INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SA-1 GENERATOR DIFFERENTIAL RELAY

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.

APPLICATION

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 = proportion of total number of CT turns in use

V_{CL} = current transformer 10L accuracy class voltage

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

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 10L200 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:

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

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 $\frac{1}{2}$ x 3.8 = 1.9. If the other set of CT's also has a burden of 0.5 ohms, a 10L100, 10L200, or 10L400 rating would be satisfactory since the burden factors are 7.6, 3.8 and 1.9 respectively.

In calculating the burden, use the one-way lead burden.

SUPERSEDES I. L. 41-348.1B
* Denotes change from superseded issue.

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CONSTRUCTION

The type SA-1 relay consists of a Restraint Circuit, Operating Circuit, Sensing Circuit, Amplifier Circuit, Trip Circuit and Indicating Circuit. The principal parts of the relay and their location are shown in Figs. 1 through 4.

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.

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 phase current with the largest magnitude.

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.

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 amplfier. To trigger the amplifier requires that the output voltage of the operating filter be greater than the output voltage of the restraint filter.

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.

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.

OPERATION

The type SA-1 relay is connected to the protected apparatus as shown in Fig. 5. 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 voltages 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 sum of the current flowing in each of the windings of the restraint transformer and sufficient operating voltage is available to overcome the restraint voltage.

CHARACTERISTICS

The percentage slope curves are shown in Figs. 6 & 7. It will be observed that the relay operates at 5% unbalance at 5 amperes restraint 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. 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 Fig. 8.

The frequency response characteristic of the type SA-1 relay is shown in Fig. 9.

ENERGY REQUIREMENTS

Each Restraint Circuit

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

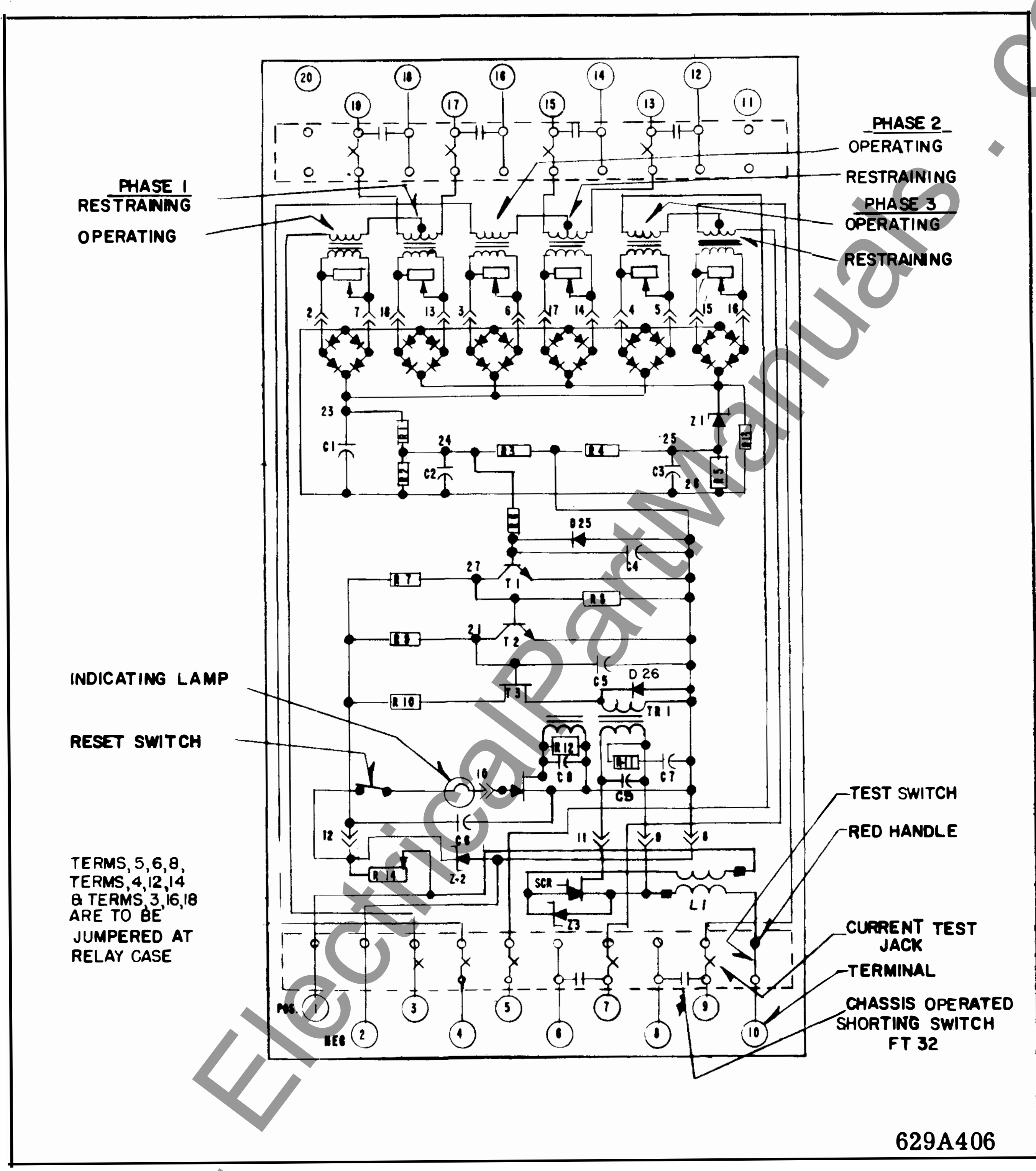


Fig. 3 Internal Schematic of Type SA-1 Relay.

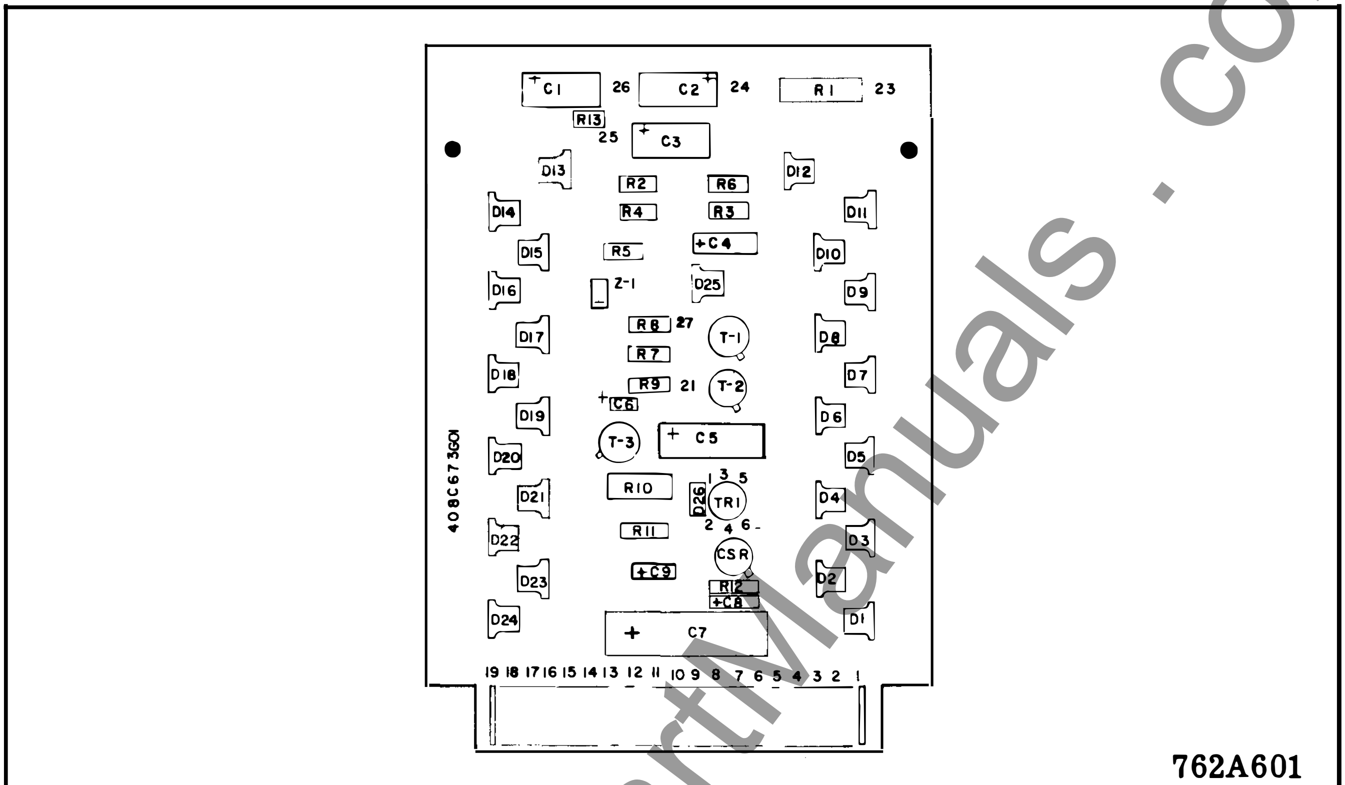
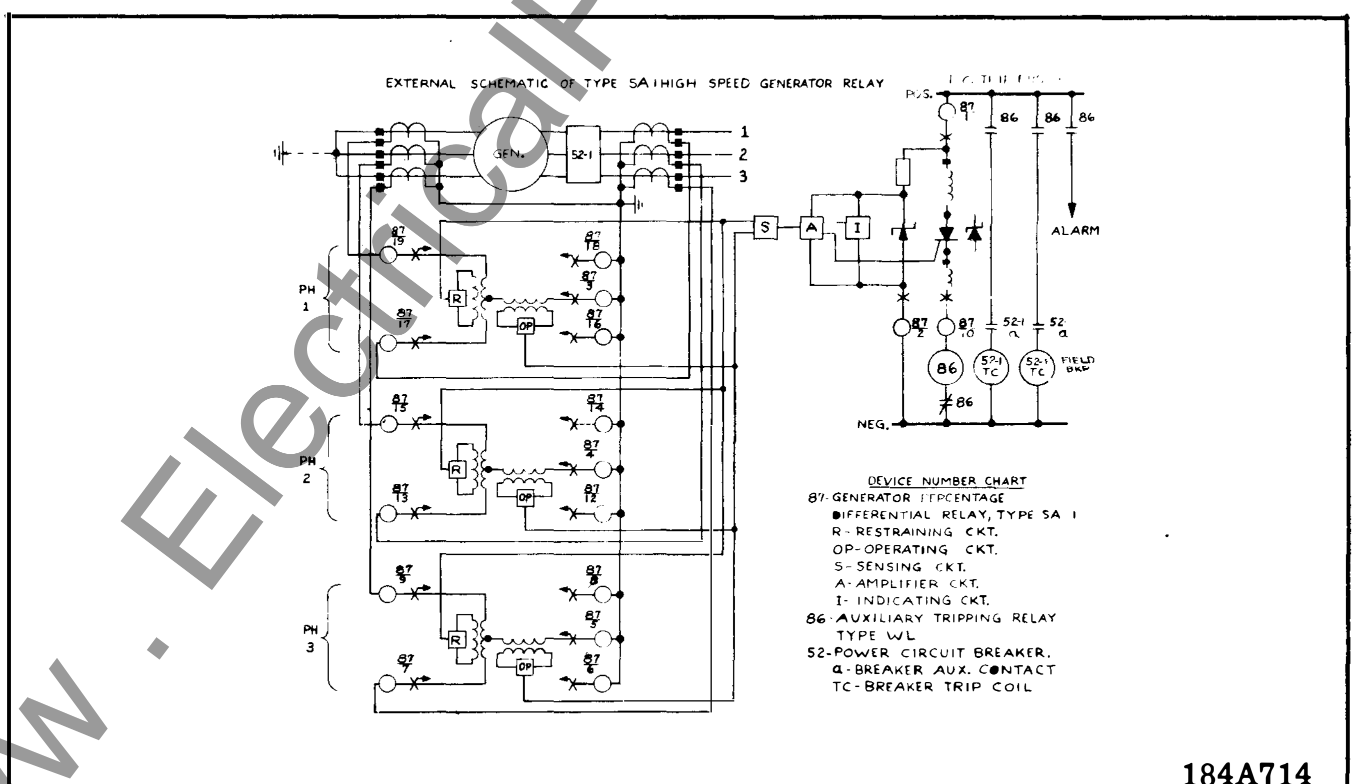
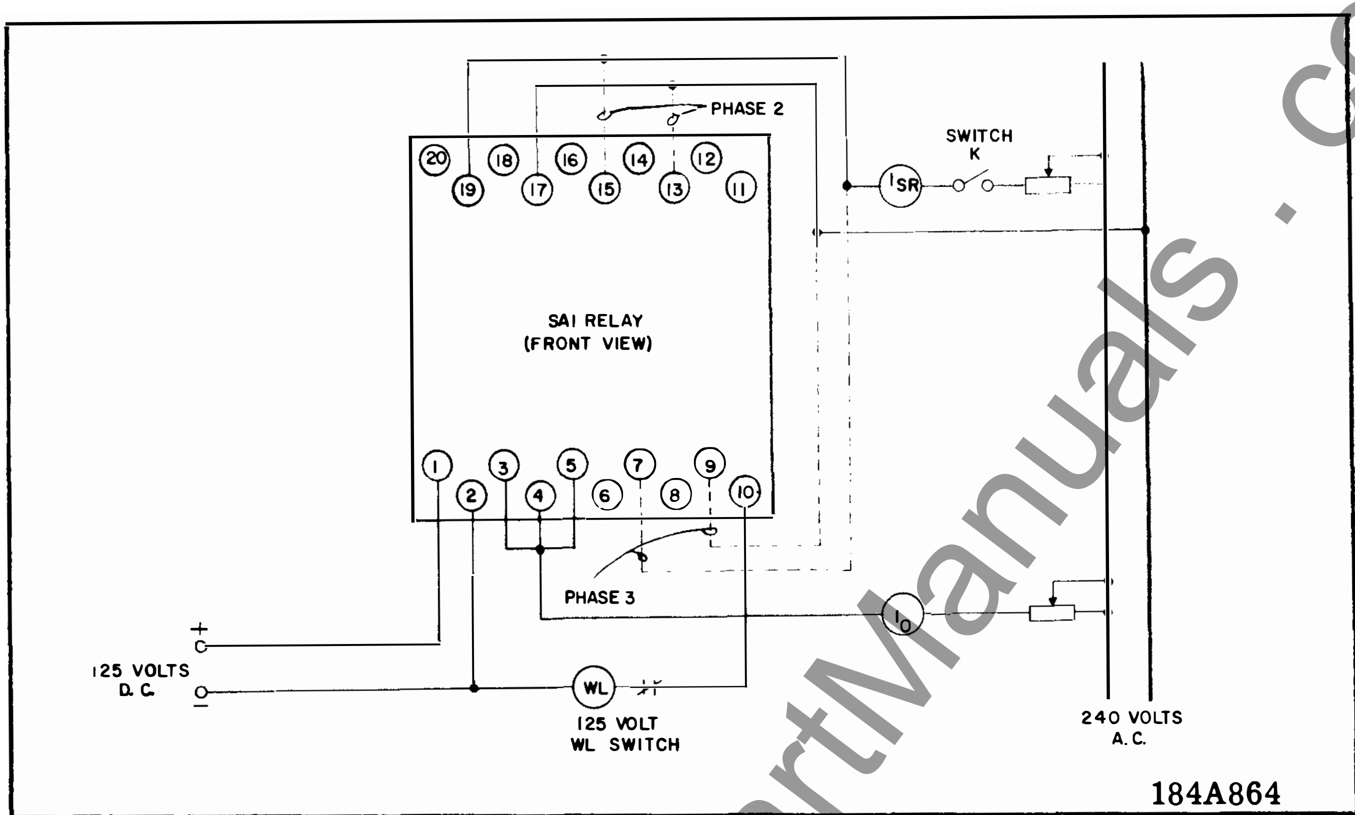


Fig. 4 Component Location on Printed Circuit Board for Type SA-1 Relay.



* Fig. 5 External Schematic of Type SA-1 Relay for Generator Protection.



* Fig. 10 Test Diagram for Type SA-1 Relay

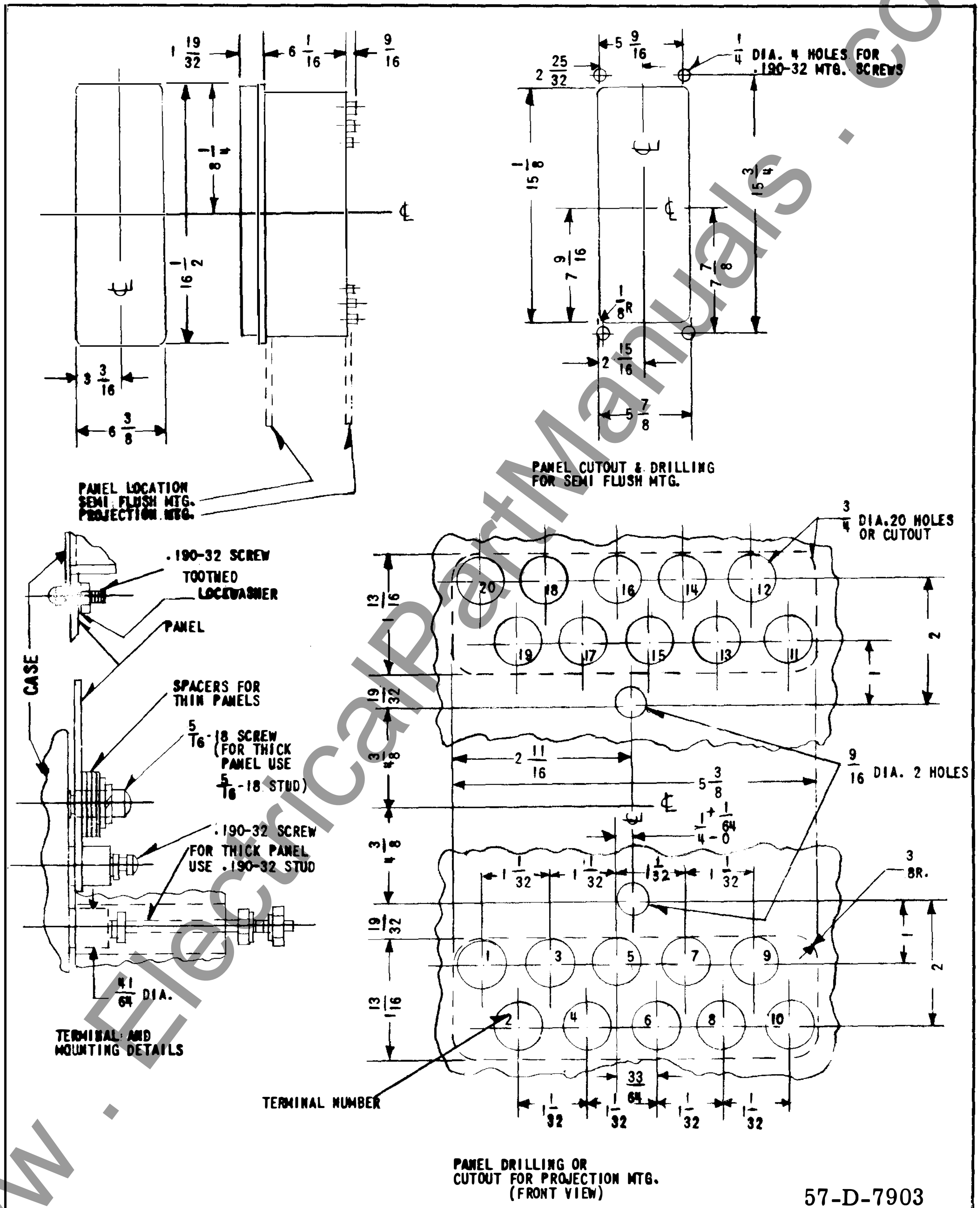


Fig. 11 Outline & Drilling Plan for Type SA-1 Relay in Type FT-32 Case.

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION **NEWARK, N. J.**

Printed in U.S.A.

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APPLICATIONS

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 = proportion of total number of CT turns in use

V_{CL} = current transformer 10L accuracy class voltage

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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 10L200 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 the burden factor, BF is:

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

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 ½ x 3.8 = 1.9. If the other set of CT's also has a burden of 0.5 ohms, a 10L100, 10L200, or 10L400 rating would be satisfactory since the burden factors are 7.6, 3.8 and 1.9 respectively.

In calculating the burden, use the one-way lead burden.

CONSTRUCTION

The type SA-1 relay consists of a Restraint Circuit, Operating Circuit, Sensing Circuit, Amplifier Circuit, Trip Circuit and Indicating Circuit. The principal parts of the relay and their location are shown in Figs 1 through 7.

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.

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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 phase current with the largest magnitude.

Sensing Circuit

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

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

SUPERSEDES I.L. 41-348.1E
*Denotes change from superseded issue.

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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.

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.

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.

OPERATION

The type SA-1 relay is connected to the protected apparatus as shown in Fig. 8. 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 voltages will exist to prevent the operating voltage from triggering the amplifier.

The precentage 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 sum of the current flowing in each of the windings of the restraint transformer and sufficient operating voltage is available to overcome the restraint voltage.

CHARACTERISTICS

The percentage slope curves are shown in Fig.9&10. It will be observed that the relay operates at 5% unbalance at 5 amperes restraint 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. 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 Fig. 12.

The frequency response characteristic of the type SA-1 relay is shown in Fig. 13.

The percentage slope curve for the 0.5 minimum pickup desensitized SA-1 relay is shown in Fig. 11.

ENERGY REQUIREMENTS

Each Restraint Circuit

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

Operating Circuit

The burden imposed by the operating circuit on each circuit transformer is variable because of the saturating transformer. At 0.5 amperes, it is 0.37 va., and at 60 amperes, it is 170 va.

Continuous rating 10 amperes

1 second rating 200 amperes.

Amplifier

The dc burden on the station battery is:

Volts	Milliamperes	Watts
125 dc	55	6.9
48 dc	60	2.9

SETTING

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 top on the resistor mounted at top of the relay. The red dot on the resistor is the common point- do not remove.

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 or by means of the rear mounting stud or studs for projection 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 for steel-panel mounting or to the terminals' studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT case information,refer to I.L. 41-076.

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.

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 Fig. 14. For 250 VDC relay, refer to Fig. 4 for relay terminals.

1. Minimum Trip Current with I_R set at zero amperes, apply 0.14 ± 5% (0.5 ±5% for desensitized SA-1) 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 .25 ±5% amperes. (.71 ±5% for desensitized SA-1). 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 ±7% amperes. Repeat for each phase of the relay. (I_R = 40 amperes and I_O = 24 ±8% for desensitized SA-1). *

Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

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 Fig. 14. Adjust the operating resistor in the rear of the relay until the relay operates with I_0 equal to 0.14 amperes. (0.5 for desensitized SA-1) 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 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 ± .010 amperes. (I_0 = .695 to .735 for desensitized SA-1) 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.

3. Electrical Checkpoints – See Table I.

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.

ELECTRICAL CHECKPOINTS

Connect relay per test circuit of Fig. 14: All voltage readings should be made with a high resistance voltmeter. Refer to Fig. 6 or 7 for location of checkpoints. Voltage readings are approximate. The voltage readings to amplifier should not be taken with relay in service.

TABLE I

(Values in Parenthesis Represent Desensitized SA-1)

CIRCUIT	PRIMARY CURRENT	PHASE	CHECKPOINTS (TYPICAL VALUE) TERMINAL	VALUE	FUNCTION
Operating	0.14 A	1	2–7	(4.3 ac) 2.5 ac	Input to operate rectifier
	(0.5 A)	2	3–6	(4.3 ac) 2.5 ac	Input to operate rectifier
		3	4–5	(4.3 ac) 2.5 ac	Input to operate rectifier
Sensing (Operating	0.14 A	Any Phase	+ to –		
			23–26	(8.5 dc) 2.1 dc	Output to rectifier
			24–26	1.85 dc	a. Output to operating sensing circuit
			24–8	0.55 dc	b. Input to amplifier
	(0.5 A)		8–25	0.65 dc	c.
			25–26	0.65 dc	d. Output to restraint sensing circuit
					Ref.: a = b + c + d
	(24A) 30.0 A	Any Phase	+ to – 24–26	(40 dc) 51.0 dc	
Restraint	5.0A	1	18–13	6.0 ac	Input to restraint rectifier
		2	17–14	6.0 ac	Input to restraint rectifier
		3	15–16	6.0 ac	Input to restraint rectifier
Sensing (Restraint)	5.0A	Any Phase	+ to –		
			25–26	2.1 dc	a. Output of restraint sensing circuit
			25–8	1.2 dc	b.
			8–24	0.6 dc	c. Input to amplifier
			24–26	0.3 dc	d. Output to operating sensing circuit
					Ref.: a = b + c + d
	(40 A) 60.0 A	Any Phase	+ to – 25–26	(33 dc) 42.0 dc	
Amplifier	0		+ to –		
			27–8	0.7 dc	
			12–8	24.0 dc	
			10–8	24.0 dc	
	Minimum Trip Current + 5%	Any Phase	+ to –		
			27–8	0.5 dc	
			12–8	24.0 dc	
			21–8	10.0 dc	

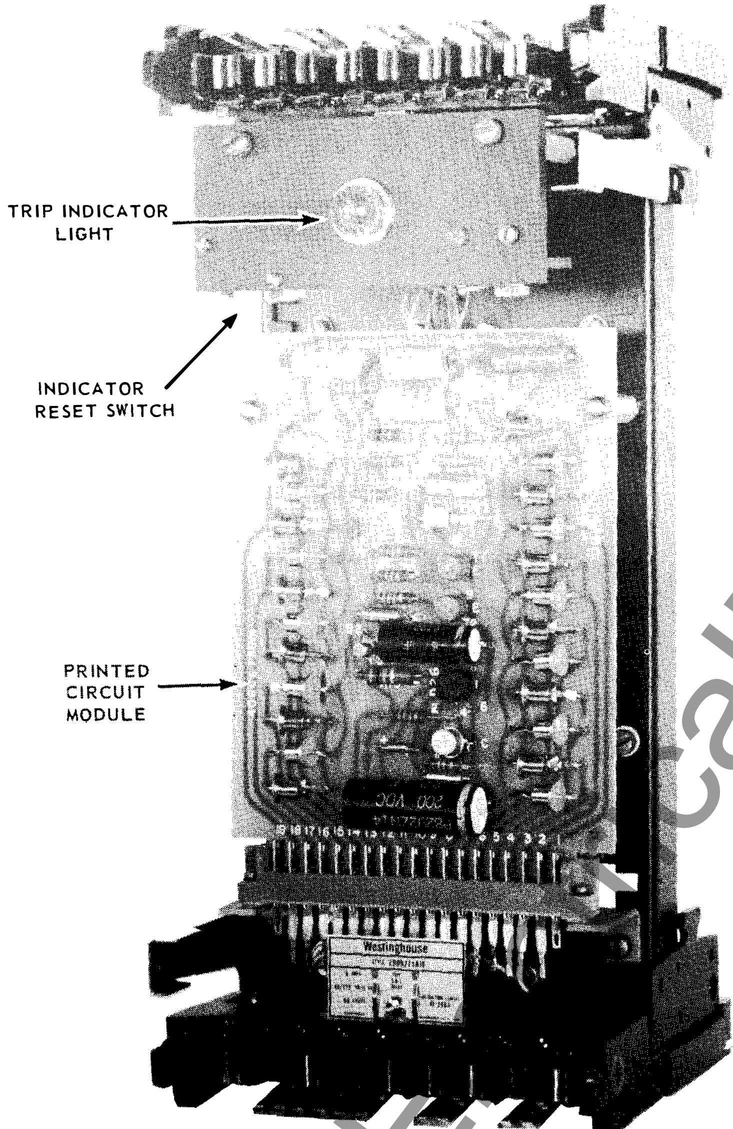


Fig. 1 Type SA-1 Generator Differential Relay without Case. (Front View)

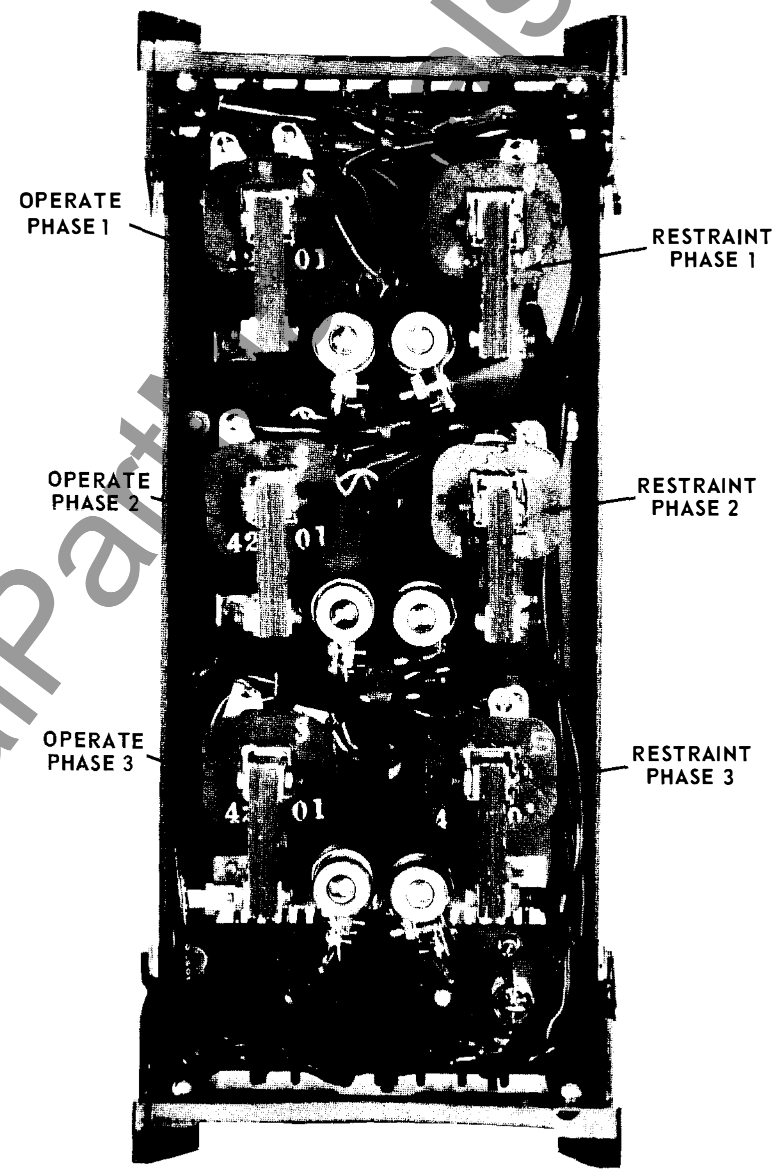


Fig. 2 Type SA-1 Generator Differential Relay without Case. (Rear View)

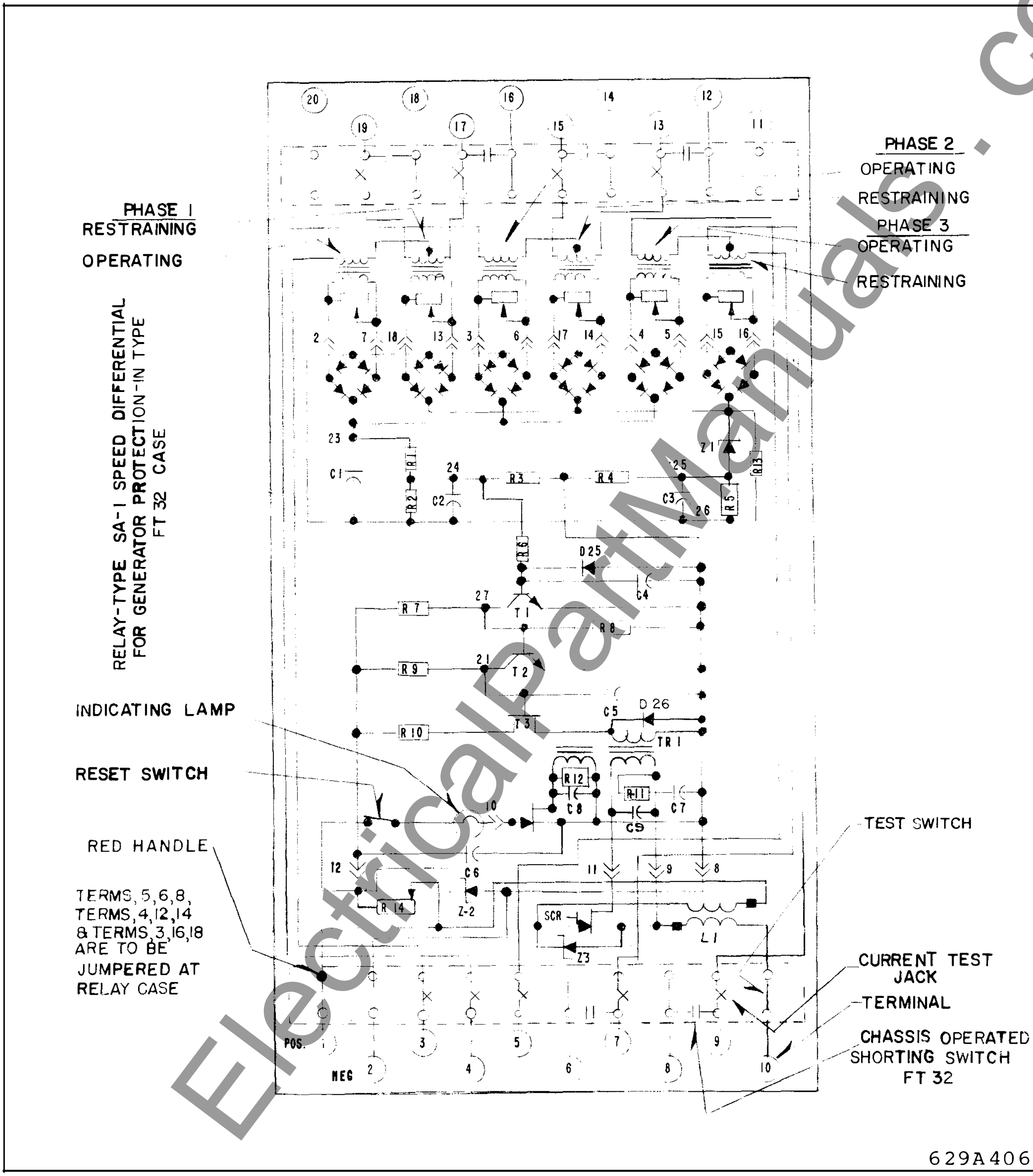


Fig. 3 Internal Schematic of Type SA-1 Relay 48/125 VDC

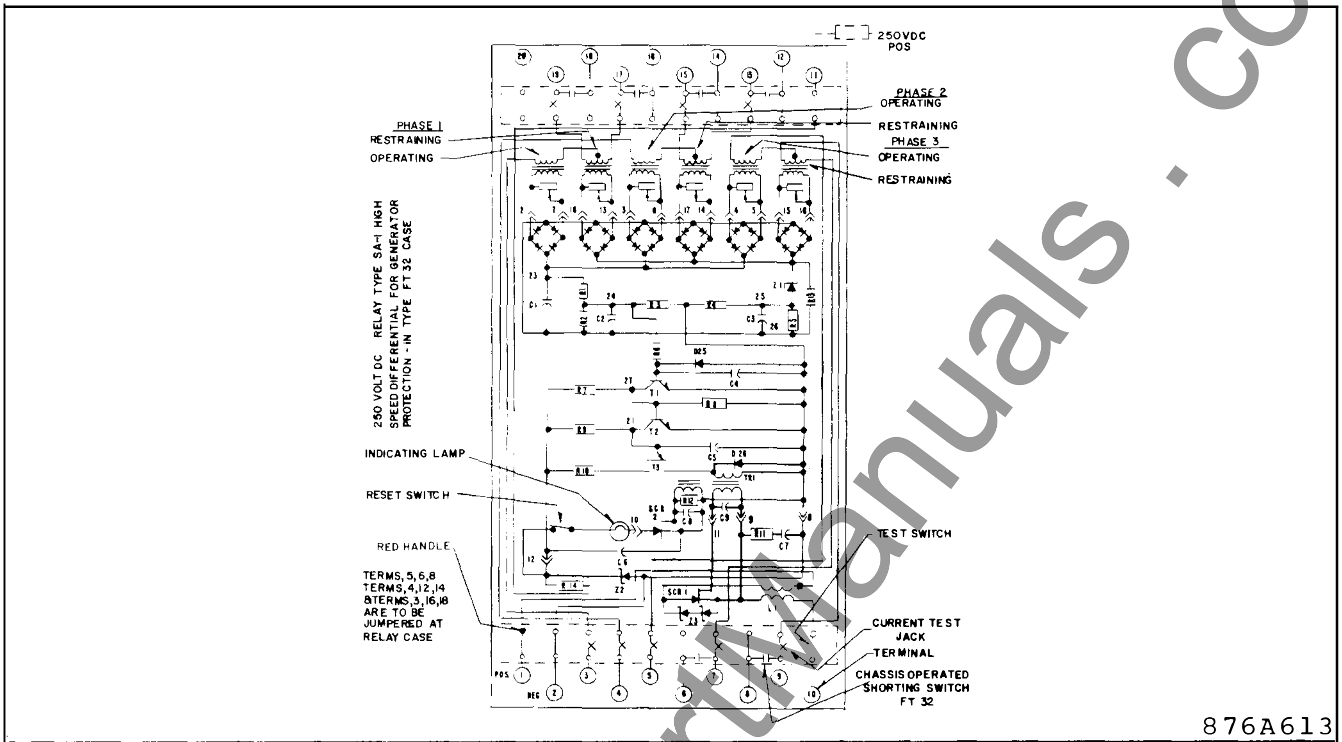


Fig. 4 Internal Schematic of Type SA-1 Relay 250 VDC

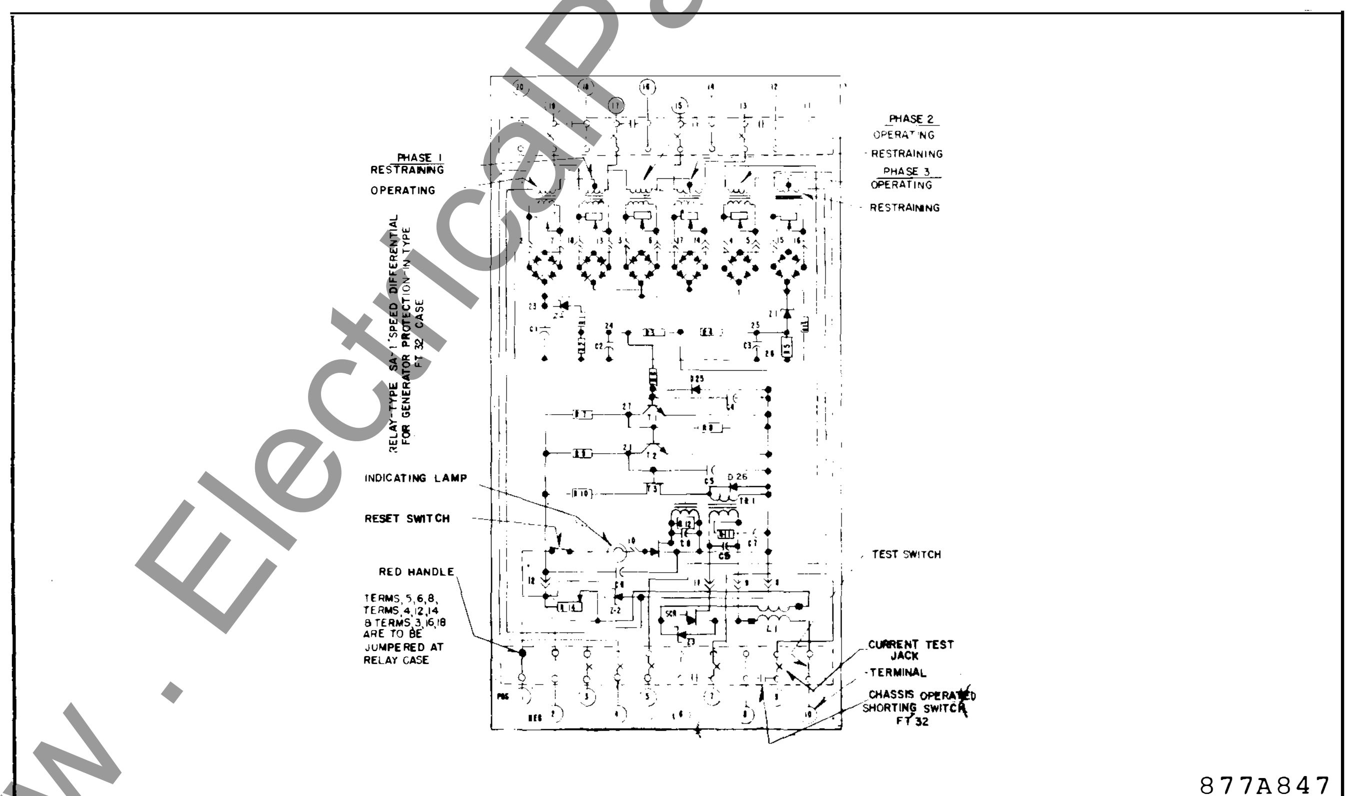


Fig. 5 Internal Schematic of Desensitized SA-1 Relay

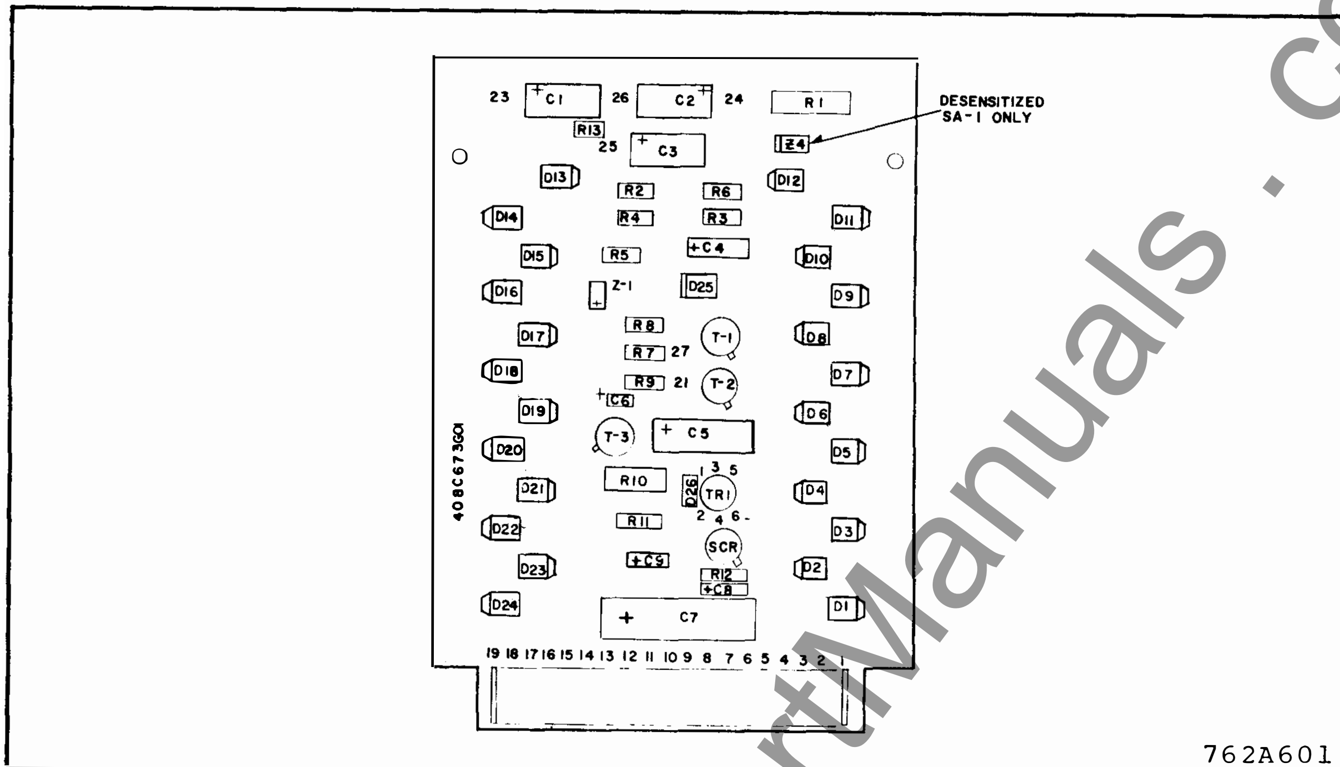


Fig. 6 Component Location on Printed Circuit Board for Type SA-1 Relay 48/125 VDC

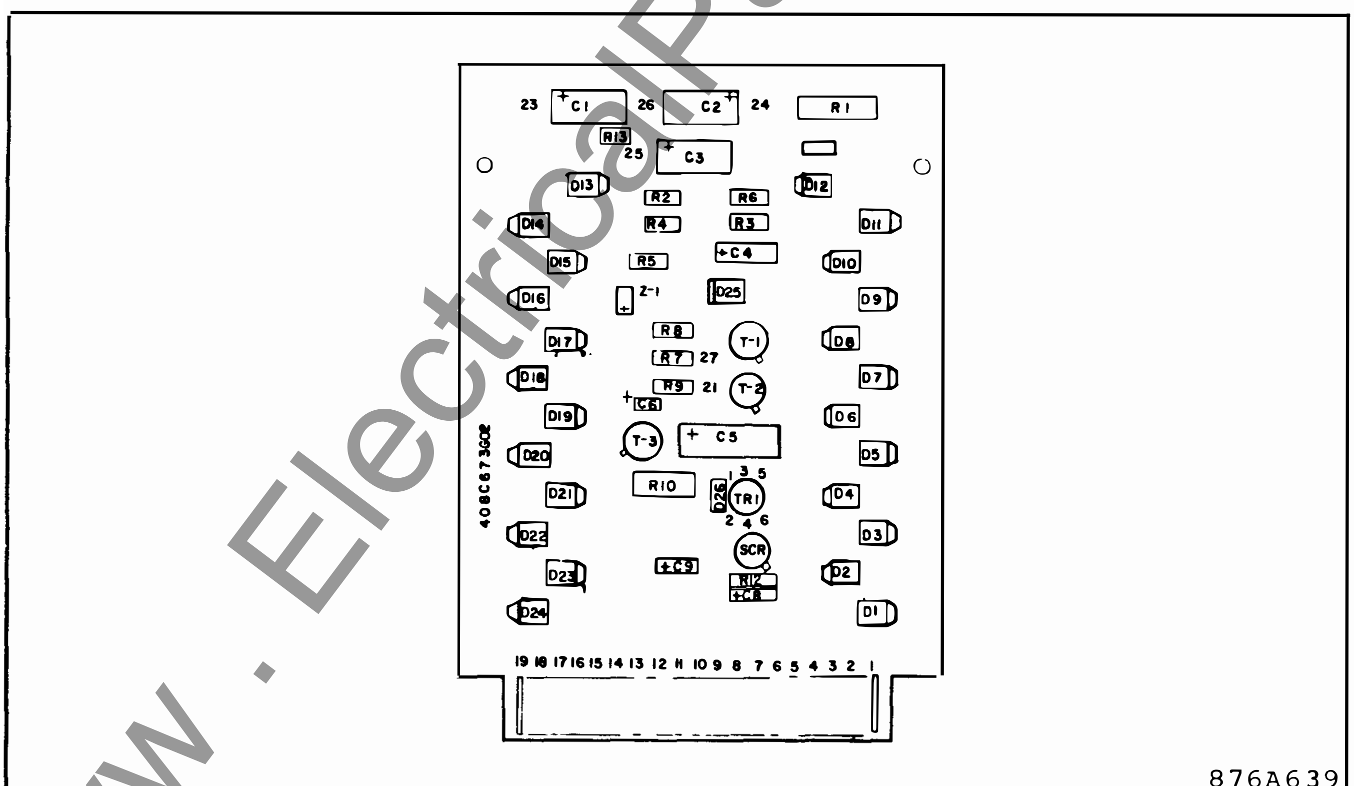


Fig. 7 Component Location on Printed Circuit Board for Type SA-1 Relay 250 VDC

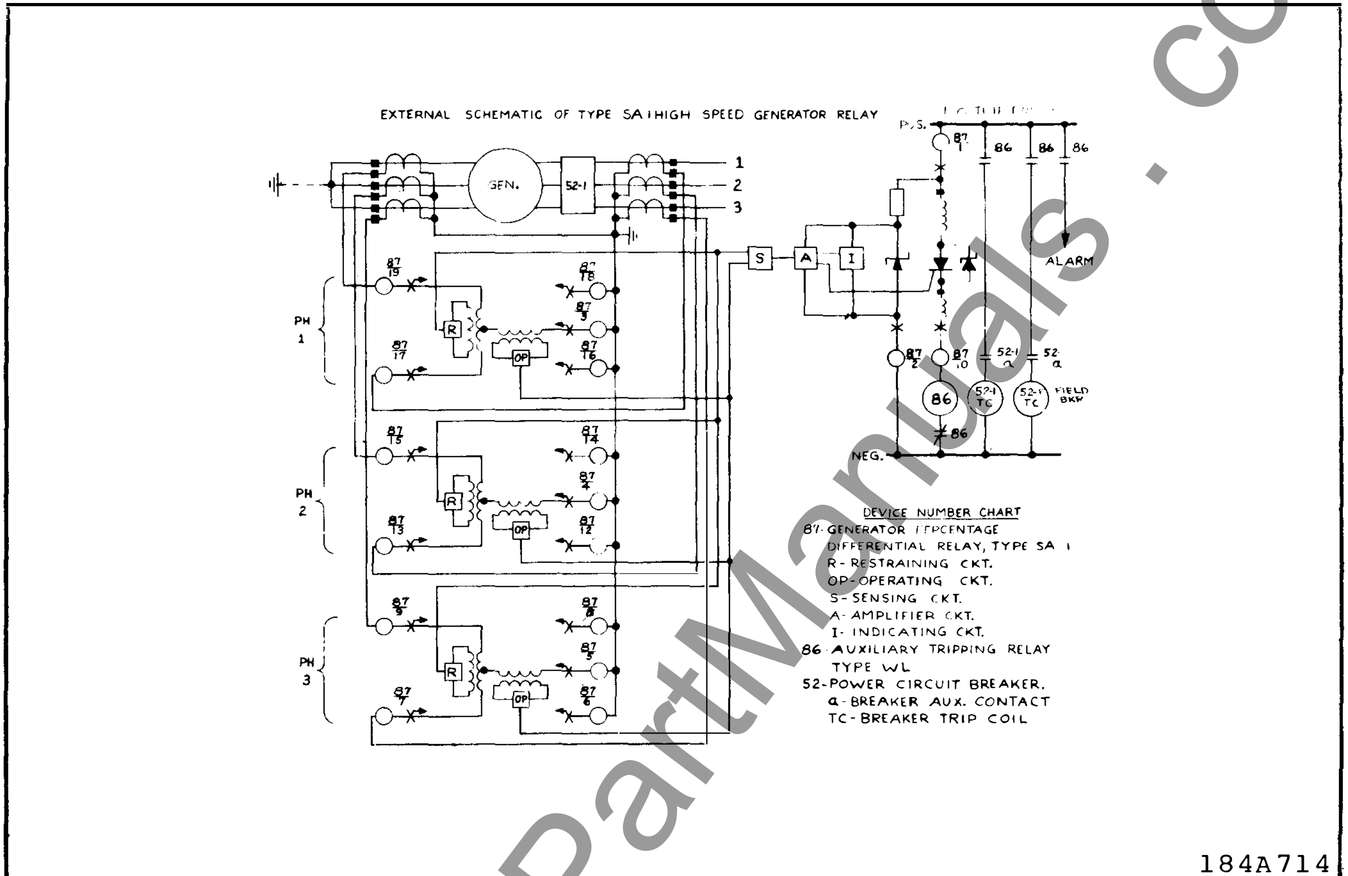


Fig. 8 External Schematic of Type SA-1 Relay for Generator Protection

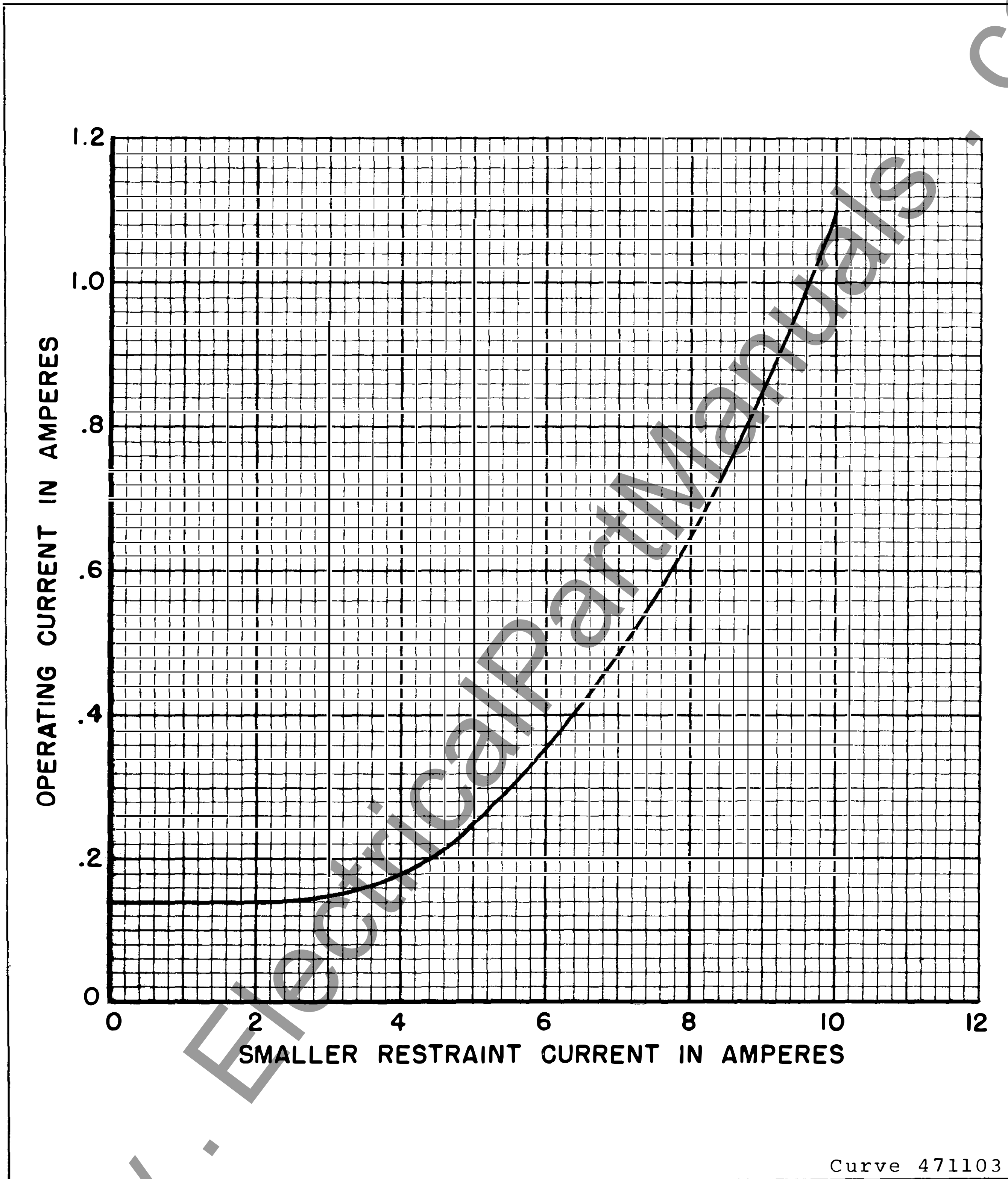


Fig. 9 Percentage Slope Characteristic at Low Values of Restraint Current.

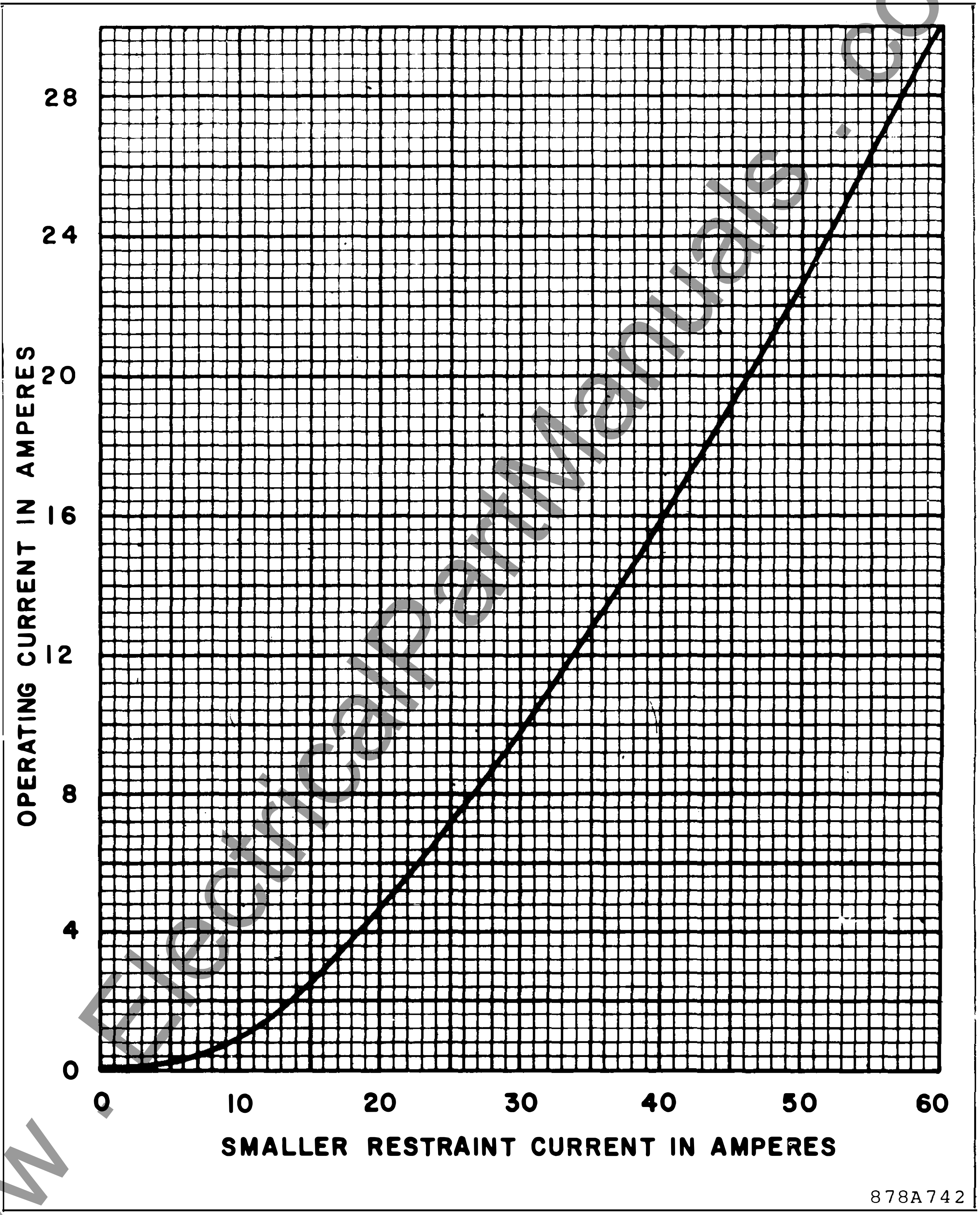


Fig. 10 Percentage Slope Characteristic at High Values of Restraint Current.

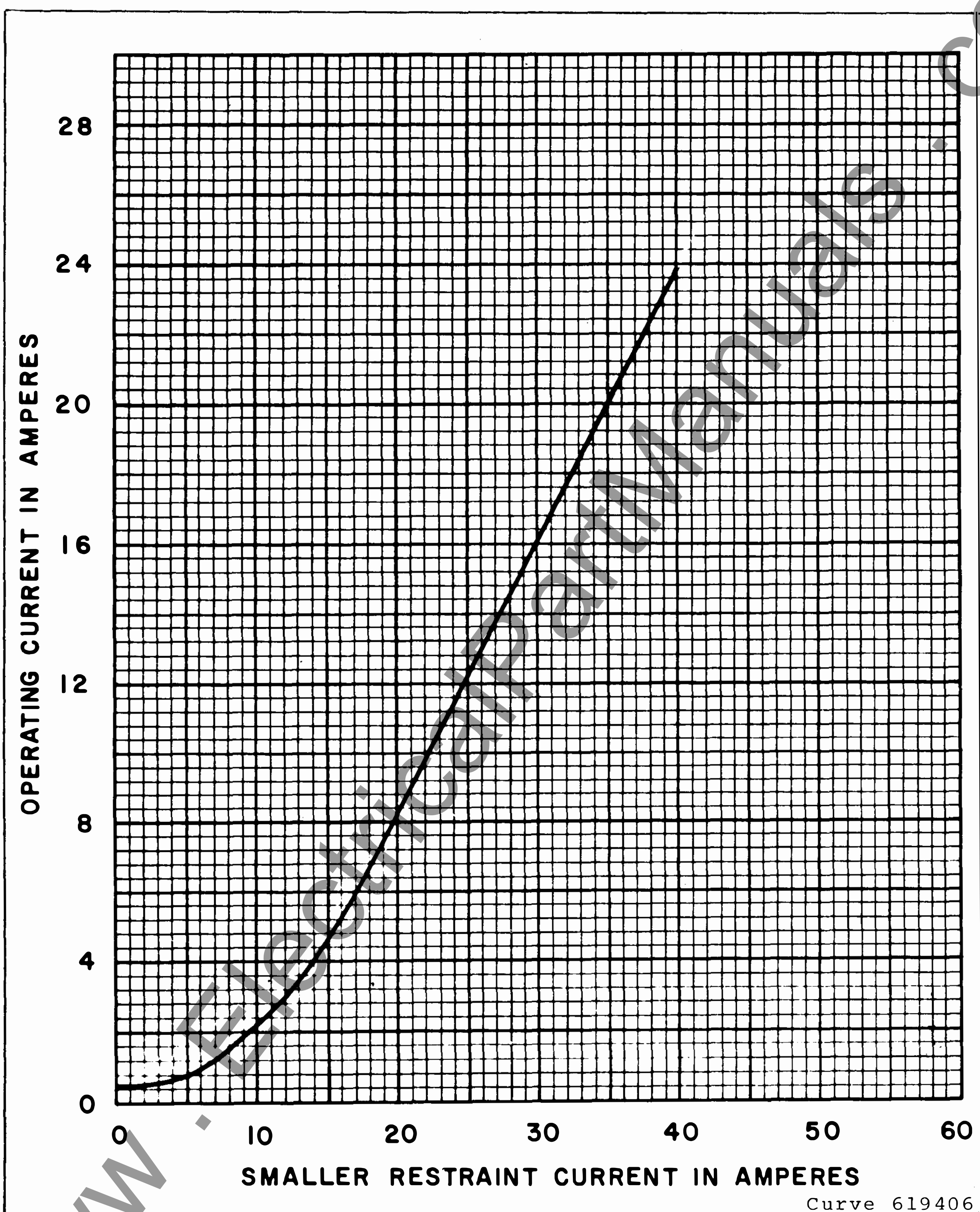


Fig. 11 Percentage Slope Characteristic at High Values of Restraint Current For Desensitized SA-1 Relay.

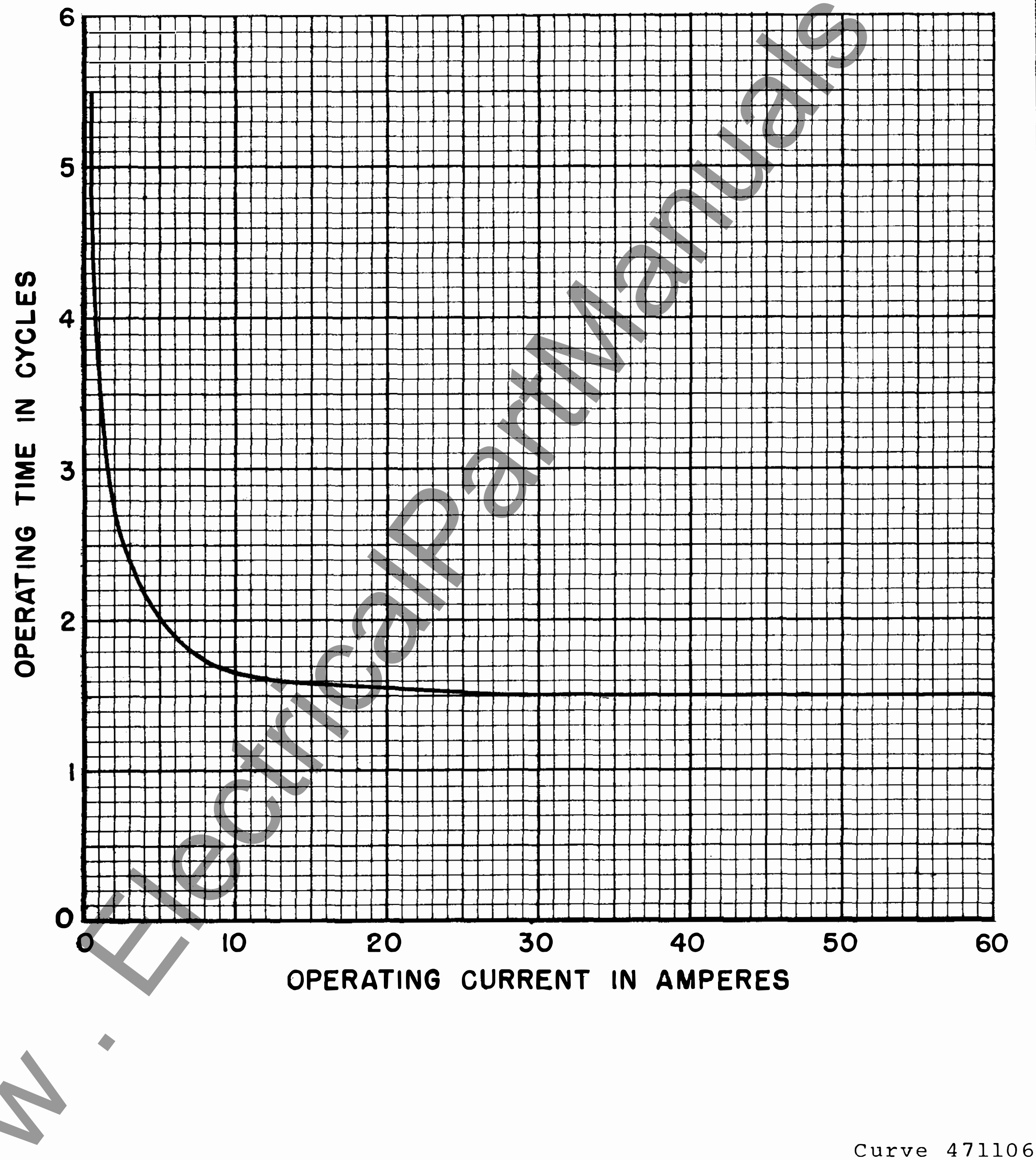
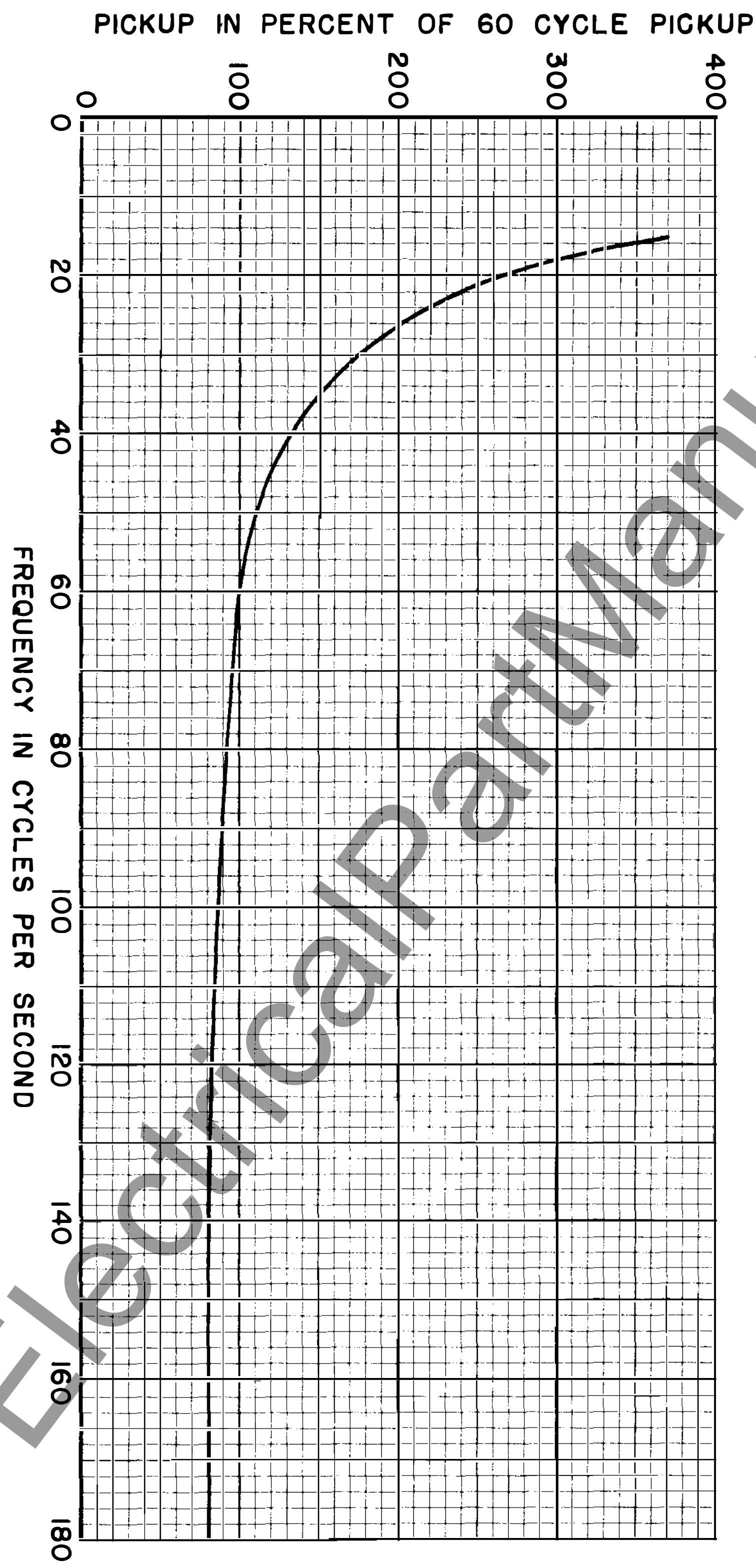


Fig. 12 Typical Operation Time Characteristic.



Curve 471105

Fig. 13 Typical Frequency Response Curve.

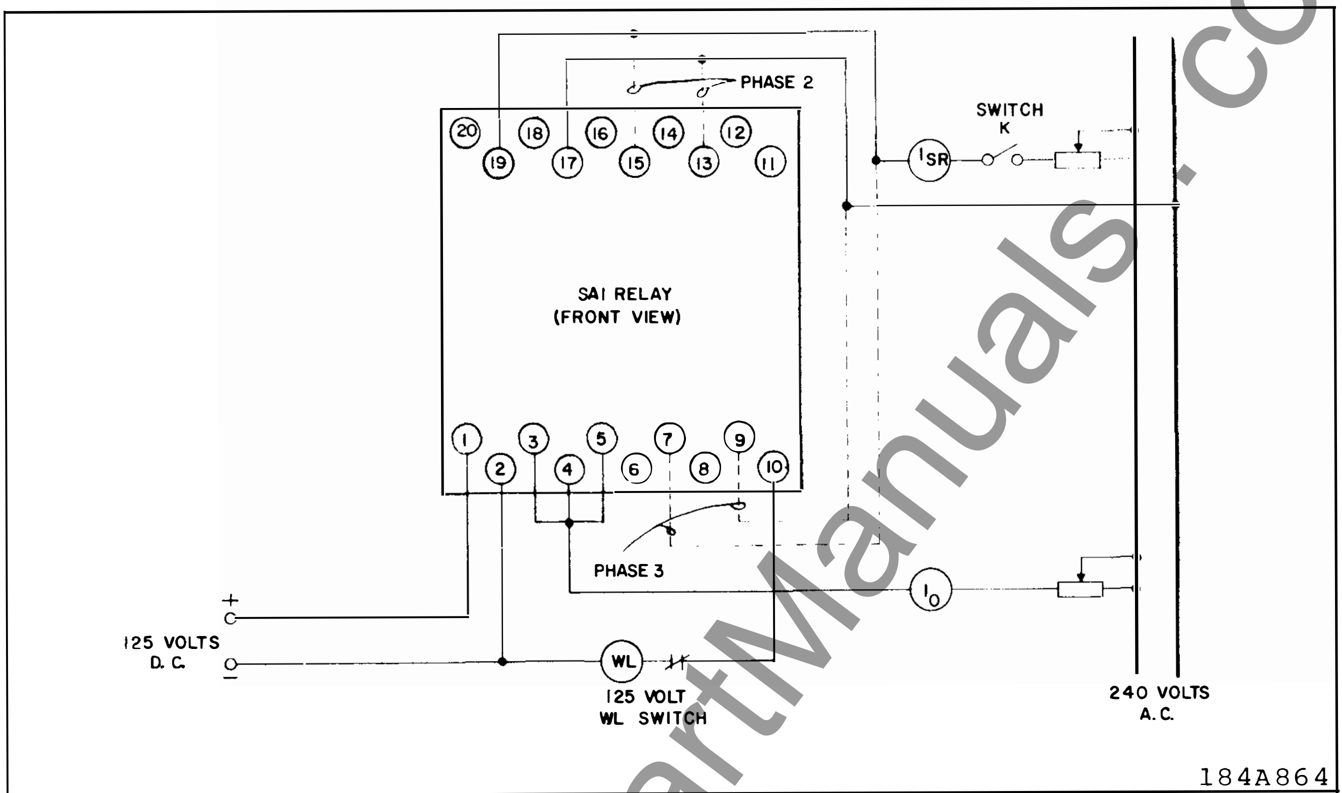


Fig. 14 Test Diagram for Type SA-1 Relay.

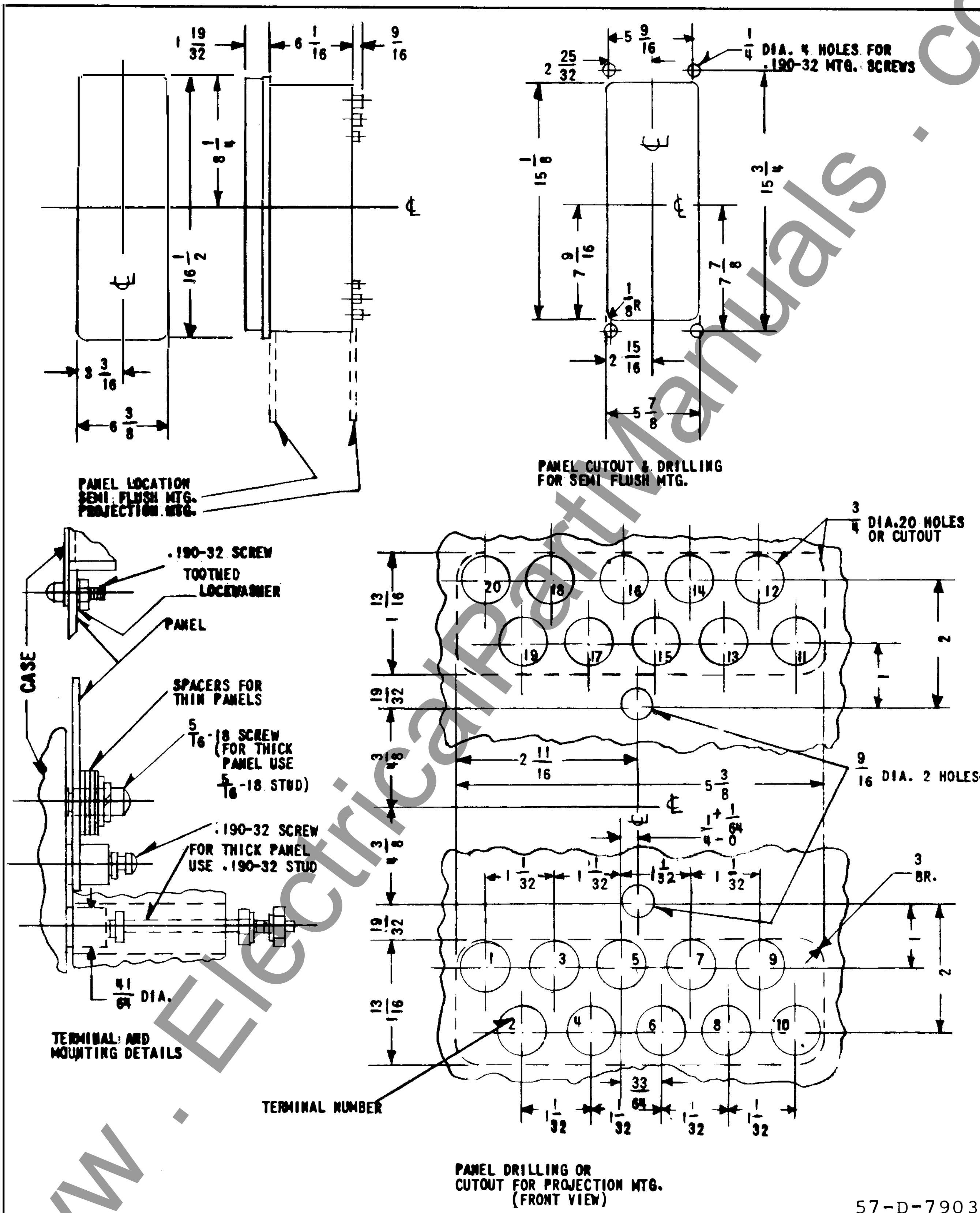


Fig. 15 Outline & Drilling Plan for Type SA-1 Relay in Type FT-32 Case.