GEK-27887H

INSTRUCTIONS

LOSS OF EXCITATION RELAY
TYPE CEH51A

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CONTENTS

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LOSS OF EXCITATION RELAY

CEH51A

DESCRIPTION

The CEH51A is a single phase, single zone, offset mho distance type relay. The relay is designed to detect a loss of excitation on synchronous machines. An offset mho characteristic was chosen to provide selectivity between loss of excitation and other normal or abnormal conditions that may exist on the system. A 66-83 millisecond fixed time delay auxiliary unit is employed in the CEH51A relay to prevent undesired tripping due to shock, vibration or sudden complete loss of AC potential, any of which might result in momentary closure of the main unit contacts. Depending on the application, one CEH51A relay and a suitable lock-out relay, or two CEH51A relays plus an adjustable timing relay and a lock-out relay are required. This is discussed in the section under **APPLICATION.**

The CEH51A relay complete with target seal-in unit and auxiliary time-delay unit is packaged in a standard M2 drawout case, the outline and panel drilling dimensions for which are illustrated in Fig. 20. The internal connection diagram for the CEH51A is illustrated in Fig. 17.

APPLICATION

The CEH51A relay is a single phase offset mho relay and it is used to detect a loss of excitation on synchronous machines. Loss of excitation can be damaging to the machine and/or detrimental to the operation of the system. It is recommended that loss of excitation protection be considered for all synchronous generators.

When a synchronous generator loses excitation it will tend to act as an induction generator. It will run above normal speed, operate at reduced power and receive its excitation (VARS) from the system. The impedance seen by a relay looking into the generator will depend on the machine characteristics, the load flow to the loss of excitation, and the type of excitation failure.

Fig. 1 illustrates a unit type generator connected to a power system with an offset mho distance relay at its terminals set as indicated on the R-X diagram. The relay is set with an offset equal to one-half the direct axis transient reactance and a diameter equal to the direct axis synchronous reactance of the generator. Typical impedance loci as seen by the relay when the excitation is lost as a result of a short circuit across the field windings are also shown in Fig. 1. Curve A represents loss of excitation from full load conditions. This locus terminates in a region near the negative X axis at about a point located approximately at the average of the direct and quadrature axis sub-transient impedances of the generator. In the case of no load or very light load prior to the loss of excitation, the impedance seen by the relay terminates in an area near the negative X axis as shown by point C. The impedance seen by this case is approximately equal the average of the direct and quadrature synchronous impedances of the generator. Curve B applies for some moderate condition between full and no load.

In the event of an open-circuited field in which the slip rings flash, the field will then be effectively shorted and the curves of Fig. 1 apply. If the slip rings do not flash and field remains open circuited, the impedance loci will terminate at approximately the same points as shown in Fig. 1 (for the same initial conditions), but since the slip rates are different they will generally follow different paths in getting there.

Thus, the characteristic of Fig. 1 will suffice to detect a loss of excitation from any initial loading due to an open or a shorted field circuit.

Since a characteristic with settings as illustrated in Fig. 1 is required to detect a loss of excitation, it should be ascertained that such an application is secure against undesired operation on stable system swings resulting from system disturbances. Fig. 2 illustrates typical impedance loci as viewed by an offset mho relay located at the generator terminals for different system conditions after a nearby fault is cleared.

The dash curve A represents the case for conditions of a three-phase short circuit at (F) the high side of the unit transformer occurring when the machine is running at full load and unity power factor (L_a). When the fault is cleared in nominal relay plus breaker times with the voltage regulator in service, the impedance jumps to point S_a and follows the path of the dash lines back to the region around L_a. This is a stable swing and the impedance path does not enter the required CEH characteristic.

The solid curve B illustrates an extreme case of a similar set of circumstances. In this case:

a) The machine was running underexcited prior to the fault (L_b).
b) The fault was not cleared until the critical switching time for the machine in question.
c) The voltage regulator was out of service.

While the resultant swing was stable and would eventually settle back to the area around L_b, the impedance locus entered the larger relay characteristic. Studies indicate that the duration of its stay in the characteristic is in the order of 0.2 to 0.4 seconds. Thus, if the larger relay characteristic is employed with a time-delay auxiliary relay which is set for about 0.5 - 0.6 seconds, undesired tripping will not take place.

Under these conditions it is recommended that two mho characteristics be employed as indicated in Fig. 2. Both characteristics should be set with an offset equal to the ohmic value of $X_d/2$ per unit. The smaller one should be set with a diameter equal to the ohmic equivalent of (1.0) per unit impedance on the machine base and the larger one set with a diameter equal to the ohmic equivalent of X_d per unit. The relay with the smaller set characteristic would operate in conjunction with a built-in four-to-five cycle time-delay auxiliary while the relay with the larger set characteristic would operate in conjunction with an external timing relay having a range in the order of 0.15 - 3.0 seconds.

In actual practice, whether a fault condition will produce a swing similar to that of curve A or B in Fig. 2 will depend on system and generator operating conditions. This can be fully evaluated only by a study of the system. Thus, whether one or two relay characteristics are required will depend on the possible modes of operation of the generator, the generator characteristics and the particular system involved.

There is some concern about the performance of the voltage regulator when it is operating on the underexcited limit. It is feared that the regulator will "undershoot" while trying to maintain the limit and thereby cause the apparent impedance to momentarily enter the relay characteristic. Thus, if one single characteristic is used as illustrated in Fig. 1, there may exist the possibility of undesired operation as a result of regulator "undershoot." When two characteristics are used as illustrated in Fig. 2, the large one with time delay, this problem could be avoided. The generator regulator manufacturer should be consulted to establish the time delay to be used with the relay.

It should be recognized when using the two characteristics as illustrated in Fig. 2, that a bonafide loss of excitation from the lighter load conditions may be detected only by the larger characteristic. This will result in a delayed trip which may have some adverse effects on the system. This should be evaluated by the user.

The basic considerations discussed above apply to generators with all types of prime movers. However, in the case of hydro machines which may be operated severely underexcited during light load to compensate for system distributed capacitance, the operating condition can approach the loss of field condition in terms of impedance seen by the CEH at the machine terminals. These applications, along with underexcited synchronous condenser applications, should be referred to the factory for additional information.

The CEH relay is designed for use with line-to-line voltages (E_A-E_B) and delta currents (I_A-I_B). Wye or delta connected PTs rated 120 volts phase-to-phase may be used. External connection diagrams for this application are shown in Fig. 3 and 4. It may also be applied with a single line-to-neutral PT with a secondary voltage rating of 69 or 120 volts, but in this case only one current coil is connected in the CT circuit. External connections for this application are shown in Fig. 5. Regardless of which connections are used, the relay settings are calculated as indicated in the section under **CALCULATION OF SETTINGS**. However, it should be noted when the CEH is used with one single phase-to-ground PT that the actual PT ratio on the tap selected (69 or 120 volts) must be used in the calculation of secondary ohms.

The external connections to the CEH51A relay as illustrated in Fig. 3 through 6 indicate that breaker contacts 52/a must be used in the DC circuits. These 52/a contacts are required in order to prevent the relay from misoperating during start-up procedures when there might be low frequencies or no voltage (restraint) applied to the relay.

An important consideration in the application of the CEH relay relates to the PT secondary fusing practice. In general, the PTs that provide potential to the CEH relay will have other burdens connected between phases and possibly between phases and neutral. If a secondary fuse or circuit breaker on one phase is open, the potential on that phase will not necessarily go to zero. It will generally assume some potential depending on the impedance of the total burdens connected between that phase and the other phase and ground. If this resulting potential is applied to the CEH relay the diameter of the characteristic will usually increase and the angle of maximum torque will shift clockwise or counterclockwise depending on the circumstances. This can result in improper operation during load conditions. Thus, when PT secondary fuses are employed it is recommended that the CEH relay be fused separately from all other devices, as indicated in Fig. 7A, so that any blown fuse, except a main fuse, will result in either zero voltage or normal voltage to the CEH relay. This will not cause the relay to operate falsely under normal load conditions. However, if the short circuit that caused the fuse to blow or other burden is maintained across the CEH relay, false operation may occur after clearing a prolonged nearby system fault. Fig.7B illustrates two examples of how not to fuse the PT circuits to the CEH relay.

The blowing of a PT primary fuse (where used) presents a similar problem that cannot generally be solved as easily as the secondary fuse situation. In the case of three wye connected PTs, a blown primary fuse can result in the CEH relay receiving low and phase shifted voltage. This can result in the relay operating falsely on load or possibly after clearing a nearby system fault depending on the circumstances.

In the case of two open-delta connected PTs, with primary fuses as illustrated in Fig. 3, a blown primary fuse on the associated PT can result in a characteristic that is larger than the setting and with its angle of maximum torque shifted in phase angle. However, this shift is in the direction of non-operation under load conditions.

If a single PT Is used, connected either phase-to-neutral or phase-to-phase, a blown primary or secondary fuse will remove potential from the relay. The relay will not operate to trip correctly or incorrectly for this condition.

Using the connections and secondary fusing shown in Fig. 3 through 7A will prevent undesired tripping under load conditions when a secondary fuse is removed or blown. In order to prevent such tripping on the loss of a primary fuse with wye connected PTs, a Type CVFB voltage balance relay is suggested to supervise the CEH51A tripping contacts.

CALCULATION OF SETTINGS

There are two settings that must be made on the CEH51A relay. They are the offset tap setting and circle diameter restraint tap setting. It is recommended that the following offset and diameter settings be used.

1. If only one CEH relay is required

   OFFSET = one-half transient reactance ($X'_d/2$)

   DIAMETER = synchronous reactance (X_d)

2. If two CEH relays are required:

   OFFSET = one-half transient reactance ($X'_d/2$) for both relays

   SMALL DIAMETER = 1.0 per unit reactance on machine base

   LARGE DIAMETER = synchronous reactance (X_d)

The offset tap setting is made directly in terms of secondary ohms via the L and H leads on the offset tap block. Settings can be made in the range indicated on the nameplate in 0.5 ohm steps. Note that the offset setting is equal to the difference between the two offset taps used. If the offset tap setting cannot be made exactly, the next higher tap setting should be used.

The circle diameter setting is made via the upper and lower leads on the restrain tap block. The tap setting is expresed in percent and is a function of the basic minimum diameter of the relay and the desired ohmic diameter in secondary ohms. It is adjustable in a range of zero to 100 percent in one percent steps, but the setting should never be set below ten percent. It is calculated as follows:

$$\text{Restraint Tap Setting (\%)} = \frac{\text{(Basic minimum diameter) (X) (100)}}{\text{(Desired diameter in secondary ohms)}} \qquad (1)$$

INFORMATION REQUIRED TO MAKE SETTINGS

Transient Reactance (X'_d) - in percent or per unit on the associated machine base.

Synchronous Reactance (X_d) - in percent or per unit on the associated machine base.

Base MVA - MVA base equals generator rating in MVA

Base KV - KV base equals generator rating in KV

CT Ratio

PT Ratio

EXAMPLES OF CALCULATIONS

Given the following:

X'_d	=	50%	=	0.50 per unit
X_d	=	196%	=	1.96 per unit
Base MVA	=	600		
Base KV	=	14.0		
CT Ratio	=	25,000/5	=	5000/1
PT Ratio	=	14,400/120	=	120/1

then

$$Z_{base}\ (sec) = \frac{(\text{KV base})^2}{\text{MVA base}} \times \frac{\text{CT Ratio}}{\text{PT Ratio}}$$

$$= \frac{14^2}{600} \times \frac{5000}{120}$$

$= 13.8$ secondary ohms

$X'_d(\text{sec}) = (Z_{base}) \times (X'_d \text{ per unit})$

$= 13.8 \times 0.5$

$= 6.9$ secondary ohms

$X_d(\text{sec}) = (Z_{base}) \times (X_d \text{ per unit})$

$= 13.8 \times 1.96$

$= 27.0$ secondary ohms

1.0 per unit secondary $= (Z_{base})$

$= 13.8$ secondary ohms

In the following calculations the 5-50 ohm relay with 0.5 - 4.0 ohm offset is assumed. Note that the offset setting is the difference between the two offset taps used.

I. If only one CEH relay is used,

a) Set offset tap $= \frac{X'_d}{2} = \frac{6.9}{2} = 3.45$ ohms

Use the next higher tap setting = 3.5 ohms

Set L lead on 0.5 and H lead on 4.0

b) Set restraint tap to value corresponding to actual synchronous reactance of machine in secondary ohms ($X_d = 27.0$ ohms)

From equation (1) above

$$\text{Restraint tap} = \frac{5 \times 100}{27.0} = 18.5\%$$, use next lower tap - 18%

Set upper number one lead on tap 8
Set lower number one lead on tap 10

II. When either regulator undershoot or stable swings are of concern, then two CEH relays should be used.

a) Set offset on both relays for 3.5 ohms as in Ia above.

b) Set small diameter relay restraint tap to value corresponding to 1.0 per unit reactance which is given above as 13.8 ohms.

$$\text{Restraint tap} = \frac{5 \times 100}{13.8} = 36.2\%, \text{ use next lower tap - 36\%}$$

Set upper number one lead on tap 6
Set lower number one lead on tap 30

c) Set the larger diameter restraint tap to a value corresponding to the actual synchronous reactance of machine in secondary ohms as described in Ib above. Determine time delay necessary to ride over regulator undershoot and/or stable swing and make appropriate time-delay setting on the SAM relay.

Equation (1) above is based on the input taps to the autotransformer being set at 100 percent. Diameter settings that are exactly equal to the calculated values can be obtained only if the result of operation (1) is an integer. If the result is not an integer, the diameter setting will not be exactly equal to the desired value. The resulting error that is introduced may or may not be significant. The diameter setting can be made to give closer results by using the following procedure if it is felt that the error is significant.

a. Calculate the restraint tap setting using equation (1) and select the <u>next lower</u> tap setting; i.e., if restraint tap = 18.5, select restraint tap = <u>18.</u>

b. Using the value from (a), calculate a new input tap setting as follows:

$$\text{Input Tap} = \frac{(\text{Restraint Tap}) \times (\text{desired diameter in secondary ohms})}{(\text{Basic minimum diameter})} \qquad (2)$$

As an example, in the case illustrated above, the desired diameter in secondary ohms = 27.0 and basic minimum diameter = 5 ohms, then, using equation (1)

$$\text{Restraint Tap} = \frac{5 \times 100}{27.0} = 18.5\%$$

If the 18 percent restraint tap is used, the relay diameter will be 27.8 ohms, or the diameter will be 26.3 ohms if the 19 percent tap is used. A closer setting can be obtained if equation (2) is used and the restraint tap is set for 18 percent.

From equation (2),

$$\text{Input tap} = \frac{18 \times 27.0}{5} = 97.1\%$$

The input tap leads are attached to the tap block by hex-headed tap screws. The input tap setting is equal to the sum of the two input taps used, and it is normally set at 100 percent, i.e., the upper lead at ten percent and the lower lead at 90 percent. To change the input tap setting, the lower lead should be maintained at 90 percent. The upper lead only should be moved, and it should only be moved between the 0-10 percent tap positions. This combination of settings allows the input tap setting to be varied between 90-100 percent in one percent steps. In the example cited above, the upper input lead would be set at seven percent, thus giving an input tap setting of 97 percent. The input tap setting should never be set below 90 percent, and this will be so if the procedure noted above is followed.

The relay would then be set with the restraint tap at 18 percent and the input tap at 97 percent to give:

$$\text{Diameter} = \text{Basic Minimum Diameter} \times \frac{\text{Input Tap}}{\text{Restraint Tap}}$$

$$= 5 \times \frac{97}{18} = 27.0 \text{ ohms}$$

RATINGS

There are several combinations of ratings available in the 12CEH51A(-)A relays.

VOLTAGE RATING	CURRENT RATING	FREQUENCY RATING	TRANSACTOR (OFFSET) RATING
115V	1 amp	50 Hz	0, 2.5, 5.0, 12.5, 20 ohms
115V	5 amps	50 Hz	0, 0.5, 1.0, 2.5, 4.0 ohms
115V	5 amps	60 Hz	0, 0.5, 1.0, 2.5, 4.0 ohms
115V	5 amps	25 Hz	0, 0.5, 1.0, 2.5, 4.0 ohms

The offset transactor has two leads marked H and L for setting the offset reach. The two leads can be used to vary the offset ohms on the four ohm offset transactor in 0.5 ohm steps. The 20 ohm transactor can be varied in steps of 2.5 ohms.

The one second thermal rating for this relay is 150 amperes.

BURDENS

Because of the presence of a transactor in the relay, the burdens imposed upon the current and potential transformers are not constant, but vary with the ohmic reach, amount of offset, and amount and phase angle of the current.

CURRENT CIRCUITS

The maximum burden imposed on each current transformer is:

RELAY RATING "I"	FREQUENCY	R	X	Z
5A	60	0.064	0.102	0.120
1A	60	1.60	2.55	3.00
5A	50	0.028	0.045	0.053
1A	50	0.704	1.122	1.325

The current burden was measured under phase-to-phase conditions which yield higher burden readings than balanced three-phase conditions. Also any other change caused by different conditions of offset will cause the burden to be less than indicated.

POTENTIAL BURDEN

The maximum potential burden at 115 volts is:

FREQUENCY	WATTS	VARS	VOLT-AMPS
60	10.0	7.8	12.7
50	12.0	9.35	15.2

The potential burden will decrease as the restraint tap is decreased. The maximim burden, given above, occurs with a restraint tap setting of 100 percent. The potential burden will also depend upon the angle between the voltage and current applied to the relay. Maximum potential burden occurs when the current (I_1 - I_3) lags the voltage (V_{1-3}) by 90 degrees (generator at zero P.F. overexcited).

The DC auxiliary unit (A) will draw approximately 35 milliamperes at rated voltage.

The ratings of the seal-in unit for its various taps (0.2/0.6 or 0.2/2.0) are given in Table A below.

TABLE A

		TAP				
		0.2	0.6	1	2	4
DC RESISTANCE ±10%	(OHMS)	8.3	0.78	0.32	0.24	0.04
MINIMUM OPERATING	(AMPERES)	0.2	0.6	1.0	2.0	4.0
CARRY CONTINUOUSLY	(AMPERES)	0.37	1.2	1.8	2.3	5.5
CARRY 30 AMPS FOR	(SECONDS)	0.05	0.5	0.85	2.2	13
CARRY 10 AMPS FOR	(SECONDS)	0.45	5.0	7.5	20	125
60 Hz IMPEDANCE	(OHMS)	50	6.2	2.6	0.65	0.16
50 Hz IMPEDANCE	(OHMS)	42	5.1	2.2	0.54	0.13

CHARACTERISTICS

The offset mho unit is similar to the basic mho unit with the addition of a transactor. The transactor is an air gap reactor with a secondary winding for obtaining the desired voltage at a given primary current. It also provides electrical isolation between the current and potential circuits. By adding the transactor-secondary voltage in series with terminal voltage of the potential transformer and applying the vector sum to the mho unit potential circuit, the effect is to offset the ohmic characteristic without changing its diameter.

The internal connections to the transactor secondary are of such polarity that the offset is in the direction to move the center of the circle away from the origin. Fig. 11 shows the effect of changing the offset tap when the restraint tap is left at 100 percent. This shows that the diameter of the characteristic does not change with the offset, but that the center of the circle is moved away from the origin by the value of the offset tap. Fig. 10 shows the effect of changing the restraint tap when the offset tap is set on one ohm. The diameter of the circle in phase-to-neutral secondary ohms is equal to

$$\frac{500}{\text{restraint tap \%.}}$$

In other words, the diameter is five ohms if the restraint tap is 100, or 12.5 if the restraint tap is 40. The one ampere rated relay has a 25 ohm diameter circle.

The auxiliary element (A), a telephone type relay, is mounted centrally. The purpose of this auxiliary is to prevent the relay from tripping the breaker falsely due to vibration when no voltage is applied to the potential circuit, or on contact bounce if the voltage falls to zero. The operating time of this unit is 0.067 to 0.083 seconds.

RECEIVING, HANDLING AND STORAGE

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

INSPECTION

Before placing a relay in service the following mechanical adjustments should be checked, and faulty conditions corrected:

The armature and contacts of the target and seal-in unit should operate freely by hand.

There should be a screw in only one of the taps on the right-hand contact of the target and seal-in unit.

The target should reset promptly when the reset button at the bottom of the cover is operated with the cover on the relay.

There should be no noticeable mechanical friction in the rotating structure of the units, and the moving contacts should return to the right when the relay is de-energized.

There should be approximately 0.012 inch end play in the shaft of the rotating structure. The lower jewel screw bearing should be screwed firmly into place, and the top pivot locked in place by its set screw.

All nuts and screws should be tight, with particular attention paid to the tap plugs.

If possible, the relay contact circuit should be given an electrical test in place by closing the mho unit contacts by hand and allowing tripping current to pass through the contacts and the target and seal-in unit.

The rotating structure of the mho unit is not balanced, so that any slight torque caused by a tilt of the shaft when the relay is installed ready for operation should be compensated for by using the control spring adjusting arm at the top of the unit. Rotate the control spring adjusting ring so as to return the moving contact arm to the right-hand backstop. The control spring should hold the contacts definitely open.

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 OPENED.

ELECTRICAL TESTS

Drawout Relays General

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

Power Requirements General

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

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

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

Polarity Check

The polarity of the relay can be checked by making the connections shown in Fig. 13. With these connections the mho unit contacts should close when the restraint taps are on ten percent and open when the restraint taps are on 100 percent, using the zero offset tap in each case.

A check of the relay reach can be made as follows:

1. Connect the relay as shown in Fig. 15.

2. Set the test reactor on the 24 ohm tap.

3. Set the relay restraint tap on 55 percent and the offset tap on two ohms.

4. Determine the minimum test box dial setting that will cause the mho unit contacts to close. The dial setting should be between 15 and 19.

5. Determine the maximum test box dial setting that will cause the mho unit contacts to close. The dial setting should be between 87 and 97.

6. The minimum and maximum test box dial settings, between which the mho unit contacts should close, can be determined for any relay setting by the following equations. However, for low restraint setting of the mho unit, the calculated dial setting will be over 100 percent if a test reactor with a maximum tap of 24 ohms is used. The phase-to-neutral reach can be checked by

applying current to one of the two current circuits (either studs 3-4 or 5-6). When only one of the two current circuits is used the test box dial setting will be one-half the value calculated from the following equation:

$$\text{Minimum dial setting} = \frac{200 \sin\theta \text{ (offset ohms)}}{X}$$

$$\text{Maximum dial setting} = 200 \sin\theta \; \frac{\frac{500}{TR} + \text{offset ohms}}{X}$$

Where θ = the power factor angle of the test reactor

X = actual reactance of reactor

TR = restraint tap setting of relay.

If the test reactor 6054975G1 is used, the term sin θ can be assumed to be unity, as any of the taps above three ohms have a power factor angle of 83 degrees or more.

INSTALLATION PROCEDURE

INSPECTION

Inspect the relay as described under ACCEPTANCE TESTS.

LOCATION

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

MOUNTING

The relay should be mounted on a vertical surface. The outline and panel drilling dimensions are shown in Fig. 20.

CONNECTIONS

Internal connections are shown in Fig. 17.

Unless mounted on a steel panel which adequately grounds the relay case, it is recommended that the case be grounded through a mounting stud or screw with a conductor not less than #12 B&S gage copper wire or its equivalent.

OFFSET TAP BLOCK

The two leads to this tap block are marked L and H. The ohmic offset of the relay is the difference between the H and L tap settings. By variation, any combination of ohmic offset may be obtained up to four ohms in 0.5 ohm steps, phase-to-neutral. As an example, placing the L lead in the 0.5 ohm tap and the H lead in the 4.0 ohm tap gives

3.5 ohms offset. The H lead must be in a higher tap than the L lead to keep the offset in the proper direction.

For the one ampere rated relay multiply the values listed by five.

RESTRAINT TAP BLOCK

Variation of the restraint tap setting varies the size of the ohmic characteristic. See Fig. 10. The variation is in one percent steps up to ten percent and in ten percent steps up to 100 percent, thus providing for a restraint adjustment of 1-100 percent in one percent steps.

CHECK OF CHARACTERISTIC

1. Connect as shown in Fig. 18. Allow relay potential coils to warm up by energizing at rated voltage for 15 minutes prior to testing.

2. Turn phase shifter to make angle 90 degrees (current leads voltage).

3. Set offset ohms on four ohms and transformer taps on 100 percent.

4. Increase current until contacts just close.

   Current should be:

$$\frac{\text{Voltage across studs 7-8}}{2 \times \text{Min. Ohms} + 2 \times \text{Offset}} = \frac{115}{10+8} = 6.39\text{A}$$

   The relay should operate within plus or minus ten percent (±10%) of this value.

5. To check any particular setting required for a specific application, proceed as follows:

   A. Calculate diameter of circle.

$$\text{Diameter} = \frac{\text{Min. Ohms}}{\text{Tap Setting}} \ (\text{ø-N ohms})$$

   Example: Assume 23 percent tap setting

$$\text{Diameter} = \frac{5}{0.23} = 21.7 \text{ ohms (ø-N)}$$

   B. Center of circle = radius + offset

   Example: Assume two ohms (ø-N) offset

$$\text{Center} = \frac{21.7}{2} + 2 = 10.85 + 2 = 12.85 \text{ ohms}$$

C. Draw relay characteristic on polar paper with center at 90 degrees lead using distance from origin and diameter calculated above. See Fig. 9.

D. Set current in current coils at any test value.

I - Calculate Ø-N ohms as follows:

$$\text{Ohms } (\text{Ø-N}) = \frac{\text{Voltage on studs 7-8}}{2 \text{ X I}}$$

Example: Assume I set at five amperes.

$$\text{Ø-N ohms} = \frac{115}{2 \text{ X } 5} = 11.5 \text{ ohms (Points A and B)}$$

E. Turn phase shifter and determine the two angles between which the contacts of the relay are closed. These should check with the angles at which the relay characteristic, drawn in step C above, crosses the impedance calculated for the test current I in step D above.

F. Set phase shifter for 90 degrees lead and determine the minimum current for which the relay contacts are closed.

$$\text{Min. I} = \frac{\text{Voltage studs 7-8}}{2 \text{ (Diameter + Offset)}} \text{ (for Point C)}$$

For example above:

$$\text{Min. I} = \frac{115}{2 \, (21.7 + 2)} = \frac{115}{43.8} = 2.63 \text{ amps}$$

Three points have now been determined on the relay characteristic. These three points should be enough to show the relay characteristic is the proper size and has the correct angle of maximum torque. If more points are desired repeat step D above using a different value of test current. During these checks endeavor to keep the test current in the order of 20 amperes or less. The maximum current under abnormal conditions is limited by the generator impedance and will usually be less than 20 amperes.

If the angle of maximum torque is not correct, it can be corrected by adjustment of reactor (X_{21}) or R22. If the diameter of the circle is not correct for the particular tap setting, it can be corrected by adjustment of resistor (R13).

There is no adjustment on the offset, the offset taps are determined by the turns of the transactor.

ALTERNATE CHECK OF CHARACTERISTIC

If no phase shifter is available, the relay characteristic may be checked at the points shown in Fig. 19. The test connections are shown in Fig. 12.

Apply a low current and gradually increase the current until the contacts close. Increase the current further until the contacts reopen. The higher currents should be removed quickly as they can be several times the relay rating.

For connections for test 1, the points on the R-X diagram of the relay characteristic will be:

$$R = \frac{0.5V}{2\ I_{pickup}} = \frac{0.25V}{I_{pickup}}$$

$$X = \frac{-0.866V}{2\ I_{pickup}} = \frac{-0.433V}{I_{pickup}}$$

For test 2, the points on the R-X diagram will be:

$$R = \frac{0.5V}{2\ I_{pickup}} = \frac{0.25V}{I_{pickup}}$$

$$X = \frac{-0.866V}{2\ I_{pickup}} = \frac{-0.433V}{I_{pickup}}$$

INSTALLATION TESTS

When relay is installed and the generator is running, the following tests should be made to check the overall connections.

To avoid an undesirable drop in system voltage due to operation far into the underexcited region, this installation check is made with relay potential reversed as shown in Fig. 14, and with the restraint reduced to zero or five percent. The reversal of potential inverts the operating characteristic from its normal position, and the reduction of restraint increases the diameter of the characteristics. Fig. 16 shows these effects, and also the characteristic with zero restraint and zero offset.

With zero restraint, zero offset, and power out of the generator, the relay contacts should be closed for all values of lagging power factor (overexcited), and open for all values of leading power factor (underexcited). For this polarity test, it is not necessary to change the field from the unity power factor condition any farther than enough to open and close the relay contacts.

If the relay, with the potential circuit reversed by the test plug, does not pass the above polarity test, then it probably has reversed potential connections. Reverse the connections from the potential transformers to studs 7 and 8. Repeat the above polarity test. If the relay now passes the polarity test, then the potential connections to the relay are now correct.

With five percent restraint and the value of offset chosen for the installation being checked, the relay contacts should close as the excitation is increased from the unity power factor condition sufficiently to cross the corresponding relay characteristic of Fig. 16 into the more lagging (overexcited) area.

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 fine silver 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.

SERVICING

The relay is adjusted at the factory and it is advisable not to disturb the adjustments. If for any reason they have been disturbed, the following points should be observed in restoring them.

CLUTCH ADJUSTMENT

The induction-cup units have a clutch so that cup and shaft can slip with respect to the moving contact whenever the torque in either the opening or the closing direction becomes greater than a predetermined value. The grams to slip the clutch should be measured by holding the cup and pushing with a gram gage against the moving contact. The moving contact should slip relative to the cup at approximately 50 grams pressure. The pressure at which the clutch slips can be changed by inserting a special flat open-end wrench underneath the green composition head directly above the spool body of the front coils so that it engages with the flats on the bakelite on the cup shaft. Hold this wrench and with a 5/16 inch open-end wrench, loosen or tighten the clutch by turning the nut below the spring wind-up sprocket. Turn the nut clockwise (top-front view) to tighten the clutch setting. Turn counterclockwise to loosen it.

CONTACT ADJUSTMENT

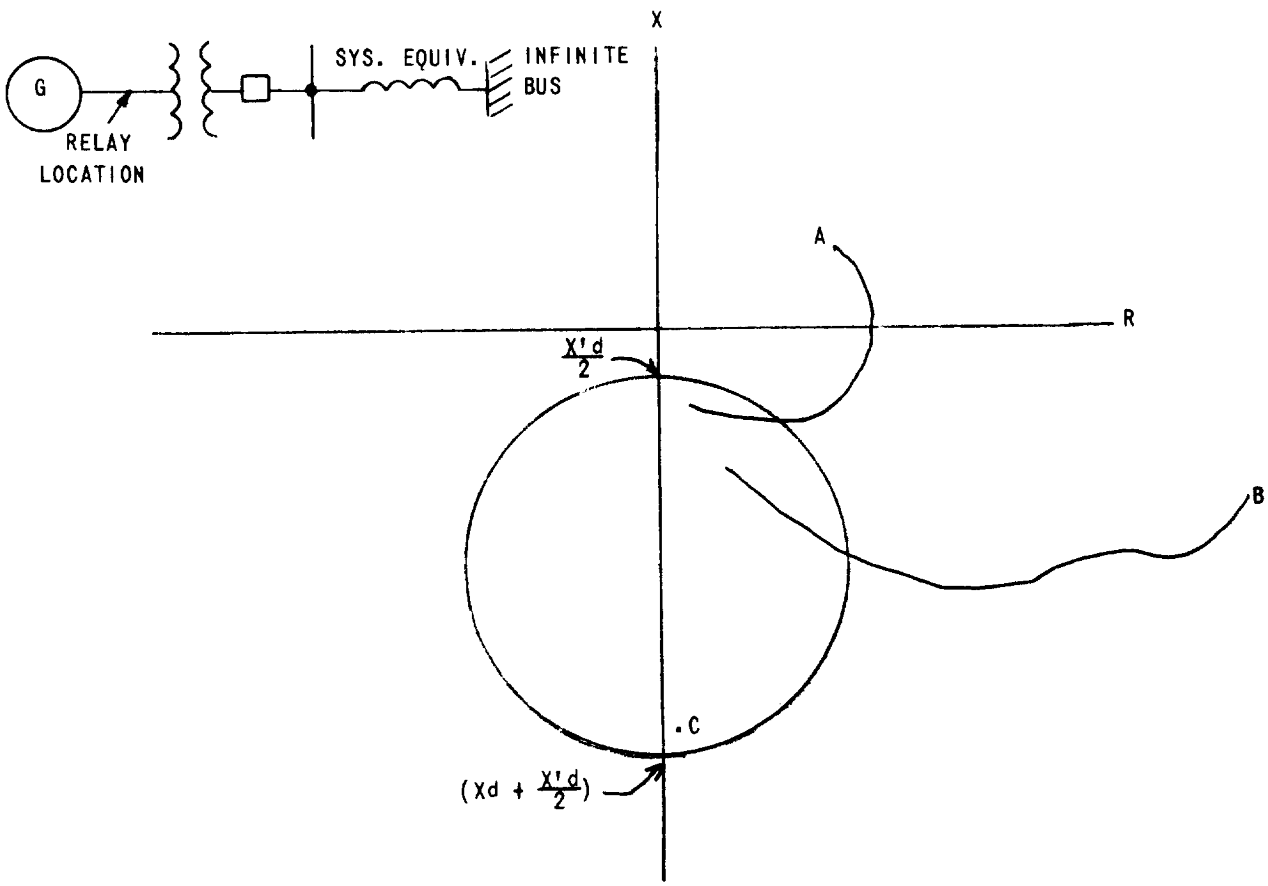
The stationary contact should rest against its felt backstop and should have about 1/16-3/32 inch gap.

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 give the complete model number of the relay for which the part is required.

Since the last edition, Figures 3-6 have been changed, Figures 7 and 8 have been relabeled 7A and 7B, the cover photograph and Figure 8 have been added, and paragraph 4 of the INSTALLATION PROCEDURE Check of Characteristic has been changed.

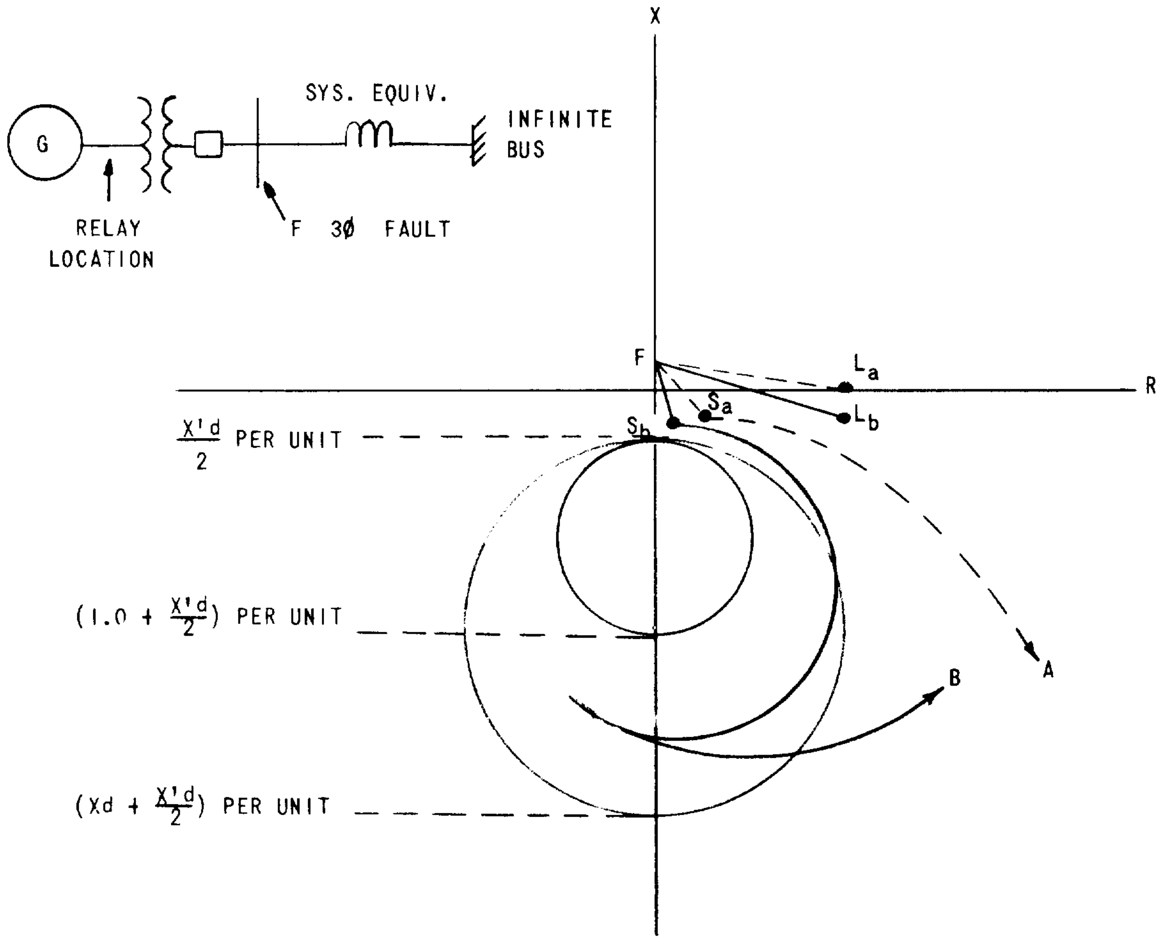


A - SHORT-CIRCUITED FIELD AT FULL LOAD

B - SHORT-CIRCUITED FIELD AT MODERATE LOAD

C - SHORT-CIRCUITED FIELD AT NO LOAD OR OPEN-CIRCUITED FIELD AT NO LOAD.

Fig. 1 (0246A3385-0) Typical Impedance Loci on Loss of Field Excitation



F - THREE PHASE FAULT LOCATION

A - LOCUS OF SWING IMPEDANCE FOR CONDITIONS OF UNITY POWER FACTOR LOAD, AND/OR FAST FAULT CLEARING, AND/OR VOLTAGE REGULATOR IN SERVICE (DASHED LINES)

L_a- UNITY POWER FACTOR 1.0 PER UNIT LOAD IMPEDANCE.

Sa- IMPEDANCE IMMEDIATELY AFTER FAULT IS CLEARED

B - LOCUS OF SWING IMPEDANCE FOR CONDITIONS OF LEADING 0.95 POWER FACTOR LOAD, AND FAULT CLEARING AT CRITICAL SWITCHING TIME, AND VOLTAGE REGULATOR OUT OF SERVICE. (SOLID LINES)

L_b- 0.95 LEADING POWER FACTOR 1.0 PER UNIT LOAD IMPEDANCE

S_b- IMPEDANCE IMMEDIATELY AFTER FAULT IS CLEARED.

Fig. 2 (0246A3386-0) Typical Impedance Loci for Swings Resulting from System Disturbances

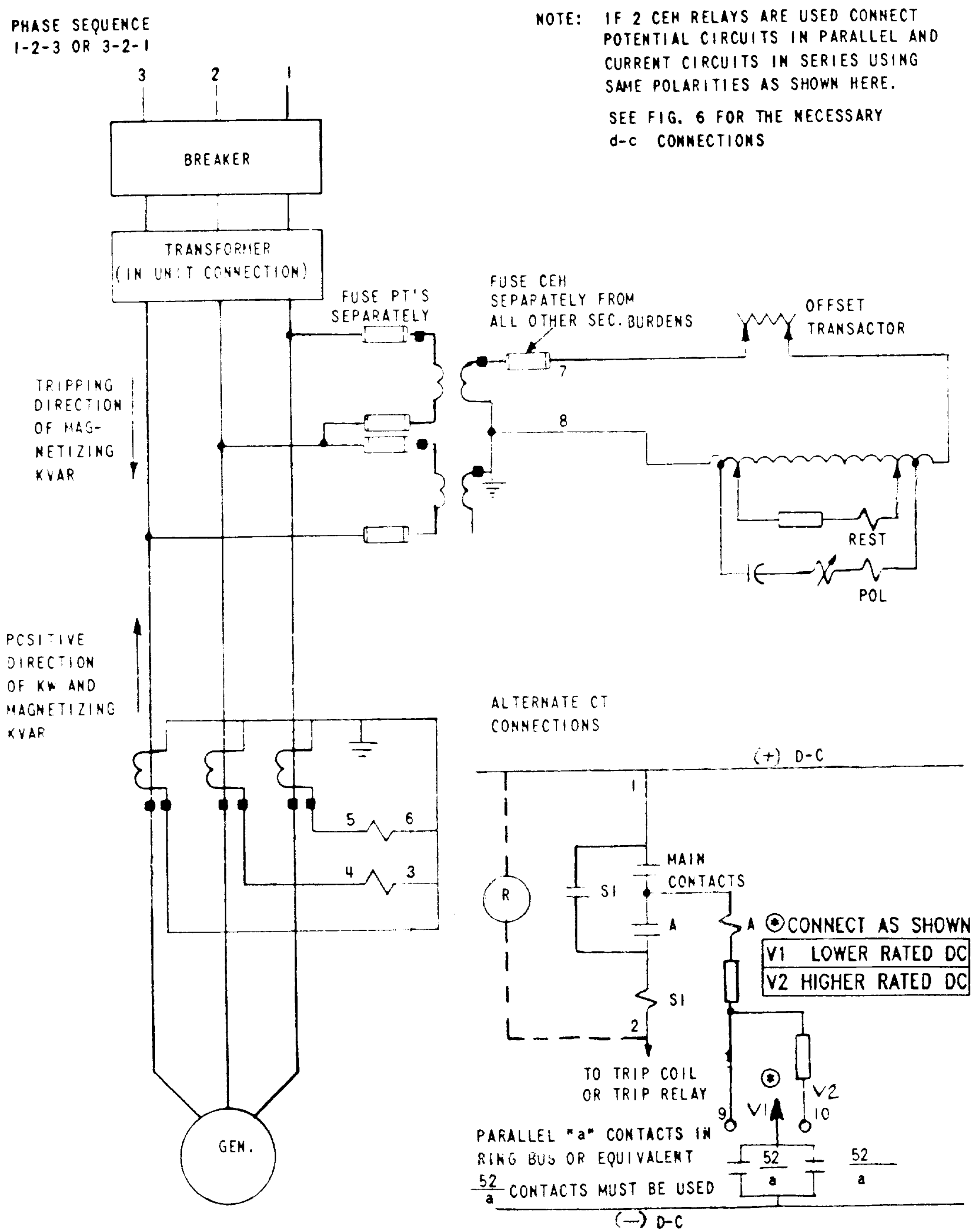


Fig. 3 (0246A3387-5) External Connection Diagram for Type CEH Relay Using PT's Connected in Open-Delta, Either CT Connection

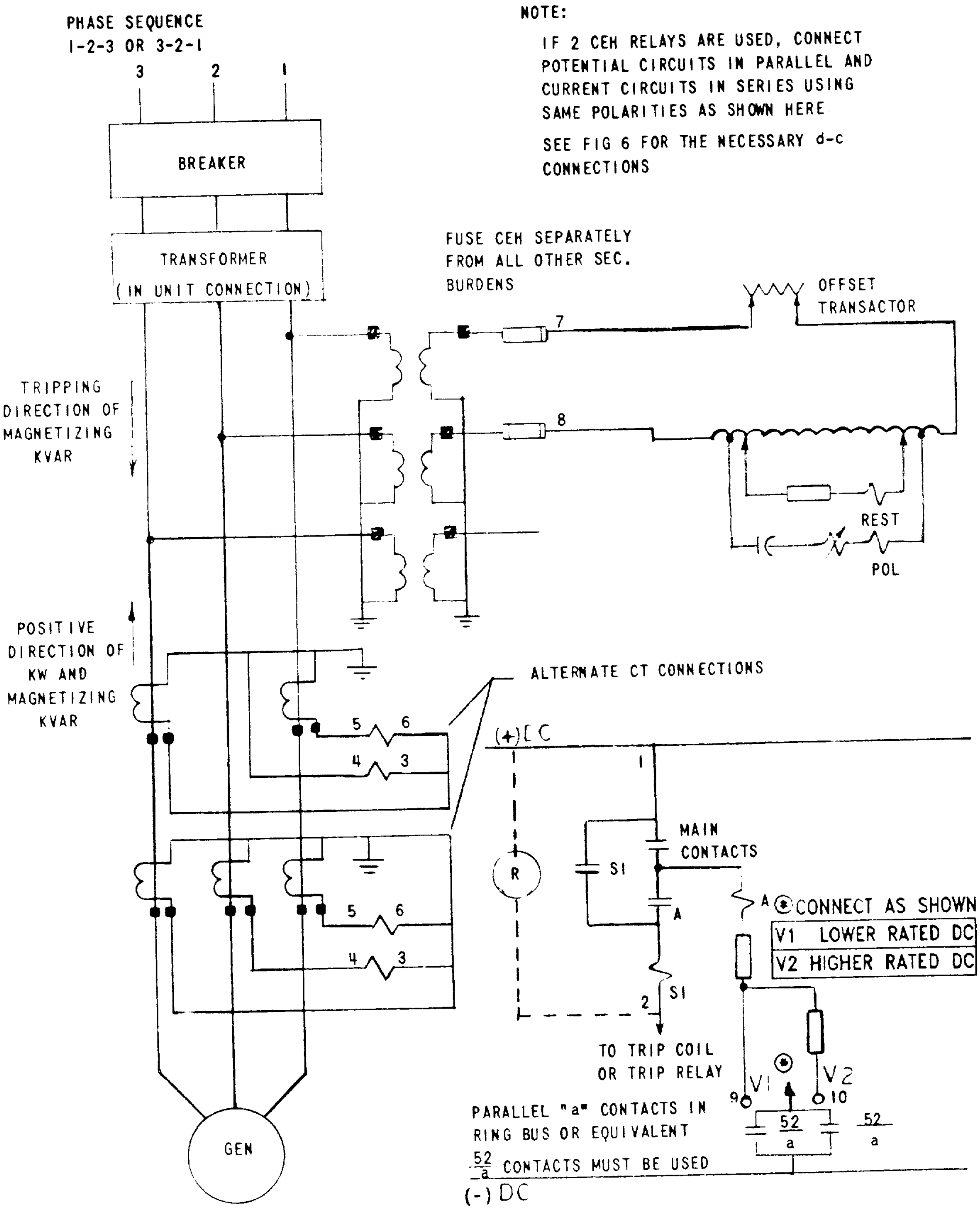


Fig. 4 (0246A3388-5) External Connection Diagram for CEH51A Relay Using Wye Connected PT's

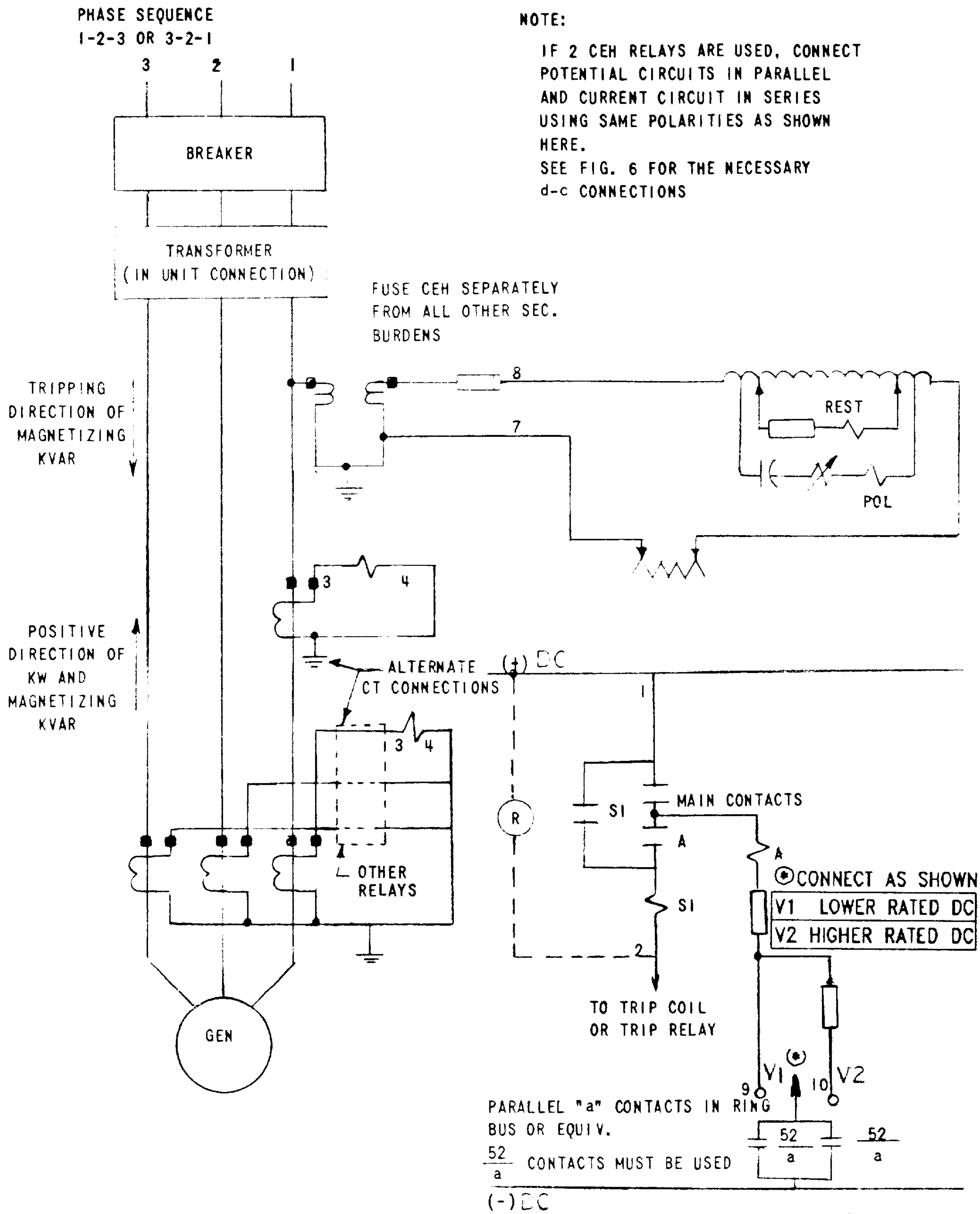
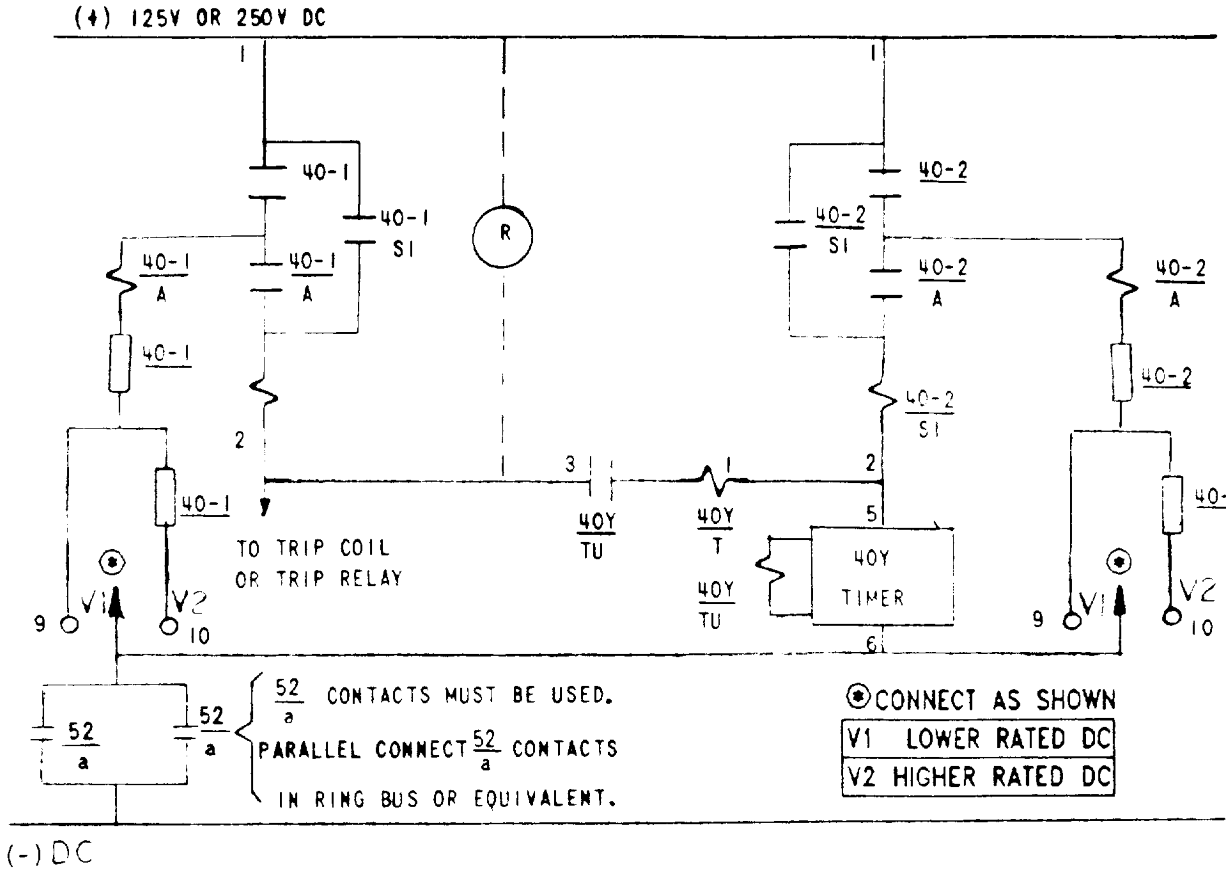


Fig. 5 (0246A3389-6) External Connection Diagram for Type CEH51A Relay Using Line-to-Neutral Connected PT



TABULATION OF DEVICES

DEVICE NO.	RELAY MODEL	INCLUDING UNITS	DESCRIPTION	INTERNAL
40-1	CEH51A		LOSS OF EXCITATION UNIT	0227A2540
40-2	CEH51A		LOSS OF EXCITATION UNIT	0227A2540
		SI	TARGET AND SEAL-IN	
		A	AUXILIARY UNIT	
40Y	SAM11B22A		TIMER	208A2421-0-SH 1,2
	TU		TIMING UNIT	
	T		TARGET	

Fig. 6 (0246A3390-3) DC Connections for Scheme Using Two CEH51A Relays and a SAM Timing Relay

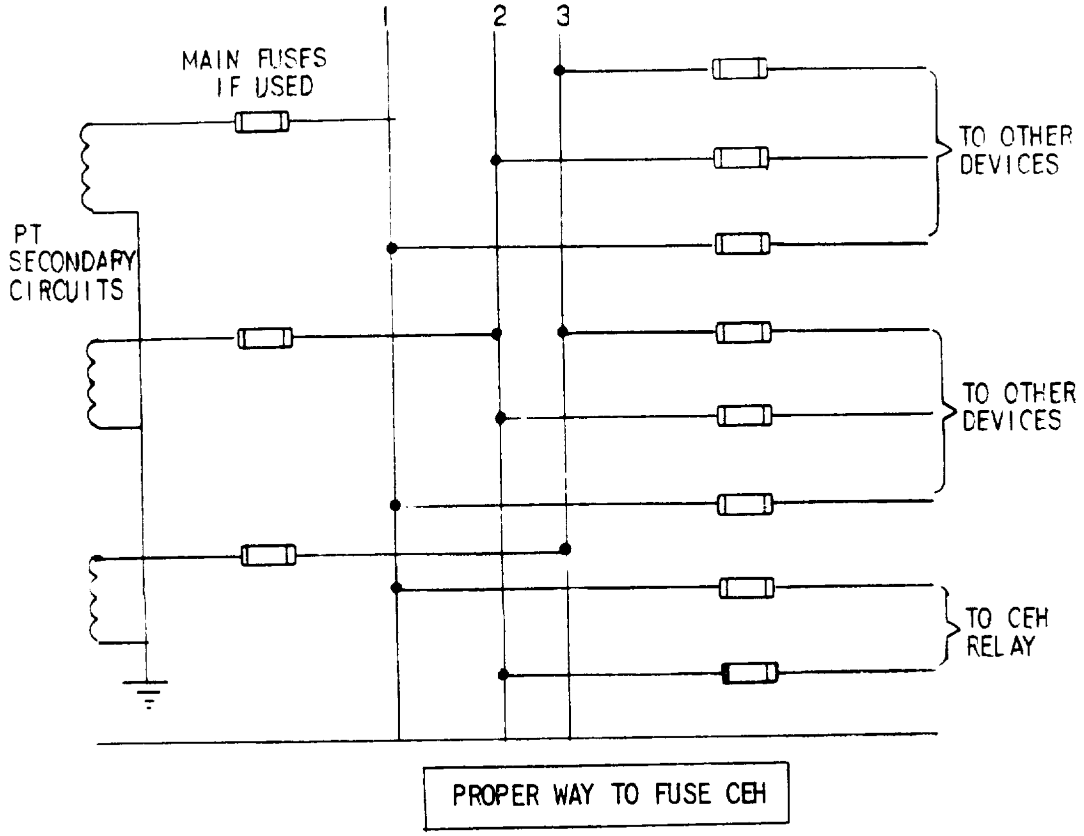


Fig. 7A (0246A3391-1) Correct Secondary PT Fusing for CEH51A Relay

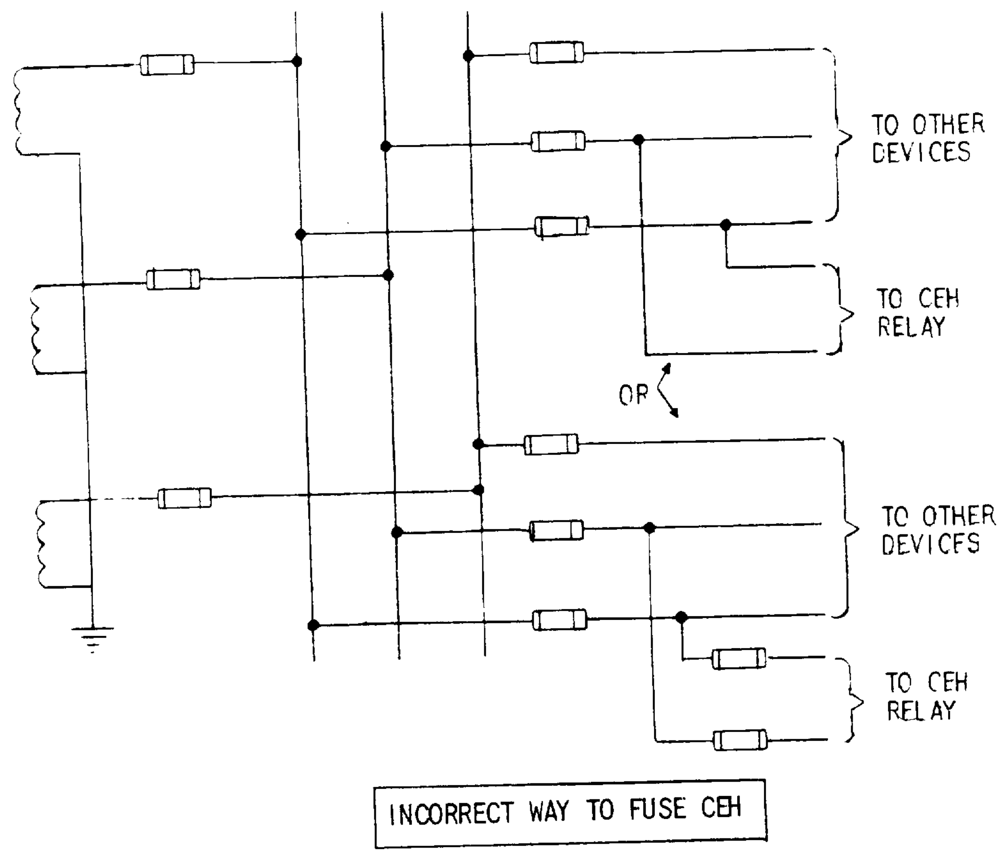


Fig. 7B (0246A3392-1) Incorrect Secondary PT Fusing for CEH51A Relay

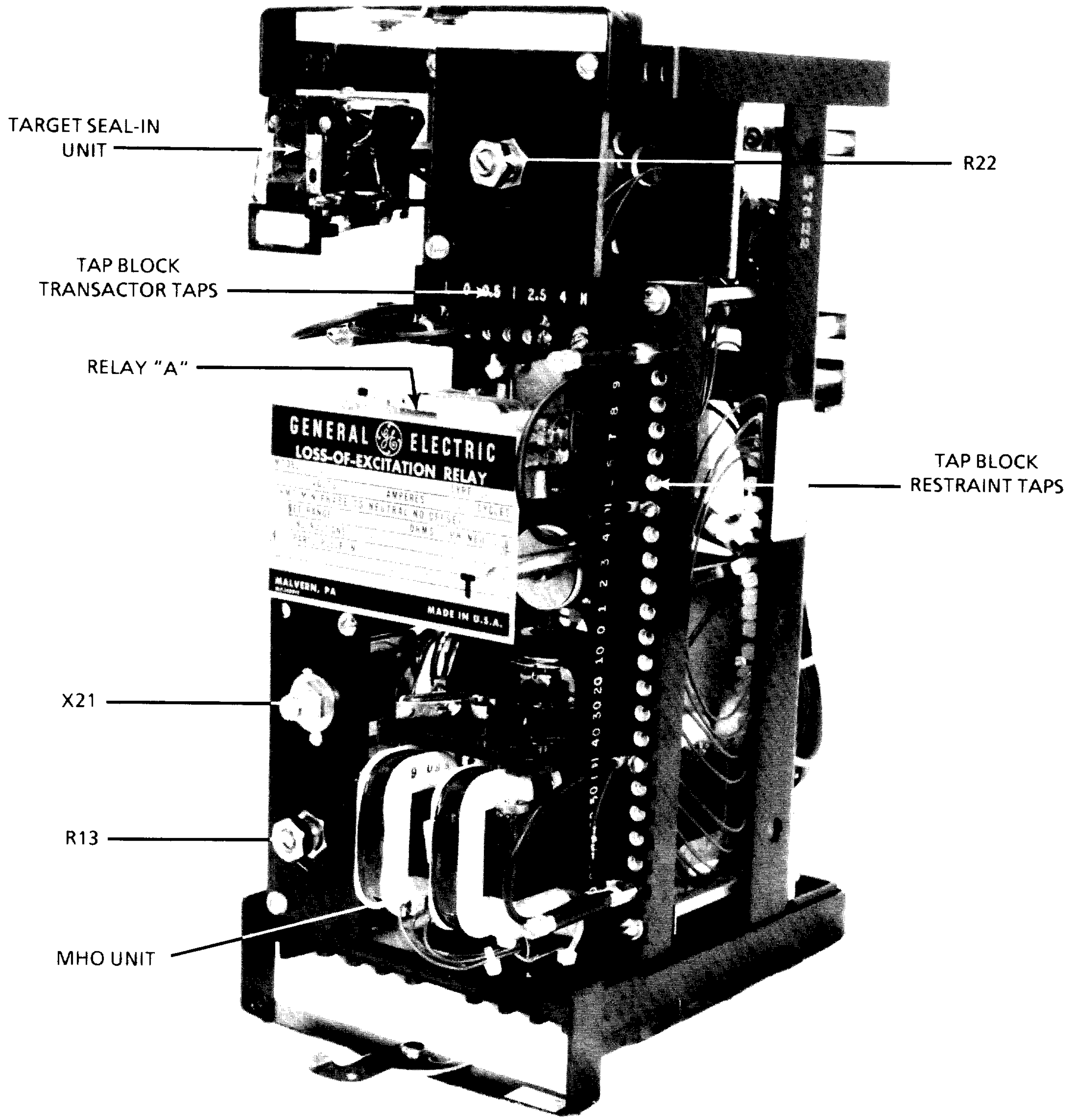


Fig. 8 (8919506) CEH51A Relay Removed from Case

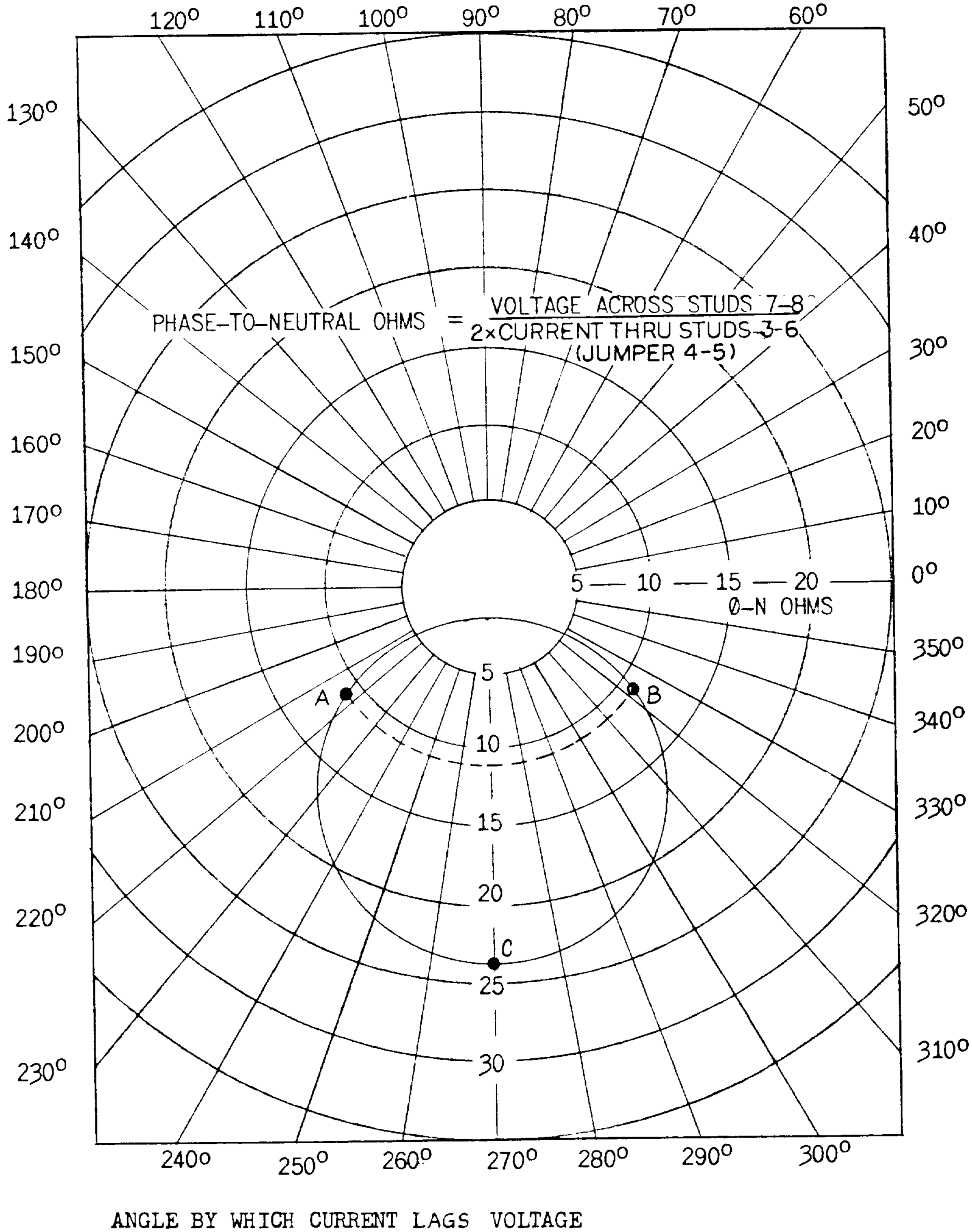


Fig. 9 (402A977-5) Characteristics of Type CEH51A Relay with Two Ohm (Phase-to-Neutral) Offset and 23 Percent Tap Setting

TYPE CEH11A RELAY
CHARACTERISTICS OF RELAY WITH VARIOUS TAP SETTING WHEN SET FOR 1 OHM OFFSET.
ALL VALUES ARE PHASE - TO - NEUTRAL OHMS

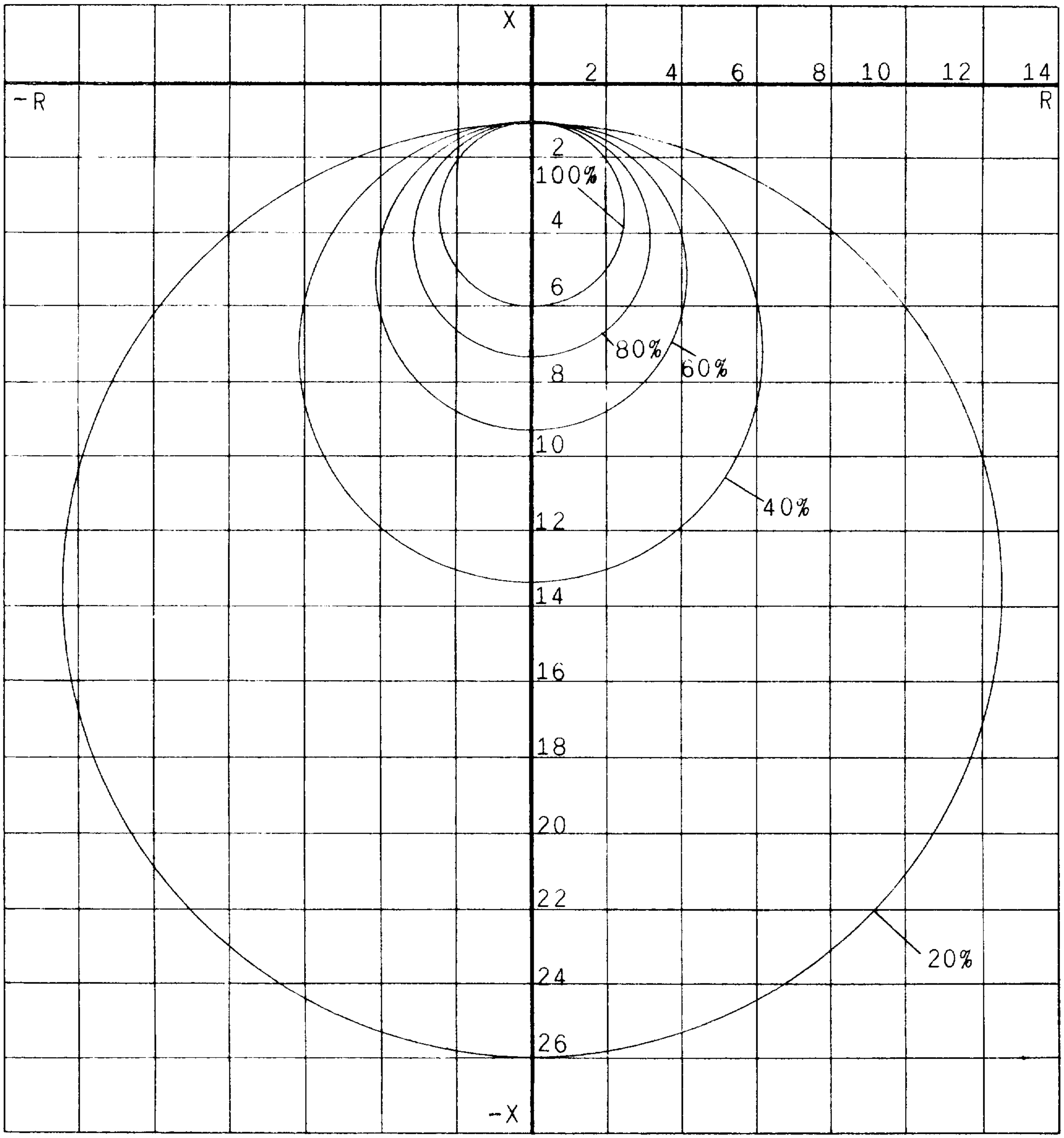


Fig. 10 (402A978-0) Characteristics of Type CEH51A Relay at Various Restraint Tap Settings, One Ohm Offset. All Values Phase-to-Neutral

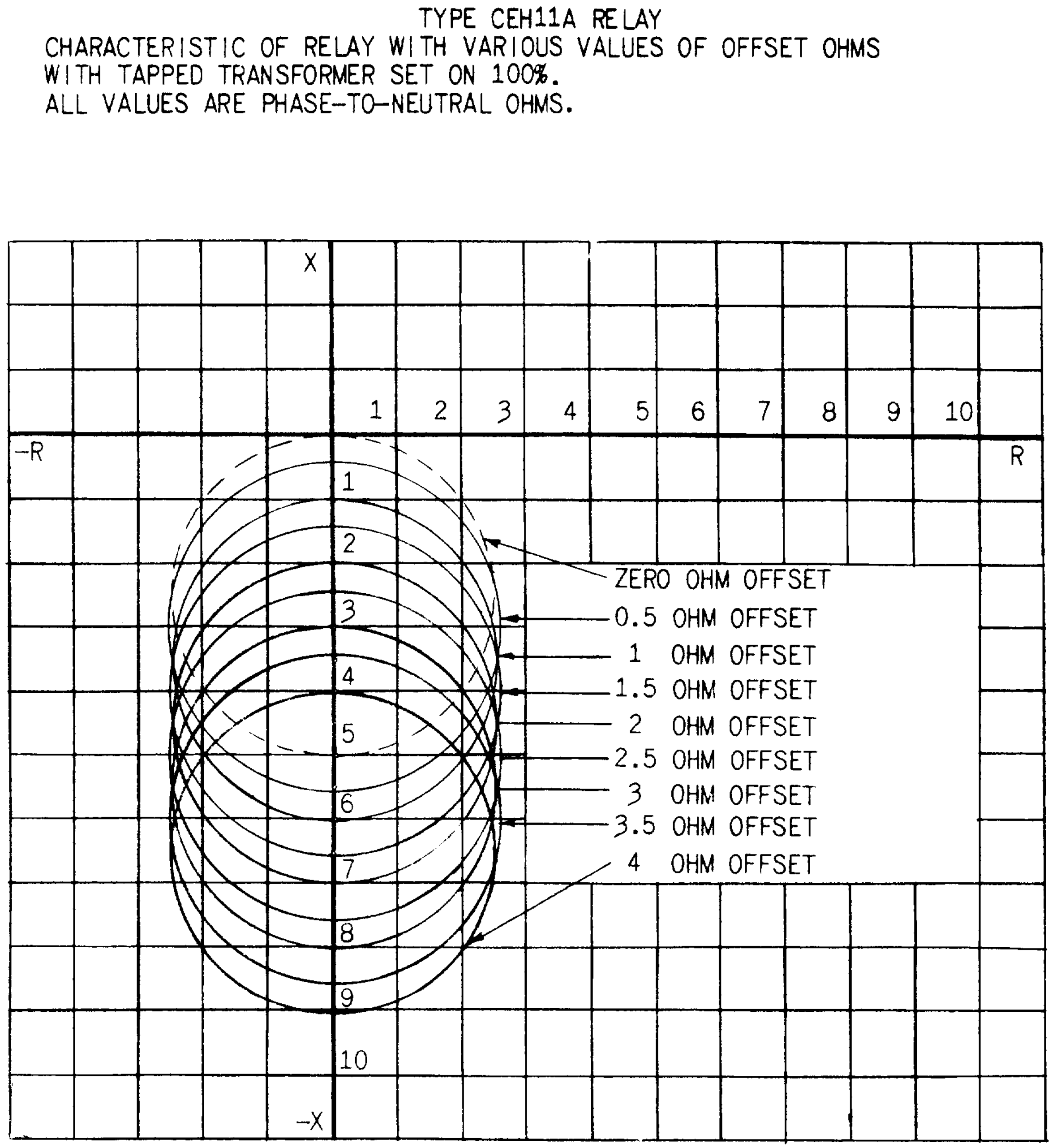
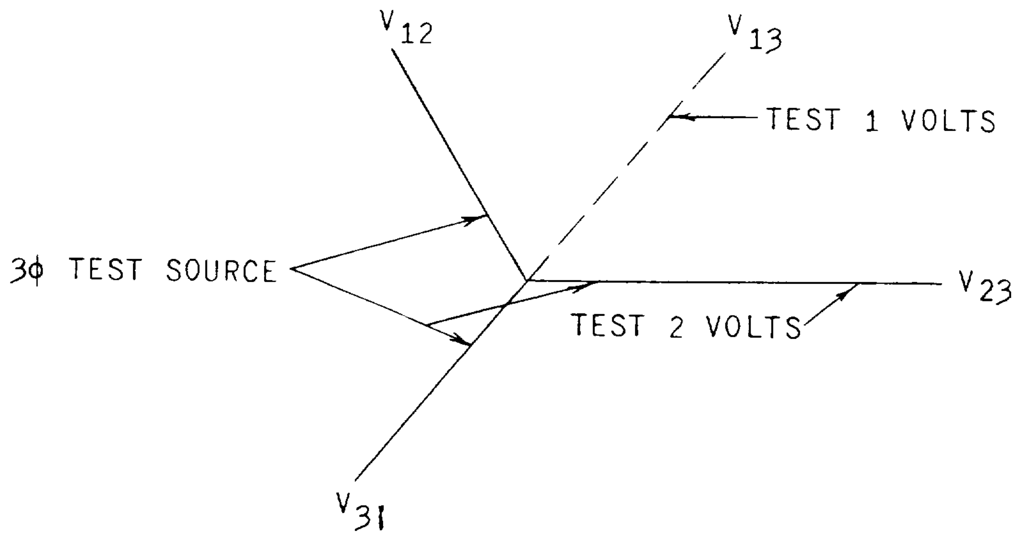


Fig. 11 (402A974-2) Characteristics of Type CEH51A Relay, 100 Percent Tap Setting, Various Values of Offset



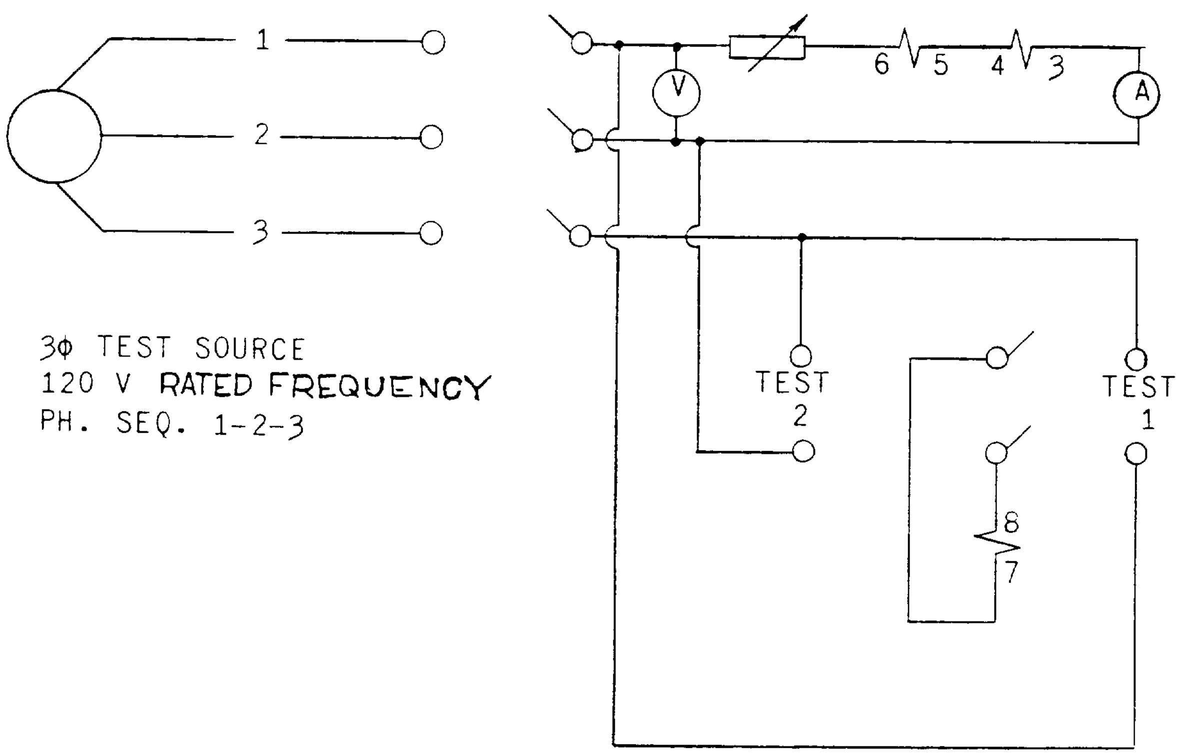


Fig. 12 (402A994-1) Test Connections for Determining the Characteristics of a CEH51A

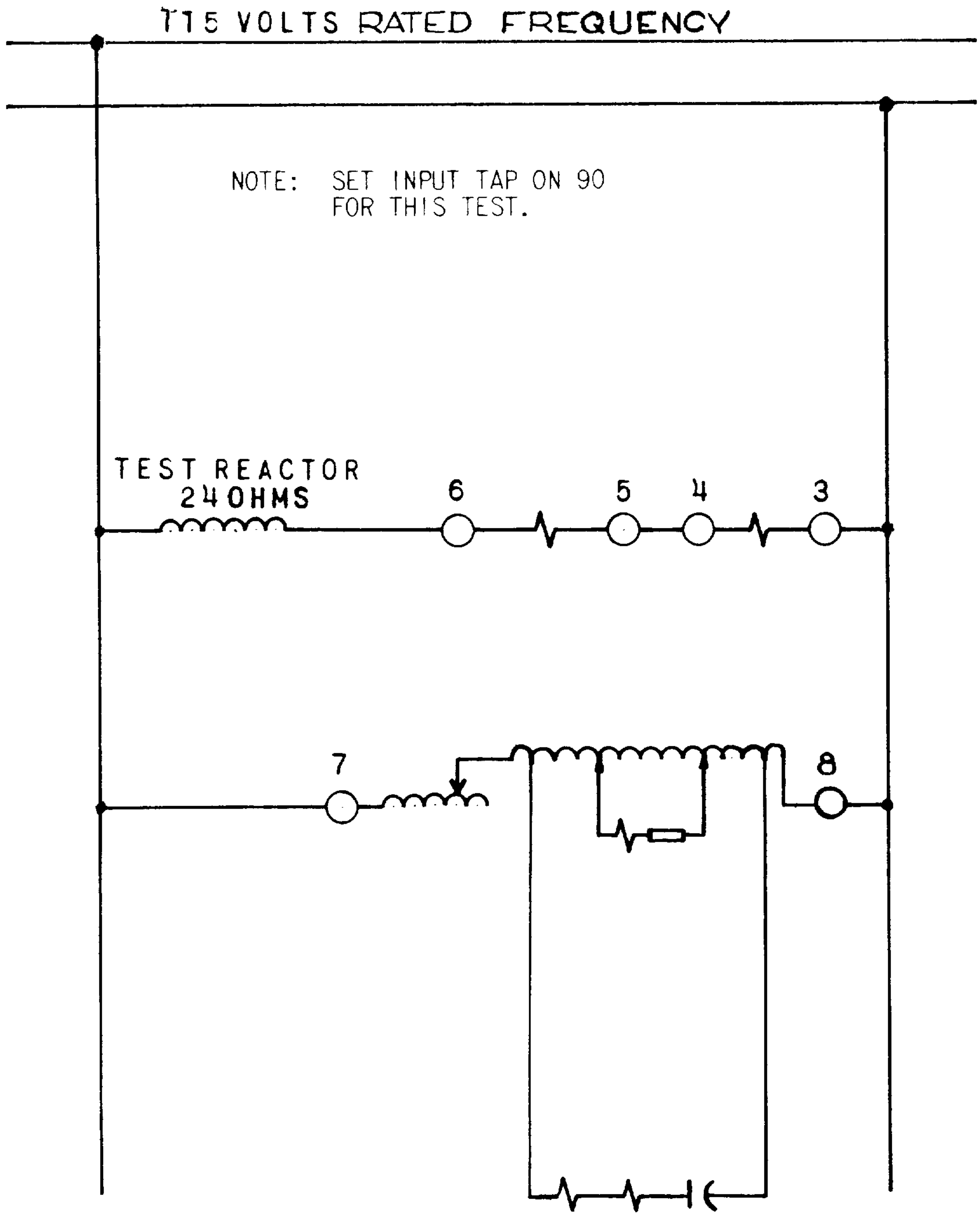


Fig. 13 (362A502-3) Polarity Test for Type CEH51A Relay

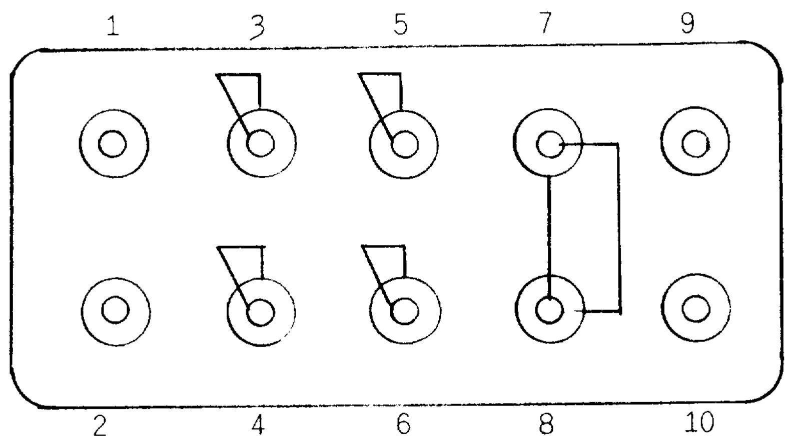


Fig. 14 (0127A9516) Test Plug Connections to Reverse Potential of Polarizing and Restraint Circuits

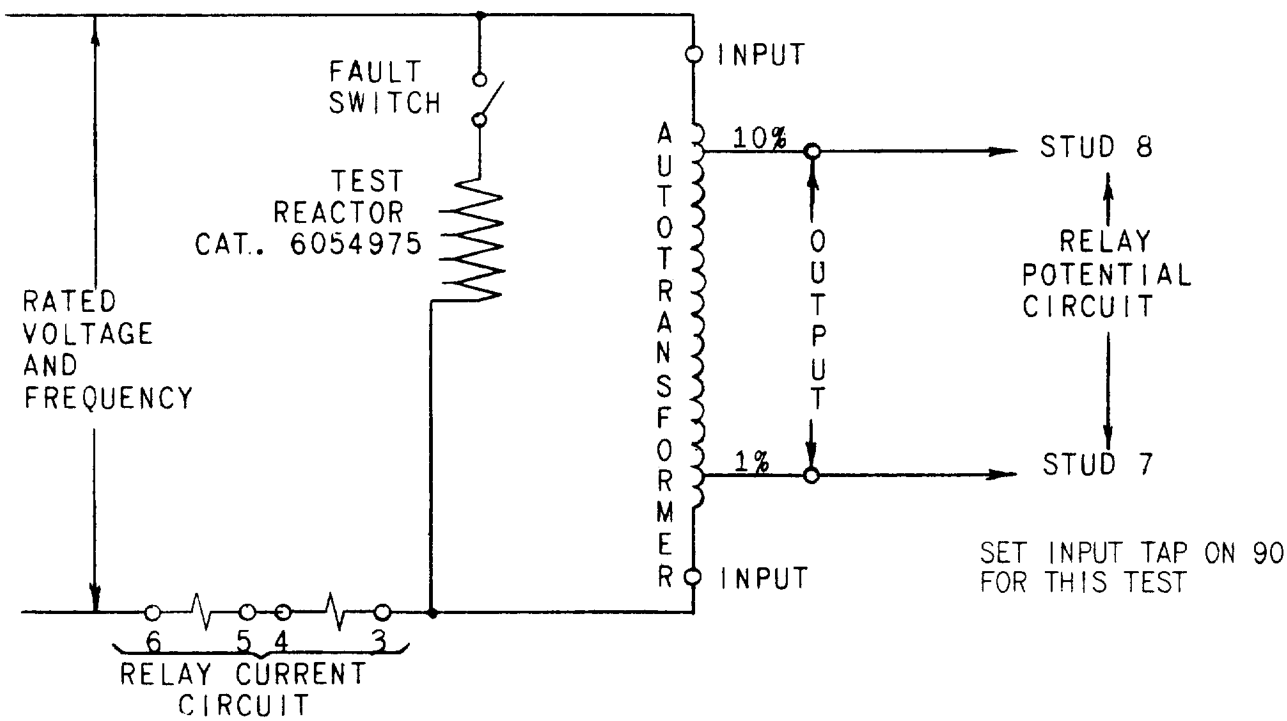


Fig. 15 (402A959-1) Test Connections for Type CEH51A Relay

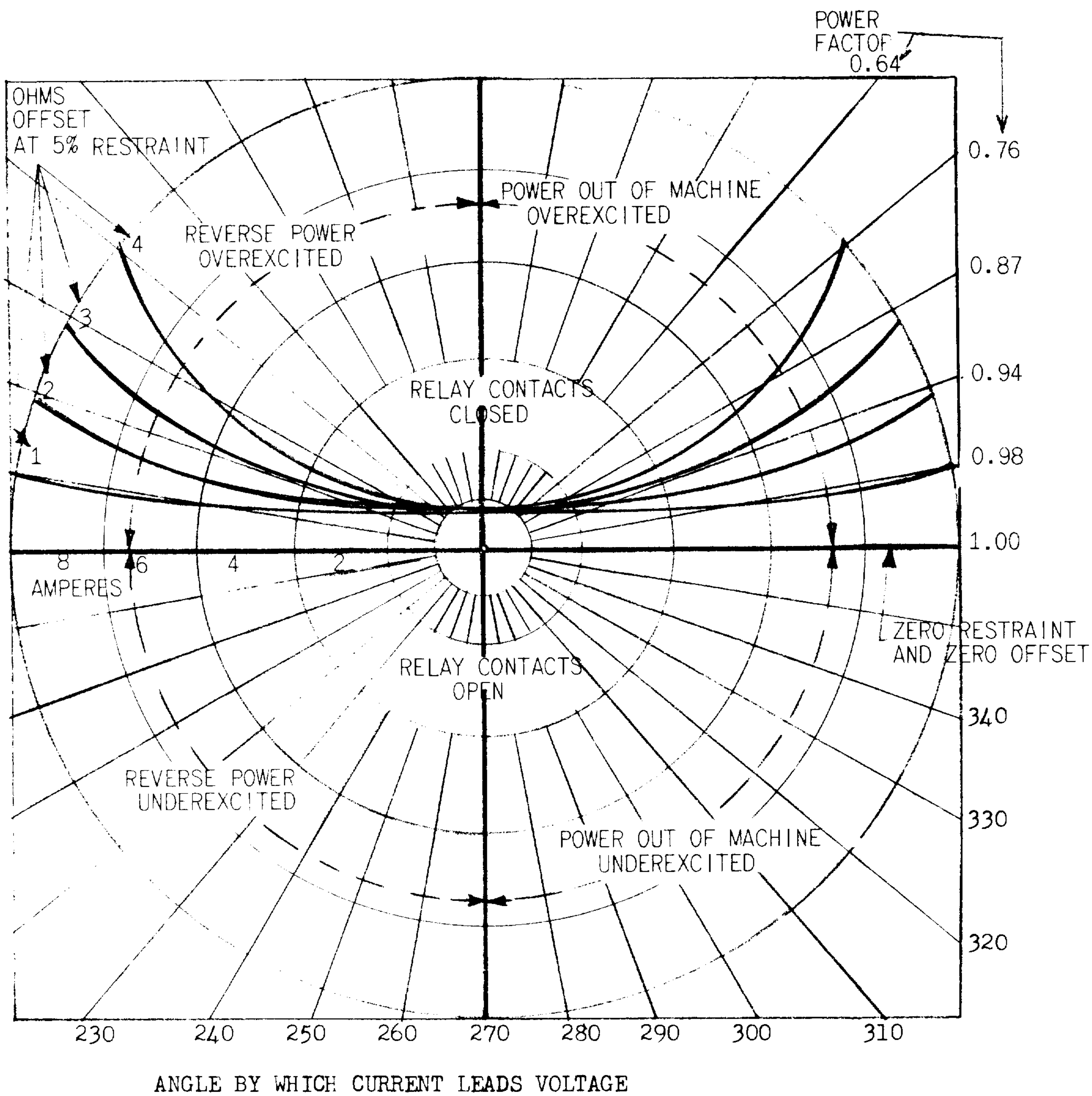
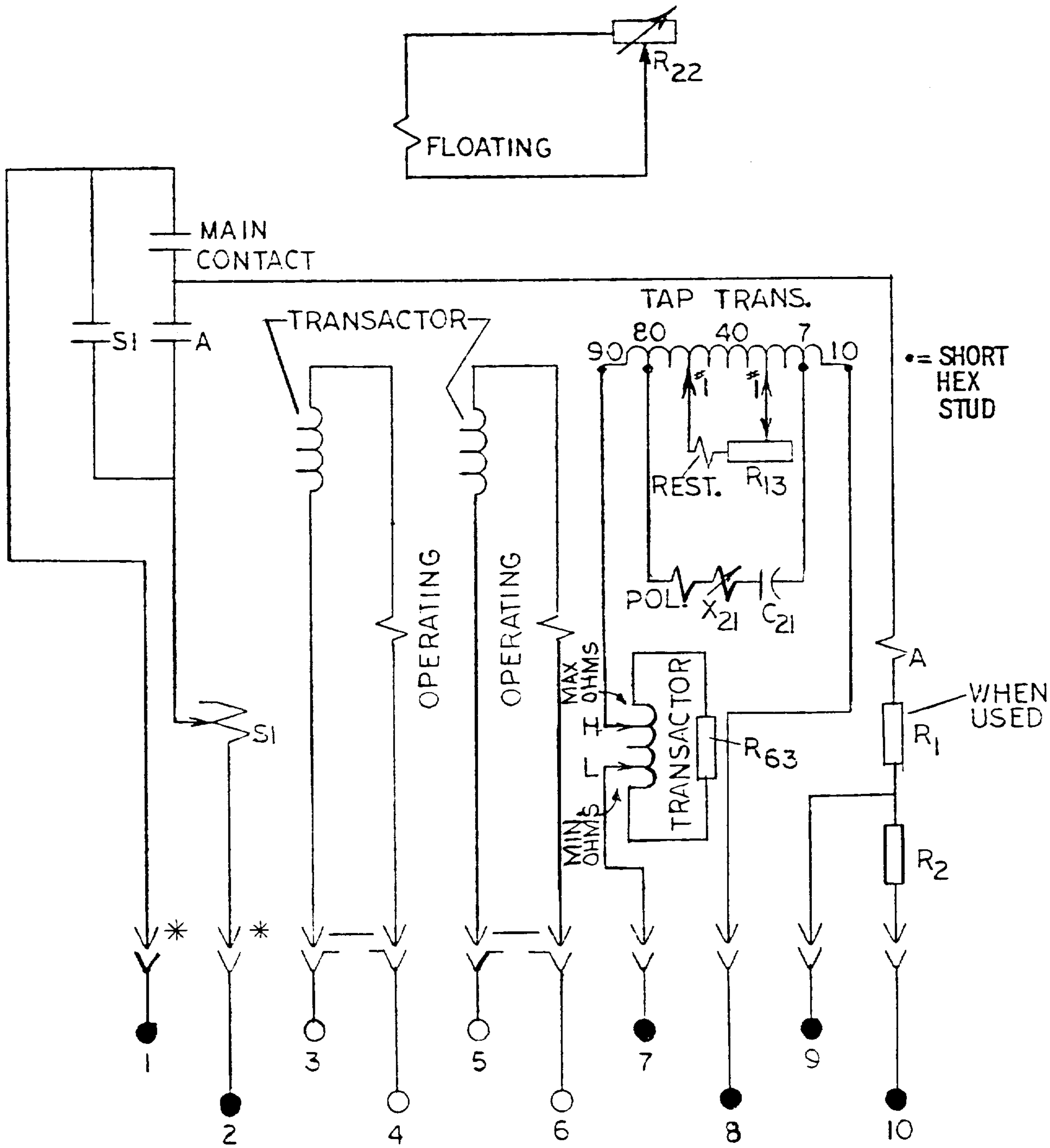


Fig. 16 (402A924-2, Sh. 2) Characteristics of Type CEH51A Relay with Potential Reversed and Five Percent Tap Setting



✱ =SHORT FINGER

Fig. 17 (0227A2540-4) Internal Connections for Type CEH51A Relay

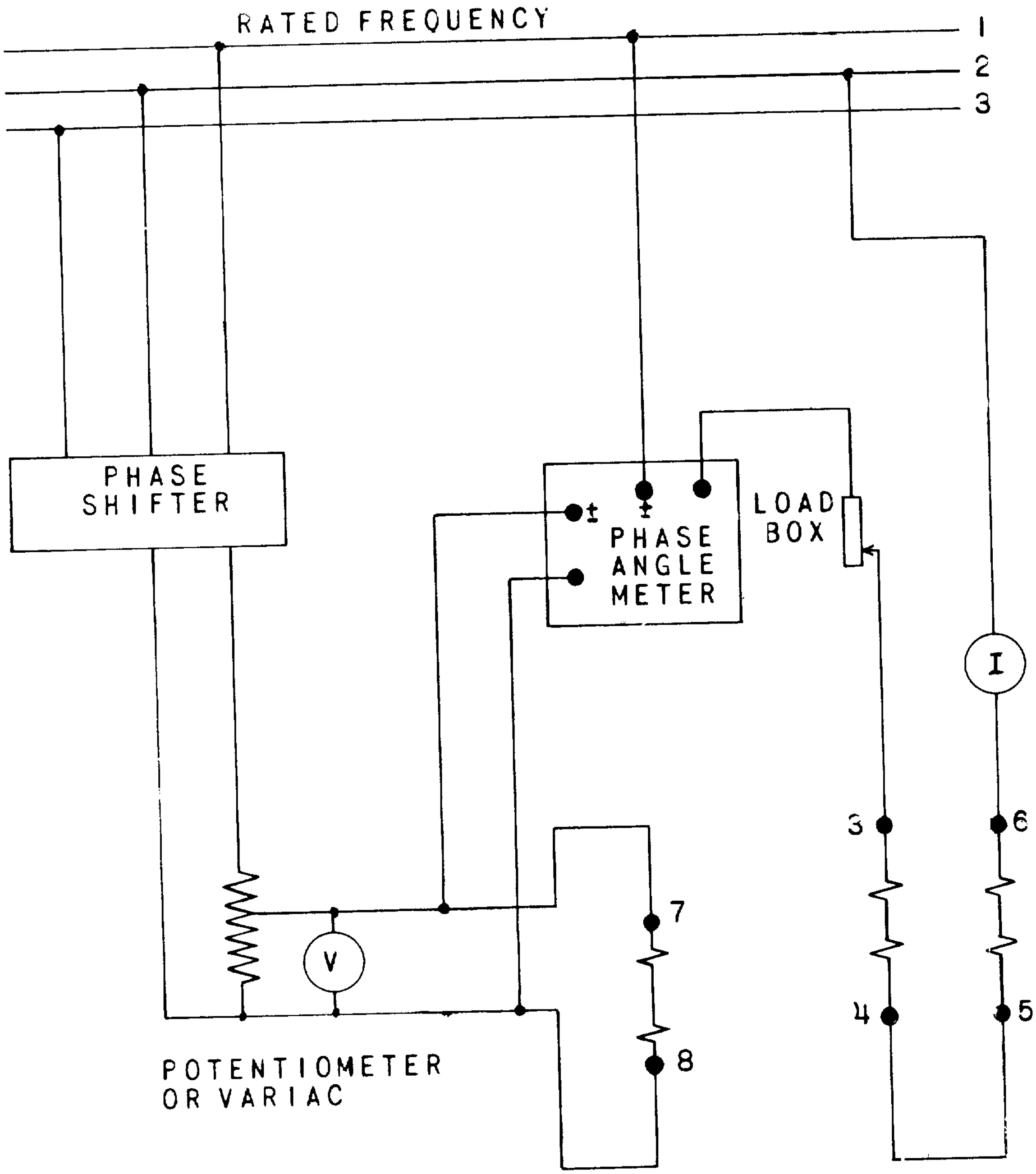


Fig. 18 (0362A501-3) Test Connections for Type CEH51A Relay

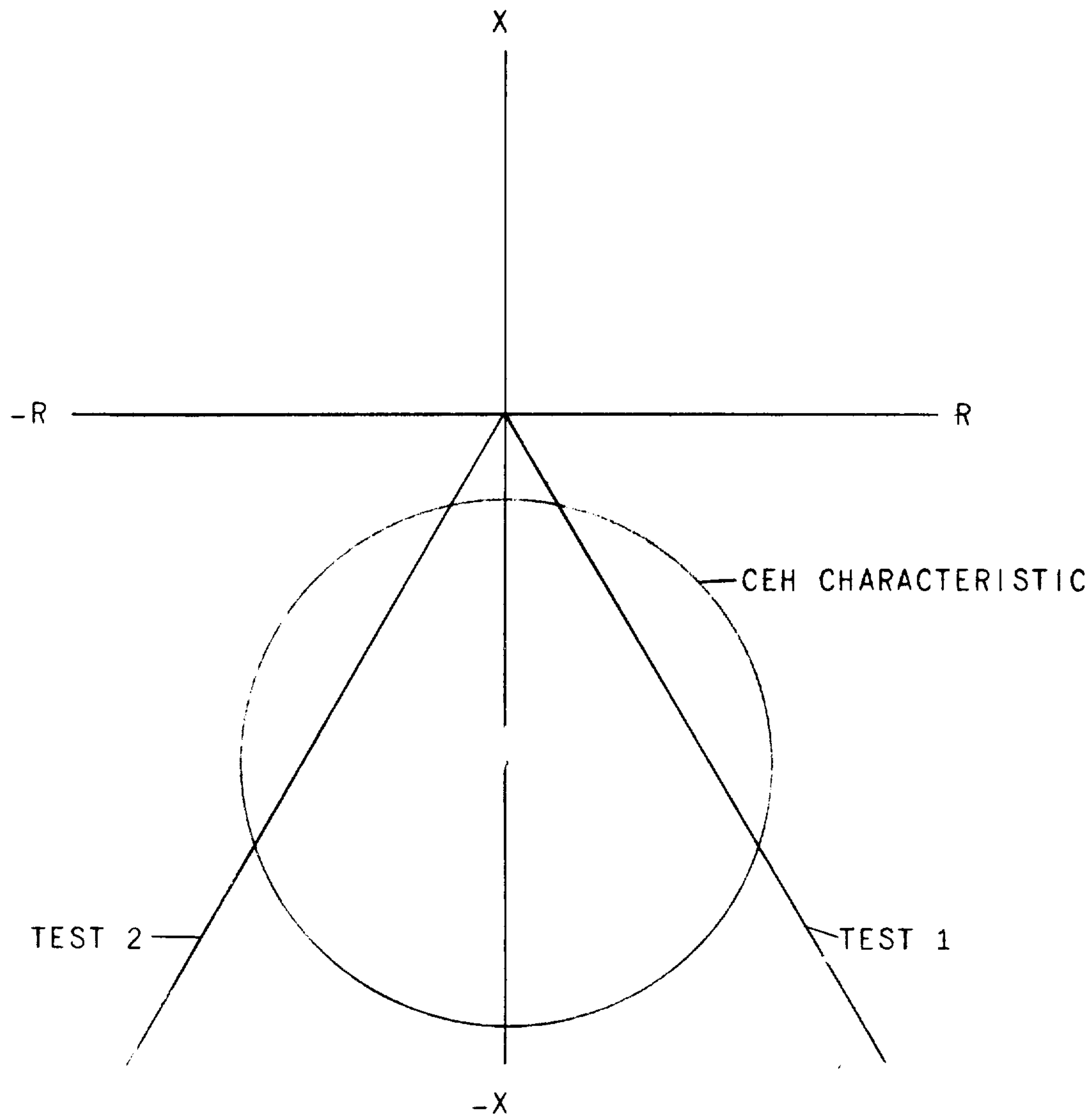


Fig. 19 (402A993-0) Test Points to Determine the Characteristics of a CEH51A Relay

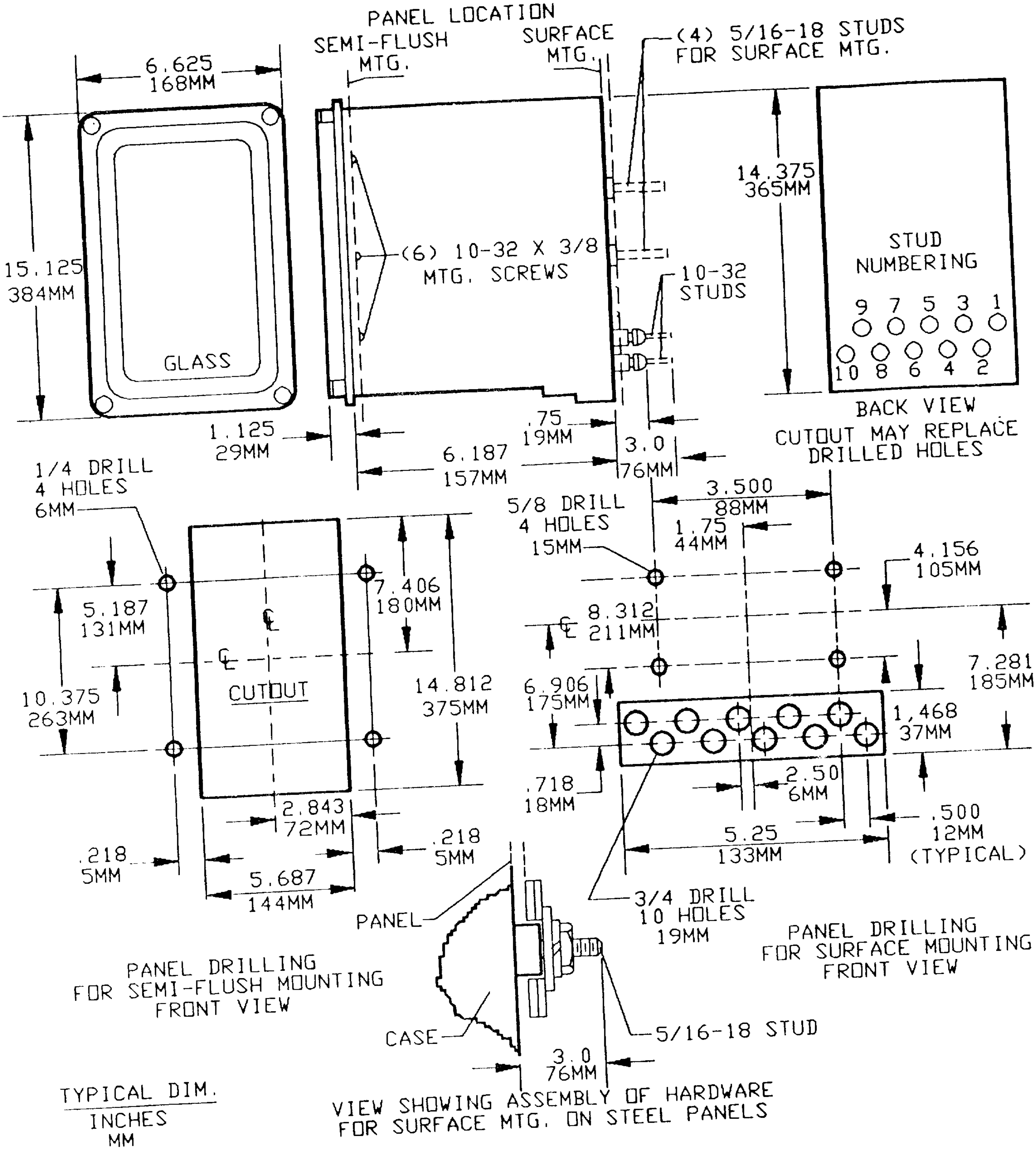


Fig. 20 (K-6209273-5) Outline and Panel Drilling Dimensions for Type CEH51A Relay