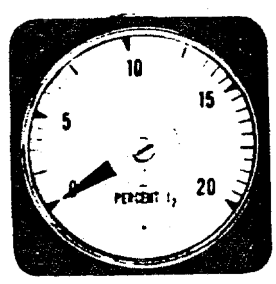
INSTRUCTIONS

GEK-41896 D
Supersedes GEK-41896 C

STATIC RELAYING FOR GENERATOR PROTECTION

NEGATIVE SEQUENCE TIME OVERCURRENT RELAY

SGC 12A
SGC 12B



GENERAL ELECTRIC

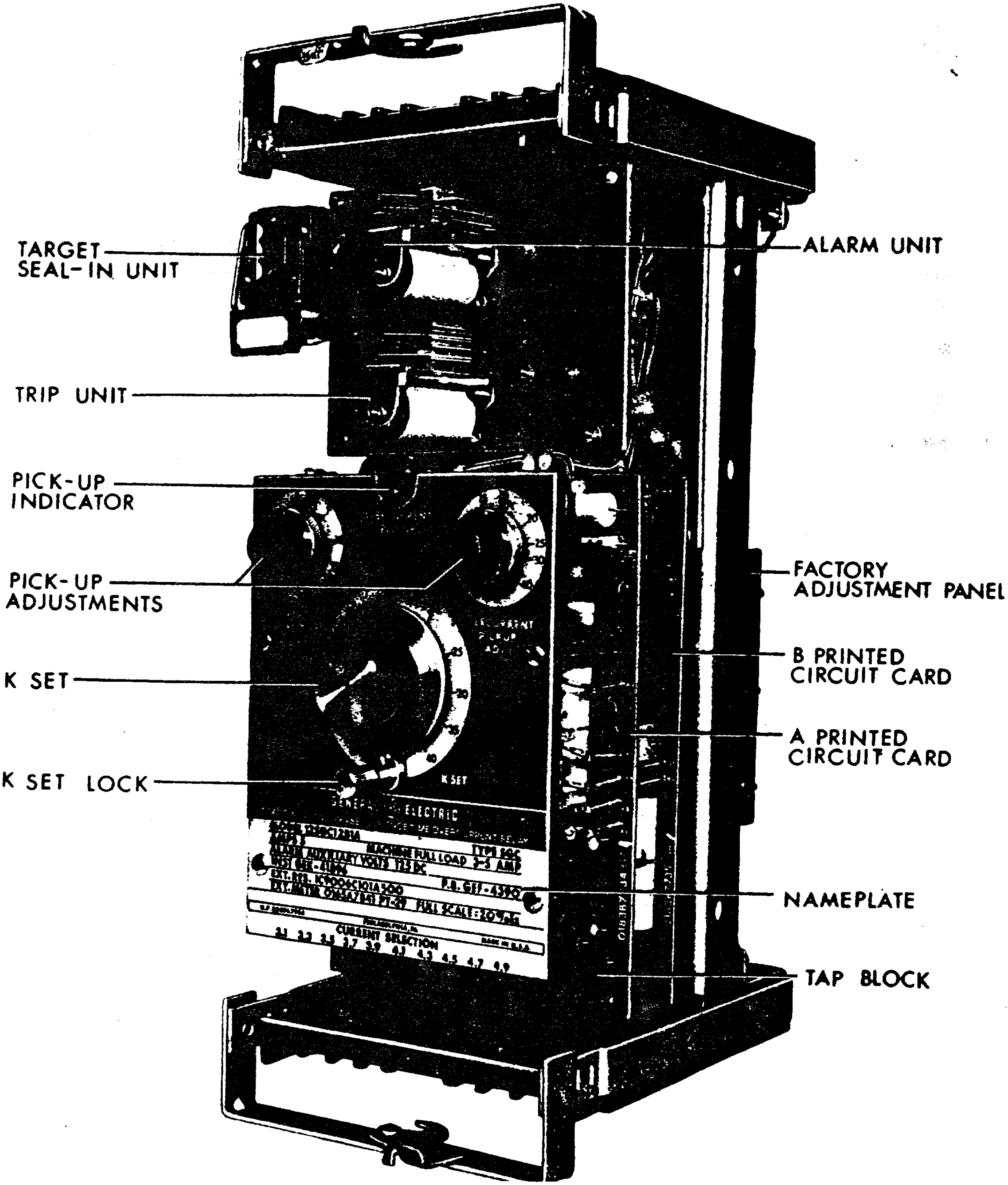


FIG. 2 (8917573B) FRONT VIEW OF THE SGC12B PROTECTIVE RELAY REMOVED FROM ITS DRAWOUT CASE

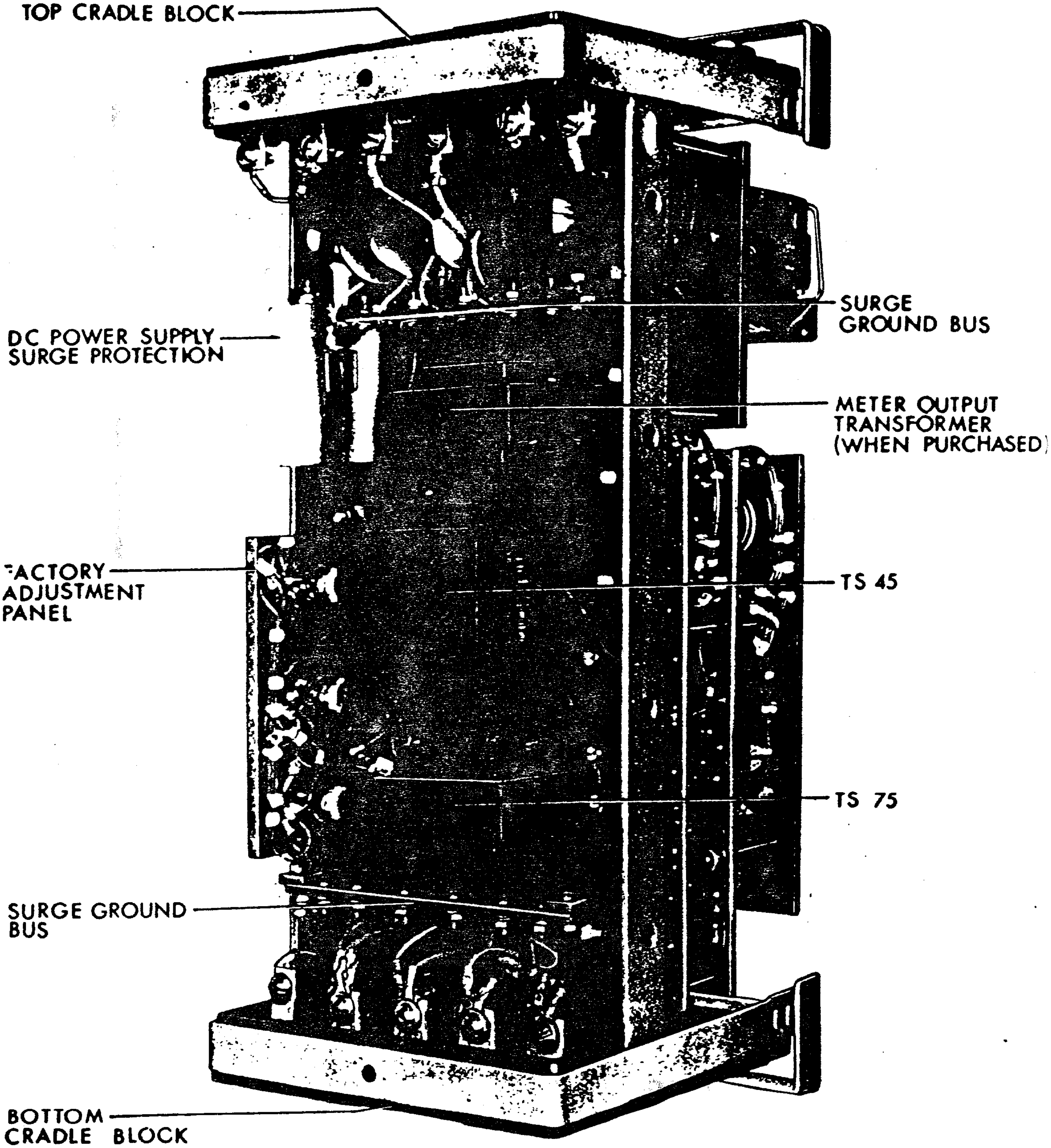


FIG. 3 (8917573A) REAR VIEW OF THE SGC12B PROTECTIVE RELAY REMOVED FROM ITS DRAWOUT CASE

CONTENTS

TIME OVERCURRENT RELAY
TYPE SGC

INTRODUCTION

These instructions furnish the information needed to test and install the General Electric SGC12A and SGC12B relays.

DESCRIPTION

GENERAL

The type SGC relay is a static relay intended to protect generators against possible damage from un-balanced phase currents. The time-overcurrent unit of the relay responds to negative sequence current. One relay is required for each machine to be protected. The time-overcurrent and alarm functions in the relay respond to the negative sequence component (I_2) of generator current. Both of these functions provide a contact output as shown on the internal connections diagram in Figure 5, in addition, a target seal-in unit is included in the trip circuit.

There are curently available two models of the SGC relay. The model SGC12A has the elements described above. The model SGC12B includes all the features of the SGC12A and one additional feature. The SGC12B relay includes a metering output at the relay terminals and a meter calibrated in percent[1] of negative sequence current (I_2).

This difference in the models is illustrated in TABLE I below.

TABLE I

MODEL	EXTERNAL METER	CASE
12SGC12A(-)A	NO	M2
12SGC12B(-)A	YES	M2

The relay is matched to the CT-secondary-full-load current of the generator by means of a tap block on the front panel. The tap block serves to match this secondary full-load current of the generator over a spread of 3.0 to 5.0 amperes. The boundaries of the I_2 pickup ranges of the time overcurrent and alarm units are referenced to generator full-load current. The pickup ranges are:

1) 0.09 to 0.4 per unit for the time-overcurrent function, and
2) 0.03 to 0.2 per unit for the alarm function.

The relation between operating time of the time overcurrent unit and the negative sequence current is represented by the following expression:

$$I_2^2 t = K.$$

Where: I_2 = negative-sequence current in per unit,

* t = time in seconds, and
k = design constant of the protected machine. On the type SGC relay, K is continuously adjustable from 2 to 40.

Cover Photo (8042240)

*Indicates Revision

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

To the extent required the products described herein meet applicable ANSI, IEEE and NEMA standards; but no such assurance is given with respect to local codes and ordinances because they vary greatly.

* I_2 is the magnitude of rms negative-sequence current referred to the CT secondary. All references throughout this book to percent or per unit I_2 are based on the following algorithms.

$$\text{per unit } I_2 = \frac{I_2}{\text{TAP SELECTED}}$$

$$\text{percent } I_2 = 100 \times \text{per unit } I_2$$

APPLICATION

The Types SGC12A and SGC12B relays are negative-sequence, time-overcurrent relays designed to protect generators against possible damage from unbalanced currents resulting from prolonged faults or unbalanced load conditions. External connections to the relay for such an application are shown in the typical elementary diagram in Figure 4.

When a generator is subjected to an unbalanced fault or load its stator currect will include a negative-sequence component (I_2) which sets up a counter-rotating flux field in the machine. This in turn caused double-frequency currents to flow in the rotor iron and slot wedges which result in local heating. The capability of machines to operate with unbalanced stator currents has been expressed in terms of negative-sequence current and time by the following relationship.

$$\int_0^t I_2^2 dt = K$$

Where: I_2 = negative-phase sequence current expressed in per unit of full load stator current,

t = duration of the unbalanced condition in seconds, and

K = a constant for the protected machine.

The values of the constant K may vary over an approximate range of 5 to 40 depending on the type, rating, and design of the generator to be protected. Also the range of time t over which the relationship applies may vary for machines of recent manufacture and for older machines. The manufacturer of the machine to be protected should be consulted to determine the correct value of K and range of t for each application.

Since the capability of machines to withstand the heating caused by unbalanced faults or loads has been expressed in terms of I_2^2t, it is logical that the relay used to protect the machine from such conditions should be sensitive only to the negative-sequence component of generator current and have a time characteristic matching the I_2^2t characteristic of the protected machine. The Type SGC relays meet this requirement. Their trip and alarm functions are responsive only to negative-sequence current, and the time characteristic of the trip circuit is expressed as $I_2^2t=K$, with K being continuously adjustable from 2 to 40. This permits matching the characteristics of the negative sequence protictive relay with the capability curve of the machine to be protected.

The Type SGC relays protect the generator from damage due to abnormal conditions on the system rather than from damage caused by internal faults. The relays are therefore in a sense providing backup protection for other relays and hence should be selective with these relays. In other words while it is essential that the time characteristic (i.e., value of "K") be selected so that the machine will be cleared before it suffers damage from an external unbalanced condition, it is also necessary that the relaying schemes responding to external faults on the system be selected so that their correct operation will remove the fault before the SGC operates, even in the event of a circuit breaker failure following an automatic reclosure onto a sustained phase-to-phase fault. This requirement is discussed in more detail in the section CALCULATION OF SETTINGS.

RATINGS

AMBIENT TEMPERATURE

The type SGC relay is designed to operate within 10% of the set time curve over an interval of ambient temperatures; the boundaries of this interval are -20°C (-4°F) and +55°C (+131°F).

This specification applies to relay settings made at room temperature (25°C).

SURGE WITHSTAND CAPABILITY

The SGC relay will withstand the following test voltage waveform without incorrect operation or damage to any component.

The test voltage waveform consists of a high frequency damped oscillation with frequency of 1.5 megahertz. The source has an internal impedance of 150 ohms. The initial value (zero to peak) is 2500 volts and the damping is such that the envelope of the waveform decays to half the initial value (1250 volts) in 6.0 microseconds. The test voltage is applied between relay surge ground and each of the other relay terminals.

POWER SUPPLY

All the SGC relays covered by this book contain a regulated power supply. This power supply regulates the voltage to the logic functions so that they perform properly over a range of applied d-c voltage from from 80 percent to 110 percent of rated voltage. The SGC is currently available in rated voltages of 125 and 250.

TIME OVERCURRENT (TOC) UNIT: CURRENT INPUT

The SGC static TOC unit receives an analog representation of I_2 from the negative-sequence network. The network is composed of two transactors whose inputs are currents and whose outputs are voltages. These two transactors are shown in Figure 14. The electrical limitation of the TOC unit is dependent on the current windings of the sequence network transactors. The sequence network relay terminal studs are 3 through 8 as shown in the internal connections diagram, Figure 5. The ratings of this unit are summarized below in Table II.

TABLE II

SEQUENCE NETWORK RATINGS

Continuous Current (any tap)	6.25 amperes (any or all CT secondaries)
One-second Current (any tap)	100 amperes (any or all CT secondaries)

TIME OVERCURRENT UNIT: FREQUENCY EFFECTS

The SGC relay is not affected by frequency within ±.05 hertz of rated frequency. Outside this range there are measurable effects of frequency for balanced (i. e. no negative sequence present) inputs. To discuss these effects consider the range from 57 to 63 Hz. (47-53 Hz for relays rated 50Hz.) For balanced three phase inputs in this frequency range, but outside the tighter limits, the relay sees an apparent I_2 level. In no case does this apparent level exceed 0.04 per unit I_2 based on the selected relay tap setting.

There are an infinite number of ways that negative-sequence current may be produced in the lab; it is impossible to test all these combinations. However, some random testing does indicate that the error factor is no greater than 0.04 per unit for negative-sequence frequencies outside the tighter limits discussed above.

TIME OVERCURRENT UNIT: OUTPUT CIRCUIT

The internal connection diagram, Figure 5, shows the schematic of the output circuit of the TOC unit. It is wired between terminals 1 and 11. Electrical continuity is initiated by closure of TR, a telephone relay contact controlled by the static portion of the TOC unit. Closure of TR, energizes the T and SI coil which limits the tripping duty of the output circuit. Included in Table III are the ratings for two different T and SI units--the 0.2/2.0 and the 0.6/2.0 amperes.

TABLE III

TARGET SEAL-IN UNITS	0.6/2.0 UNIT		0.2/2.0 UNIT	
	0.6 AMP TAP	2.0 AMP TAP	0.2 AMP TAP	2.0 AMP TAP
maximum to insure operation (amperes)	0.6	2.0	0.2	2.0
carry continuously (amperes)	1.5	3.5	0.4	3.5
carry 30 amps for (seconds)	0.5	4	---	4
carry 10 amps for (seconds)	4	30	0.1	30
dc resistance (ohms)	0.6	0.13	7	0.13
60 cycle impedance (ohms)	6	0.53	52	0.53

ALARM UNIT: OUTPUT CIRCUIT

The Alarm unit output is provided by a single normally open contact. This contact is designated AL and is wired between relay terminal studs 2 and 12 as shown in the internal connections diagram, Figure 5.

Table IV below gives the alarm contact interrupting ratings. These contacts will make and carry 3 amperes continuously or 30 amperes for two seconds.

TABLE IV

ALARM UNIT CONTACT INTERRUPTING RATINGS

CIRCUIT VOLTAGE	INDUCTIVE*	NON-INDUCTIVE
115 a-c	0.75 amperes	2.0
230	0.5	1.5
48 d-c	1.0 amperes	3.0
125	0.5	1.5
250	0.25	1.0

* The inductive rating is based on the inductance of a coil having an X_L/R ratio of 3 to 1.

METER

An external meter is provided with the 12SGC12B(-)A model. The meter is a 15v a-c rectifier-type movement, 2000 ohms per volt. The meter is internally protected from damage; it cannot be damaged by the SGC meter signal.

The meter is labeled in percent of nominal tap value; and meets a $\pm$10% tolerance specification over the entire temperature range of the relay.

The meter output may be used to drive peripheral equipment in lieu of the SGC meter. However, this output is designed to be linear to 20% I_2. Above 20% I_2 the signal representing I_2 is clipped by the meter output circuitry. Therefore the output displays a saturation - like phenomenon. This means that peripheral recording equipment will receive a signal that is a linear representation of I_2 up to 20% I_2.

Any peripheral device that is substituted for the SGC meter must have an input impedance that is similar to the SGC meter. The similar impedance is necessary to maintain the regulation of the output transformer at a specified value. This regulation has been considered in establishing the tolerance for this output. Therefore the input of any substituted peripheral equipment must have an input impedance of approximately 30,000 ohms.

CHARACTERISTICS

OPERATING PRINCIPLES

The principles of operation of the types SGC12A static negative-sequence overcurrent relays can best be explained with the aid of the schematic block diagram in Figure 4.

The relays include a regulated d-c power supply, which is fed from the station battery, and a negative sequence segregating network which is energized by two of the CT phase currents and the CT residual current as shown on the typical external connections in Figure 9.

The output of the segregating network is a voltage proportional to the negative sequence component of the generator current. A portion of this voltage, as determined by the input tap setting, is applied to the trip and alarm circuits and to the function generator via the band-pass filter. The purpose of the input tap setting, identified as the tap set function, is to establish a negative-sequence per unit reference on the basis of the full-load generator current for a specific application. Taps are provided in 0.2 ampere steps between 3.1 and 4.9 amperes. For a specific application the tap is selected which is closest to the rated full-load current of the generator referred to the CT secondary. The negative-sequence sensitivity of the trip and alarm circuits, and the time characteristic of the function generator, can then be expressed in terms of per unit of this tap setting, or the per unit of generator full-load current rating.

The circuit to the trip output unit (TR) includes the trip level detector and the function generator integrator, both energized by the rectified output of the band-pass filter. The operating time characteristic of the integrator is expressed by the following equation.

$$I_2^2 t = K \tag{1}$$

Where: I_2 = negative phase sequence current in per unit of tap setting,

t = time in seconds, and

K = a constant, continuously adjustable between 2 and 40.

The time-current curves for the SGC relays, shown in Figure 10, are plots of equation (1) for the various values of K as shown, and for various fixed values of I_2. The negative-sequence fault current, I_2, will vary with time under actual fault conditions due to the variation in generator positive-sequence impedance with time. Thus the negative-sequence current capability of generators is expressed as follows.

$$\int_0^t I_2^2 dt = K. \tag{2}$$

If the "K" setting in the relay is made on the basis of the value of K for the protected machine, as furnished by the manufacturer, the relay time characteristic will match the machine capability with a varying negative-sequence current.

The trip level detector setting determines the level of negative-sequence current (I_2) at which the timing function will be activated. It has an adjustable range of 0.09 to 0.40 per unit, referred to the input tap setting as a base. When I_2 is below the set point of the trip level detector, the linear reset timer will hold off the function generator integrator. When I_2 exceeds the set point of the trip level detector the resulting output will energize the 250 second and 0.2 second timers, as well as the linear timer. When the reset timer is energized, the function generator integrator is gated and will commence integrating. The operating time, that is the time to energize the driver and the trip output unit, will depend upon the magnitude of generator negative-sequence current, as a per unit multiple of the tap setting, and the "K" setting of the function generator. For example, referring to the time curves in Figure 10,if the "K" factor is set for 10 and I_2 is 1 per unit referenced to tap setting, and remains constant, the driver and trip output unit TR will be energized in 10 seconds; or if I_2 were 2 per unit, the time would be 2.5 seconds.

As previously noted, the trip level detector also feeds a 0.2 second timer and a 250 second timer, which respectively determine the minimum and maximum possible operating times of the relay. The 0.2 second timer supplies the lower input of AND-1 so that operating time to trip must be at least 0.2 seconds regardless of the I_2 magnitude; the 250 second timer supplies one of the inputs to OR-1 so that operating time to trip cannot exceed 250 seconds even at very low multiples of I_2 pickup setting. These limits are reflected in the time curves of Figure 10 which are shown leveling off at 250 seconds at low input levels and 0.2 seconds at high levels of operating current.

The dropout of the trip level detector is over 99 percent of its pick-up. Thus, if the magnitude of generator negative-sequence current were to fall below the operating point of the trip level detector before the timing cycle has been completed, it would drop out removing the input to the integrator reset timer. This in turn would initiate a linear reset of the integrator. The time for the integrator to reset fully from the time the trip level detector drops out is 2.5 seconds for each percent of the full time that has expired. Thus the integrator reset time is 250 seconds if it has timed out completely, i.e. 100 percent of "full time". The term "full time" refers to the time indicated by equation (1), and by the curve in Figure 10, for the particular "K" setting and at the per unit value of I_2. Stated differently, the integrator can be considered as having a storage capacity that is being filled as the integrator times out. When this storage capacity is completely filled at the completion of the timing cycle, the overflow results in a trip output. This concept is used in understanding the operation of the relay in the following examples.

Assume again that the "K" factor is set at 10 and that I_2 is 1 per unit. From equation (1), or the K = 10 curve in Figure 10, the full time or integrator "capacity" at 1 per unit of I_2 is 10 seconds. If 6 seconds, that is 60 percent of this full operating time (or available storage capacity) has been used up when the trip level detector dropped out, because I_2 decreased below its pickup level, then the total reset time of the integrator would be 2.5 x 60 or 150 seconds. That is after 150 seconds the integrator would have been completely "emptied" and on a subsequent operation the full timing capacity as indicated on the K = 10 curve for a specific per unit of I_2 would again be available.

However, if I_2 were to increase again above the set point of the trip level detector before the integrator has fully reset, that is before it had completely "emptied", the time to obtain a trip output would be less than the time indicated by equation (1) or by the curve in Figure 10 for the particular per unit of I_2. How much less would depend upon how completely the integrator has emptied since the previous operation, that is it would depend upon available "storage capacity". In the example above, 6 seconds or 60 percent of the available total storage capacity has been used when the trip level detector dropped out, and it was determined that 150 seconds would be required to reset, that is "empty" the integrator fully. Assume now that after 60 seconds, that is 40 percent of the time required to completely "empty" the integrator, the level of I_2 again increases to one per unit, operating the trip level detector and gating the integrator. At this point the integrator would have discharged 40 percent of the time which had been "stored" on the previous operation leaving "empty", or available, (1.0 - .6 + .4 x .6) 100 or 64 percent of its full capacity. Thus the time to obtain a trip output with one per unit I_2 would be 64 percent of the full time indicated by equation (1), or the curve in Figure 10. Therefore, the actual time to trip for the K setting and I_2 value assumed, would be 0.64 (10) = 6.4 seconds.

The plot in Figure 13 provides a pictorial illustration of the solution of the previous example. The ordinate of this diagram is the time "stored" in the integrator expressed in percent of the total time for the particular value of I_2 and K factor, as determined from equation (1). The abscissa is in seconds of reset time.

In the example the trip level detector dropped out after 6 seconds of operation at 1 per unit I_2 on the K = 10 curve. At this point 60 percent of the total available storage capacity had been used up, as represented by the dotted curve to the left of the ordinate in Figure 13. The trip integrator now commences to reset, or "empty", at the rate shown by the straight line plot to the right of the ordinate. After 60 seconds, when the trip level detector is assumed to operate again, the plot in Figure 13 indicates that 36 percent of the "stored time" still remains in the integrator, or its capacity to time is 64 percent of the "full time" for the particular multiple of I_2. It was assumed that when the level detector again operated the value of I_2 was again 1 per unit so the "full time" would be 10 seconds. Actual time would be .64 x 10 = 6.4 seconds.

In the previous example it was assumed that the level of I_2 was the same, i.e. one per unit, both on the initial timing sequence and also when the trip level detector operated the second time prior to full reset of the integrator. If the value of I_2 were different the second time, the expected time to trip could be determined by the same method. Assume again that K = 10, that the initial magnitude of I_2 is one per unit, and that 6 seconds, that is 60 percent, of the integrator storage capacity had been used up when the trip level detector drops out. Further assume that after 60 seconds, i.e. 40 percent of the total reset time, the I_2 magnitude again increases above the trip level detector operating point, but now the magnitude of I_2 is two per unit. The time to obtain a trip output at this new level will be the full time indicated by equation (1), or the K = 10 curve in Figure 8, at 2 per unit (which is 2.5 seconds) multiplied by the percentage of the total storage capability of the integrator that is still "empty", or available. As in the previous example the integrator is 64 percent "empty" so that the time to operate is 0.64 (2.5)= 1.6 seconds.

Referring again to the diagram in Figure 13 we note that if after 60 seconds the magnitude of the negative-sequence current is 2 per unit, the operating time will be 0.64 (2.5) = 1.6 seconds.

The linear reset time of the integrator following a partial timing operation is intended to provide an approximate match with the cooling rate of the machine. In other words if the machine has been subjected to an unbalanced current condition, which is removed prior to operation of the SGC relay, a subsequent unbalanced condition occuring before the machine has cooled will necessitate a shorter operating time than indicated by the $I_2^2t = K$ curve.

Note that the 250 second timer that limits maximum operating time also has a 250 second reset time from its fully operated point and proportionally shorter reset times following shorter periods of operation.

The alarm circuit is also fed from the output of the tap set unit via the band-pass filter. The alarm level detector has an adjustment range of 0.03 to 0.20 per unit, referred to the tap setting as a base. When generator negative-sequence current (I_2) exceeds the set point of the alarm level detector, its output will energize the alarm unit via the driver after a 3 second delay.

A quick-acting visual indication of pickup of the trip level detector is provided by a light-emitting diode (LED), which is driven by the output of the level detector. This device facilitates calibration of the trip level detector in test by indicating when the level detector has operated.

Both SGC12A and SGC12B relays include a negative-sequence network output signal point, fed via a buffer amplifier and a band-pass filter sharply tuned to the rated frequency of the relay. This provides the means for an accurate network balance check. The network balancing is a factory setting made with the relay in a case with sine wave currents applied.

The type SGC12B relay includes, in addition to all the features of the SGC12A described above, an output point which permits measuring the negative-sequence current level by means of a remotely located instrument. This output point is fed from the output of the band-pass filter via a buffer amplifier. The instrument used is a high-impedance rectifier-type a-c voltmeter supplied with the relay and calibrated at the factory to indicate negative-sequence current in percent of the tap block setting. The meter range is 20 percent full scale.

BURDEN: A-C

Burden of the SGC relay is less than 0.200 ohms per phase and also on the neutral. In no case will the burden exceed this nominal value.

BURDEN: D-C

The SGC power supply requires less than 230 milliamperes. This current constraint does not change with voltage rating.

CALCULATION OF SETTINGS

A number of considerations are involved in determining the settings and adjustments of the type SGC negative-sequence, time-overcurrent relays. The principle purpose of these relays is to prevent the generator from being damaged by the negative-sequence current present during unbalanced load conditions or during prolonged exposure to unbalanced faults. But it is equally important that there be coordination between these relays and the system protective relays on the high side of the step up transformer to avoid unnecessary shutdown of the generator during faults that will be correctly cleared by the system relaying. This requires consideration of the line protection, bus differential, and breaker-failure backup schemes.

The most severe condition for which coordination of the SGC and system relaying will be necessary is a phase-to-phase fault on the high side of the unit transformer, or more specifically for a fault just beyond the breaker in a circuit off the high-side bus, where the breaker initially trips correctly, is automatically reclosed, and fails to trip the second time so that another breaker (or breakers) must be tripped by the breaker-failure backup scheme. For this situation the time "t" in the expression $I_2^2t = K$ defining machine capability, is the initial relay and breaker time plus the total backup breaker clearing time following the automatic reclosure, omitting the dead time in the reclosing cycle. The breakers, protective relaying, and breaker-failure backup scheme must be selected or designed so that the total time does not result in an I_2^2t that exceeds the capability of the specific generator. Or more specifically it must not result in an I_2^2t that exceeds the setting of the SGC relay protecting the machine if an undesired trip is to be avioded.

The following settings or adjustments of the SGC functions are required in the order shown:

1. tap block setting to establish the per unit reference for the pickup and the time characteristics.

2. pickup of the trip level detector.

3. Pickup of the alarm level detector, and

4. the "K" setting of the function generator.

These various settings and adjustments are discussed in detail below.

TAP BLOCK SETTING

In the equation $I_2^2t = K$, the I_2 term is expressed in per unit of stator full-load current. The tap should be selected that is closest to the generator full-load current, referred to the CT secondaries so that the relay time characteristic will be referenced to nearly the same base as the generator heating characteristic. Taps are available in 0.2 ampere steps between 3.1 and 4.9 amperes. These taps cover the load current range from 3.0 to 5.0 amperes.

TRIP LEVEL DETECTOR PICKUP

The negative-sequence current pickup of the trip level detector, which controls operation of the function generator integrator (see block diagram in Figure 4) is continuously adjustable between 0.09 and 0.40 per unit, referred to the tap block setting as a base.

While it is the ultimate responsibility of the user to select the pickup setting of the trip level detector, the following alternatives are offered.

(a) The setting can be based on the continuous I_2 rating of the machine or the minimum pickup of the trip level detector, whichever is higher. Using this basis for the setting, the machine will be "over-protected" at levels of machine I_2 at or somewhat above the pickup setting of the trip level detector. For example, if a machine has a capability of $I_2^2t = 10$ it can carry a negative-sequence current of 0.15 per unit for 444 seconds without damage. However, because the relay is designed with a maximum operating time of 250 seconds, it will overprotect in this area. For currents of 0.2 per unit and above the relay will provide "exact" protection of the machine as indicated by its $I_2^2t = 10$ capability.

If the continuous I_2 rating of the machine is below the minimum available pickup setting of the trip level detector, there will of course be a "dead zone" where the machine might eventually be damaged but where the relay will not start timing. However, at such I_2 levels the machine capability will be sufficiently long to permit the operator to take corrective action as noted in the subsequent section on the alarm level detector.

(b) The setting of the trip level detector can be based on the value equivalent to 250 seconds for the particular "K" curve. For example, if $I_2^2t = 10$, a setting of 0.2 per unit would correspond to an operating time of 250 seconds. While this approach avoids the "overprotection" of the machine, it obviously introduces a much wider "dead zone" between the I_2 continuous rating of the machine and the pickup point of the trip level detector. The operator will be warned by the operation of the alarm level detector when the I_2 magnitude falls in this range and he will have a time in excess of 250 seconds to take corrective action before the machine will be damaged. As illustrated above a machine with a capability of $I_2^2t = 10$ can tolerate a negative-sequence current of 0.15 per unit for 444 seconds without damage.

Calibration markings are provided which permit an approximate setting of the trip level detector pickup. However, it is recommended that the final setting be confirmed by test using the test circuit and procedure described in the section on SERVICING. In most cases the input tap block setting will not exactly match the generator full-load current since the taps are in finite steps of 0.2 amperes. But the level detector pickup can be set at the desired percent of full-load current during test by setting the test current at a value equivalent to the desired negative-sequence current and adjusting the level detector to operate at that value. Note that since the test circuit simulates a phase-to-phase fault condition, the test current should be $\sqrt{3}$ times the desired negative-sequence operating current. The pickup range of time-overcurrent unit extends from 0.09 to 0.40 per unit I_2.

ALARM LEVEL DETECTOR PICKUP

The negative-sequence current pickup of the alarm level detector is continuously adjustable between 0.03 and 0.2 per unit, referred to the tap setting as a base. It is essential that this level detector be sufficiently sensitive to detect any negative-sequence current that approaches or exceeds the continuous I_2 rating of the protected generator as determined from the manufacturer. For example, if a conductor cooled generator has an I_2 continuous rating of 0.06 per unit, the Alarm Detector should be set at or below 0.06 per unit (referred to generator full-load). For negative-sequence current levels that fall between this value and the operating point of the trip level detector, the alarm unit contacts can be used to sound an alarm to warn station attendants that corrective action must be taken.

The operating point of the alarm level detector should be set by test using the circuit and procedure described in the section on SERVICING, and using a test current that simulates a negative-sequence current that is the required percentage of the generator full-load current.

"K" SETTING

The setting of the "K" factor in the function generator must be made so that the relay I_2^2t characteristic matches the heating characteristic of the protected machine. Since the purpose of the relay is to protect the machine from thermal damage, its time characteristic should be set by choice of "K" factor so that it falls slightly below the machine characteristic. This is illustrated in figure 10 in which a machine characteristic of $I_2^2t = 10$ has been assumed. A relay time characteristic of $I_2^2t = 8$, as shown by the dashed line in figure 10, has been selected as typical of a setting which would provide margin below the machine characteristic. However, the user should decide for himself what margin he desires between relay and machine characteristics.

As was mentioned in the section on OPERATING PRINCIPLES if the magnitude of the negative-sequence current is greater than the trip level detector pickup setting then the maximum time to trip will never exceed 250 seconds regardless of current magnitude, nor will it be less than 0.2 seconds. The upper limit was selected as a practical design limitation and was considered to be long enough (i.e. more than 4 minutes) to provide the operator with ample time to take corrective action. The lower limit of 0.2 seconds was selected because no correct relay setting could ever result in an operating time of less than this value. This is so because, even with a K setting of 4, the maximum possible negative-sequence current for a system fault will always result in more than 0.2 seconds operating time. The 0.2 second minimum limit will insure coordination with line relays during line faults even with an improper K setting.

Although calibration markings are shown on the dial plate for the "K" adjustment, these markings are intended to provide an approximate initial trial setting which should then be refined by test. It is recommended that the test to determine the "K" setting be made on the basis of the negative-sequence generator current (I_2) for a phase-to-phase fault on the high side of the step-up transformer. If this were 3 per unit for example, and the relay time characteristic is $I_2^2t = 8$, the operating time is by calculation $t = \frac{8}{(3)^2} = 0.889$ seconds. The dashed curve in figure 10 provides an approximate verification of this. With the test current set to be equivalent to 3 per unit of generator current, that is $\sqrt{3}$ times 3 per unit times tap block setting and if the tap and generator full-load current are exactly matched, the "K" dial should be set by trial until the operating time is 0.889 seconds. Use the test circuit and procedures outlined in the section on SERVICING, noting that the test circuit is simulating a phase-to-phase fault condition so that test current must be $\sqrt{3}$ times the I_2 value that is to be simulated.

* Since the available tap block points between 3.1 and 4.9 amperes are finite steps of 0.2 amperes, in most cases it will not be possible to realize an exact match between tap setting and generator full load current. Compensation for this discrepancy can be realized by the method illustrated in the example below.

After the setting is made at the highest expected value of I_2 for a phase-to-phase fault on the high side of the transformer, the time should be checked at a lower multiple, say 1 per unit. For our example, where $I_2^2t = 8$ has been assumed, the time at 1 per unit should be 8 seconds $\pm$ 10 percent over the full temperature range.

Assume that the Type SGC relay is to be applied on a unit generator-transformer installation having the following characteristics:

1. generator — 400 MVA, 25 KV,
2. transformer — 400 MVA,
3. generator CT ratio — 10,000/5,
4. base — 400 MVA, 25 KV and
5. "K" for generator — 10.

Generator full-load current, on the basis of the 400 MVA rating, should be calculated as follows:

$$MVA = \frac{\sqrt{3}\ I(KV)}{1000}$$

$$400 = \frac{\sqrt{3}\ I(25)}{1000}$$

$$I = \frac{400(1000)}{\sqrt{3}\ (25)} = 9238 \text{ Amperes, (Pri.)}$$

$$I = \frac{9238}{2000} = 4.62 \text{ Amperes, (Sec.)}$$

The current selection device should be placed in the 4.7 ampere tap, which is closest to the calculated full-load current.

The trip level detector pickup should now be set with sufficient sensitivity to insure operation at expected minimum load with one pole of the main generator breaker open. If we assume that this value of I_2 is 0.9 amperes for our example, the level detector should be at least this sensitive. This value, however, should be considered as an upper limit of level detector pickup. It is recommended that it be set near its minimum; 0.12 per unit based on full-load is suggested. For the example this would be an I_2 pickup of 0.12 (4.62) = 0.554 negative-sequence amperes, using the procedure outlined under SERVICING.

Prior to setting the "K" factor the user should determine the negative-sequence current from the generator for a phase-to-phase fault on the high side of the step-up transformer for typical system conditions. Assume that this is determined to be 8.35 amperes, which is 8.35/4.62 = 1.81 per unit referred to generator full-load as a base. The "K" factor should be set by test, recognizing that the input tap setting of 4.7 does not exactly match the full-load current. To compensate for this the "K" factor setting should be made at the calculated secondary negative sequence current, 8.35 amperes in this example, but the operating time should be set by test on the basis of per unit current referred to the machine full load as a base. That is:

$$\frac{8.35}{4.62} = 1.81 \text{ per unit}$$

Assuming that the desired relay characteristic is $I_2^2t = 8$, the time setting at 8.35 amperes should be calculated as follows:

$$(1.81)^2t = 8$$

$$t = \frac{8}{(1.81)^2} = 2.45 \text{ seconds}$$

Using the test procedure and connections described in the section on SERVICING, the "K" adjustment should be set to obtain the desired 2.45 seconds operating time with a negative sequence current of 8.35 amperes applied to the relay. Since the test circuit simulates a phase-to-phase condition, the actual test current should be $\sqrt{3}(8.35) = 14.5$ amperes. Note that the integrator reset time from the fully operated condition is normally 250 seconds. To expedite testing of the relay it is recommended that the dc supply to the relay be opened for ten seconds following each test to discharge the integrator to verify the setting. The time should be checked at a lower multiple, again recognizing that the 4.7 ampere relay tap does not exactly match the machine full load. Referred to the relay tap the 8.35 amperes negative sequence test current is equivalent to $\frac{8.35}{4.7} = 1.78$ per unit. Hence the actual relay characteristic (i.e., "K" of the relay) is:

$$\left(\frac{8.35}{4.7}\right)^2 (2.45) = 7.73$$

If a lower test current of 4.7 amperes negative sequence is now applied to the relay, it will be one per unit on the relay tap base, and the operating time should be:

$$(I)^2(t) = 7.73$$

* $t = 7.73$ seconds ($\pm$ 10%)

Referred to the machine full-load base, this is equivalent to:

$$\left(\frac{4.7}{4.62}\right)^2 (7.73) = 8.$$

CONSTRUCTION

CASE

The components of each relay are mounted on a cradle assembly which can be easily removed from the relay case. The cradle is locked in the case by means of latches at the top and bottom. The electrical connection between the case blocks and cradle blocks are compleded through removable connection plugs. See figure 10. Separate testing plugs can be inserted in place of the connection plugs to permit testing the relay in its case. The cover is attached to the front of the case and includes two interlock arms which prevent the cover from being replaced until the connection plugs have been inserted.

The case is suitable for semiflush mounting on panels. Hardware is available for all panel thicknesses up to two inches, but panel thickness must be specified on the order to ensure that the proper hardware will be provided. Outline and panel drilling dimensions are shown in figures 11 and 12. A front view of the relay is included here in figures 1 and 2.

TESTING FACILITIES

All General Electric drawout case relays may easily be tested in the case by using either the XLA12A or XLA13A test plugs. The XLA12A has 20 fingers which bring both the ten relay connections and the ten outside world connections to the front of the relay for easy access. The XLA13A test plug brings only the ten relay connections to the front of the relay without disturbing the CT shorting bars. A circuit for testing the SGC relay using two XLA12A test plugs is shown in figure 11.

For futher information on these test plugs refer to Section 7332 in the General Electric Apparatus Handbook or contact the nearest General Electric Apparatus Sales Office.

RECEIVING, HANDLING AND STORAGE

These relays, when not included as a 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 Apparatus 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

GENERAL

The relay should be examined and tested upon delivery to ensure that no damage has been sustained in shipment and that the relay functions properly. If the examination or acceptance tests indicates that re-adjustment is necessary, refer to the section on SERVICING.

The following tests may be performed as part of the installation of the relay at the discretion of the user. Since most operating companies use different procedures for acceptance and installation tests, the following section includes all applicable tests that may be performed on the relays.

VISUAL INSPECTION

Check the nameplate stamping to ensure that the model number agrees with Table I.

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 the screws are tight.

MECHANICAL INSPECTION

1. The armature and contacts of the seal-in unit should move freely when operated by hand. There should be at least ten mils wipe on the seal-in unit contacts.

2. The target in the seal-in unit must come into view and latch when the armature is operated by hand and should unlatch when the target release level is operated.

3. The telephone relay units used in these relays should be checked to have a contact gap of at least ten mils and contact wipe of five mils. The contact wipe may be checked by inserting a five mil shim between the armature and pole piece and operating the armature by hand. The normally open contacts should make contact with the shim in place when the armature is operated by hand.

4. Make sure that the fingers and shorting bars in the relay cradle and case blocks agree with the internal connections diagram. The internal connections diagram is included here as Figure 5.

   CAUTION:

   EVERY CIRCUIT IN THE DRAWOUT CASE HAS AN AUXILIARY BRUSH. IT IS ESPECIALLY IMPORTANT ON CURRENT CIRCUITS AND OTHER CIRCUITS WITH SHORTING BARS THAT THE AUXILIARY BRUSH BE BENT HIGH ENOUGH TO ENGAGE THE CONNECTING PLUG OR TEST PLUG BEFORE THE MAIN BRUSHES DO. THIS WILL PREVENT CT SECONDARY CIRCUITS FROM BEING OPEN CIRCUITED DURING INSERTION OF THE CONNECTING PLUG. SEE FIGURE 12.

DRAWOUT CASE

Since all drawout relays in service operate in their case, it is recommended that they be tested in their case 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 jumperes and the exercise of greater care since connections are made to both the relay and the external circuitry. Test connections in Figure 11 illustrate the use of this more versatile test plug.

CAUTION:

WHEN HI-POTTING THE SGC REMOVE ALL EXTERNAL WIRING FROM TERMINAL 10. DO NOT HI-POT TERMINAL 10. THE REASON IS THAT SURGE CAPACITORS ARE RATED FOR 600 VDC AND THE HI-POT VOLTAGE MAY DAMAGE THE CAPACITORS.

POWER REQUIREMENTS GENERAL

All alternating current operated devices are affected by frequency. 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 application of non-sinusoidal waveforms.

Therefore, in order to properly test alternating current relays 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, R-L or R-C networks, or saturating electromagnets (such as time overcurrent relays) would be affected by non-sinusoidal wave forms.

The SGC relay responds to the input current waveform in a different manner than most a-c ammeters. Therefore, if the test source contains high amplitude harmonics, the ammeter and relay responses will be different. Thus the ammeter will not truly reflect the relay calibration. This relay has been calibrated using a conventional source of minimal harmonic content. It should be tested with a similar sinusoidal current source. Good waveform is necessary. The meter used should maintain a $\pm 1\%$ accuracy full scale with all readings being made in the top two-thirds of the scale.

Similarly, relays requiring d-c control power should be tested using d-c and not full-wave retified 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 d-c source should not contain more than 5% ripple.

TARGET SEAL-IN UNIT TAP SETTING

When trip coil current falls within the range of 0.2 to 2.0 (or 0.6 to 2.0) amperes at minimum control voltage, the tap screw of the target seal-in unit should be set in the low ampere tap. When the trip coil current ranges from 2 to 30 amperes at minimum control voltage, the tap screw should be placed in the 2.0 ampere tap. The tap screw for the seal-in unit is the screw holding the right-hand stationary contact of the seal-in unit. To change the seal-in unit tap setting first remove the relay connection plugs. Then take a screw from the left-hand stationary contact and place it in the desired tap. Next, remove the screw from the other tap and place it back in the left-hand contact. This procedure is necessary to prevent the right-hand stationary contact from getting out of adjustment. Screws should never be left in both taps at the same time.

TARGET SEAL-IN UNIT CHECK

The pickup and dropout of the target seal-in unit can be tested as follows.

1. Connect relay studs 1 and 11 (see figure 5) to a d-c source, ammeter, and load box so that the current can be controlled over a range of 0.1 to 2.0 amperes d-c.
2. Short the TR contacts by jumpering terminal 11 to the seal-in unit tap screw.
3. Increase the current slowly until the seal-in unit picks up. See Table V for correct pick-up values.
4. Remove the jumper and the seal-in unit should remain in the picked up position.
5. Decrease the current slowly until the seal-in unit drops out. See Table V for correct drop-out values.

TABLE V

UNIT	TAP	PICK-UP AMPERES	DROP-OUT AMPERES
0.2/2.0	0.2	0.15 - 0.195	0.05 or more
	2.0	1.50 - 1.95	0.05 or more
0.6/2.0	0.6	0.45 - 0.585	0.15 or more
	2.0	1.50 - 1.95	0.50 or more

TIME-OVERCURRENT AND ALARM UNITS: PICKUP AND TRIP CHECK

1. Connect the relay as shown in figure 11. The a-c source must be of rated frequency and at least 60 volts or more.

2. Place the current selection device in the 3.1 ampere tap.

3. Make the following settings on the front panel of the relay.

   a. alarm pickup adjustment--10 (10 percent or 0.1 per unit)
   b. overcurrent pickup adjustment--20
   c. K set--2

4. Adjust the series resistance to a great enough value to limit current to less than 0.25 ampere before applying a-c to the relay.

5. Close switch A; then close switch B; wait for 10 seconds before proceeding.

   NOTE: The d-c supply power must be interrupted for 10 seconds to ensure total discharge of the integrator. After d-c is re-applied an additional 10 second waiting period is necessary to restore the integrator to its zero state; this state is not zero volts,therefore, a fixed time is required to completely reset the integrator.

   The alternative is to wait 250 seconds between trials. This is the maximum reset time.

* 6. Increase the current to 0.39-0.41 ampere; this is $(.4A)/(\sqrt{3}\,(3.1)) =$ 0.075 per unit I_2

7. Turn the alarm pickup adjustment knob to 5. The alarm test lamp (external test equipment) should come on 3 seconds after adjustment to 5. Return the knob to the 10 position; reset should be immediate. The lamp should go out.
8. Increase the current to 0.73-.77 ampere; this is $(.75A)/(\sqrt{3}\,(3.1)) =$ .140 per unit I_2.
9. Watch the LED and turn the overcurrent pickup adjustment to approximately 10. The LED should come on. Turn the knob back to 20 and the LED should go out.

10. Increase the current to the 1.0 per unit level. That is:

$$I_{in} = \sqrt{3} \times 3.1 \text{ ampere tap} \times 1.0 \text{ per unit,}$$

$$I_{in} = 5.37 \text{ amperes.}$$

11. Open switches A and B; wait 10 seconds.

12. Close A; wait 10 seconds.

13. Prepare to time the interval between the closing of B and the lighting of the overcurrent-trip test lamps.

14. Close B; time the interval. The time should be 1.8-2.2 seconds with these approximate settings.

15. Open switches A and B.

16. These tests show that the alarm and pickup level detectors are working and the integrator is functioning.

*Indicates Revision

LONG AND SHORT TIME TIMERS CHECK

1. Make the following settings on the front panel of the relay
   a. alarm pickup adjustment -- 10
   b. overcurrent pickup adjustment -- 9
   c. K set -- 10
2. Close switches A and B and adjust the input current to 0.50-0.55 amperes. The overcurrent pickup indication (LED) will come on.
3. Open A and B for 10 seconds.
4. Close A for 10 seconds.
5. Prepare to time interval between closing B and the overcurrent-trip test lamp coming on.
6. Close B and time the interval. The time should be 225-275 seconds.

   NOTE: The following test procedure requires currents which exceed the continuous rating of the sequence network. Minimize the time this current is applied as much as possible.

7. Increase the a-c current to 17-19 amperes; this is 3.35 per unit I_2.
8. Open switches A and B and wait for 10 seconds.
9. Close A; wait ten seconds.
10. Change K set to 2 or less.
11. Prepare to time an interval of approximately 0.200 seconds between B closure and trip indication
12. Close switch B -- for as short a period of time as necessary.
13. Open A and B. The time should be 0.18-0.22 seconds.
14. This ensures that both the long and short time timers are functioning.

INSTALLATION PROCEDURE

INTRODUCTION

The relay should be installed in a clean, dry location, free from dust and excessive vibration, and well lighted to facilitate inspection and testing.

The relay should be mounted on a vertical surface. The outline and panel drilling dimensions are
* shown in figures 16, 17 and 18.

The internal connection diagrams for the relays are shown in figures 5 and 6. A typical connections diagram is shown in figure 9.

METER INSTALLATION

The connections between the relay terminals 15 and 16 and the meter should be made with a shielded, twisted pair of conductors. The shielded pair should be #18 A.W.G. or larger. It is suggested that the length of the conductor not exceed 2000 feet. The shield should be grounded at the relay.

SURGE GROUND AND RELAY CASE GROUND CONNECTIONS

One of the mounting studs or screws should be permanently connected to ground by a conductor not less less than No. 12 AWG gage copper wire or its equivalent. This connection is made to ground the relay case. In addition, the terminal designated as "surge ground" on the internal connections diagram must be tied to ground for the surge suppression networks in the relay to perform properly. This surge ground lead should be as short as possible to ensure maximum protection from surges (preferably ten inches or less to reach a solid ground connection).

With terminal 10 connected to ground, "surge ground" is connected electrically to the relay case. The purpose of this connection is to prevent high frequency transient potential differences from entering the solid state circuitry. Therefore, with terminal 10 connected to ground the surge capacitors are connected between the input terminals and the case. Caution must be exercised when hi-potting between these terminals and the case.

*Indicates Revision

The surge capacitors used in this relay are not suitable for a-c hi-pot testing, the surge ground lead must be removed from terminal 10. A red label has been fixed to the back of the relay case to indicate that caution must be exercised to avoid destroying the surge capacitors.

The surge capacitors are not subjected to high frequency surge potentials of any appreciable level. their impedance at surge frequencies is very low, less than one ohm usually, and the various source and circuit impedances along the surge path to the relay usually limit the surge currents to less than 25 amperes. Therefore, the surge voltage drop across a surge capacitor is small.

Surge capacitors of sufficient voltage rating to pass relay hi-pot tests are physically large; too large in fact to allow use of the required numbers inside most component relays as surge filter elements. We are continually monitoring developments in this area in an effort to be able to respond to requests for such ratings. To date, no practical capacitor of suitable compactness has been found.

*Hipot is defined by ANSI c37.90 under section entitled "Dielectric Tests".

TEST PLUGS

The relay may be tested without removing it from the panel by using a 12XLA13A test plug. This 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. Additional information on the XLA test plugs may be obtained from the nearest General Electric Apparatus Sales Office.

ELECTRICAL TESTS AND SETTINGS

Most operating companies use different procedures for installation tests. The section under ACCEPTANCE TESTS contains all necessary tests which may be performed as part of the installation procedure. Procedures for setting the relay are discussed in the SERVICING section in this book.

SERVICING

TARGET SEAL-IN UNIT TAP SETTING

Refer to section of this same title under ACCEPTANCE TESTS for details on changing taps.

TIME OVERCURRENT UNIT ADJUSTMENTS

As mentioned earlier, the relay should be tested in its case. Also, good waveforms are necessary to achieve accurate adjustments. If these conditions are met, testing will simulate conditions the relay "sees" in service.

The internal connections for the SGC relays are shown in figures 5 and 6. Test connections are shown in figure 11. The test connection diagram shows what is necessary to build a test set up. Power is supplied through the group of studs 17 through 20. It is of great importance that the external resistor be connected properly. The internal connections in figures 5 and 6 show that this resistor is necessary to limit current to the supply.

The group of studs 3 through 8 are the inputs to the negative-sequence network. This is the trigger of the time overcurrent unit. Wired in this manner, the relay sees an I_2 current simulating a phase-to-phase fault. The minimum negative-sequence current at which the overcurrent unit will pick up is determined by the adjustment of the overcurrent pickup adjustment on the front of the relay. This pickup setting affects the time curve (Figure 10)and should not be changed once adjusted by testing. Note that the tap markings (see figure 2) of 3.1 through 4.9 amperes do not indicate the current load which will cause the overcurrent unit to operate. Tap markings refer to machine full-load referred to CT secondaries. For example, if the relay were to be connected to a machine whose full-load rating was 3.1 amperes referred to the secondary, the tap would be set in the 3.1 ampere position.

TRIP UNIT SETTING

1. Place current selection device in the tap chosen for service.

*2. Calculate test current used in figure 11 to set the overcurrent pickup adjustment as follows.

$$I_{in} = \sqrt{3} \times I_{tap} \times (\text{per unit } I_2) \times (I_{full\ load})/I_{tap}$$

Note that the last term on the right side of the equation compensates for mismatch introduced by discrete tap setting.

Example Case: If the 3.1 ampere tap is chosen and pickup is desired when the rms level of I_2 reaches 10% of relay tap the test current is calculated as follows.

$$I_{in} = \sqrt{3} \times 3.1 \times .10 \times 1 = .537 \text{ amperes}$$

3. Close switches A and B.

4. Adjust I_{in} to value calculated for the example, the current would be .537 amperes

5. Set the overcurrent pickup adjustment at the threshold which just keeps the overcurrent pickup indicator (and LED -- light emitting diode) on. This is an approximate setting.

6. Lower the current and then increase it slowly till the LED turns on.

7. Note the current level at pickup. If it is high, lower the pot setting slightly. Repeat step 6 until the LED threshold is the calculated I_{in}. In the example this value is .537 amperes.

8. Lock the overcurrent pickup adjustment knob when it is set properly. Lock the knob by turning the knurled knob clockwise.

9. Check pickup after locking knob to ensure the setting did not change when the pot was locked.

ALARM UNIT SETTING

1. Follow the same procedure as outlined for the trip unit except it will be necessary to monitor the contacts output between terminals 2 and 12.

2. The alarm has a built-in 2.97-3.03 seconds delay. The alarm delay prevents temporary high I_2 levels from giving an alarm signal. This circuit requires the I_2 level to maintain the alarm level for at least 3 seconds. The alarm unit has instantaneous reset. Compensate for this 3 second delay when making adjustments by slowly changing the current or pickup setting.

3. Don't forget to lock the alarm pickup adjustment knob by turning the knurled knob clockwise.

4. Check the setting after locking the pot for correct setting.

K SET ADJUSTMENT

The final step is to adjust K set. Referring again to figure 11, set the input current to one per unit of chosen tap. Calculate the test current as follows.

$$I_{in} = \sqrt{3} \times I_{tap} \times 1.0 \text{ per unit} \times (I_{full\ load})/(I_{tap})$$

Where I_{in} = test current

Adjust the K set knob on the front of the relay to the approximate desired setting of K (see CALCULATION OF SETTINGS for K value selection). With the relay input adjusted to one per unit the relay trips in T seconds. The time to trip, T, equals K-Set in this special case because I_2 equals 1.0 per unit. This is shown below:

$$\int_{0}^{t_0} I_2^2 dt = K$$

$$I_2^2 t = K, \ I_2 = 1.0 \text{ per unit (constant)}$$

Therefore, t = K.

1. Close switches A and B; adjust I_{in} to the calculated 1.0 per unit level.
2. Open switches A and B for 10 seconds.
3. Adjust K-set knob to the approximate setting desired.
4. Close switch A; wait 10 seconds.
5. Prepare to time the interval between the closing of B and the lighting of the overcurrent-tap test lamp.
6. Close B; time the interval.
7. The number of seconds counted is the "K" setting of the relay.
8. Adjust the K-set knob to obtain the desired setting.
9. Repeat steps 3 through 8 until the time interval recorded is the desired "K" setting.
10. Lock the K-set pot by tightening the rim lock at the bottom of the knob.

Note that changing either of the pickup adjustments does not affect the time to trip. Changing these settings only alters the pickup level.

RENEWAL PARTS

It is recommended that sufficient quantities of renewal parts be carried in stock to enable 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 quantity required, name of the part wanted, and the complete model number of the relay for which the part is required.

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. It is recognized that 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 INSTALLATION PROCEDURE 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 consists of a flexible strip of metal with an etched-roughened surface resembling in effect a superfine file. The polishing action is so delicate that no scratches are left, yet it will clean off any corrosion thoroughly and rapidly. Its flexibility insures the cleaning of the actual points of contact. Do not use knives, files, abrasive paper or cloth of any kind to clean relay contacts.

APPENDIX I

NEGATIVE-SEQUENCE CURRENT NETWORK

INTRODUCTION

When a generator is subjected to an unbalanced fault or load the stator current includes a negative-sequence component (I_2). This negative-sequence current sets up a counter-rotating flux field in the machine which causes double frequency currents to flow in the rotor iron and slot wedges, resulting in local heating. It has been shown that this heating will not be excessive if the following condition is satisfied.

$$(I_2)^2 t = K$$

where $(I_2)^2$ is the integrated product of negative-sequence current (I_2) and the duration of the fault (t), and K is a constant for the machine in question.

Since the capability of machines to withstand unbalanced faults can be expressed as a function of $(I_2)^2t$, the ideal relay for the protection of generators against unbalanced faults is one which responds only to the negative-sequence component of fault current from the generator, and has a time characteristic matching the $(I_2)^2t$ characteristic of the machine.

The SGC relay described in the text approaches the ideal condition. The solid state unit connected across the negative- sequence segregating network, responds only to the I_2 component of generator current. The time curves (see Figure 5) closely approximate the $(I_2)^2t$ machine characteristics.

THE SEQUENCE NETWORK

The term sequence network refers to the two transactors with two winding primaries shown in Figures 5 and 6. The attempt here is to give the reader some insight into the function of this sequence network. Two phase currents and the neutral current are operated on to produce a voltage, V_{out}, proportional to the negative sequence component of the three phase system. To get a little more specific let us refer to Figure 14.

First, consider the elimination of zero sequence effects. The number of turns in each magnetic circuit is designed and wired to reject zero sequence components of the three phase currents. In the transactor Z_1 the turns of the two primaries are equal. Therefore, the I_0 component of I_b and I_c cancel in the Z_1 transactor. In transactor Z_2 the effects of I_0 due to I_c are trebeled and subtracted from I_n. Now $I_n = 3I_0$ by definition. Therefore, no effects of zero sequence current pass through either of the transactors. These last two parameters will be used to block the effects of positive sequence.

In order to delete the positive sequence elements of the incoming currents the transfer impedance of the transactors and their respective phase angles are used. The transfer impedances are chosen to eliminate the effects of the positive sequence. To aid understanding this discussion refer to Figure 15. Note that standard positive sequence rotation is used. The primary of TS75 adds I_b and $-I_c$ to get some resultant vector. This vector is attenuated and shifted 75 degrees as shown in figure 15. The vector is labeled V_x. V_y is an attenuated representation of I_c that is shifted 45 degrees. The transaction impedances are designed such that these two vectors cancel for pure positive sequence in the current circuits. The residual voltage is:

$$V_{out} = V_x + V_y$$

This conclusion can be proved more vigorously by symmetrical component theory, but such treatment is beyond the scope of this text.

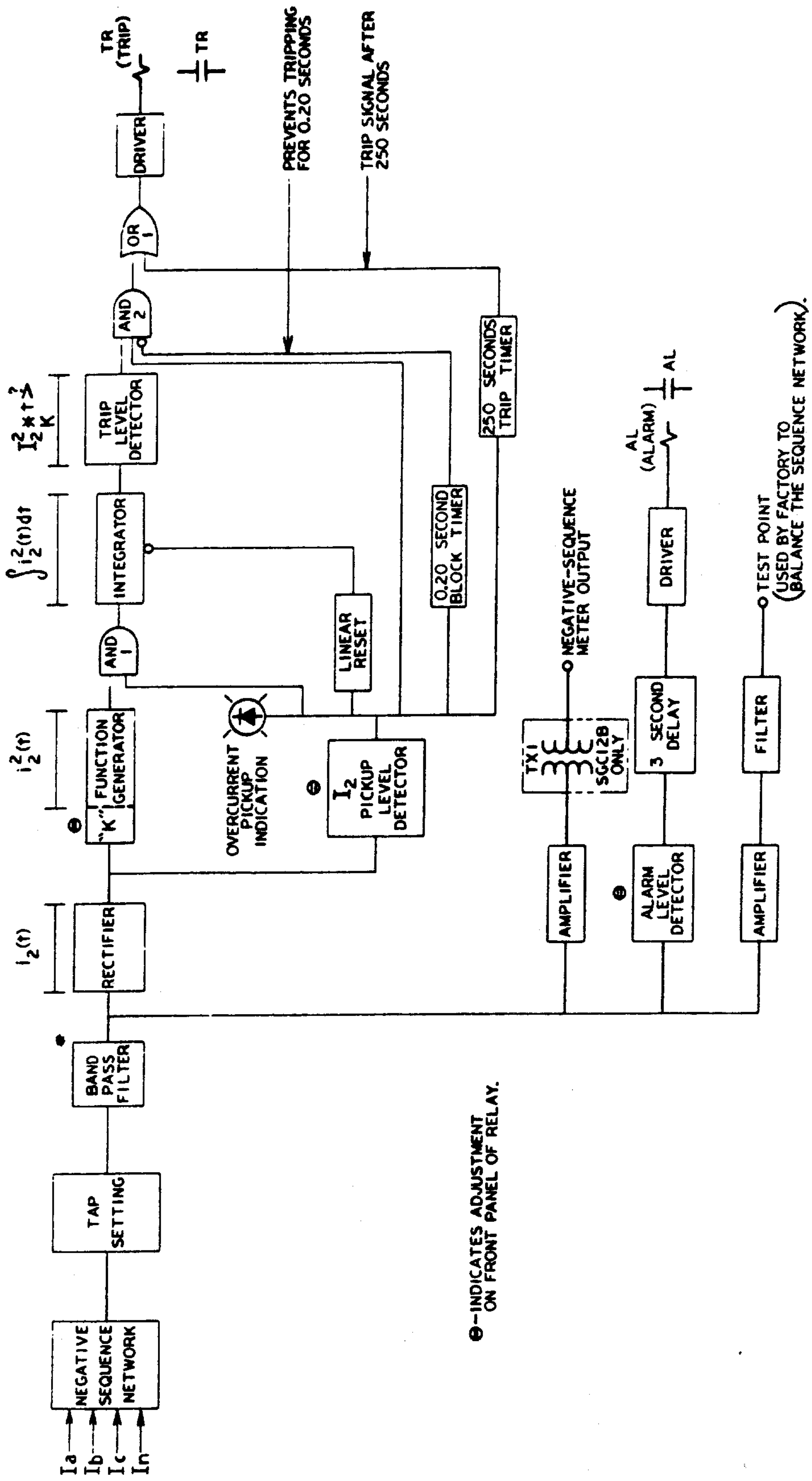


*FIG.4 (0165B2672-2) FUNCTIONAL BLOCK DIAGRAM OF THE SGC RELAY

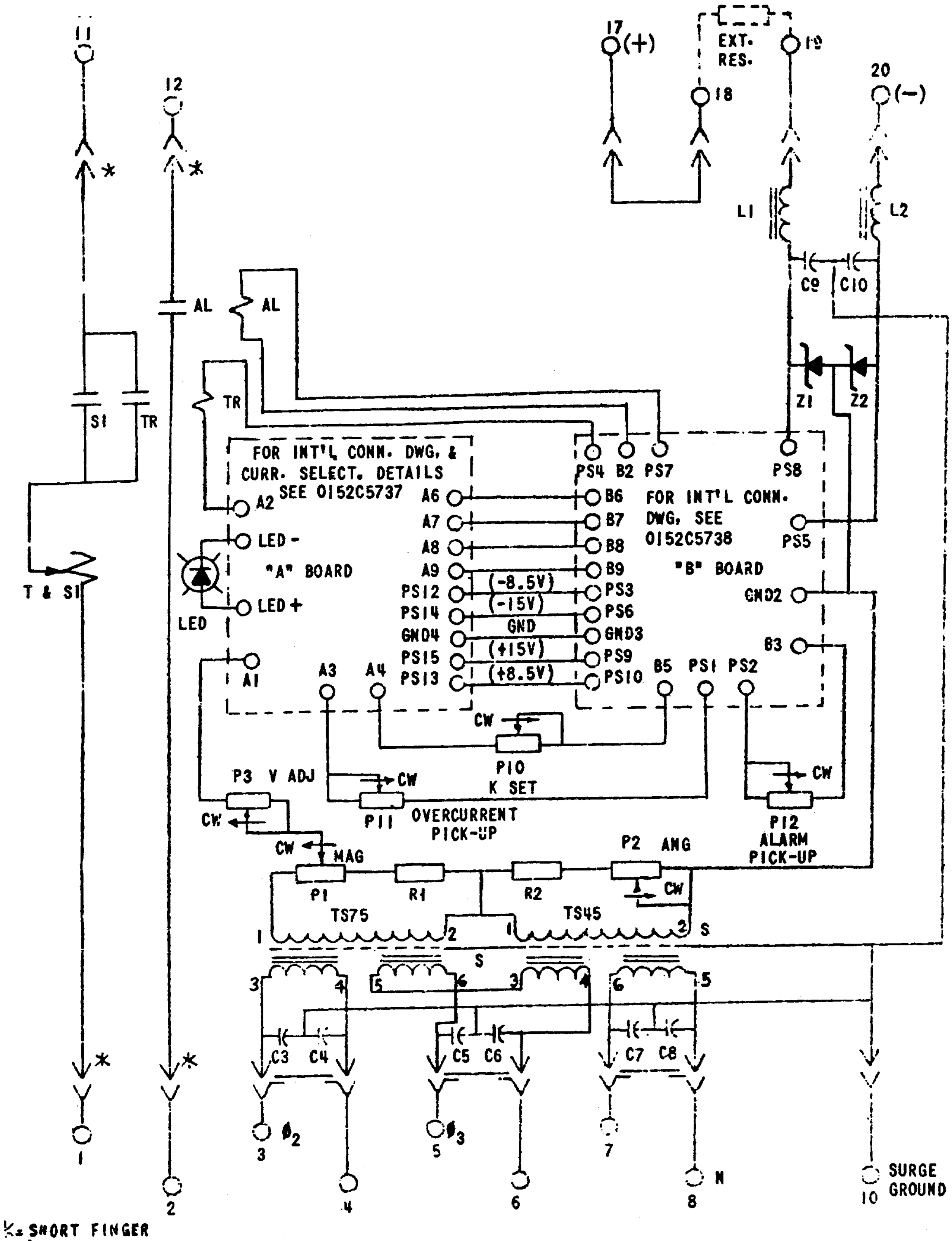


*FIG.5 (0246A6951-2 Sh.1) INTERNAL CONNECTIONS DIAGRAM FOR THE SGC12A RELAY

MODEL	FORM			
	1	2	3	4
VOLTS DC	125	250	125	250
RESISTANCE IN OHMS				
AL COIL	600	600	600	600
TR COIL	650	650	650	650
P1	100	100	100	100
P2	100	100	100	100
P3	1500	1500	1500	1500
P10	20K	20K	20K	20K
P11	100K	100K	100 K	100 K
P12	250K	250K	250K	250K
R1	300	300	300	300
R2	150	150	150	150
EXT. RES.	500	1200	500	1200
CAPACITANCE VALUE				
C3 THRU C8	.05uf	.05uf	.05uf	.05uf
C9 & C10	0.1uf	0.1uf	0.1uf	0.1uf

FIG. 5A (0246A6951-2 SH.2) TABLE OF VALUES FOR INTERNAL CONNECTIONS DIAGRAM FOR THE SGC12A RELAY

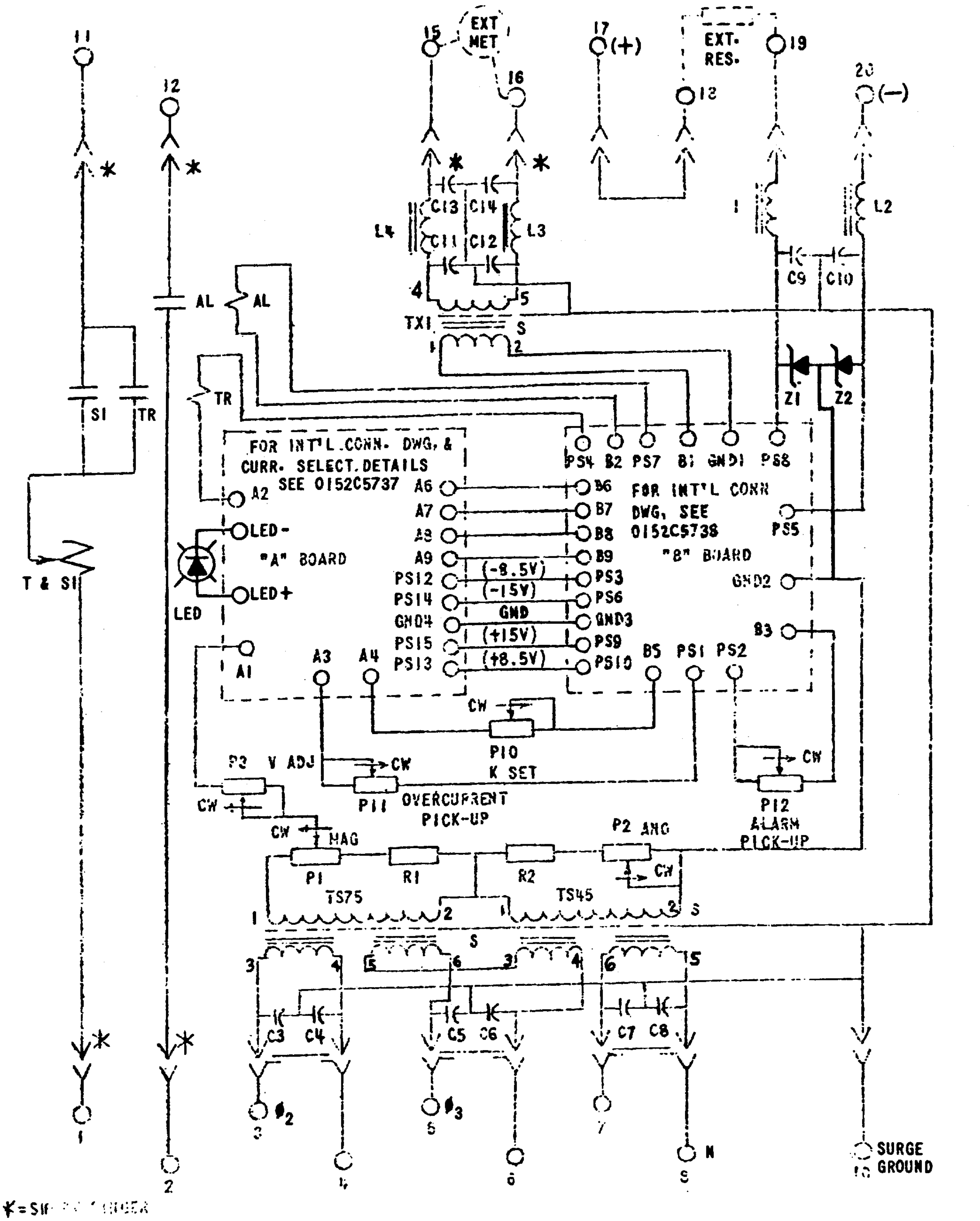


*FIG.6 (0246A6944-2 Sh.1) INTERNAL CONNECTIONS DIAGRAM FOR THE SGC12B RELAY

MODEL	FORM					
	1	2	3	4	5	6
VOLTS DC	125	250	125	250	220	250
RESISTANCE IN OHMS						
AL COIL	600	600	600	600	600	600
TR COIL	650	650	650	650	650	650
P1	100	100	100	100	100	100
P2	100	100	100	100	100	100
P3	1500	1500	1500	1500	1500	1500
P10	20K	20K	20K	20K	20K	20K
P11	100K	100K	100K	100K	100K	100K
P12	250K	250K	250K	250K	250K	250K
R1	300	300	300	300	400	400
R2	150	150	150	150	200	200
EXT. RES.	500	1200	500	1200	1000	1200
CAPACITANCE VALUE						
C3 THRU C8 C11, C12, C13, C14	.05uf	.05uf	.05uf	.05uf	.05uf	.05uf
C9 & C10	0.1uf	0.1uf	0.1uf	0.1uf	0.1uf	0.1uf

*FIG.6A (0246A6944-3 SH.2) TABLE OF VALUES FOR INTERNAL CONNECTIONS DIAGRAM FOR THE SGC12B RELAY

* Indicates revision

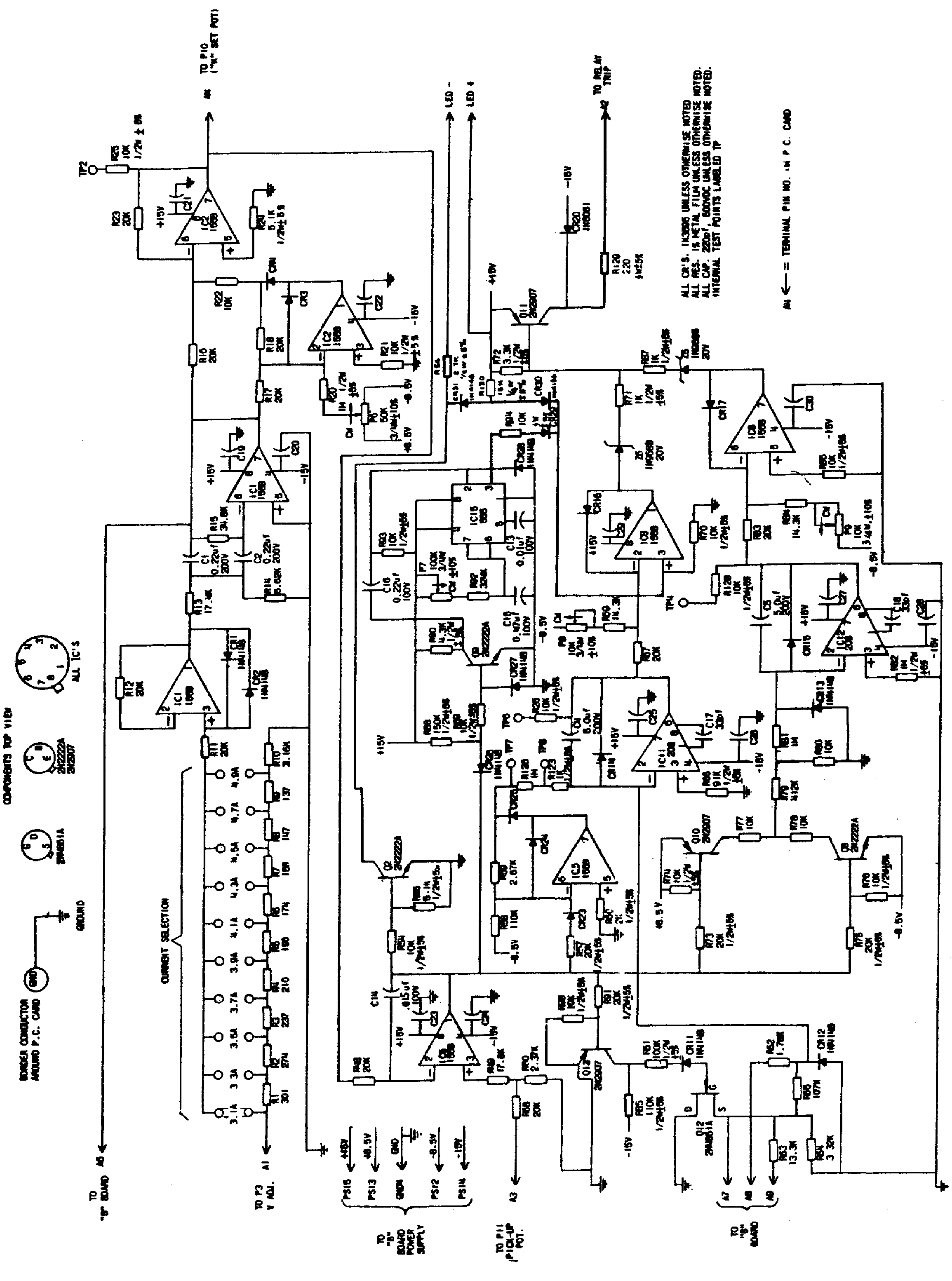


*FIG.7 (0152C5737-0 SH.2) INTERNAL CONNECTIONS DIAGRAM OF THE SGC "A" CARD

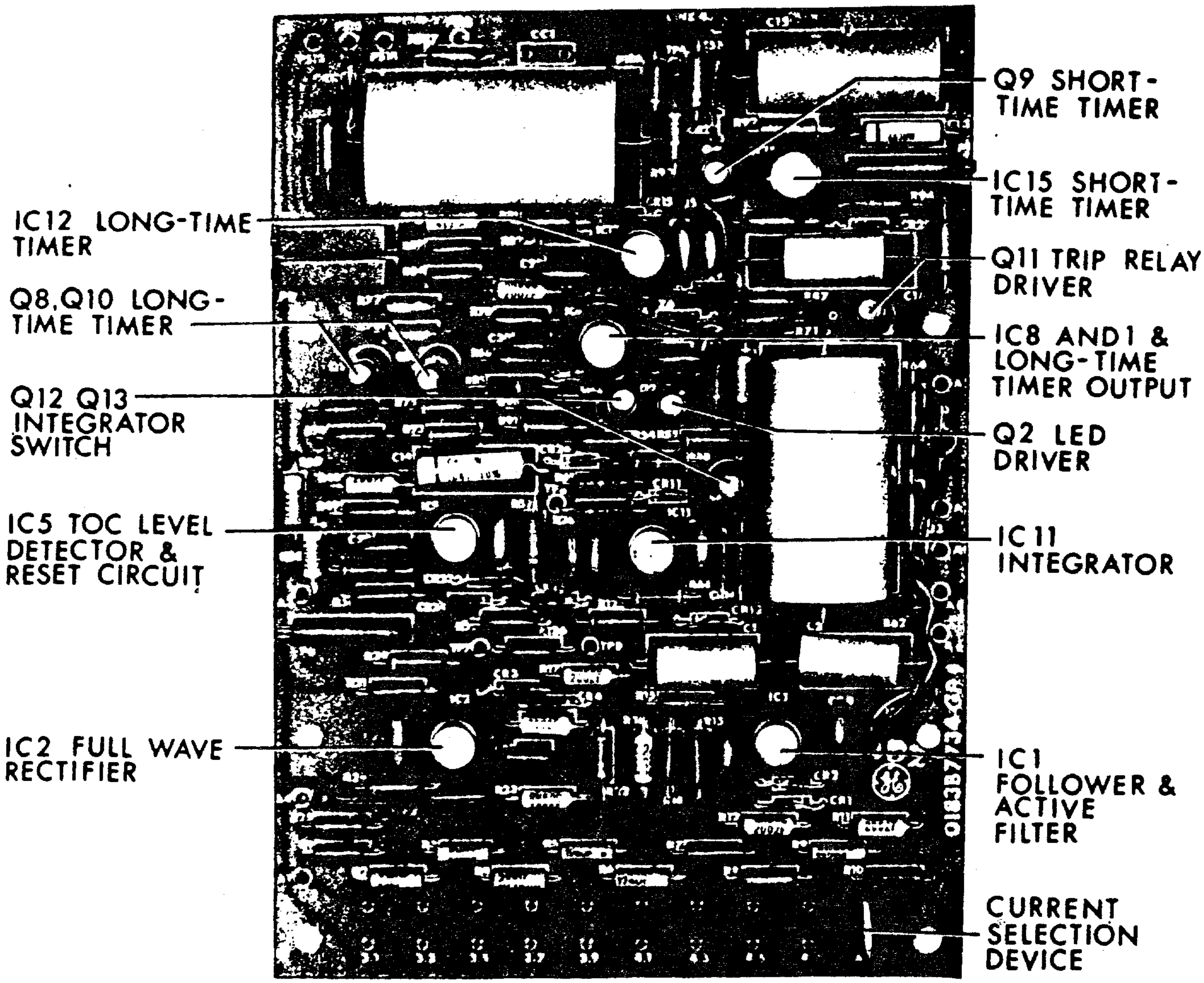


FIG. 7A (8042603) THE SGC "A" CARD

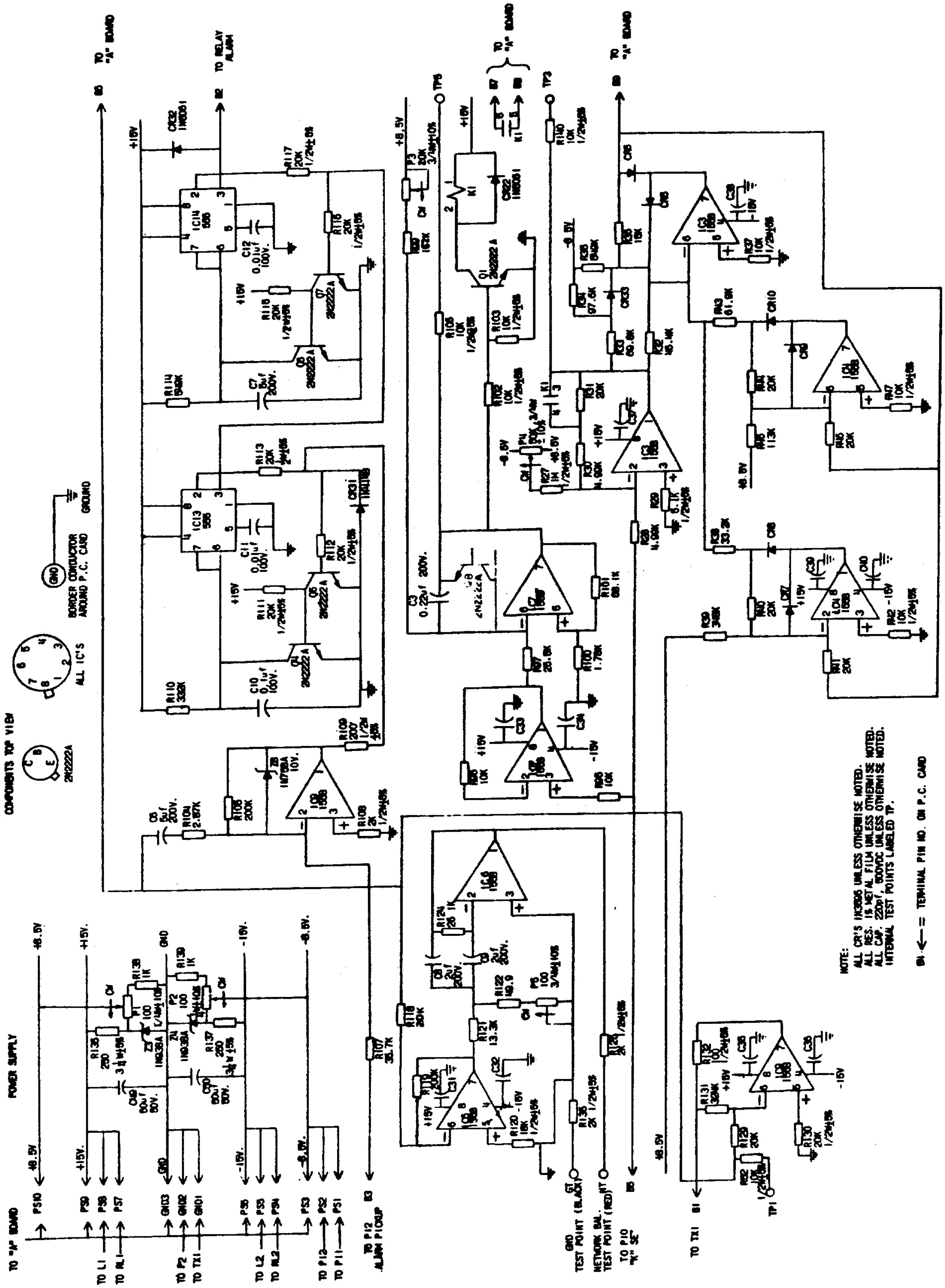


*FIG.8 (0152C5738-4) INTERNAL CONNECTIONS DIAGRAM OF THE SGC "B" CARD

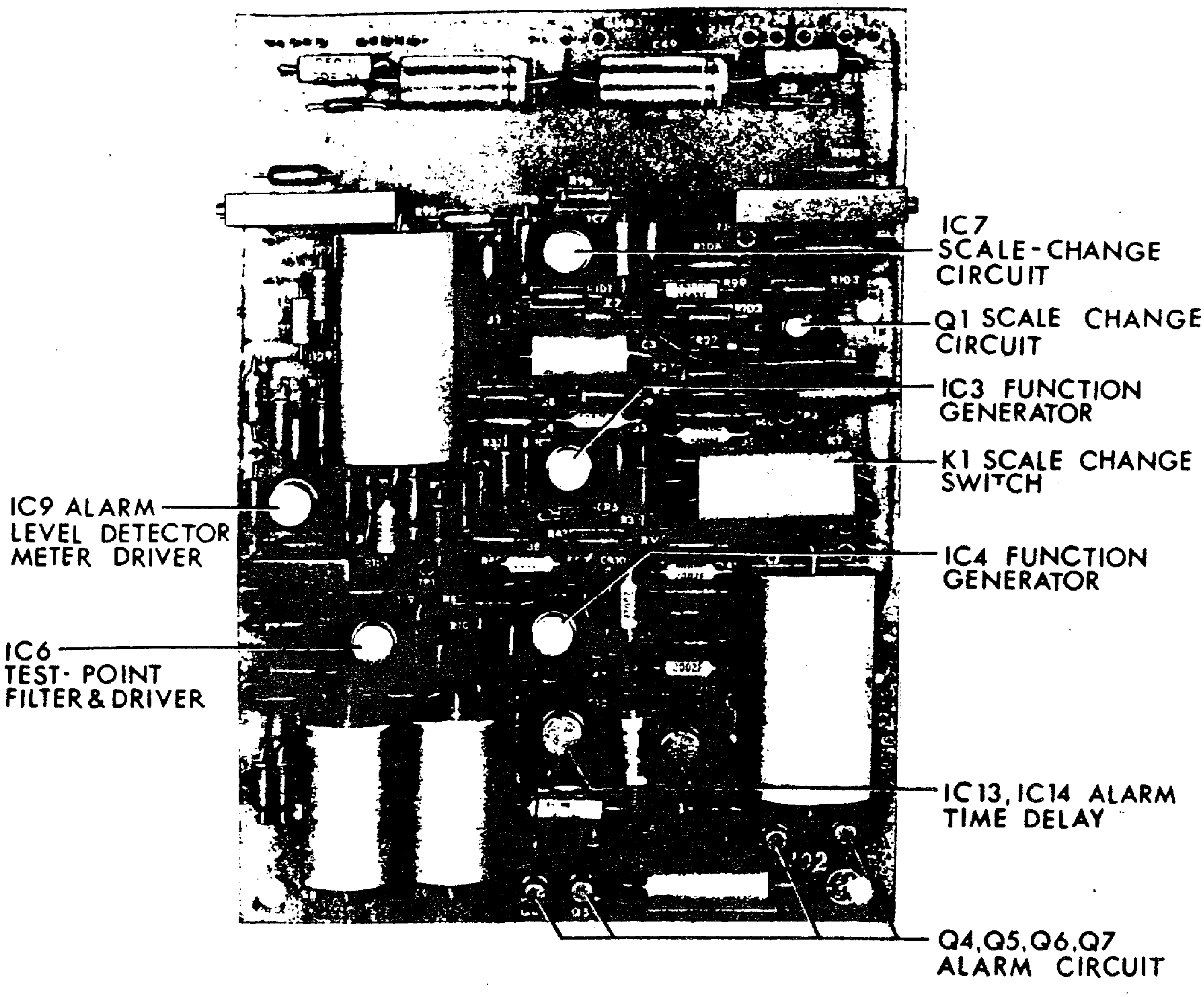


FIG. 8A (8042602) THE SGC "B" CARD

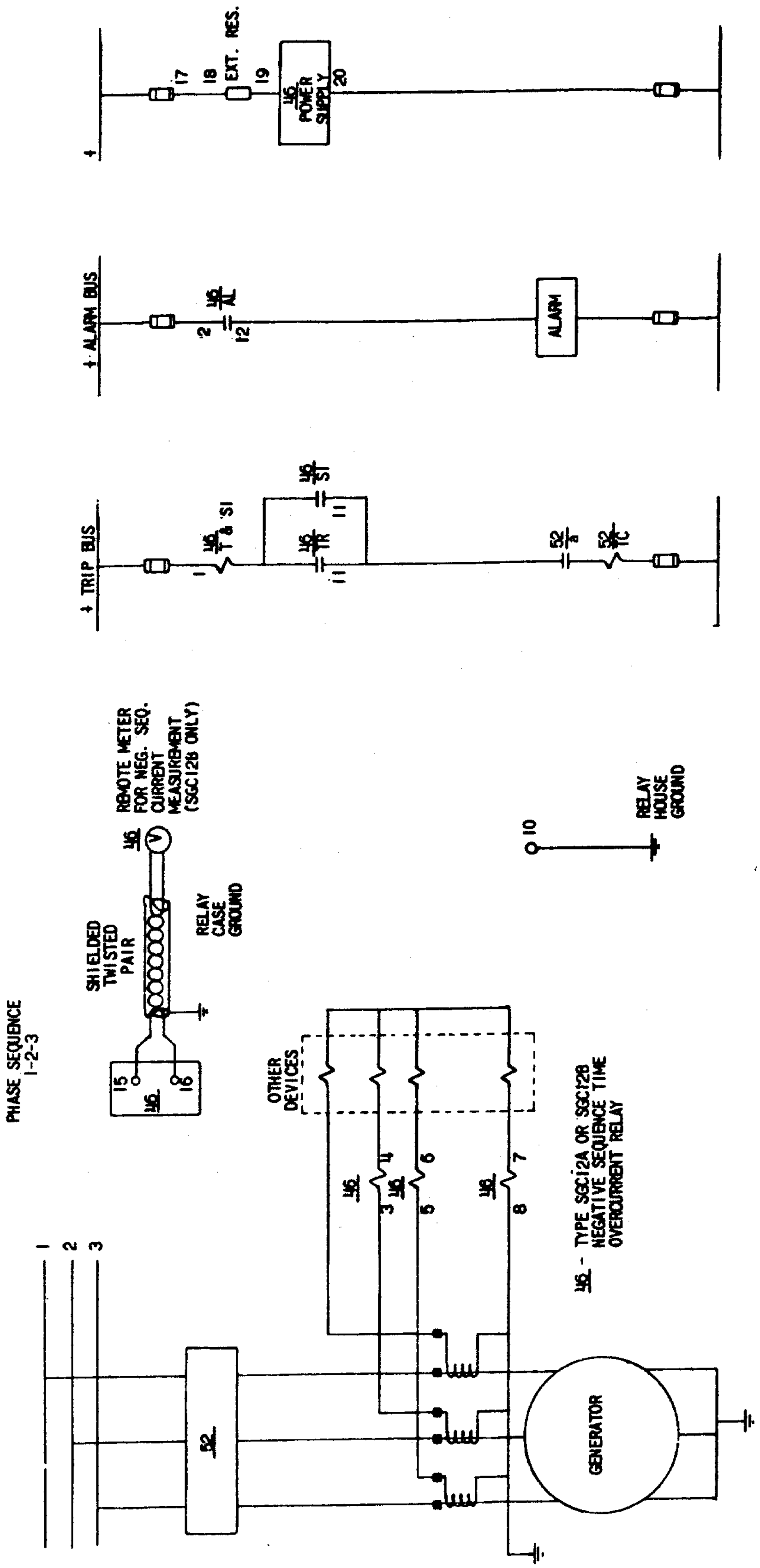


FIG. 9 (0165B2669-0) TYPICAL EXTERNAL CONNECTIONS DIAGRAM FOR THE TYPE SGC RELAY

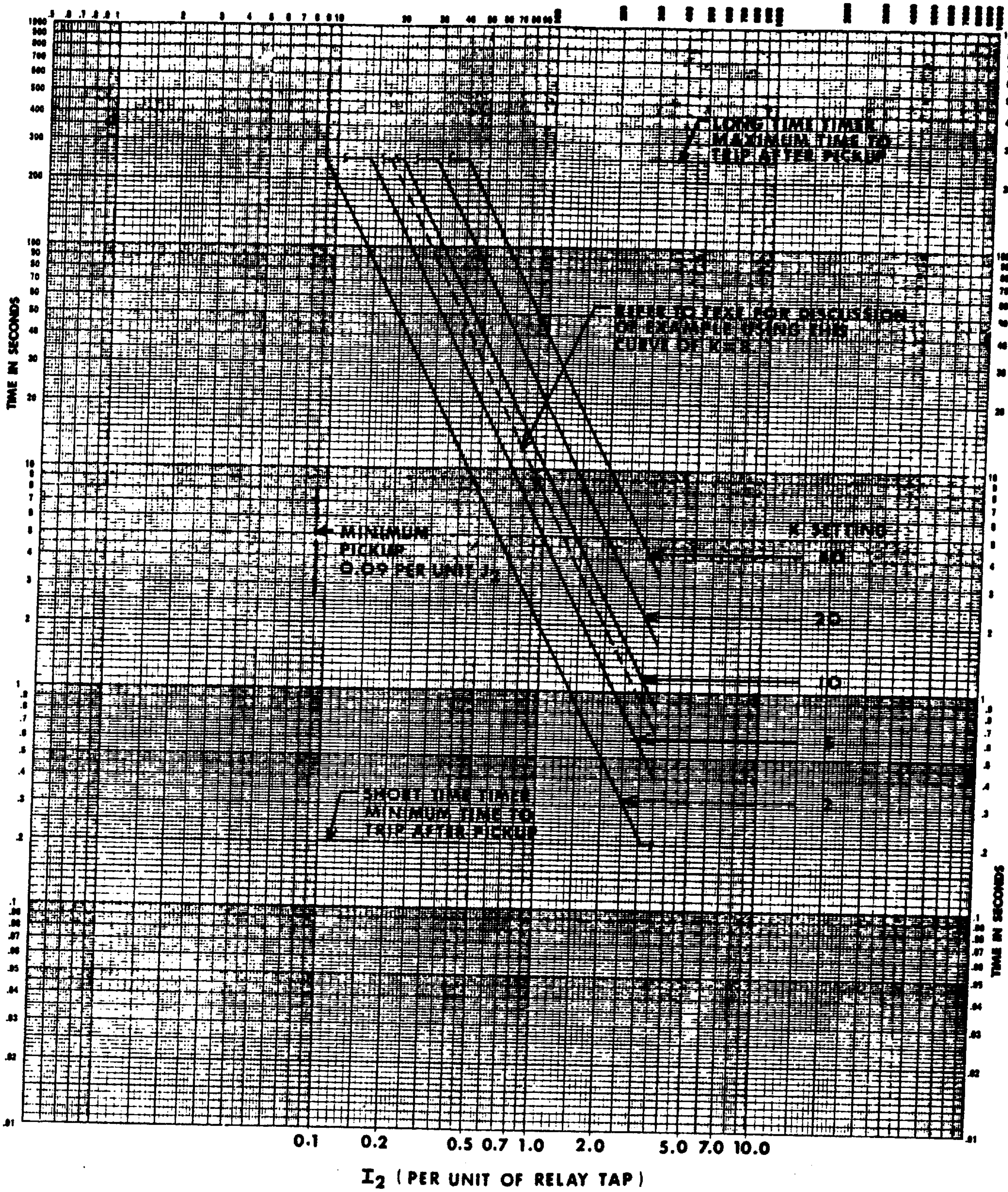


FIG. 10 (0183B7941-1) TYPICAL TIME-CURRENT CURVES FOR THE TYPE SGC RELAY

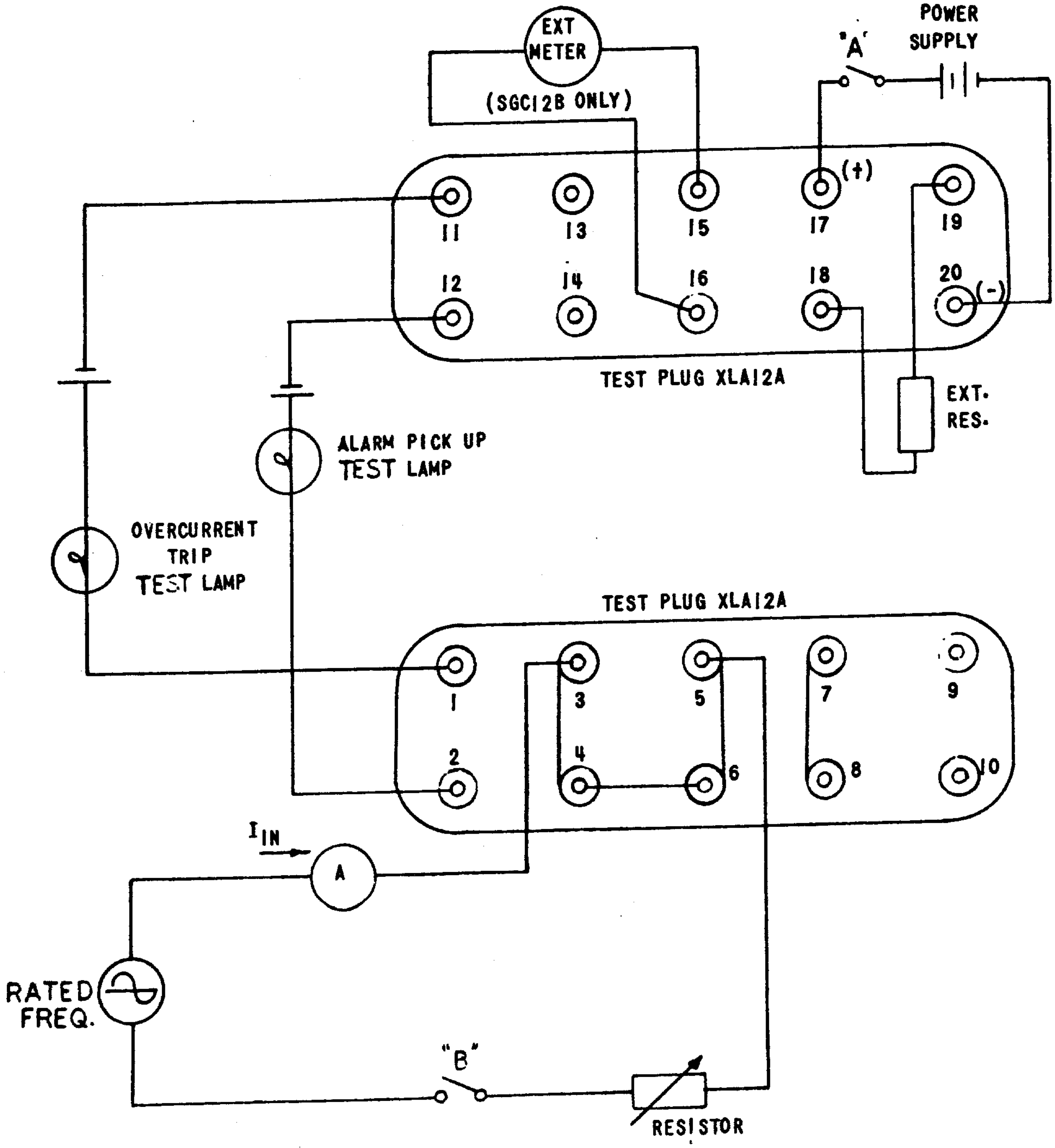


FIG. 11 (0246A6972-2) TEST CONNECTIONS FOR THE TYPE SGC RELAY USING THE XLA12A TEST PLUG

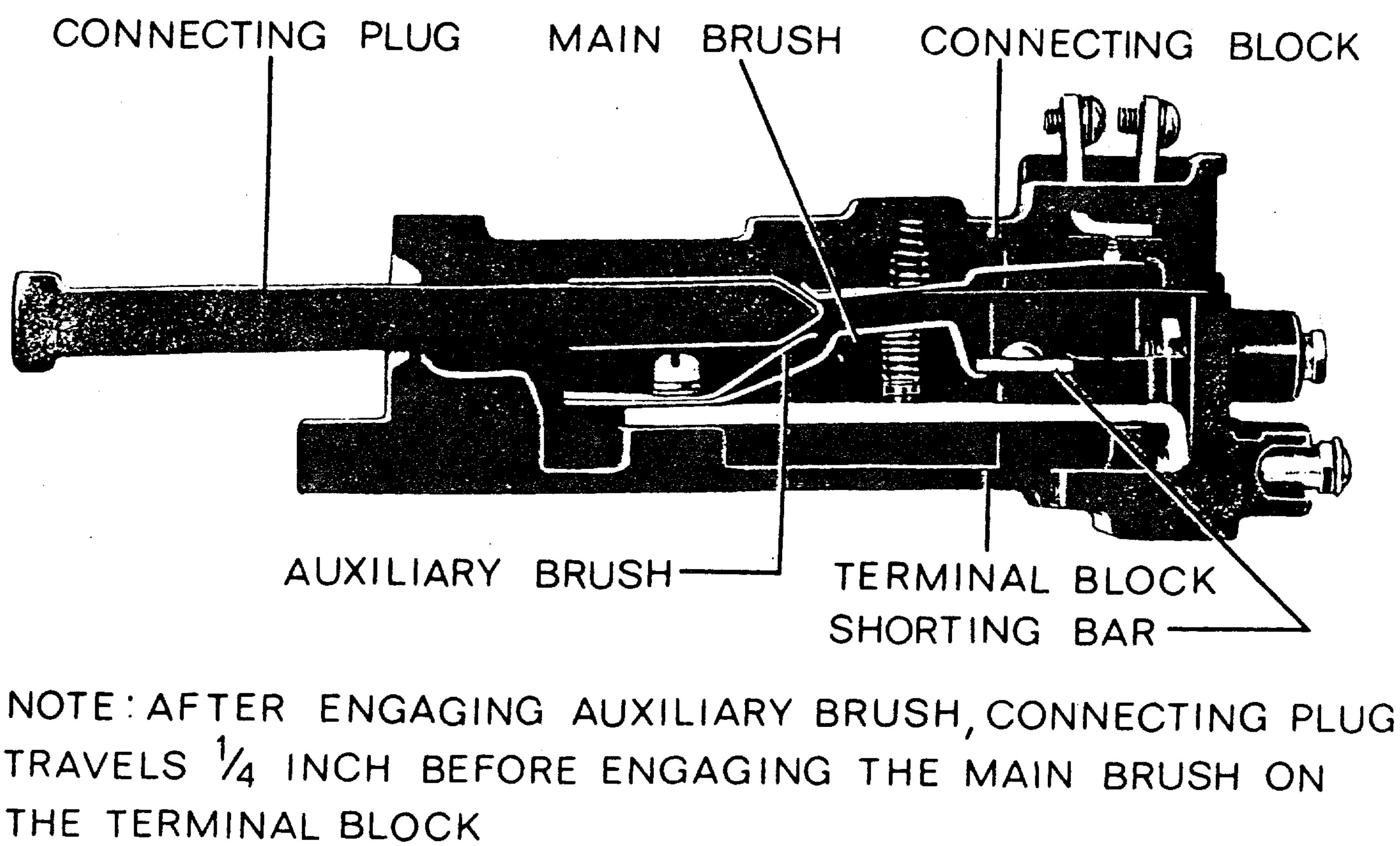


FIG. 12 (8025039) DRAWOUT CASE - CONTACT ASSEMBLY CUTAWAY

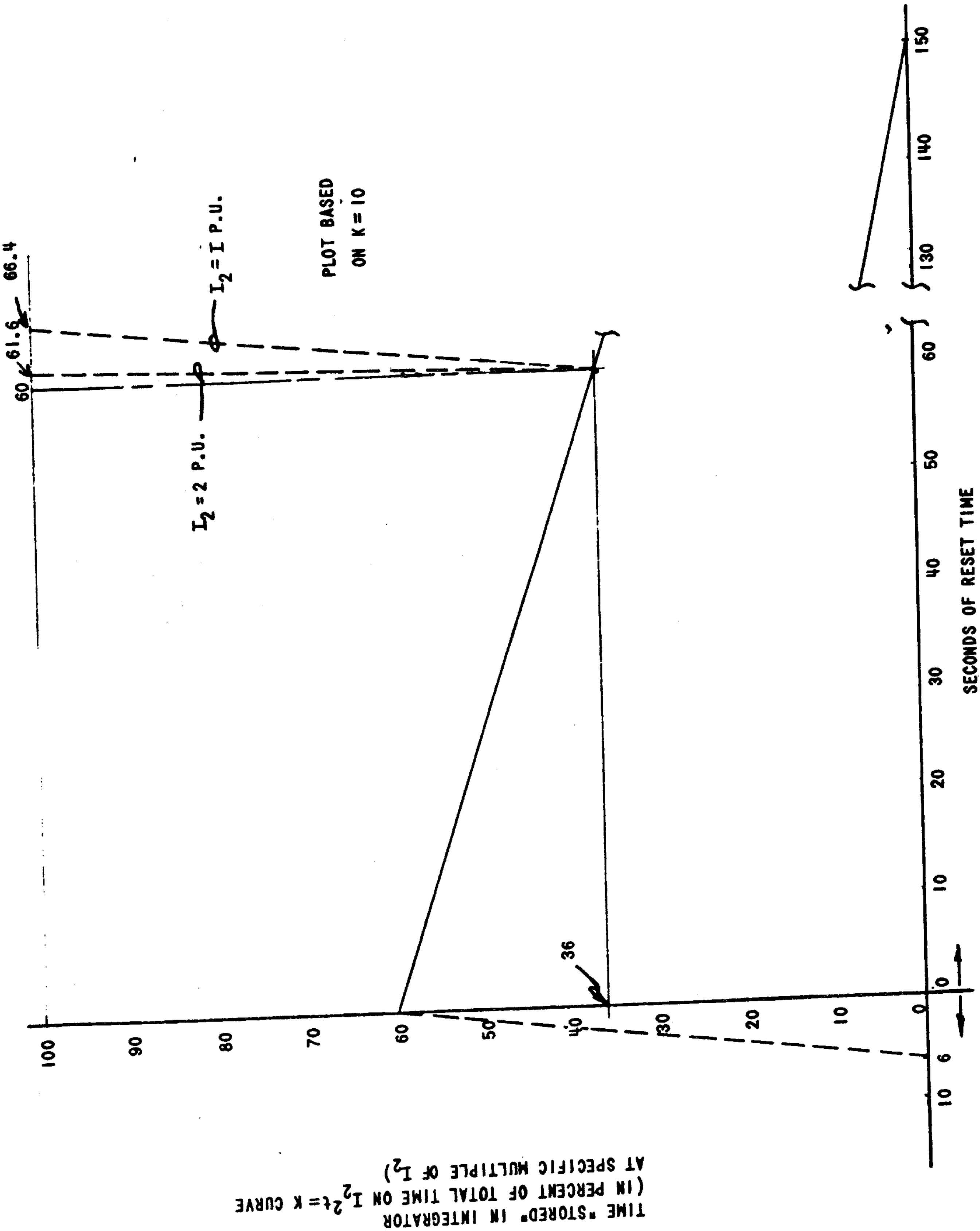


FIG.13 (0208A8592-0) GRAPHICAL PLOT OF STORAGE IN THE SGC INTEGRATOR

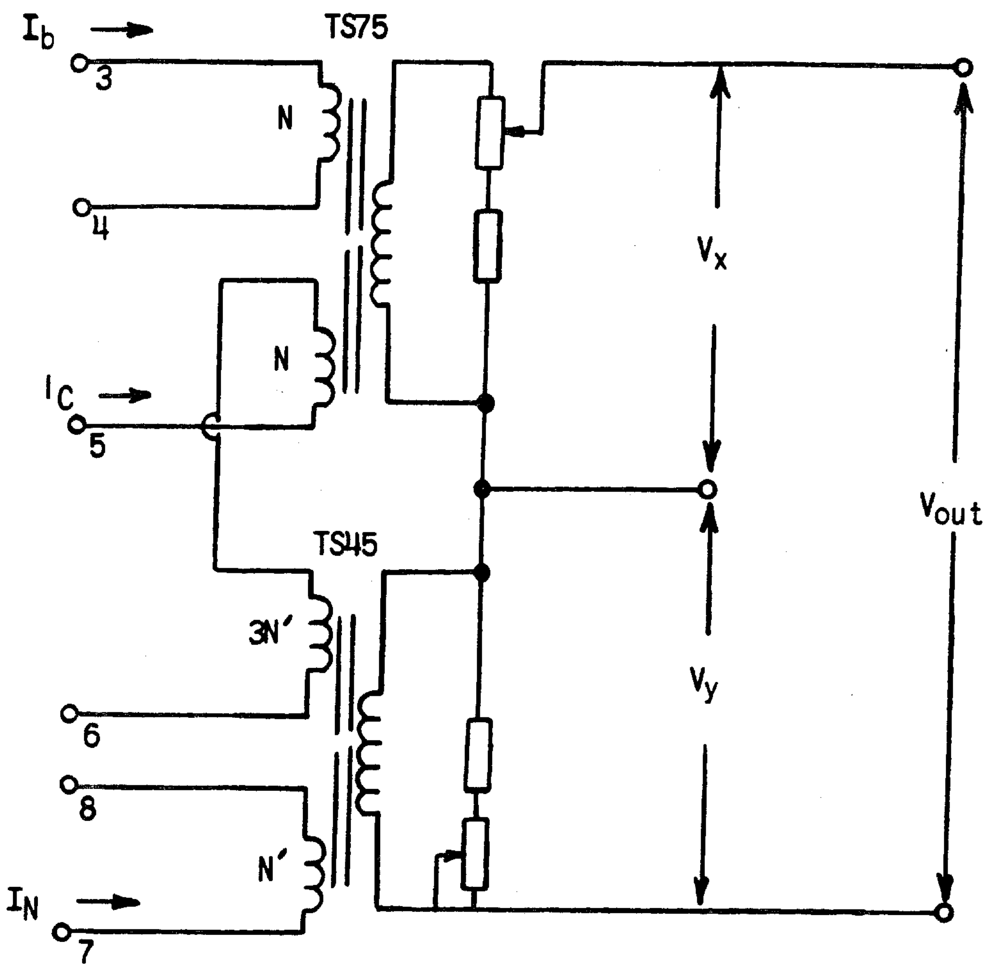


*FIG.14 (0257A5077-2 Sh.2) SCHEMATIC DIAGRAM OF THE SGC NAGATIVE SEQUENCE NETWORK

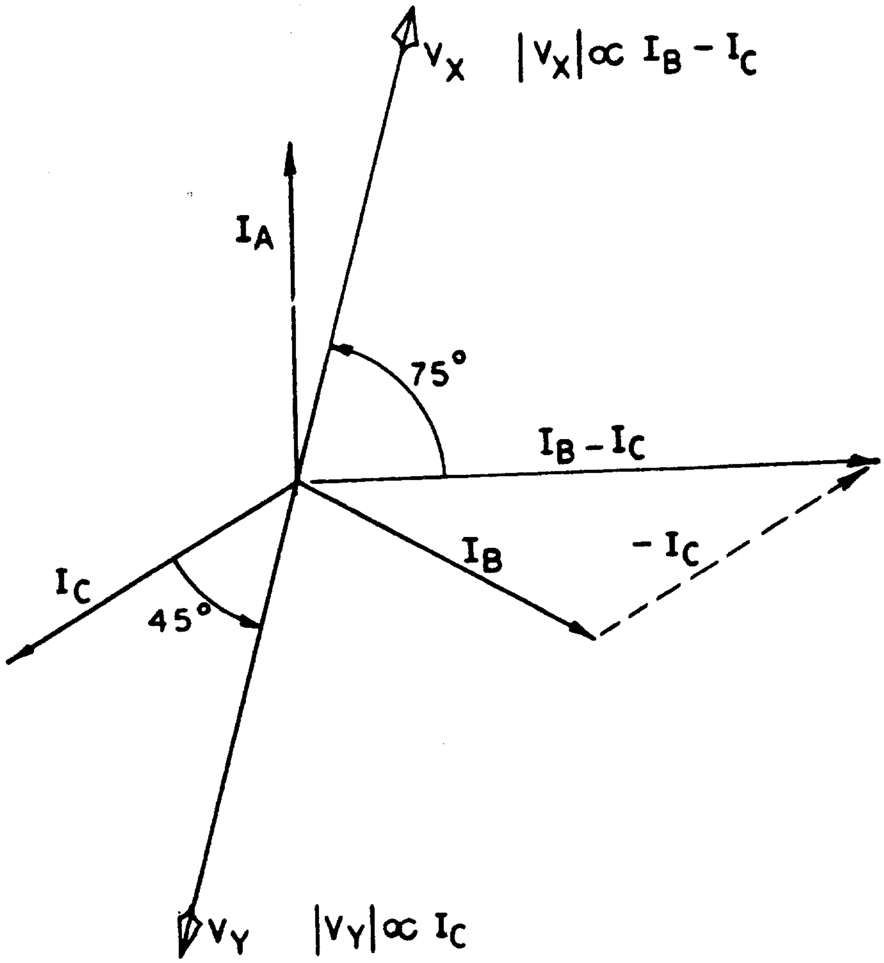


FIG.15 (0257A8365-0) PHASOR ANALYSIS OF THE SGC NEGATIVE SEQUENCE NETWORK

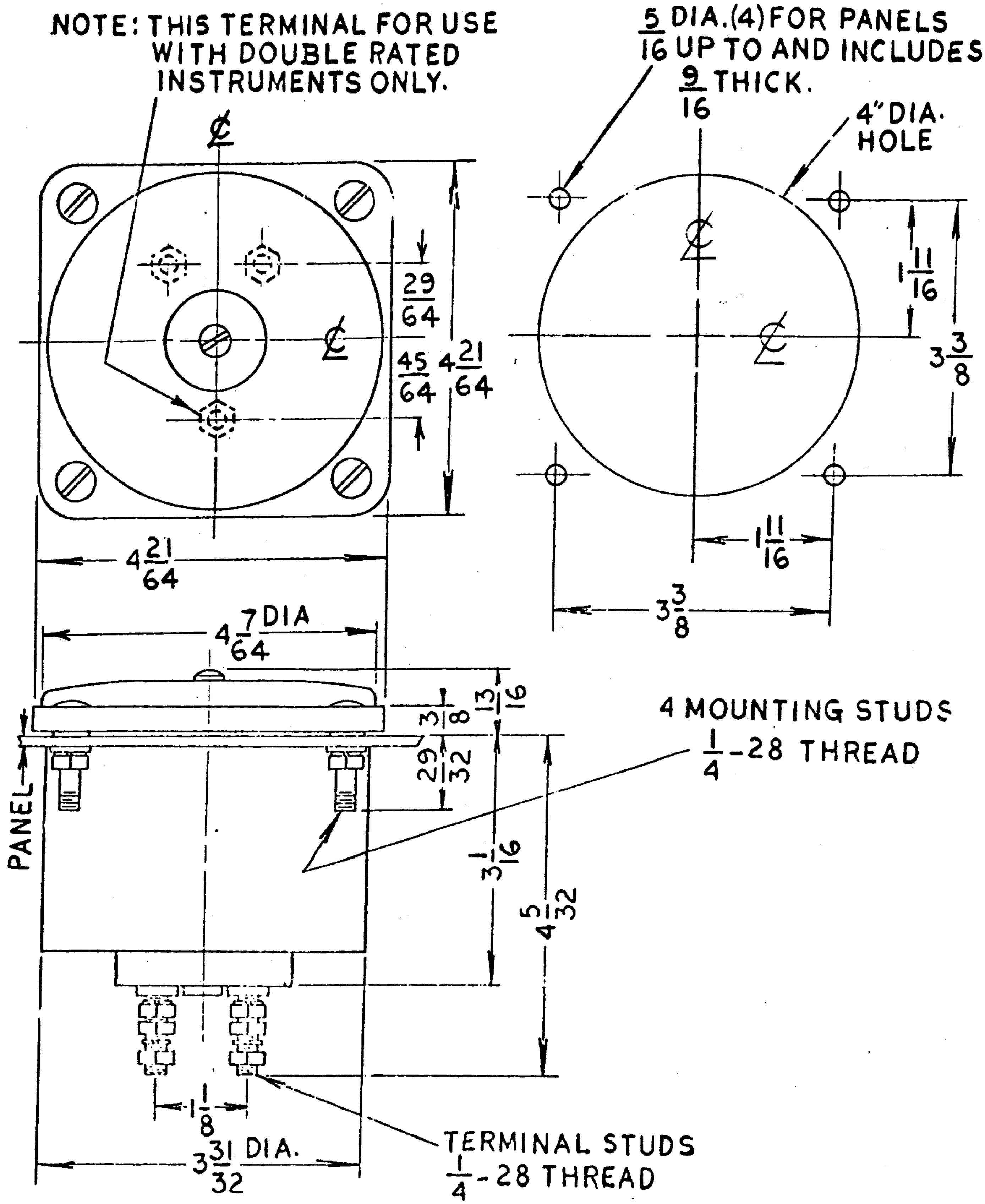


FIG.16 (0257A3152-0) OUTLINE AND PANEL DRILLING FOR THE TYPE SGC METER (SUPPLIED ONLY WITH SGC12B)

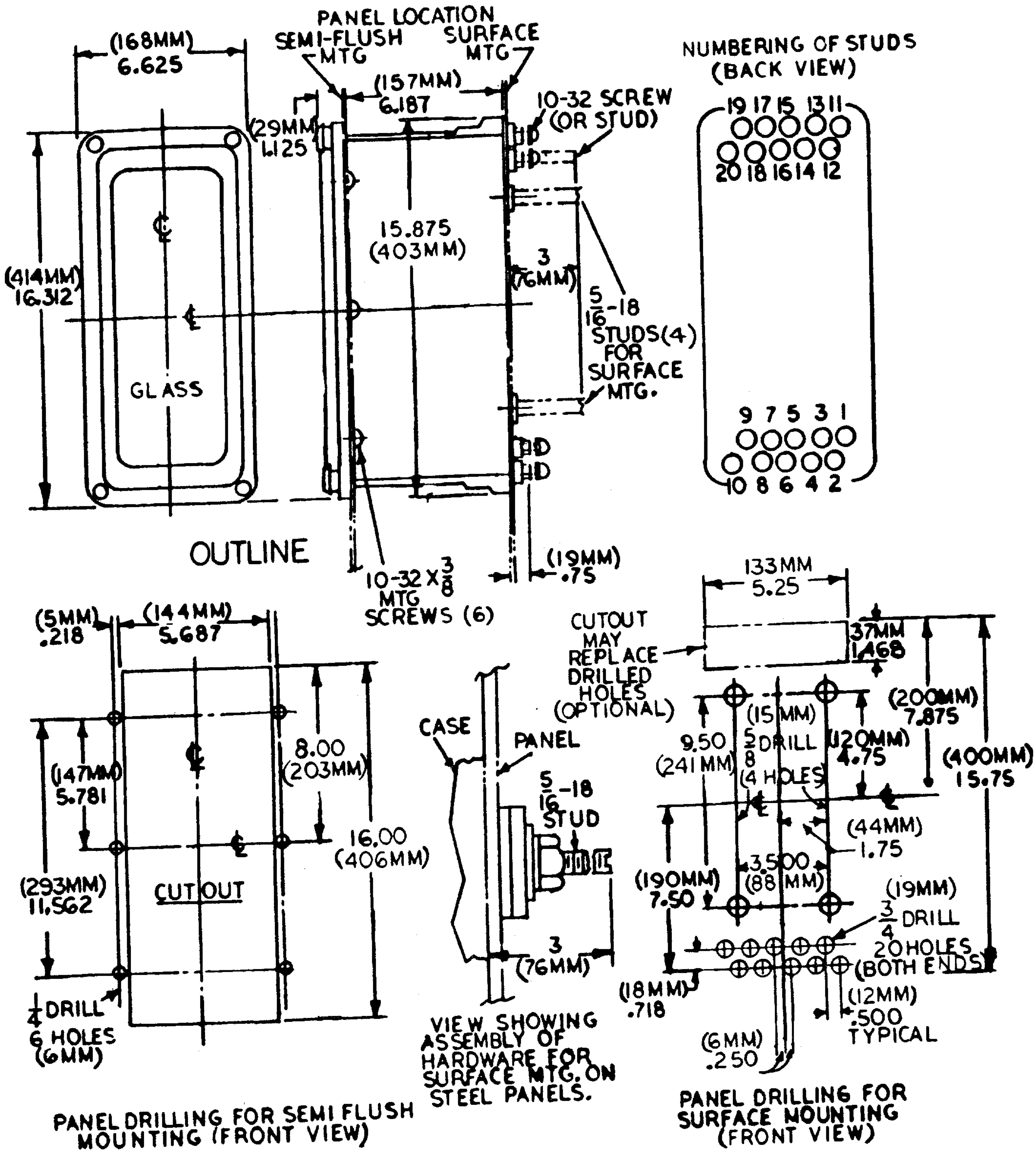


*FIG.17 (6209274-4) OUTLINE AND PANEL DRILLING FOR THE TYPE SGC RELAY CASE

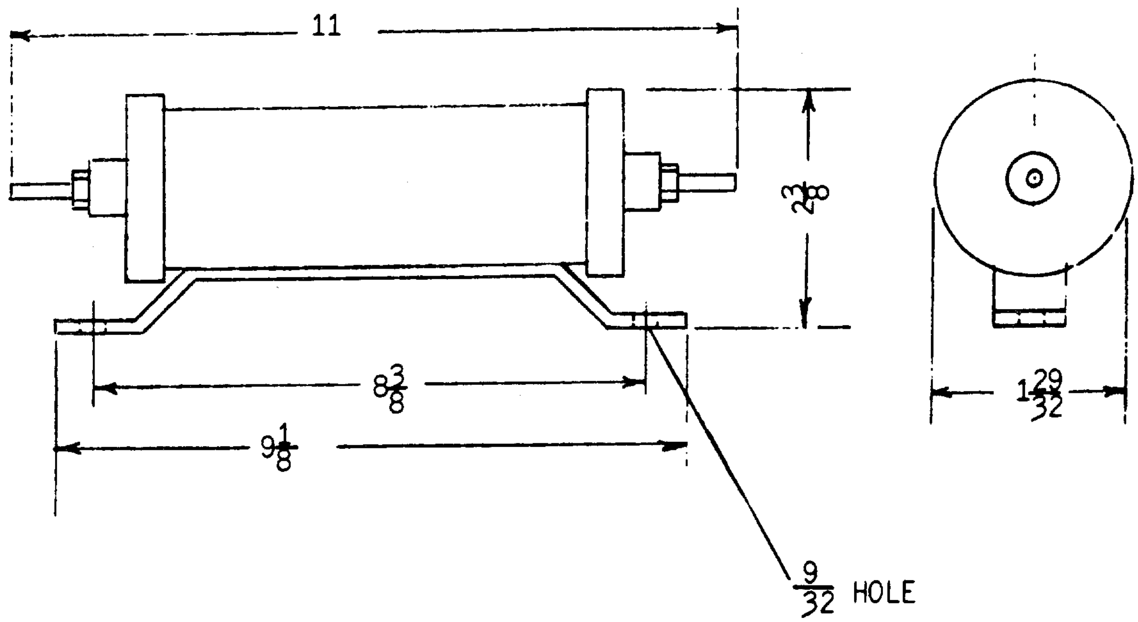


FIG.18 (389A752-1) OUTLINE AND PANEL DRILLING FOR EXTERNAL RESISTOR