apply I_R of 5 amperes and adjust the operating current until the relay operates. The relay should operate and the indicator lamp should light with an operating current of 0.25 ± 0.012 amperes. Repeat for each phase of the relay.

   b) Apply I_R of 60 amperes and adjust the operating current until the relay operates. The relay should operate and the indicator lamp should light with an operating current of 30 ± 3 amperes. Repeat for each phase of the relay.

8.2   MAINTENANCE

All relays should be checked once a year to detect the electronic component failures which occur on a random basis. The tantalum capacitors C1, C2, C3, C4 and C13 may have a common mode failure characteristic and should be checked visually for symptoms of electrolyte leakage every year and replaced if necessary.

9.0   CALIBRATION

Use the following procedure for calibrating the relay if the relay adjustments have been disturbed. This procedure should not be used until it is apparent the relay is NOT in proper working order.

1. **Minimum Trip Current** – Connect the relay per test circuit of Figure 12 (page 15). With switch K open, adjust the operating resistor in the rear of the relay until the relay operates with I_0 equal to 0.14 amperes. Do not make adjustments to the resistor unless the dc is disconnected.

   The indicator lamp should light when the relay operates.

   Repeat for each phase of the relay.

2. **Percentage Slope Characteristic (Low Current)** – Set I_R equal to 5 amperes and adjust the restraint resistor in the rear of the relay until the relay operates with $I_0 = 0.25 \pm 0.012$ amperes. Do not adjust resistor with dc applied to relay.

   The indicator lamp should light when the relay operates.

   Repeat for each phase of the relay.

   Percentage Slope Characteristic (High Current) – Set I_R equal to 60 amperes for the operating current of 30 amperes. Replace the resistor R17 if necessary. The value of R17 can be between 0 and 100 ohms. Repeat for the other two phases, if necessary, replacing R18 and R19 respectively.

3. **Electrical Checkpoints** – See Table 1 (page page 6)

10.0 ELECTRICAL CHECKPOINTS

Connect relay per test circuit of Figure 12 (page 15). All voltage readings should be made with a high resistance voltmeter. Refer to Figure 4 (page 9) for the location of checkpoints. Voltage readings are approximate. The voltage readings "Input to Amplifier" should NOT be taken with relay in service.

11.0 RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to customers who are equipped for doing repair work. When ordering parts, always give the nameplate data.
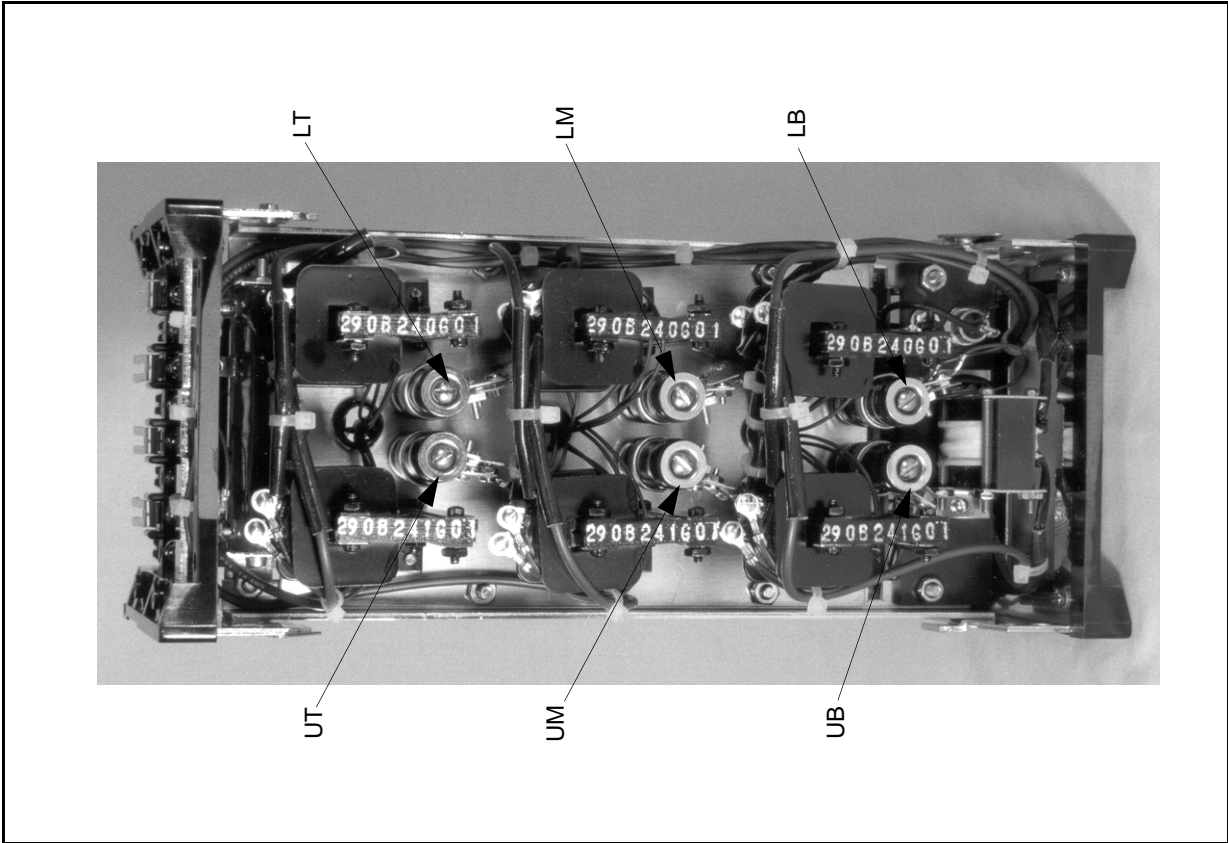
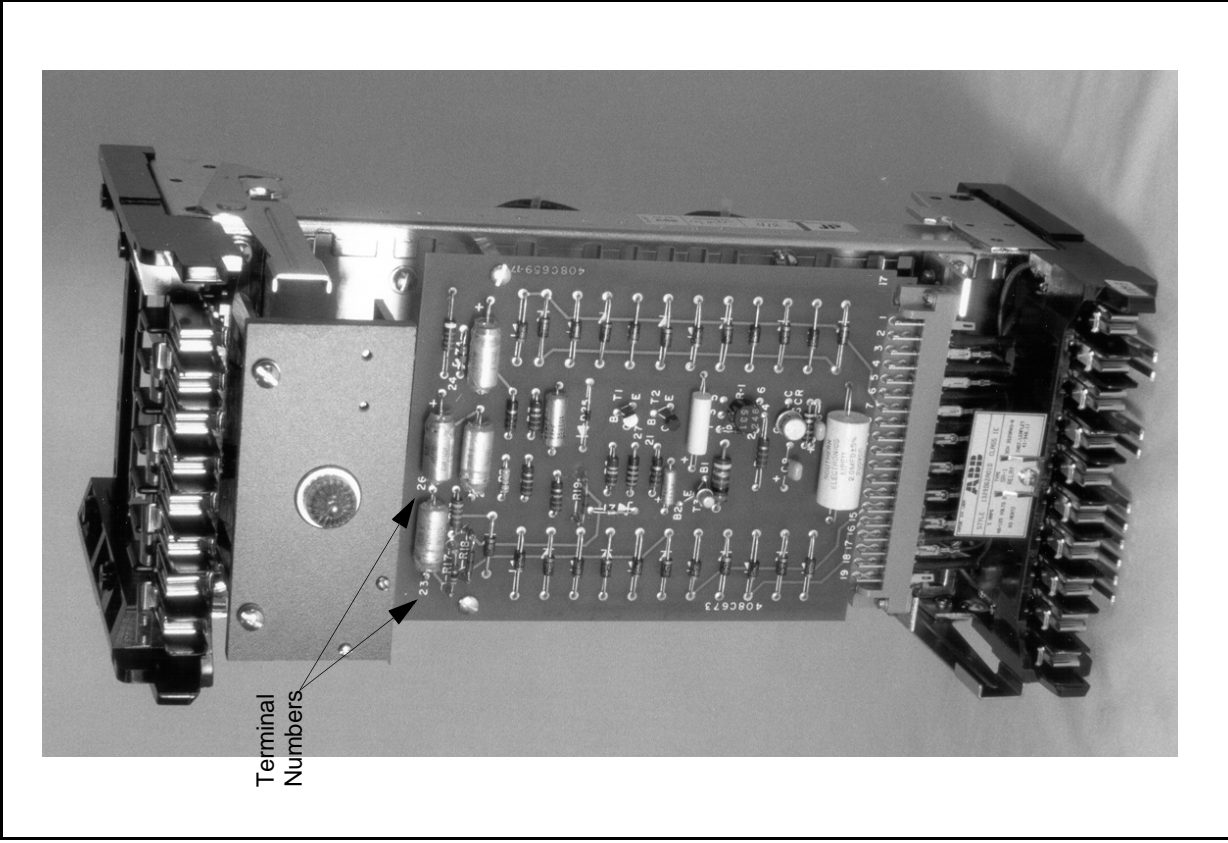*Figure 2. Type SA-1 Generator Differential Relay without Case (Rear View)*

Figure 1. Type SA-1 Generator Differential Relay without Case (Front View)

Table 1:
(Values in Parenthesis Represent Desensitized SA-1)

CIRCUIT	PRIMARY CURRENT	PHASE	CHECKPOINTS (TYPICAL VALUE)		
			TERMINAL	VALUE	FUNCTION
Operating	0.14A	1 2 3	2 - 7 3 - 6 4 - 5	2.5 ac 2.5 ac 2.5 ac	Input to operate rectifier Input to operate rectifier Input to operate rectifier
Sensing (Operating)	0.14A	Any Phase	+ to - 23 - 26 24 - 26 24 - 8 8 - 25 25 - 26	 2.1 dc 1.85 dc 0.55 dc 0.65 dc 0.65 dc	Ref: a = b + c + d Output to rectifier a. Output to operating sensing circuit b. Input to amplifier c. d. Output to restraint sensing circuit
	30.0A	Any Phase	+ to - 24 - 26	51.0 dc	
Restraint	5.0A	1 2 3	18 - 13 17 - 14 15 - 16	6.0 ac 6.0 ac 6.0 ac	Input to restraint rectifier Input to restraint rectifier Input to restraint rectifier
Sensing (Restraint)	5.0A	Any Phase	+ to - 25 - 26 25 - 8 8 - 24 24 - 26	 2.1 dc 1.2 dc 0.6 dc 0.3 dc	Ref: a = b + c + d a. Output to restraint sensing circuit b. c. Input to amplifier d. Output to operating sensing circuit
	60.0A	Any Phase	+ to - 25 - 26	42.0 dc	
Amplifier	0		+ to - 27 - 8 12 - 8 10 - 8	 0.7 dc 24.0 dc 24.0 dc	
	Minimum Trip Current +5%	Any Phase	+ to - 27 - 8 12 - 8 21 - 8	 0.5 dc 24.0 dc 10.0 dc	

NOTE: Terminal numbers refer to the printed circuit board (See Figure 4)

Table 2:
Electrical Parts List

CIRCUIT SYMBOL		REFERENCE	STYLE
Resistors	UT, UM, UB	60 Ohms, 25W	1875676
Resistors	LT, LM, LB	265 Ohms, 25W	1725542
Resistors	R14	1.8K, 40W	187A321H06
Zener	Z2	IN2986B	629A798H03
SCR			184A614H05
Reactor	L1		1478B98G01
SA Module Style Number 408C673G01 Sub 45			
Resistor	R1	270 Ohms, 1W	629A531H18
Resistor	R2	2K, 5%	184A763H34
Resistor	R3, R4, R5	15K, 5%	184A763H55
Resistor	R6	2.7K, 5%	184A763H37
Resistor	R7	68K, 5%	184A763H71
Resistor	R8	27K, 5%	184A763H61
Resistor	R9	2.2K, 5%	184A763H35
Resistor	R10	100 Ohms, 10%	187A643H03
Resistor	R11	220 Ohms, 5%	184A763H11
Resistor	R12	680 Ohms, 5%	184A763H23
Resistor	R13	47K, 5%	184A763H67
Resistor	R17, R18, R19	33 Ohms, 5%	187A290H13
Capacitor	C1, C2, C3, C13	25 MFD, 125V	184A637H01
Capacitor	C4	22 MFD, 35V	184A661H16
Capacitor	C5	0.5 MFD, 200V	187A624H11
Capacitor	C6	2.2 MFD, 35V	837A241H16
Capacitor	C7	2.0 MFD, 200V	187A624H05
Capacitor	C8, C9	0.47 MFD, 50V	762A680H04
Diode	D1 to D24	IN4821	188A342H16
Diode	D25, D26	IN645A	837A692H03
Zener	Z1	IN752A	186A797H12
SCR		K1149-13	184A640H13
Transistor	T1, T2	2N3417	848A851H02
Transistor	T3	2N2647	629A435H01
Transformer	TR-1		629A372H02
SPK Module Style Number 1584C01G01			
Resistor	R15	470 Ohms, 1W	187A643H19
Capacitor	C10, C11	0.01 MFD, 1.5KV	3536A32H02
Capacitor	C12	2.0 MFD, 200V	3509A33H01
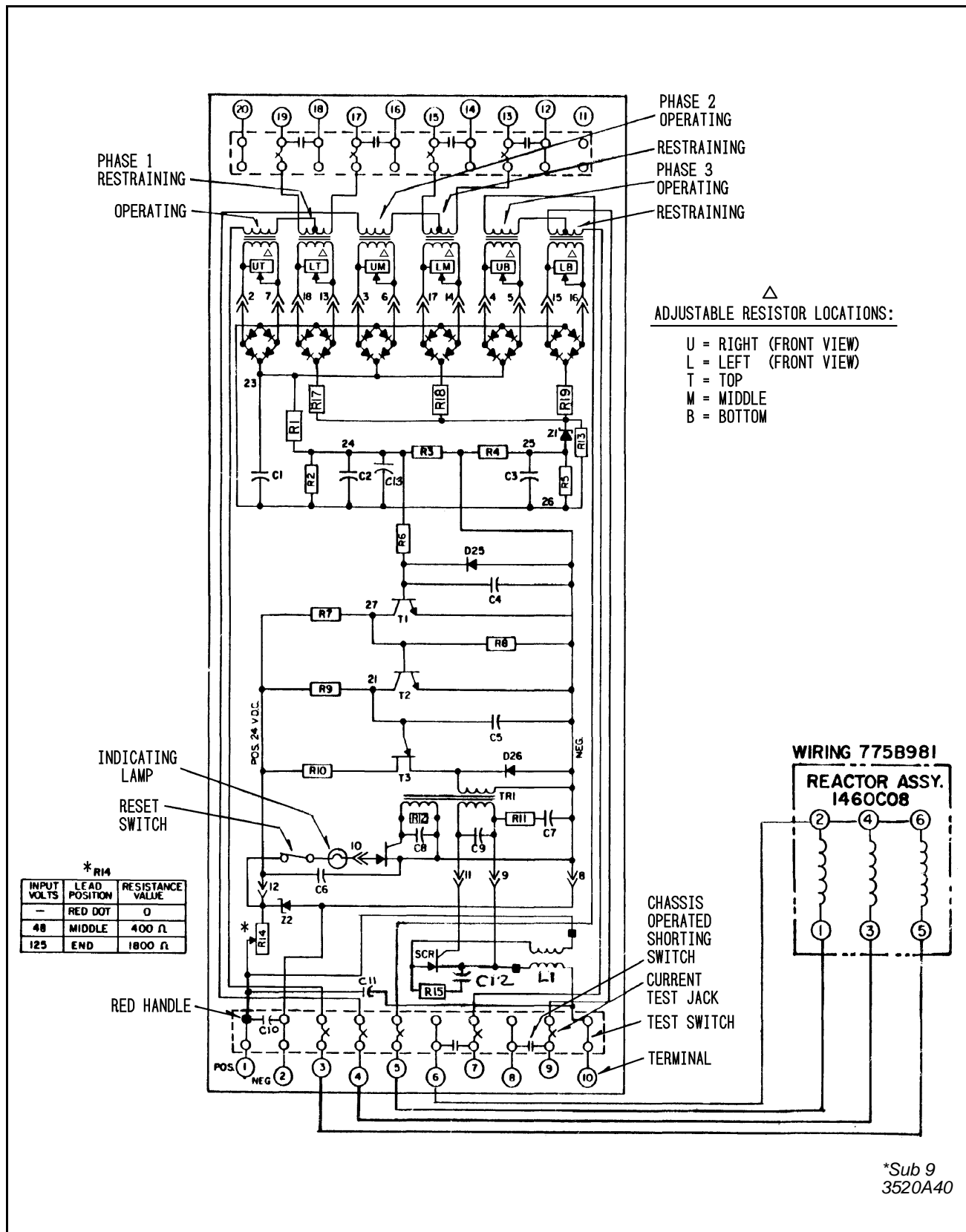
Figure 3. Internal Schematic of Type SA-1 Relay in Type FT-32 Case 48/125 Vdc
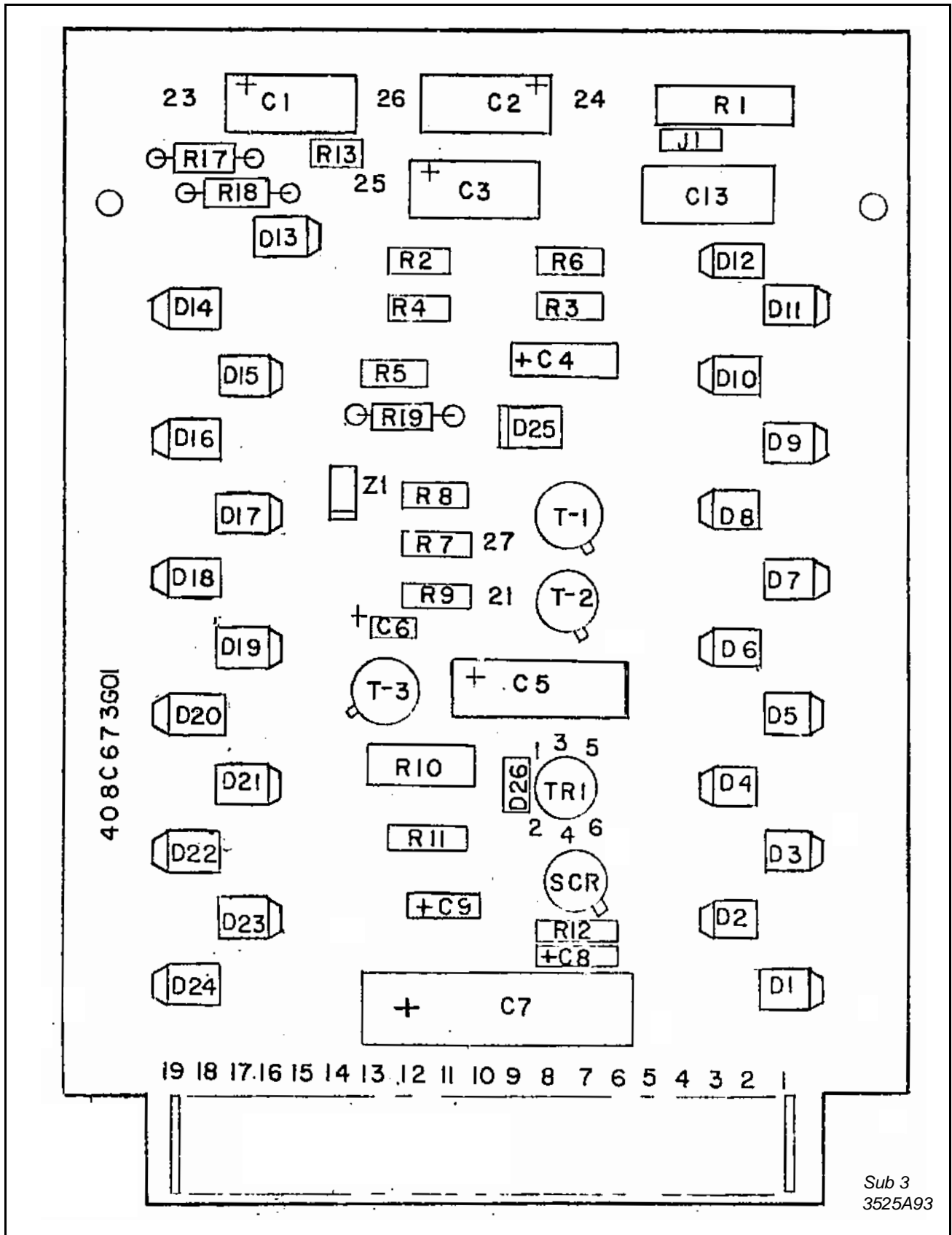
Figure 4. Component Location on Printed Circuit Board Type SA-1 Relay 48/125 Vdc
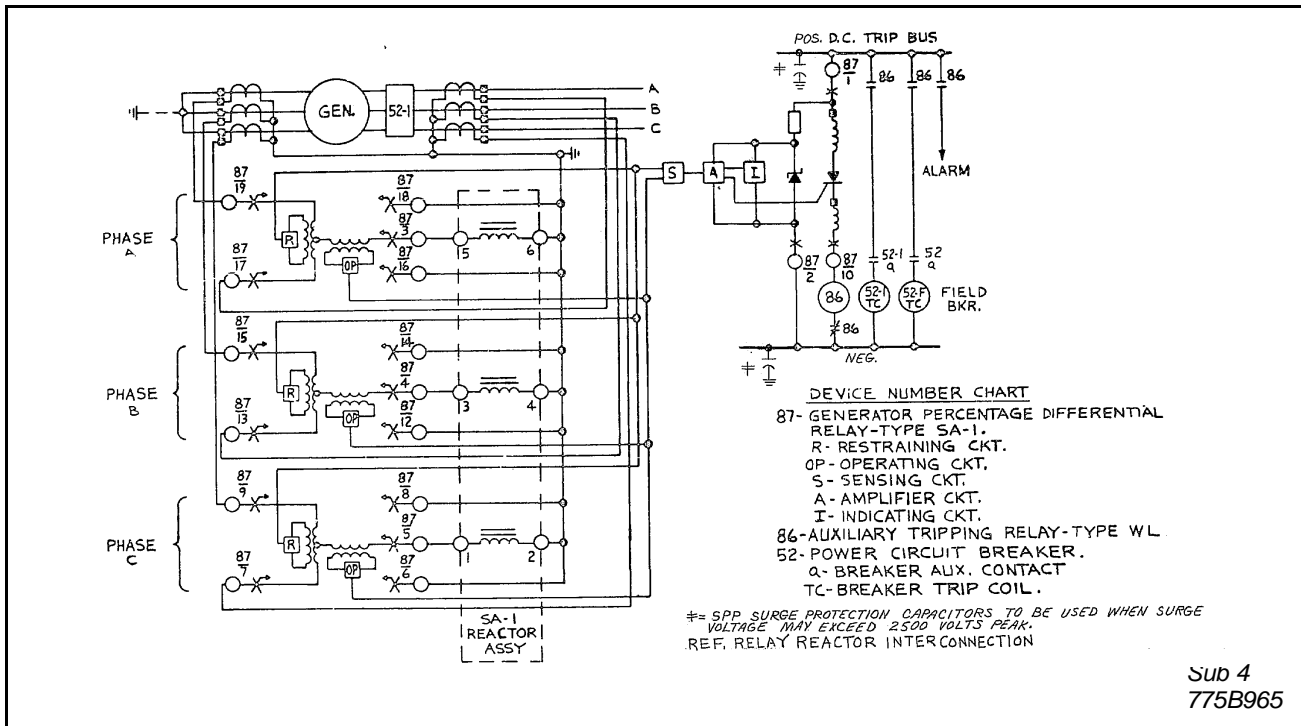
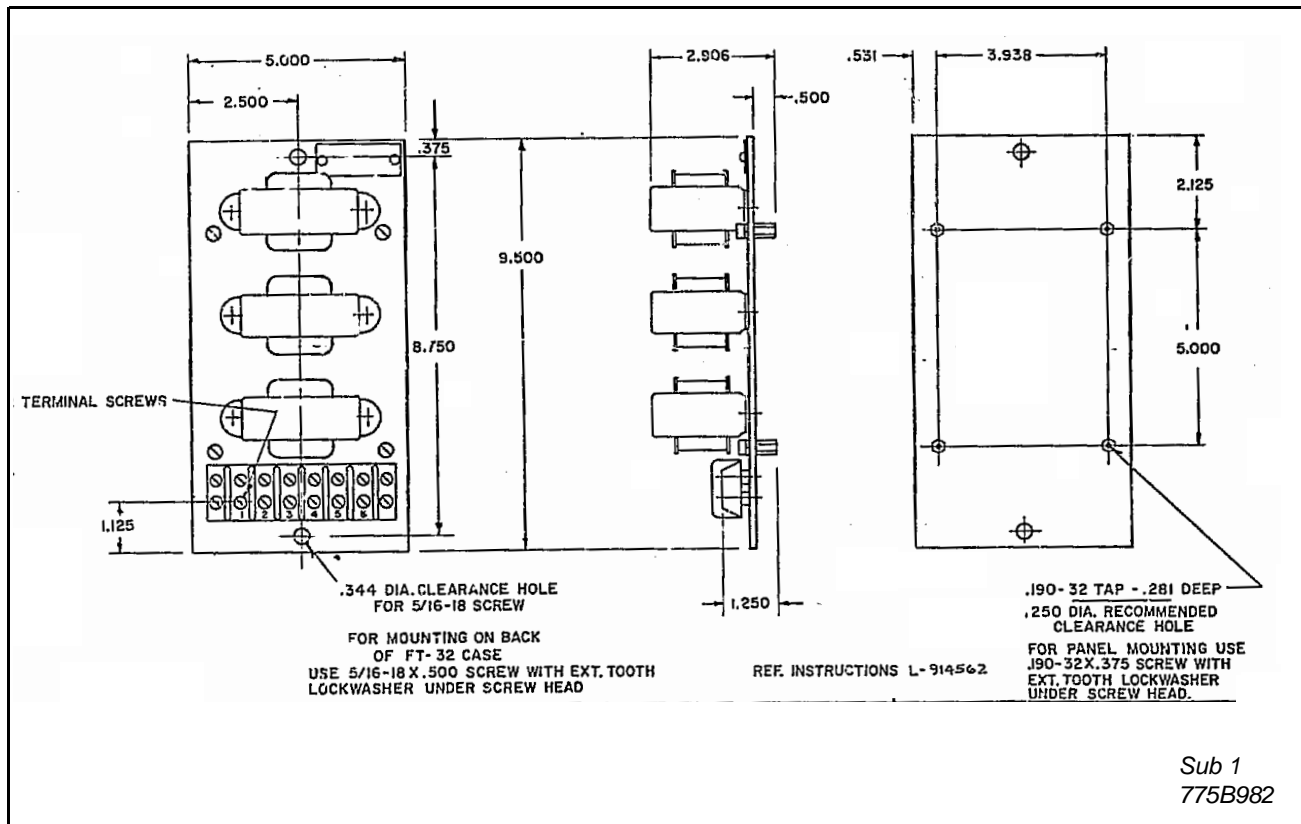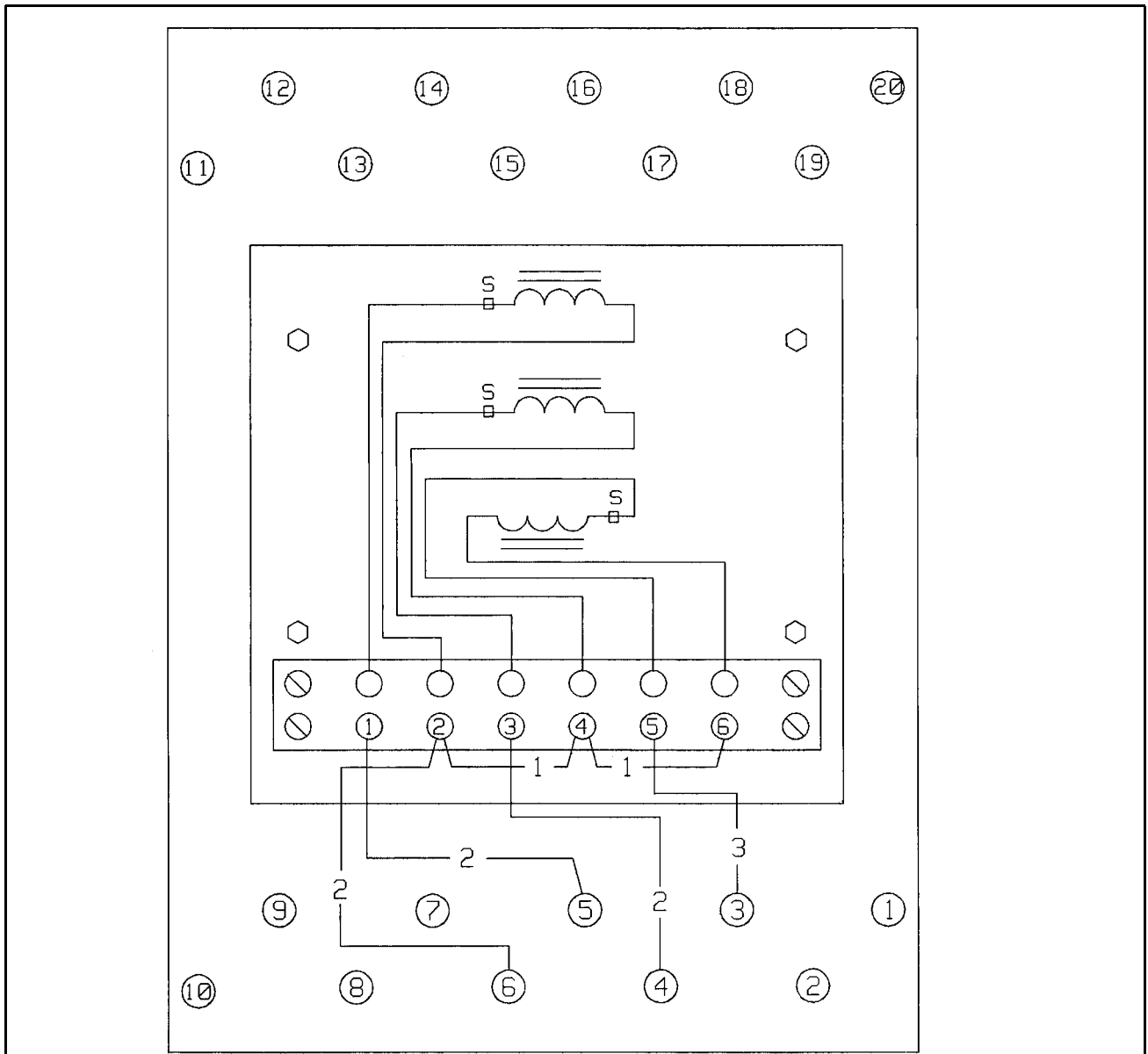Figure 5. External Schematic of Type SA-1 Relay for Generator Protection

Figure 6. Reactor Outline

Figure 7. Relay and Reactor Interconnection

NOTE: A - PLACE IT. 1 TO 3 IN IT. 5 FOR SHIPPING

Lead IT.	L	SCREW SIZE	
		A	B
1	3.00	.164 - 32	.164 - 32
2	4.00	.164 - 32	.190 - 32
3	3.00	.164 - 32	.190 - 32
4	13.438	.164 - 32	.190 - 32

ITEM	PART NAME	STYLE DWG.	ITEM GR.	NOTE CODE	ENG. REF.	REQ
01	LEAD	57Z0301	616	A	63-D-653	2
02	LEAD	57Z0401	622	A	63-D-655	3
03	LEAD	57Z0301	622	A	63-D-655	1
05	BAG	836A618	H04	B	27-D-5478	1

Sub 5
775B981
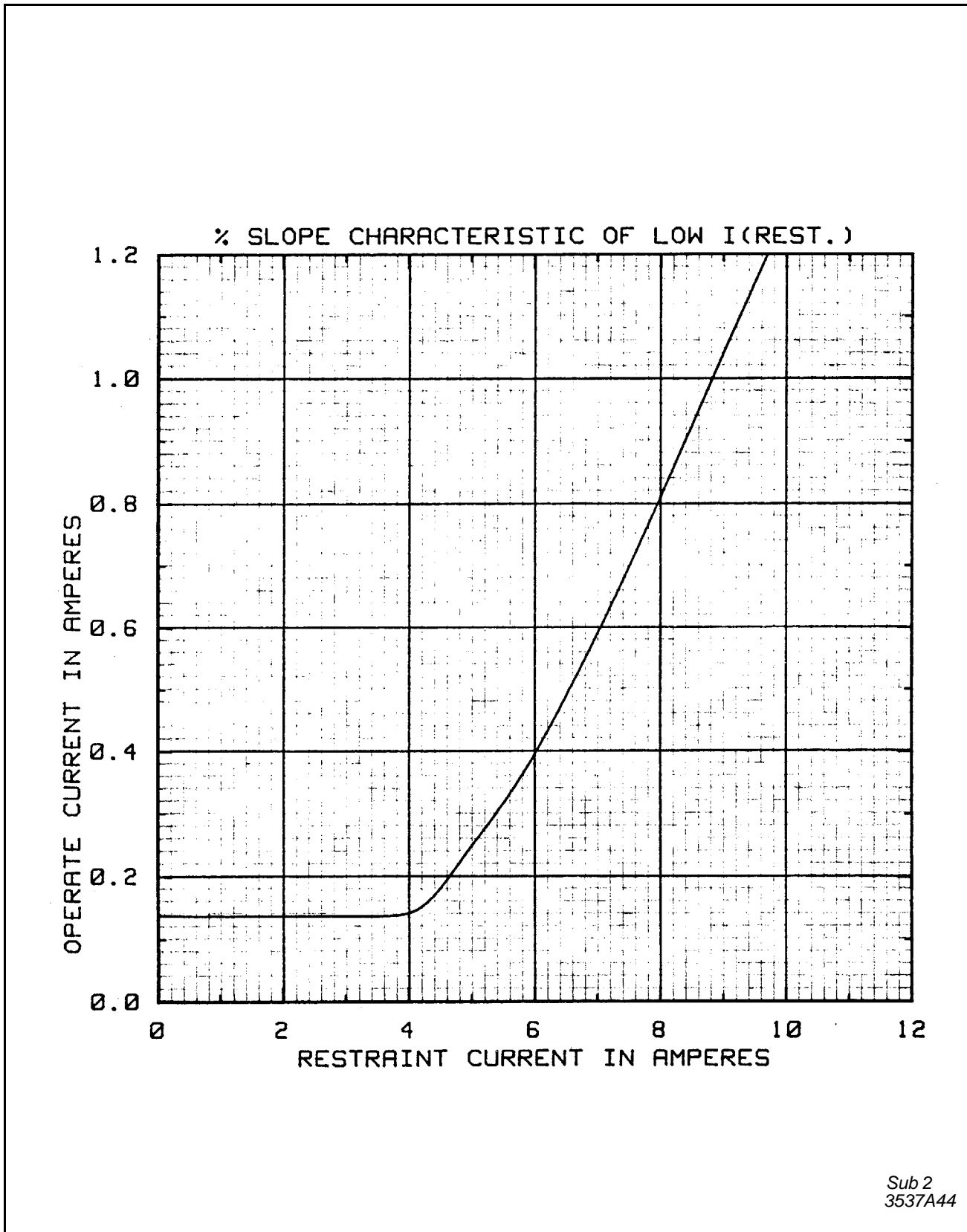
Figure 8. *Percentage Slope Characteristic at Low Value of Restraint Current*
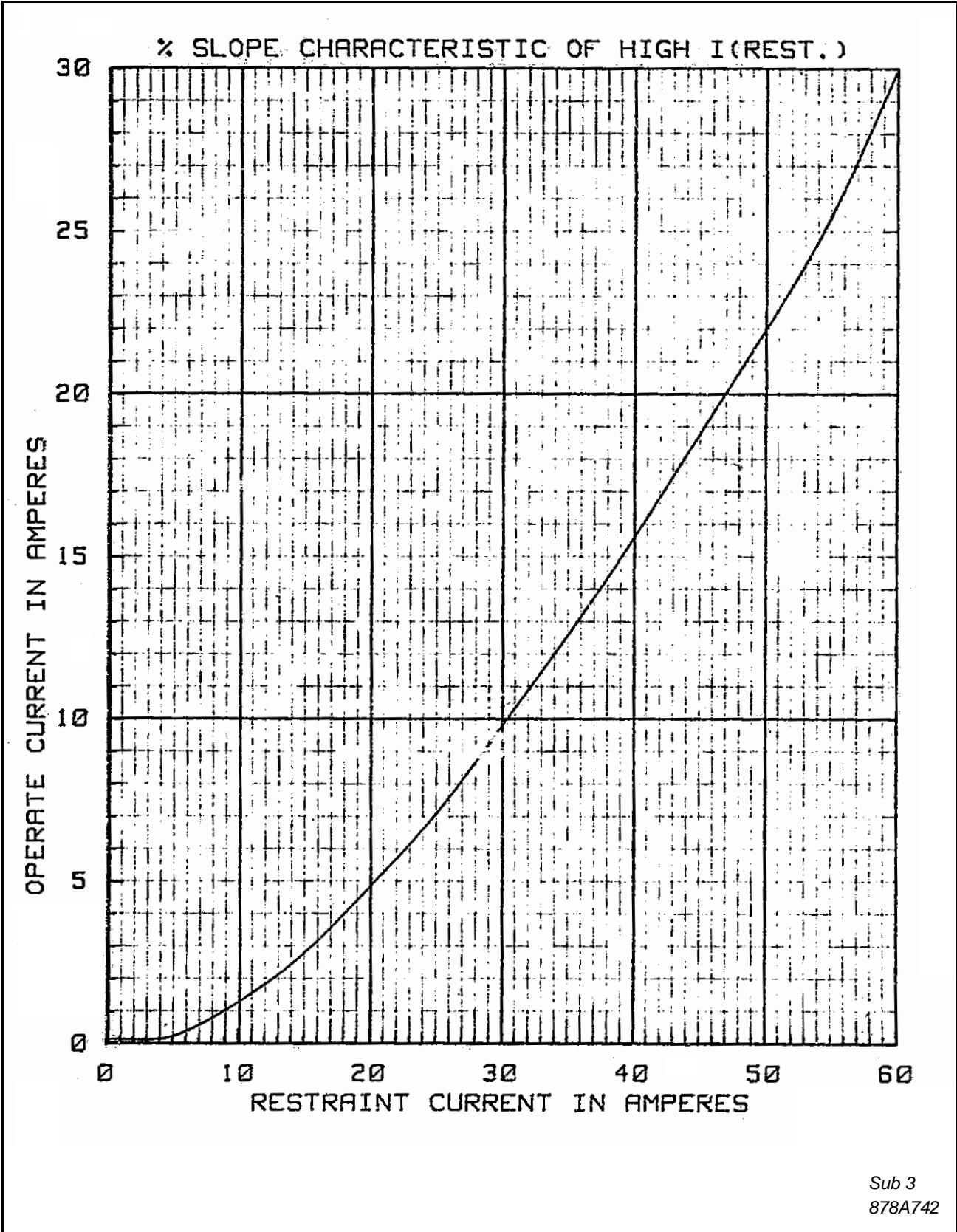
Figure 9. Percentage Slope Characteristic at High Value of Restraint Current
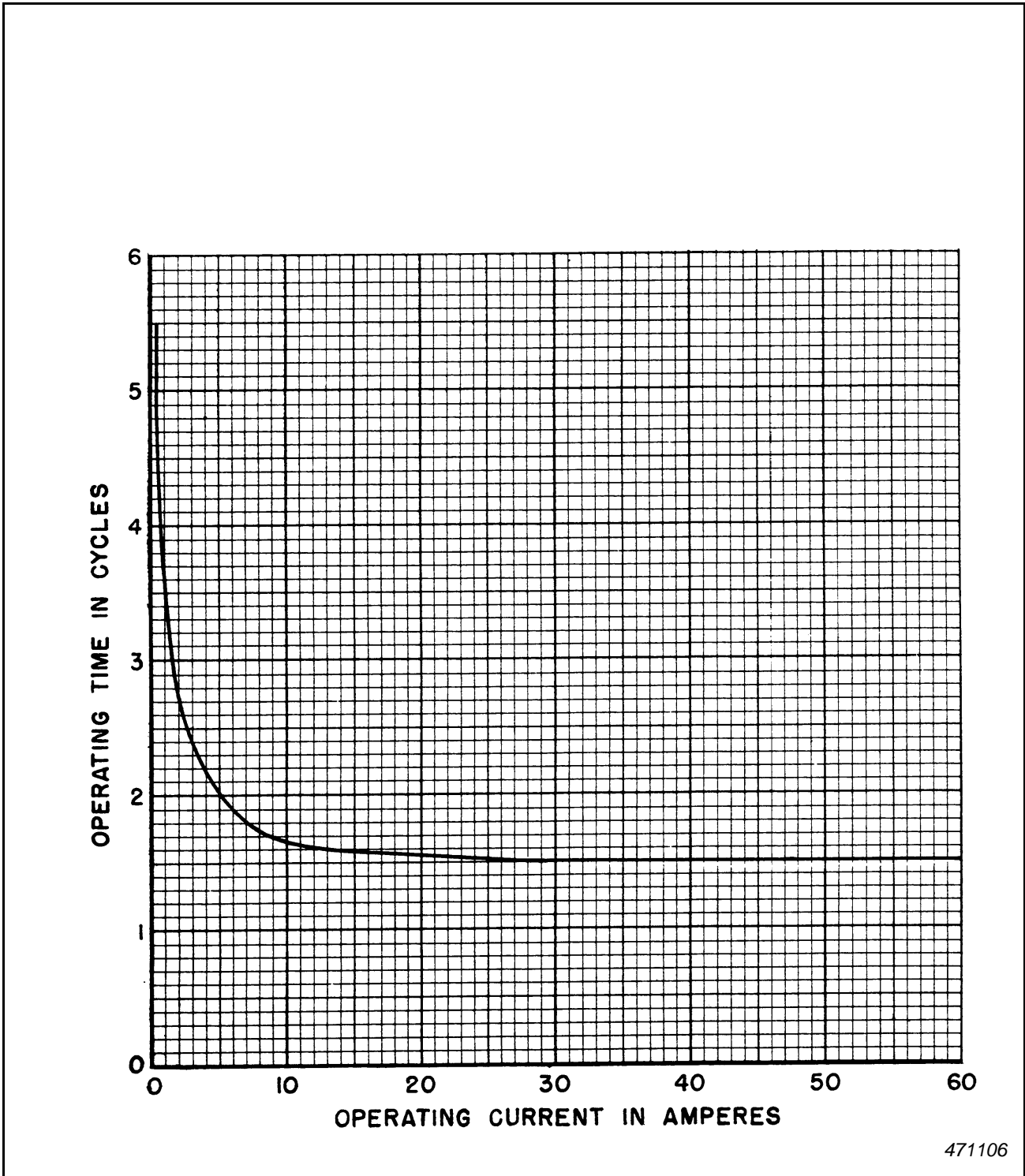
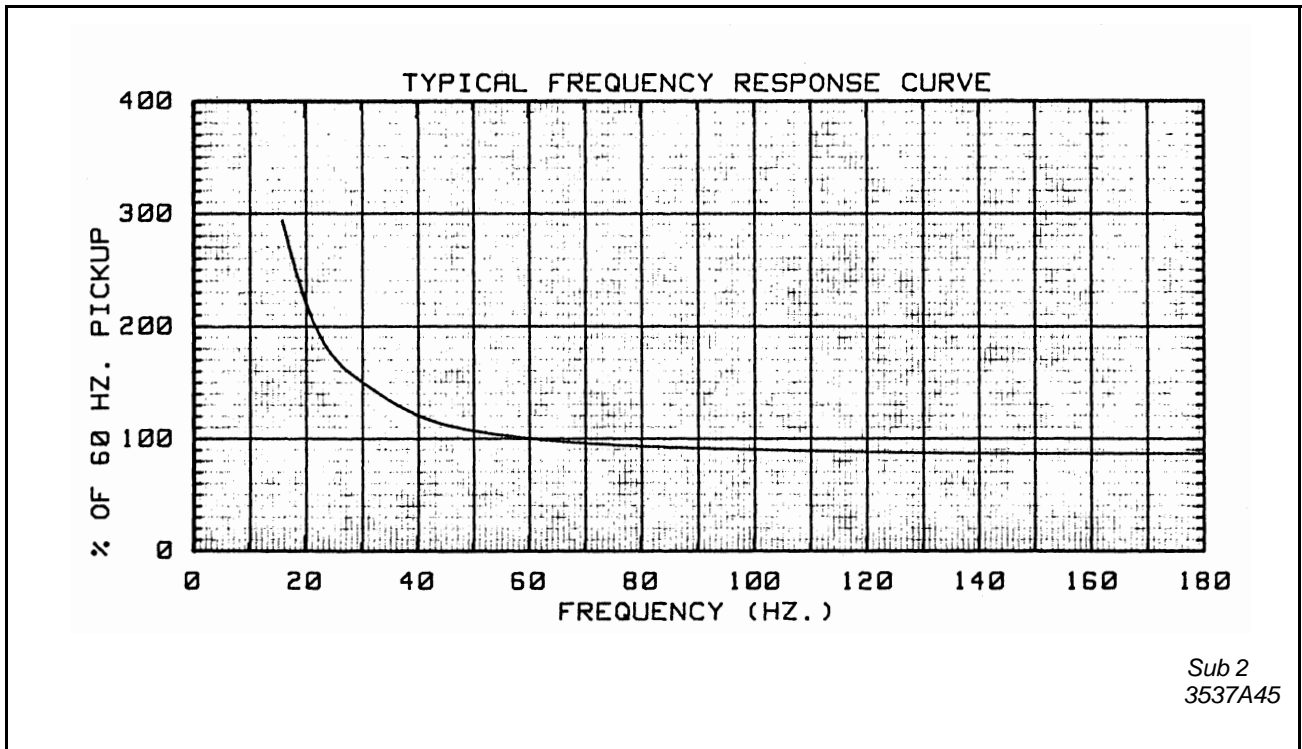*Figure 10. Typical Operation Time Characteristic*

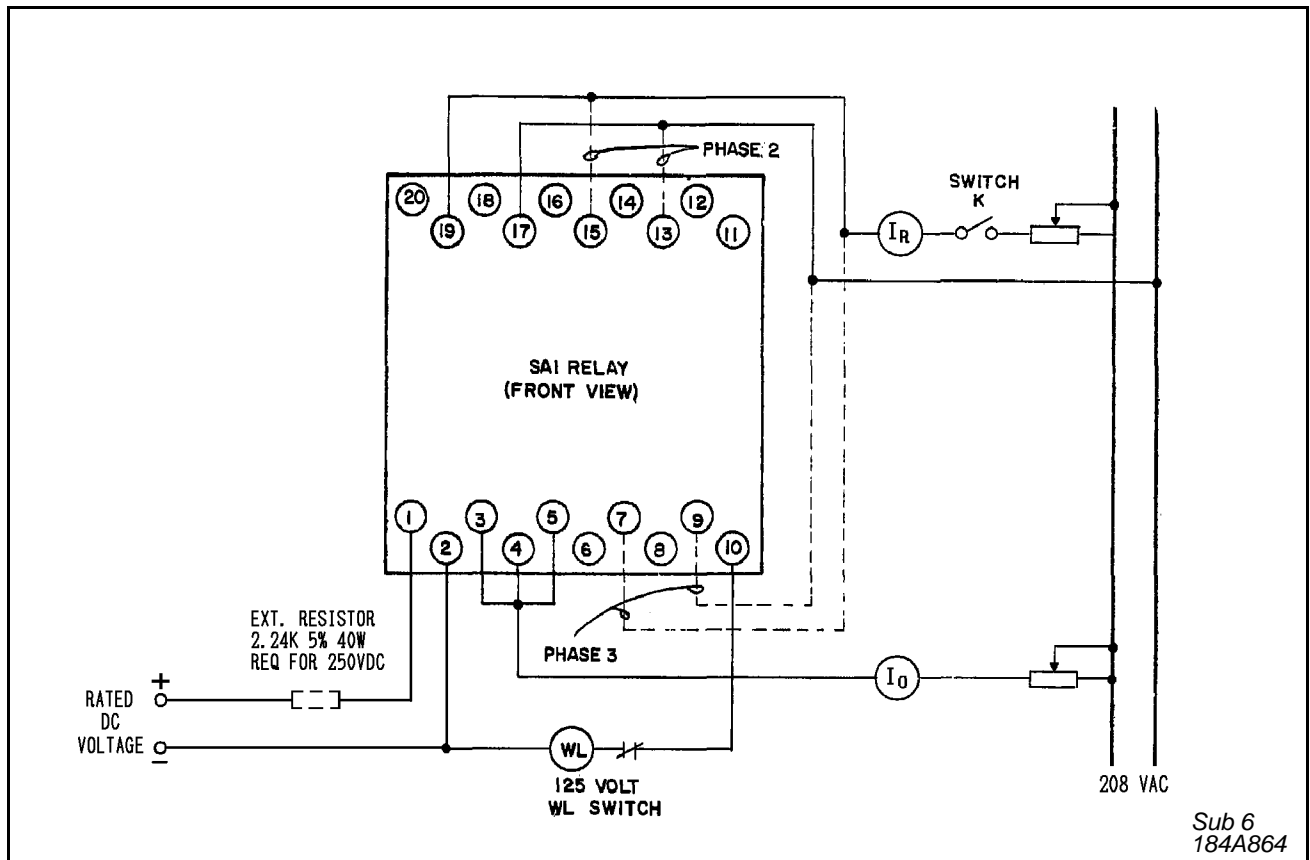Figure 11. Typical Frequency Response Curve
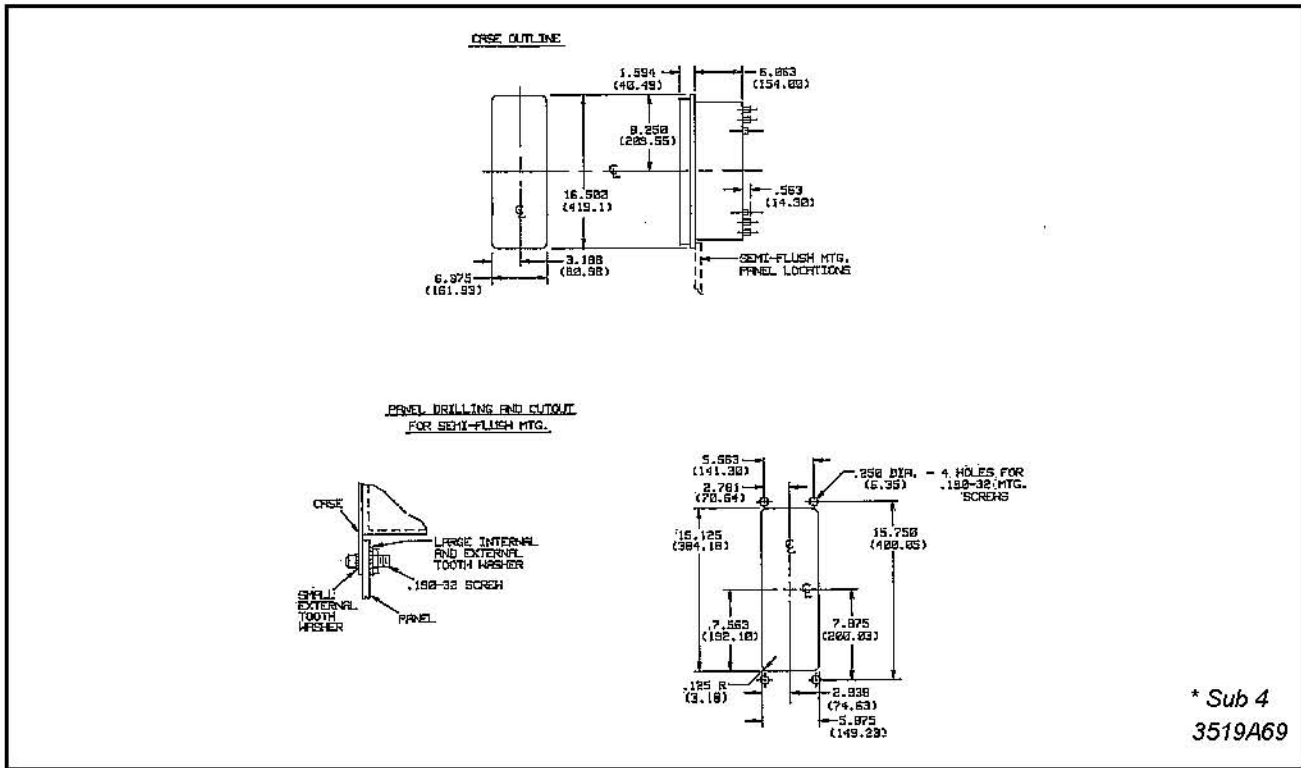

Figure 12. Test Diagram for Type SA-1 Relay

Figure 13. Outline and Drilling Plan for Type SA-1 Relay in Type FT-32 Case for Class 1E Application
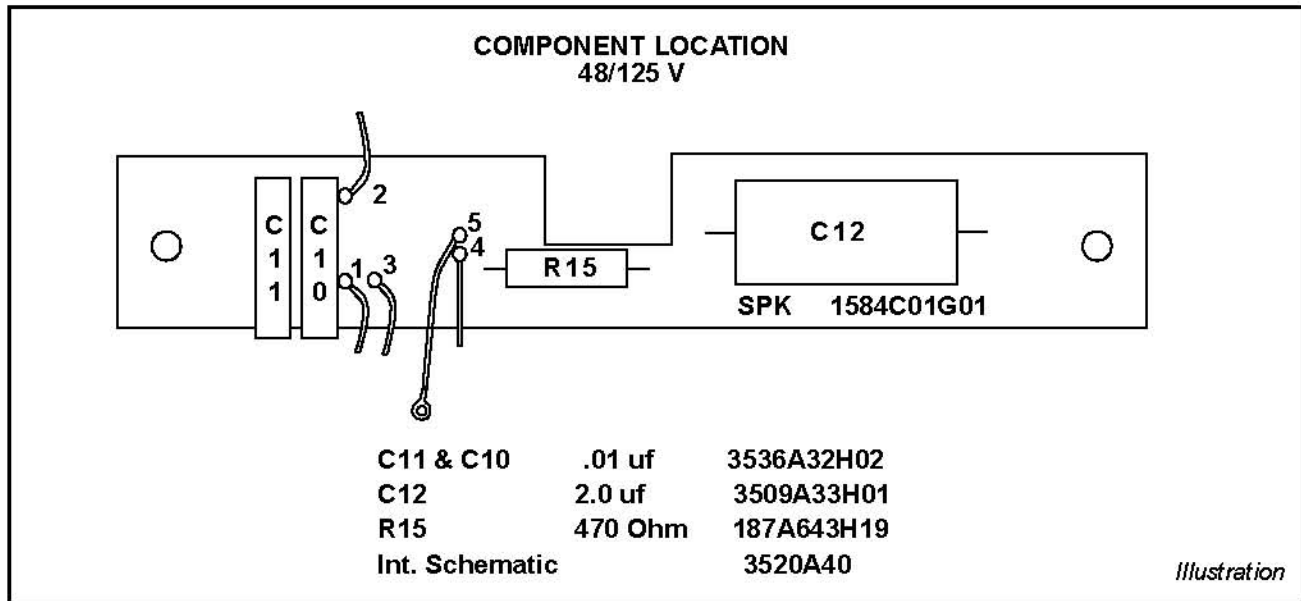

Figure 14. Relay Type SA-1 Class 1E Component Location of the SPK Module