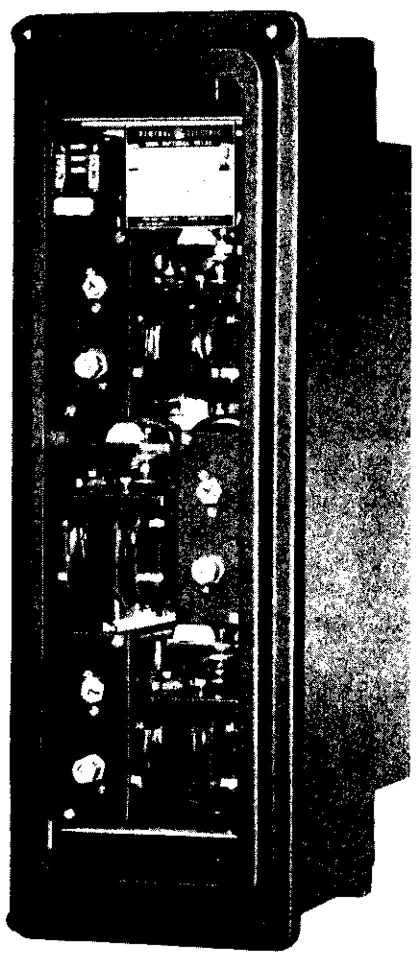
INSTRUCTIONS

MHO DISTANCE RELAY

TYPE CEY51A



GE Protection and Control
205 Great Valley Parkway
Malvern, PA 19355-1337

CONTENTS

Cover (8036548)

MHO DISTANCE RELAY

TYPE CEY51A

INTRODUCTION

The CEY51A relay is an extended-range, three-phase, high-speed, single-zone, mho directional distance relay. It is constructed of three single-phase units in one L2-D case with provisions for single-phase testing. One target and seal-in unit provides indication of operation for all three units. The transient overreach of this relay is limited by design so that it is suitable for use as a first-zone device. One CEY51A relay will provide complete one-zone protection for three-phase, phase-to-phase and double phase-to-ground faults.

APPLICATION

The CEY51A relay, because of its low transient overreach (maximum of six percent) and its memory action, is primarily a first-zone tripping relay. As such, it is applicable as a high-speed tripping unit in direct and permissive underreaching transferred tripping schemes, as well as a first-zone tripping relay in straight distance and carrier schemes.

When applying this relay for the protection of a given circuit, it is advantageous to set the relay on the highest basic-minimum-reach tap that will accomodate the desired reach setting. This will ensure the highest possible operating torque level. For first-zone applications, the relay may be set for as much as 90% of the distance to the remote terminal.

Since all forms of the CEY51A relay have adjustable maximum-torque angle available, a consideration of which angle to use may arise. It is suggested that arc resistance for faults near the relay should be considered in this regard. The smaller the angle of maximum torque, the greater the arc resistance that the unit will accommodate.

The basic sensitivity of the CEY51A relay will depend on the basic minimum tap that is used. Figure 2 gives the steady-state and dynamic sensitivity of the relay. In order to be sure that the relay will reach no less than 90% of its setting, the minimum three-phase fault current flowing in the relay for a fault at the remote end of the line should be at least those values given in table I.

TABLE I

Basic Minimum Tap Setting	Restraint Tap Setting	Min. 3-phase Fault Current Required
0.2 ohms	25%	15.0 amps
0.2 "	50%	22.5 "
0.2 "	100%	30.0 "
0.375 "	25%	8.0 "
0.375 "	50%	12.0 "
0.375 "	100%	16.0 "
0.4 "	25%	7.5 "
0.4 "	50%	11.25 "
0.4 "	100%	15.0 "
0.75 "	25%	4.0 "
0.75 "	50%	6.0 "
0.75 "	100%	8.0 "
0.8 "	25%	3.75 "
0.8 "	50%	5.6 "
0.8 "	100%	7.5 "
1.5 "	25%	2.0 "
1.5 "	50%	3.0 "
1.5 "	100%	4.0 "
3.0 "	25%	1.0 "
3.0 "	50%	1.5 "
3.0 "	100%	2.0 "
6.0 "	25%	0.5 "
6.0 "	50%	0.75 "
6.0 "	100%	1.0 "

The CEY51A and its companion zone-packaged relays may be combined in many different ways for use in different schemes, including straight distance protection, directional-comparison carrier protection, permissive overreaching, permissive- and direct-underreaching transferred tripping and many different back-up schemes. Figure 3 illustrates the external connections to the CEY51A when used in conjunction with a CEY52A, a CEB52A and an RPM21D for three-zone protection of a transmission line against all multi-phase faults.

The section under **CALCULATION OF SETTINGS** provides a worked example for a typical application of the CEY51A relay.

CALCULATION OF SETTINGS

Consider a 230 kV transmission line 50 miles long having a phase-to-neutral impedance of:

$Z_{prim} = 0.14 + j0.80$ ohms per mile

$Z_{prim} = 50(0.14 + j0.80) = 7 + j40$ ohms total

PT Ratio = 230,000/115 = 2000/1

CT Ratio = 600/5 = 120/1

Assume that the minimum three-phase fault current flowing in the relay for a three-phase fault at the remote end of the line is about 8 secondary amperes, and for a close-in fault, it is 11 secondary amperes.

$$Z_{sec.} = Z_{prim} \frac{\text{CT Ratio}}{\text{PT Ratio}}$$

$$Z_{sec.} = (7.0 + j40.0) \frac{120}{2000} = 0.42 + j2.4 \text{ ohms}$$

$$Z_{sec.} = 2.43 \quad \underline{/80.5^{o}} \text{ ohms}$$

Assume that the CEY51A is to be used to provide first-zone protection and it is desired to set the relay to protect 90% of the line

$$0.9 (Z_{sec}) = 0.9(2.43) \quad \underline{/80.5} = 2.19 \underline{/80.5}$$

For this application, the highest suitable basic minimum tap is 1.5 ohms.

The ohmic-reach equation given in the section under **OPERATING CHARACTERISTICS - TAPPED AUTOTRANSFORMER** is used to obtain the required tap setting.

$$\text{Percent Tap Setting} = \frac{(100)\ (\text{Min. Ohms})\ \text{Cos}\ (\emptyset-\theta)}{Z}$$

Minimum Ohms = 1.5

$Z = Z_{sec.} = 2.19$ ohms

$\emptyset = 80.5^{o}$

The selection of the maximum-torque angle for a first-zone relay should depend primarily on accommodation of arc resistance. Smaller maximum-torque angles will accommodate more arc resistance than larger maximum-torque angles. Since arc resistance is independent of line length, the shorter lines will provide the greatest problem on this score because of the shorter reach setting on the relay. Thus, on short lines it is desirable to use smaller angles of maximum torque. On longer lines, where the mho unit must be set with a longer reach, it would have more significant arc-resistance capability even with a larger angle of maximum torque.

Another factor to consider is immunity to system swings. In general, an angle of maximum torque approaching the angle of the line will provide the greatest immunity to system swings. Thus, for most lines, the 75^{o} setting would provide the greatest immunity.

Since system swings are not usually a problem on short lines, but arc resistance is, and since arc resistance may not be a problem on long lines but system swings might be, it is a good general practice to use the lower maximum-torque angle universally except where system swings may be a problem.

Since this is a short line, the normal 60° angle of maximum torque will be used. Thus, $\theta = 60°$.

$$\text{Percent Tap Setting} = \frac{100(1.5)\,\text{Cos}\,(80.5-60)}{2.19} = 64\%$$

T = 64%

A check with the table in the **APPLICATION** section will indicate that the minimum fault current of 8 amperes is sufficient to operate the relay for the settings selected.

A plot of this characteristic on the R-X diagram will show that the unit will accommodate approximately 1.15 secondary ohms of arc resistance for a fault at the origin.

A rough estimate of the arc resistance that a relay will see for a multi-phase fault is given by

$$R_A = \frac{3}{I_{3\phi}}$$

where $I_{3\phi}$ = three-phase fault current flowing in the relay.

Since the minimum three-phase fault current in the relay for a close-in fault was given as 11 amperes, the maximum arc resistance is

$$R_A = \frac{3}{11} = 0.27 \text{ secondary ohms}$$

The 60° relay setting will accommodate this very easily and so would a 75° setting. However, the 60° setting will accommodate more arc resistance near the balance point, and since the line is short, and if system swings are not apt to be a problem, the 60° setting is desirable.

RATINGS

The type-CEY51A relay covered by these instructions is available for 120 volts, 5 amperes, 60 cycle rating. The one-second rating of the current circuits is 225 amperes. The basic minimum reach and adjustment ranges of the mho units are given in Table II.

TABLE II

MHO UNIT	MINIMUM REACH	RANGE	ANGLE
Ø1-2	0.2/0.4/0.8	0.2 to 8	60**
or	0.375/0.75/1.5	0.375 to 15	60**
Ø2-3	0.75/1.5/3.0	0.75 to 30	60**
or	or	or	
Ø3-1	1.5/3.0/6.0	1.5 to 60	60**

Adjustment taps are set for 1.5 ohms (or 0.4 ohms)
** The angle of maximum torque can be adjusted up to 75o. The reach of the mho units at the 75o setting will increase to approximately 103% of its reach at the 60o setting.

It will be noted that three basic-minimum-reach settings are listed for the mho units. Selection of the desired basic-minimum-reach setting for each unit is made by means of two tap screws on a two-section tap block located at the back of the relay (see Figure 1). The position of these screws determines the tap setting of the two primary windings of the transactors (TR-Ø1-2, TR-Ø2-3, TR-Ø3-1). The ohmic reach of the mho units can be adjusted in 1% steps over a 10/1 range for any of the basic-minimum-reach settings listed in Table II by means of autotransformer tap leads on the tap blocks at the right side of the relay.

CONTACTS

The contacts of the CEY51A relay will close and momentarily carry 30 amperes DC. However, the circuit-breaker trip circuit must be opened by an auxiliary switch contact or other suitable means, since the relay contacts have no interrupting rating.

TARGET SEAL-IN UNIT

The target seal-in unit used in the CEY51A relay has ratings as shown in Table III.

TABLE III

	0.2/2.0 Amp		0.6/2.0 Amp	
	0.2	2.0	0.6	2.0
Carry 30 Amps for (seconds)	0.05	2.2	0.5	3.5
Carry 10 Amps for (seconds)	0.45	2.0	5.0	30.0
Carry Continuously (Amp)	0.37	2.3	1.2	2.6
Minimum Operating (Amp)	0.2	2.0	0.6	2.0
Minimum Dropout (Amp)	0.05	0.5	0.15	0.5
DC resistance (Ohms)	8.3	0.24	0.78	0.18
60 Hz Impedance (Ohms)	50	0.65	6.2	0.65
50 Hz impedance (Ohms)	42	0.54	5.1	0.54
DC Resistive Interrupting Rating (Amps)	2.5 Amp @ 125 VDC			

OPERATING PRINCIPLES

The mho units of the CEY51 relay are of the four-pole induction-cylinder construction in which torque is produced by the interaction between a polarizing flux and fluxes proportional to the restraining or operating quantities.

The schematic connections of the M_1 unit are shown in Figure 4. The two side poles, energized by phase-to-phase voltage, produce the polarizing flux. The flux from the front and rear poles, energized by the difference between the secondary voltage of transactor TR-$\emptyset_{1-2}$ and a percentage of the same phase-to-phase voltage, interacts with the polarizing flux to produce torque. The torque equation can be written as follows:

$$\text{Torque} = KE(IZ_{T1} - TE)\cos\beta \qquad (1)$$

where:

E = phase-to-phase voltage (E_{12})
I = delta current ($I_1 - I_2$)
Z_{T1} = transfer impedance of transactor TR-$\emptyset_{1-2}$ (design constant)
β = angle between E and (IZ_{T1} - E)
K = design constant
T = autotransformer tap setting

That this equation (1) defines a mho characteristic can be shown graphically by means of Figure 5. The vector IZ_{T13} at an angle θ determines the basic minimum reach of the unit for a particular tap setting of the transactor TR-$\emptyset_{1-2}$ primary. Assuming finite values of E and (IZ_{T1} - TE), the balance point, torque = 0, will occur where cos = 0, that is, where the angle β is 90o. The locus of the terminus vector TE (Point A in Figure 5) that will cause the angle β to be always 90° in a circle passing through the origin and with the vector IZ_{T1} as a diameter.

Considering further the diagram in Figure 5, we note that the angle β is less than 90° for an internal fault (point C) and net torque will be in the closing direction (cos β is positive); and that the angle β is greater than 90° for an external fault (point D) and the net torque will be in the opening direction (cos β is negative).

See Figure 5, Graphical Representation of Mho Operating Principle.

CHARACTERISTICS

MHO UNIT

Impedance Characteristic

The impedance characteristic of the mho unit is shown in Figure 6 for the 0.75-ohm basic-minimum-reach setting at a maximum-torque angle of 60o. This characteristic is obtained with the terminal voltage of the relay supplied directly to the restraint circuit of the mho unit, that is, with the mho taps on the auto-transformer tap block set at 100%. This circular impedance characteristic can be enlarged, that is, the mho-unit reach can be increased by up to 10/1 by reducing the percentage of the terminal voltage supplied to the restraint circuit by means of the taps on the autotransformer tap blocks, and the circle can be further enlarged, providing a total range adjustment of up to 40/1, by means of the basic-minimum-reach tap screws. The circle will always pass through the origin and have a diameter along the 60o impedance line equal to the ohmic reach of the unit as expressed by the following equation:

$$\text{Ohmic Reach} = \frac{(100)\ Z_{min}}{\text{Tap Setting } (\%)}$$

where:

Z_{min} = Basic minimum phase-to-neutral ohmic reach of the unit (as set by taps).

The angle of maximum torque of the mho unit can be adjusted up to 75o (see **SERVICING**) with negligible effect on the reach of the unit.

Directional Action

The mho unit is carefully adjusted to have correct directional action under steady-state, low-voltage and low-current conditions. For faults in the non-tripping direction, the contacts will remain open at zero volts between 0 and 60 amperes. For faults in the tripping direction, the unit will close its contacts between the current limits in Table IV for the three basic-minimum-reach settings (see Table II) at the voltage shown.

TABLE IV

Basic-Minimum-Reach Tap	Volts (See Figure 10)	Current Range For Correct Directional Action
0.2	2.0V	22.5 - 60A
0.375	2.0V	12.0 - 60A
0.4	2.0V	11.25 - 60A
0.75	2.0V	6.0 - 60A
0.8	2.0V	5.6 - 60A
1.5	2.0V	3.0 - 60A
3.0	2.0V	1.5 - 60A
6.0	2.0V	0.75 - 60A

The unit is set at the factory on the 1.5 ohm or 0.4 ohm tap for correct directional action over the indicated current range. A variation of ± 10% can be expected on the values listed.

For performance during transient low-voltage conditions, where the voltage was normal at 120 volts prior to the fault, refer to the paragraph on MEMORY ACTION.

Underreach

At reduced voltage the ohmic value at which the mho unit will operate may be somewhat lower than the calculated value. This "pullback" or reduction in reach is shown in Figure 2. The unit reach in percent of setting is plotted against the three-phase fault current for three ohmic-reach tap settings. Note that the fault-current scale changes with the basic-minimum-reach setting. The mho unit will operate for all points to the right of the curve. The steady-state curves of Figure 2 were determined by tests performed with no voltage supplied to the relay before the fault was applied. The dynamic curves were obtained with full-rated voltage of 120 volts supplied to the relay before the fault was applied. See Figure 2, Steady-State and Dynamic-Reach Curves for the MHO Unit of the CEY51A Relay.

Memory Action

The dynamic curves of Figure 2 illustrate the effect of memory action in the mho unit, which maintains the polarizing flux for a few cycles following the inception of the fault. This memory action is particularly effective at low voltage levels, where it enables the mho unit to operate for low-fault currents. This can be most forcefully illustrated for a zero-voltage fault by referring to Figure 2. A zero-voltage fault is likely to be right at the relay bus and therefore, to protect for this fault, it is imperative that the relay reach zero percent of its setting. Figure 2 shows that the mho unit, under static conditions, will not see a fault at 0% (zero percent) of the relay setting, regardless of the tap setting. However, under dynamic conditions when the memory action is effective, Figure 2 shows that an mho unit with a 3-ohm basic-minimum-reach and 100% tap setting will operate if $I3\phi$ is greater than 1.5 amperes.

Transient Overreach

The operation of the mho unit under transient conditions at the inception of a fault is important because the relay is normally connected so that the mho contacts will trip a circuit breaker independently of any other contacts. The impedance characteristic of Figure 6 and the steady-state curves of Figure 2 represent steady-state conditions. If the fault current contains a DC transient, the unit may close its contacts momentarily even though the impedance being measured is slightly greater than the calculated steady-state reach. This overreaching tendency will be at a maximum when a fault occurs at the one instant in either half-cycle that produces the maximum DC offset of the current wave. The maximum transient overreach of the mho unit will not exceed 6% of the steady-state reach for line angles up to 85^{o}.

Operating Time

The operating time of the mho unit is determined by a number of factors such as the basic-minimum-reach setting of the unit, fault-current magnitude, ratio of fault impedance to relay reach, and magnitude of relay voltage prior to the fault. The curves in Figure 7 are for the condition of rated volts prior to the fault. Time curves are given for four ratios of fault impedance to relay-reach setting. In all cases, the mho taps were in the 100% position and the angle of maximum torque was set at 60^{o} lag.

See Figure 7, Operating-time Curves for the Mho Unit in the CEY51A Relay.

TAPPED AUTOTRANSFORMER

The ohmic reach of the mho units may be adjusted by means of taps on the two autotransformers. Each autotransformer has two windings. One winding is tapped in 10% steps from 15% to 95%. The other winding is tapped at 0%, 1%, 3% and 5%.

The desired tap setting is made by the proper location of the (two) leads marked #1 and the jumper connecting the two windings of the autotransformer. Note that the 0%-to-5% winding may be added or subtracted from the 15%-95% winding.

The tap setting required to protect a zone Z-ohms long, where Z is the positive phase-sequence-phase-to-neutral impedance expressed in secondary terms, is determined by the following equation.

$$\text{Tap Setting} = \frac{(100)\ (\text{Min. Ohms Setting})\ \text{Cos}\ (\phi-\theta)}{Z}$$

where:

θ = Angle of maximum torque
ϕ = Power factor angle of fault impedance.

Example 1:

TAP SETTING DESIRED = 91

Set one end of jumper lead to 95%. Set the other end to 5%. Set #1 on 1%. (Note the 4% setting of the 0%-to-5% winding subtracts from the 95% setting.)

Example 2:

TAP SETTING DESIRED = 89

Set one end of jumper lead to 85%. Set the other end to 1%. Set #1 to 5%. (Note the 4% setting of the 0%-to-5% winding adds to the 85% setting.)

CURRENT CIRCUITS

The maximum current burden imposed on each current transformer at 5 amperes and 60 cycles is listed in Table V.

TABLE V

AMPS	CYCLES	R	X	P.F.	W	VA
5	60	0.089	0.019	0.98	2.22	2.5

This data is for the 3.0-ohm basic-reach tap setting. The burden for other tap settings may be calculated from the following equation:

$$B_{new} = \left(\frac{B.R.}{3}\right)^2 \times B_3 \text{ ohms}$$

where:

B_{new} = Burden at new tap setting
B.R. = Basic reach of new tap setting
B_3 ohms = Burden from Table V

POTENTIAL CIRCUITS

The maximum potential burden (with restraint tap set for 100%) imposed on each potential transformer at 120 volts and 60 cycles is listed in Table VI.

TABLE VI

CIRCUIT	R	X	P.F.	WATTS	VA
Polarizing	1300	-j680	0.89	8.7	9.8
Restraint	3200	j0	1.0	4.5	4.5

The restraint circuit burden, and hence the total relay burden, will decrease when the restraint tap setting is less than 100%.

The potential burden at tap settings less than 100% can be calculated from the following formula.

$$VA = (a + jb) \quad \frac{\text{Tap Setting}}{100} \; 2 \quad + \quad (c + jd)$$

The terms (a + jb) (c + jd), etc., represent the burdens of the mho-unit-potential circuit expressed in watts and vars with their taps on 100%. The values of these terms for 60-cycle relays are given in Table VII.

TABLE VII

CIRCUIT	TERM (Watts + j Vars)	TERM (Watts + j Vars)
Restraint	(a + jb)	(4.5 + j0)
Polarizing	(c + jd)	(8.7 - j4.5)

CONSTRUCTION

The type CEY51A relays are assembled in a deep, large-size, double-end (L2D) drawout case having studs at both ends in the rear for external connections. The electrical connections between the relay units and the case studs are made through stationary molded inner and outer blocks, between which nests a removable connecting plug that completes the circuits. The outer blocks attached to the case have the studs for the external connections, and the inner blocks have the terminals for the internal connections.

Every circuit in the drawout case has an auxiliary brush, as shown in Figure 8, to provide adequate overlap when the connecting plug is withdrawn or inserted. Some circuits are equipped with shorting bars (see internal connections in Figure 9), and on those circuits it is especially important that the auxiliary brushes make contact, as indicated in Figure 8, with adequate pressure to prevent the opening of important interlocking circuits.

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

The relay case is suitable for either semi-flush or surface mounting on all panels up to two inches thick and appropriate hardware is available. However, panel thickness must be indicated on the relay requisition in order to make sure that proper hardware will be included.

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

Figure 1A and 1B show the relay removed from its drawout case, with all major components identified. Symbols used to identify circuit components are the same as those that appear on the internal connection diagram in Figure 9.

The relay includes three similar mho subassembly elements mounted on the front of the cradle and a plate with transformers and transactors mounted on the back of the cradle.

The mho subassembly includes the four-pole unit and associated circuit components. Adjustable reactors X11, X12, X13, used in setting the angle of maximum torque, and rheostats R11, R12, R13, used in setting the basic minimum reach, can be adjusted from the front of the relay.

The transactors (TR-Ø1-2, TR-Ø2-3, TR-Ø3-1) with their tap blocks are mounted on the back. The relay must be removed from its case to make the transactor (or minimum ohm) settings.

See Figure 8, Cross Section of Case and Cradle Block Showing Auxiliary Brush and Shorting Bar.

RECEIVING, HANDLING AND STORAGE

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

Reasonable care should be exercised in unpacking the relay in order that none of the parts are injured nor 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

Immediately upon receipt of the relay, an inspection and acceptance test should be made to make sure that no damage has been sustained in shipment and that the relay calibrations have not been disturbed. If the examination or the test indicates that readjustment is necessary, refer to the section on **SERVICING.**

VISUAL INSPECTION

Check the nameplate stamping to make sure that the model number and rating of the relay agree with the requisition.

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

MECHANICAL INSPECTION

1. It is recommended that the mechanical adjustments in Table VIII be checked.

2. There should be no noticeable friction in the rotating structure of the units.

3. Make sure control springs are not deformed and spring convolutions do not touch each other.

4. With the relay well-leveled in its upright position, the contacts of all three units must be open. The moving contacts of the units should rest against the backstop.

5. The armature and contacts of the seal-in unit should move freely when operated by hand. There should be at least 1/32 inch wipe on the seal-in contacts.

6. Check the location of the contact brushes on the cradle and case blocks against the internal connection diagram for the relay.

TABLE VIII

Check Points	MHO Units
Rotating Shaft End Play	0.010 - 0.015 inch
Contact Gap	0.030 - 0.035 inch
Contact Wipe	0.003 - 0.005 inch

ELECTRICAL CHECKS - MHO UNIT

Before any electrical checks are made on the mho units, the relay should be connected as shown in Figure 10 and be allowed to **warm up** for approximately 15 minutes with the potential circuit **alone** energized at rated voltage and the restraint taps set as shown in Table IX. The units were warmed up prior to factory adjustment, and if rechecked when cold will tend to underreach by 3% or 4%. Accurately-calibrated meters are of course essential for correct test results.

It is desirable to check the factory setting and calibrations by means of the tests described in the following sections. The mho units were carefully adjusted at the factory and it is not advisable to disturb these settings unless the following checks indicate **conclusively** that the settings have been disturbed. If readjustments are necessary, refer to the section on **SERVICING** for the recommended procedures.

(a) Control-Spring Adjustment

Be sure that the relay is level in its upright position. Leave the relay connected as shown in Figure 10 and position the restraint taps according to Table XII.

Use the following procedure in checking each unit. With the current set at 5 amperes and the voltage across the relay voltage studs at 120 volts, set the phase shifter so that the phase-angle meter reads the value shown in Table IX for the unit being tested; that is, so current lags voltage by an angle equal to the angle of maximum torque of the unit. Now reduce the voltage to the low test voltage of 2.0 volts, and reduce the current to about 2 amperes. Gradually increase the current until the contacts of the unit just close. This should occur between 2.7 and 3.3 amperes for the 1.5 ohm setting or 10.1 and 12.4 for the 0.4 ohm setting.

(b) Clutch Adjustment

The mho units include a high-set clutch between the cup-and-shaft assembly and the moving contact to prevent damage during heavy fault conditions. These clutches have been set at the factory to slip at approximately 40-60 grams applied tangentially at the moving contact. This can best be checked in the field in terms of volt-amperes by the following method.

Use the connections of Figure 10 and set the phase shifter so that the phase-angle meter reads 300o at 120 volts and 5 amperes. Disconnect the No. 1 restraint tap leads from the tap block and short to stud 16, then set the

mho units for 3-ohm basic minimum reach. With the voltage across the relay studs set at 120 volts, increase the current until the clutch just slips.
This should occur between 35 and 55 amperes.

On short range 0.375/1.5 ohms (or 0.2 ohms), set the tap in 1.5 (or 0.8 ohms); clutch must not slip below 60 amperes.

TABLE IX

OHMIC REACH ADJUSTMENT TABLE

Unit Location	Unit	Reach Tap Ohms	Restraint Tap	Connect Lead to Relay Studs as Follows: Lead A	Lead B	Lead C	Lead D	Jumper Relay Studs	Phase Angle Meter Reads	V_{A-B} Set At	Pickup Amps
Top	ø1-2	1.5	100%	14-15	13-16-17	5	7	6-8-10	300°	45V	14.6-15.4
Middle	ø2-3	1.5	100%	13-16-17	18-19-20	7	9	6-8-10	300°	45V	14.6-15.4
Bottom	ø3-1	1.5	100%	18-19-20	14-15	9	5	6-8-10	300°	45V	14.6-15.4
Top	ø1-2	0.4	50%	14-15	13-16-17	5	7	6-8-10	300°	45V	27.3-29.0
Middle	ø2-3	0.4	50%	13-16-17	18-19-20	7	9	6-8-10	300°	45V	27.3-29.0
Bottom	ø3-1	0.4	50%	18-19-20	14-15	9	5	6-8-10	300°	45V	27.3-29.0
Top	ø1-2	3.0	100%	14-15	13-16-17	5	7	6-8-10	300°	90V	14.5-15.4
Middle	ø2-3	3.0	100%	13-16-17	18-19-20	7	9	6-8-10	300°	90V	14.5-15.4
Bottom	ø3-1	3.0	100%	18-19-20	14-15	9	5	6-8-10	300°	90V	14.5-15.4
Top	ø1-2	.75	100%	14-15	13-16-17	5	7	6-8-10	300°	45V	29.1-30.6
Middle	ø2-3	.75	100%	13-16-17	18-19-20	7	9	6-8-10	300°	45V	29.1-30.6
Bottom	ø3-1	.75	100%	18-19-20	14-15	9	5	6-8-10	300°	45V	29.1-30.6

(c) Ohmic Reach

With the relay still connected as shown in Figure 10, make connections shown in Table IX and set the phase shifter so that the phase-angle meter reads the angle shown in Table IX for the unit to be checked.

Now reduce the voltage to the value shown in Table IX and increase the current gradually until the normally-open contacts of the unit just close. This should occur within the pickup limits shown in Table IX. Note that the tap screws on the transactor tap blocks are set to the position which gives the basic minimum reach shown in the table.

Note that for the test conditions, the mho units see a phase-to-phase fault of twice the basic minimum reach.

The relays are normally shipped from the factory with the basic minimum reach adjustment taps of the units (on the back of the relay) in the intermediate setting, that is, 1.5 ohms or 0.4 ohm (the value shown in Table IX). If the units are set on either of the remaining basic minimum reach taps, the basic reach of the units will be within ± 4% of the tap plate marking.

(d) Angle of Maximum Torque

For checking the angle of maximum torque the connections of Figure 10 will be used with the restraint tap leads, and the voltage, set at the value shown in the upper and lower portions, respectively, of Table X for the unit to be checked. The minimum reach taps should be set to the 1.5 ohm or 0.4 ohm position.

In checking the mho units the following procedure should be used. First set the phase shifter so that the phase-angle meter reads 330°. Note that while the phase angle is being set, the current should be 5 amperes and the voltage at 120 volts. Now set the voltage at the value shown in Table X, and increase the current slowly until the mho unit picks up. The pickup current should be within the limits shown in the table. Now reset the phase angle at 270° and again check the current required to pick up the mho unit. This current should fall within the same limits as for the 330° check.

Note that the two angles used in the previous check, i.e., 330° and 270°, are 30° away from the angle of maximum torque. An examination of the mho unit impedance characteristic in Figure 6 shows that the ohmic reach of the unit should be the same at both 330° and 270° and should be 0.866 times the reach at the angle of maximum torque.

TABLE X
ANGLE OF MAXIMUM TORQUE ADJUSTMENT TABLE

Unit Location	Unit	Reach Tap Ohms	Restraint Tap	Connect Leads to Relay Studs as Follows: Lead A	Lead B	Lead C	Lead D	Jumper Relay Studs	Ø-Angle Meter Reading: Angle of Max.Torque	Test Angles	V_{A-B} Set At	Pickup Amps +
Top	ø1-2	1.5	100%	14-15	13-16-17	5	7	6-8-10	300°	330 & 270	45V	16.8 - 17.8
Middle	ø2-3	1.5	100%	13-16-17	18-19-20	7	9	6-8-10	300°	330 & 270	45V	16.8 - 17.8
Bottom	ø3-1	1.5	100%	18-19-20	14 15	9	5	6-8-10	300°	330 & 270	45V	16.8 - 17.8
Top	ø1-2	3.0	100%	14-15	13-16-17	5	7	6-8-10	300°	330 & 270	90V	16.8 - 17.8
Middle	ø2-3	3.0	100%	13-16-17	18 19 20	7	9	6-8-10	300°	330 & 270	90V	16.8 - 17.8
Bottom	ø3-1	3.0	100%	18-19-20	14-15	9	5	6-8-10	300°	330 & 270	90V	16.8 - 17.8
Top	ø1-2	0.4	50%	14-15	13-16-17	5	7	6-8-10	300°	330 & 270	45V	31.5 - 33.5
Middle	ø2-3	0.4	50%	13-16-17	18-19-20	7	9	6-8-10	300°	330 & 270	45V	31.5 - 33.5
Bottom	ø3 1	0.4	50%	18-19-20	14-15	9	5	6-8-10	300°	330 & 270	45V	31.5 - 33.5
Top	ø1-2	0.75	50%	14-15	13-16-17	5	7	6-8-10	300°	330 & 270	45V	16.8 - 17.8
Middle	ø2-3	0.75	50%	13-16-17	18 19 20	7	9	6-8-10	300°	330 & 270	45V	16.8 - 17.8
Bottom	ø3-1	0.75	50%	18-19-20	14-15	9	5	6-8-10	300°	330 & 270	45V	16.8 17.8

+ Pickup amps should be as close to equal as possible for the 330o & 270o tests.

ELECTRICAL TESTS - TARGET SEAL-IN

The target seal-in unit has an operating coil tapped at either 0.6 and 2.0 amperes, 0.2 and 2.0 amperes, or 0.2 and 0.6 amperes.

The relay is shipped from the factory with the tap screw in the lower ampere position. The operating point of the seal-in unit can be checked by connecting from DC source (+) to stud 11 of the relay and from stud 1 through an adjustable resistor and ammeter back to (-). Connect a jumper from stud 12 to stud 11 also, so that the seal-in contact will protect the mho unit contacts. Then close the mho unit contact by hand and increase the DC current until the seal-in unit operates. It should pick up at tap value or slightly lower. Do **not** attempt to interrupt the DC current by means of the mho contacts.

INSTALLATION PROCEDURE

LOCATION

The location of the relay should be clean and dry, free from dust, excessive heat and vibration, and should be 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 Figure 14.

CONNECTIONS

The internal connections of the CEY51A relay are shown in Figure 9. An elementary diagram of typical external connections is shown in Figure 3.

VISUAL INSPECTION

Remove the relay from its case and check that there are no broken or cracked component parts and that all screws are tight.

MECHANICAL INSPECTION

Recheck the six adjustments mentioned under MECHANICAL INSPECTION in the section on **ACCEPTANCE TESTS.**

PORTABLE TEST EQUIPMENT

To eliminate the errors that may result from instrument inaccuracies, and to permit testing the mho units from a single-phase AC test source, the test circuit shown in schematic form in Figure 12 is recommended. In this figure $R_S + jX_S$ is the source impedance, S_F is the fault switch, and $R_L + jX_L$ is the impedance of the line section for which the relay is being tested. The autotransformer T_A, which is across the fault switch and line impedance, is tapped in 10% and 1% steps so that the line impedance $R_L + jX_L$ may be made to appear to the relay very nearly the same as the actual line on which the relay is to be used. This is necessary since it is not feasible to provide the portable test reactor X_L and the test resistor with enough taps so that the combination may be made to match any line.

For convenience in field testing, the fault switch and tapped autotransformer of Figure 12 have been arranged in a portable test box, Catalog No. 102L201, which is particularly adapted for testing directional and distance relays. The box is provided with terminals to which the relay current and potential circuits, as well as the line and source impedances, may be readily connected. For a complete description of the test box, the user is referred to GET-3474.

ELECTRICAL TESTS ON THE MHO UNITS

The manner in which reach settings are made for the mho units is briefly discussed in the **CALCULATION OF SETTINGS** section. Examples of calculations for typical settings are given in that section. It is the purpose of the electrical tests in this section to check the ohmic pickup of the mho units at the settings that have been made for a particular line section.

To check the calibration of the mho units it is suggested that the portable test box, Catalog No. 102L201; portable test reactor, Catalog No. 6054975; and test resistor, Catalog No. 6158546, be arranged with Type XLA test plugs according to Figure 13. These connections of the test box and other equipment are similar to the schematic connections shown in Figure 12, except that the Type XLA test plug connections are now included.

Use of the source impedance R_S + jXS, simulating the conditions that would be encountered in practice, is necessary only if the relay is to be tested for overreach or contact coordination which are not normally considered necessary at the time of installation or during periodic testing. Some impedance will usually be necessary in the source connection to limit current in the fault circuit to a reasonable value, especially when a unit with a short reach setting is to be checked, and it is suggested that a reactor of suitable value be used for this purpose since this will tend to limit harmonics in the fault current.

Since the reactance of the test reactor may be very accurately determined from its calibration curve, it is desirable to check mho unit pickup with the fault reactor alone, due account being taken of the angular difference between the line reactance, XL, and mho-unit angle of maximum reach. The line reactance X_L selected should be the test-reactor tap nearest above twice the mho-unit phase-to-neutral reach, with account being taken of the difference in angle of the test-reactor tap impedance and unit angle of maximum reach. From Figure 11 it is seen that twice the relay reach of the angle of the test reactor impedance is:

$$2Z \text{ Relay} = 200 \times \frac{Z \text{ Min.}}{\text{Tap Setting } \%} \times \cos(\emptyset - \theta)$$

where:

$\emptyset$ = the angle of the test reactor impedance
θ = mho unit angle of maximum reach
Z Min = Basic minimum reach of mho units

To illustrate by an example let us consider the percent tap required on the test box autotransformer for a unit that has been factory adjusted to pick up at 3 ohms minimum and at a maximum torque angle of 60o. In determining the reactor tap setting to use, it may be assumed that the angle (Ø) of the test reactor impedance is 80o. From the above, twice the relay reach at the angle of the test-reactor impedance is:

$$2Z \text{ relay} = 200 \times \frac{3}{100} \cos(80 - 60) = 5.64 \text{ ohms}$$

Therefore, use the reactor 6-ohm tap. Twice the relay reach at the angle of test-reactor impedance should be recalculated, using the actual angle of the reactor tap impedance rather than the assumed 80o. Table XI shows the angles for each of the reactor taps.

TABLE XI

TAP	ANGLE	COS Ø-60
24	88	0.883
12	87	0.891
6	86	0.899
3	85	0.906
2	83	0.921
1	81	0.934
0.5	78	0.951

From Table XI it is seen that the angle of the impedance of the 6-ohm tap is 86o. Therefore:

$$2Z \text{ relay} = 200 \times \frac{3}{100} \cos(86-60) = 5.4 \text{ ohms}$$

The calibration curve for the portable test reactor should again be referred to in order to determine the exact reactance of the 6-ohm tap at the current level being used. For the purpose of this illustration assume that the reactance is 6.1 ohms. Since the angle of the impedance of the 6-ohm tap is 86o, the impedance of this tap may be calculated as follows:

$$Z_L = \frac{XL}{\sin 86} + \frac{6.1}{0.9976} = 6.115$$

From this calculation it is seen that the reactance and the impedance may be assumed the same for this particular reactor tap. Actually the difference need only be taken into account on the reactor 3, 2, 1 and 0.5 ohm taps.

The test-box-autotransformer-tap setting required to close the mho-unit contacts with the fault switch closed is:

$$\% = \frac{5.4}{6.1}(100) = 88.5\% \text{ (use 88\% tap)}$$

Figure 7 should be checked to determine that the test current to be used is high enough to produce a characteristic at the calculated value.

If the ohmic pickup of the mho unit checks correctly according to the above, the chances are that the angle of the characteristic is correct. The angle may, however, be very easily checked by using the calibrated test resistor in combination with various reactor taps. The calibrated test-resistor taps are pre-set in such a manner that when used with the 12- and 6-ohm taps of the specified test reactor, impedances at 60° and 30° respectively will be available for checking the mho-unit reach at the 60° and 30° positions. The mho-unit ohmic reach at the zero-degree (0°) position may be checked by using the calibrated test resistor alone as the line impedance. The calibrated test resistor is supplied with a data sheet that gives the exact impedance and angle for each of the combinations available. The test-box auto-transformer percent tap for pickup at a particular angle is given by:

$$\% \text{ Tap} = \frac{200 \text{ Z MIN} \cos(\phi - \theta)}{Z_L \text{ (Tap Setting \%)}} \quad (100)$$

where θ is the angle of maximum torque of the unit, ϕ is the angle of the test impedance (Z_L), Z is the 60°, 30° or 0° impedance value taken from the calibrated resistor data sheet. As in the case of the previous tests, the load box that serves as the source impedance should be adjusted to allow approximately 10 amperes to flow in the fault circuit when the fault switch is closed.

When checking the mho unit at angles of more than 30° off the maximum reach position, the error becomes relatively large with phase-angle error. This is apparent from Figure 11 where it is seen, for example at the zero-degree position, that a 2° or 3° error in phase angle will cause a considerable apparent error in reach.

OVERALL TESTS

An overall check of current transformer polarities, and connections to the relay, can be made on the complete installation by means of the test connections and tabulation in Figure 13. A check of the phase angle meter readings in the table for power factor angle and phase sequence involved will indicate whether the relay is receiving the correct voltage and currents for the conventional connections shown in Figure 3.

INSPECTION

Before placing a relay into service, the following mechanical adjustments should be checked, and faulty conditions corrected according to instructions in the ADJUSTMENTS subsection of this section or under the **MAINTENANCE** section.

TARGET AND SEAL-IN UNITS

The armature and contacts of the target and seal-in units 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.

MHO UNITS

There should be no noticeable friction in the rotating structure of the mho unit. The mho unit moving contact should just return to the backstop when the relay is de-energized and in the vertical position.

There should be approximately 0.010 - 0.015 inch end play in the shafts of the rotating structures. The lower jewel screw bearing should be screwed firmly into place and the top pivot locked in place by its set screw.

If there is reason to believe that the jewel is cracked or dirty, the screw assembly can be removed from the bottom of the unit and examined. When replacing a jewel, have the top pivot engaged in the shaft while screwing in the jewel screw.

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

The felt gasket on the cover should be securely cemented in place in order to keep out dust.

Determine the impedance and phase angle seen by the relays. Knowing the impedance and phase angle seen by the relay, the tap value at which the relay will just operate can be calculated. It is then only necessary to reduce the tap setting of the relay until the mho units operate, and see how close the actual tap value found checks with the calculated value. The calculated value should take into account the shorter reach of the mho unit at low currents. This effect is shown in Figure 2.

A shorter test that will check for most of the possible open circuits in the AC portion of the relay can be accomplished by disconnecting the current circuits. This can be done by removing the lower connection plug. All units should have strong torque to the right when full voltage is applied.

Replace the lower plug and open the restraint taps. All units should operate if power and reactive flow are away from the station bus and into the protected line section. If the direction of reactive power flow is into the station bus, the resultant phase angle may be such that the units will not operate.

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 once a year.

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 ensures 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

If it is found during the installation or periodic tests that the mho unit calibrations are out of limits, they should be recalibrated as outlined in the following paragraphs. It is suggested that these calibrations be made in the laboratory. The circuit components listed below, which are normally considered as factory adjustments, are used in recalibrating the units. These parts may be physically located from Figure 1A and 1B. Their locations in the relay circuit are shown in the internal connection diagrams of Figure 9.

R_{11} - ϕ_{1-2} Unit ohmic reach adjustment

X_{11} - ϕ_{1-2} Unit angle of maximum torque adjustment

R_{12} - ϕ_{2-3} Unit ohmic reach adjustment

X_{12} - ϕ_{2-3} Unit angle of maximum torque adjustment

R_{13} - ϕ_{3-1} Unit ohmic reach adjustment

X_{13} - ϕ_{3-1} Unit angle of maximum torque adjustment

NOTE: Before making pickup or phase-angle adjustments on the mho units, the units should be allowed to **heat** up for approximately 15 minutes energized with **rated voltage** alone and the restraint tap leads set for **100%.** Also it is important that the relay be mounted in an **upright** position so that the units are level.

CONTROL SPRING ADJUSTMENTS

Make connections to the relay as shown in Figure 10. Set the restraint-tap leads and the basic-reach taps as shown in Table IX. Make sure that the relay is in an upright position so that the units are level. With the current set at 5 amperes and the voltage V_{A-B} at 120 volts, set the phase shifter so that the phase-angle meter reads the value shown in Table XII.

Now reduce the voltage to the test voltage value and set the current at the value shown in Table XII for the unit being adjusted. Insert the blade of a thin screwdriver into one of the slots in the edge of the spring-adjusting ring and turn the ring until the contacts of the unit just close. If the contacts were closing below the set point shown in Table XII, the adjusting ring should be turned to the right. If they were closing above the set point, the adjusting ring should be turned to the left.

TABLE XII
CONTROL SPRING ADJUSTMENT

Unit Location	Unit	Reach Tap Ohms	Res. Tap	Connect Lead to Relay Studs as Follows: Lead A	Lead B	Lead C	Lead D	Jumper Relay Studs	Phase-Angle Meter Reads	V_{A-B} Set At	Set Value of Current
Top	ø1-2	1.5	100%	14-15	13-16-17	5	7	6-8-10	300°	1.5V	3.0A
Middle	ø2-3	1.5	100%	13-16-17	18-19-20	7	9	6-8-10	300°	1.5V	3.0A
Bottom	ø3-1	1.5	100%	18-19-20	14-15	9	5	6-8-10	300°	1.5V	3.0A
Top	ø1-2	0.4	50%	14-15	13-16-17	5	7	6-8-10	300°	1.5V	9.0A
Middle	ø2-3	0.4	50%	13-16-17	18-19-20	7	9	6-8-10	300°	1.5V	9.0A
Bottom	ø3-1	0.4	50%	18-19-20	14-15	9	5	6-8-10	300°	1.5V	9.0A
Top	ø1-2	3.0	100%	14-15	13-16-17	5	7	6-8-10	300°	1.5V	3.0A
Middle	ø2-3	3.0	100%	13-16-17	18-19-20	7	9	6-8-10	300°	1.5V	3.0A
Bottom	ø3-1	3.0	100%	18-19-20	14-15	9	5	6-8-10	300°	1.5V	3.0A
Top	ø1-2	.75	50%	14-15	13-16-17	5	7	6-8-10	300°	1.5V	9.0A
Middle	ø2-3	.75	50%	13-16-17	18-19-20	7	9	6-8-10	300°	1.5V	9.0A
Bottom	ø3-1	.75	50%	18-19-20	14-15	9	5	6-8-10	300°	1.5V	9.0A

OHMIC-REACH ADJUSTMENT

The basic minimum reach of the mho units can be adjusted by means of the rheostats, which are accessible from the front of the relay. Connect the relay as show in Figure 10. Set the restraint tap and the basic-minimum-reach taps in the positions shown in Table IX. With current at 5 amperes, and voltage at 120 volts, set the phase shifter so that the phase-angle meter reads the angle shown in the table for the unit to be checked. Now reduce the voltage V_{AB} to the set value shown in Table IX and adjust the appropriate rheostat so that the unit picks up in the ampere range shown in Table IX.

ANGLE OF MAXIMUM TORQUE

The angle of maximum torque of the mho units can be adjusted by means of adjustable reactors that are accessible from the front of the relay. Use the connections in Figure 10. Set the restraint taps and the basic-minimum-reach taps in the positions shown in Table XIII.

The procedure used in setting the angle of maximum torque is to adjust the reactor so that the pickup amperes, at a specified set voltage, V_{AB}, will be the same at angles leading and lagging the maximum-torque angle by 30°. The test angles, set voltages and the pickup amperes are shown in Table XIII. First, the reach of the unit at its angle of maximum torque should be checked, and adjusted if necessary as described in paragraph (c) in the **ACCEPTANCE TESTS** section and Table IX. Next, set the phase shifter so that the phase angle meter reads 330° (**Note** that

TABLE XIII
ANGLE OF MAXIMUM TORQUE ADJUSTMENT FOR 60° ANGLE

Unit Location	Unit	Reach Tap Ohms	Restraint Tap	Connect Leads to Relay Studs as Follows: Lead A	Lead B	Lead C	Lead D	Jumper Relay Studs	ø-Angle Meter Reads: Angle of Max Torque	Test Angles	V_{A-B} Set At	Pickup Amps	Adjust
Top	ø1-2	1.5	100%	14-15	13-16-17	5	7	6-8-10	300°	330 & 270	45	17.3	X11
Middle	ø2-3	1.5	100%	13-16-17	18-19-20	7	9	6-8-10	300°	330 & 270	45	17.3	X12
Bottom	ø3-1	1.5	100%	18-19-20	14-15	9	5	6-8-10	300°	330 & 270	45	17.3	X13
Top	ø1-2	0.4	50%	14-15	13-16-17	5	7	6-8-10	300°	330 & 270	45	28.1	X11
Middle	ø2-3	0.4	50%	13-16-17	18-19-20	7	9	6-8-10	300°	330 & 270	45	28.1	X12
Bottom	ø3-1	0.4	50%	18-19-20	14-15	9	5	6-8-10	300°	330 & 270	45	28.1	X13
Top	ø1-2	3.0	100%	14-15	13-16-17	5	7	6-8-10	300°	330 & 270	90	20	X11
Middle	ø2-3	3.0	100%	13-16-17	18-19-20	7	9	6-8-10	300°	330 & 270	90	20	X12
Bottom	ø3-1	3.0	100%	18-19-20	14-15	9	5	6-8-10	300°	330 & 270	90	20	X13
Top	ø1-2	.75	50%	14-15	13-16-17	5	7	6-8-10	300°	330 & 270	48	20	X11
Middle	ø2-3	.75	50%	13-16-17	18-19-20	7	9	6-8-10	300°	330 & 270	48	20	X12
Bottom	ø3-1	.75	50%	18-19-20	14-15	9	5	6-8-10	300°	330 & 270	48	20	X13

phase angle adjustments should be made at 120 volts and 5 amperes). Then set V_{AB} at 5 volts and adjust the proper reactor so that the mho unit closes its contacts at pickup amperes ± 2%. The pickup should then be checked at 270° with the same set voltage. Pickup should be at pickup amperes ± 2%. Refine the adjustments of the reactors until the pickup is within limits at both 270° and 330°.

Note that an adjustment of the angle of maximum torque will have a secondary effect on the reach of the unit, and vice versa. Therefore, to ensure accurate settings it is necessary to recheck the reach of a unit whenever its angle of maximum torque setting is changed, and to continue a "cross-adjustment" routine of reach and angle of maximum torque until both are within the limits specified above.

As noted in Table II Under the section on **RATINGS**, the angle of maximum torque of the mho units can be adjusted up to 75° if desired. If this change is made, the reach of the mho units will increase slightly. To make this adjustment, refer to Table XIV and proceed as outlined below.

TABLE XIV
ANGLE OF MAXIMUM TORQUE ADJUSTMENT FOR 75° ANGLE

Unit Location	Unit	Reach Tap Ohms	Restraint Tap	Connect Leads to Relay Studs as Follows: Lead A	Lead B	Lead C	Lead D	Jumper Relay Studs	ø-Angle Meter Reads: Angle of Max Torque	Test Angles	V_{A-B} Set At	Pickup Amps	Adjust
Top	ø1-2	1.5	100%	14-15	13-16-17	5	7	6-8-10	285°	315 & 255	45	17.3	X11
Middle	ø2-3	1.5	100%	13-16-17	18-19-20	7	9	6-8-10	285°	315 & 255	45	17.3	X12
Bottom	ø3-1	1.5	100%	18-19-20	14-15	9	5	6-8-10	285°	315 & 255	45	17.3	X13
Top	ø1-2	0.4	50%	14-15	13-16-17	5	7	6-8-10	285°	315 & 255	45	28.1	X11
Middle	ø2-3	0.4	50%	13-16-17	18-19-20	7	9	6-8-10	285°	315 & 255	45	28.1	X12
Bottom	ø3-1	0.4	50%	18-19-20	14-15	9	5	6-8-10	285°	315 & 255	45	28.1	X13
Top	ø1-2	3.0	100%	14-15	13-16-17	5	7	6-8-10	285°	315 & 255	90	20	X11
Middle	ø2-3	3.0	100%	13-16-17	18-19-20	7	9	6-8-10	285°	315 & 255	90	20	X12
Bottom	ø3-1	3.0	100%	18-19-20	14-15	9	5	6-8-10	285°	315 & 255	90	20	X13
Top	ø1-2	.75	50%	14-15	13-16-17	5	7	6-8-10	285°	315 & 255	48	20	X11
Middle	ø2-3	.75	50%	13-16-17	18-19-20	7	9	6-8-10	285°	315 & 255	48	20	X12
Bottom	ø3-1	.75	50%	18-19-20	14-15	9	5	6-8-10	285°	315 & 255	48	20	X13

With restraint tap settings and connections as per Table XIV, set the phase shifter so that the phase-angle meter reads 315°, set V_{AB} to 45 volts and the current to pickup amperes. Adjust the appropriate reactor so that the unit just picks up. Now check the pickup current at 255°. The pickup current at both test angles should be within ± 2% of the value listed in the table. After the setting is made make sure the reactor lock nuts are tight.

DIRECTIONAL CHECK

With the relay connected per Figure 10, and restraint taps in 100%, allow the relay to **preheat** for approximately 15 minutes at rated voltage.

Set the phase-angle meter at the angle of maximum torque and reduce the voltage to 2 volts. The relay contact must close over the range of 6-60 amperes.

With the potential circuit short-circuited on itself, the contacts must remain open over the range of 0-30 amperes.

Should the MB unit fail to pass either test, the core must be adjusted. The core and coil assembly is shown in Figure 1?.

By use of a special wrench (0178A9455 Pt.1) the core may be rotated 360° in either direction without having either to hold nut "F" or to retighten any parts after the final position of the core has been determined.

The final position of the core is that position where the unit passes both the above directional check tests.

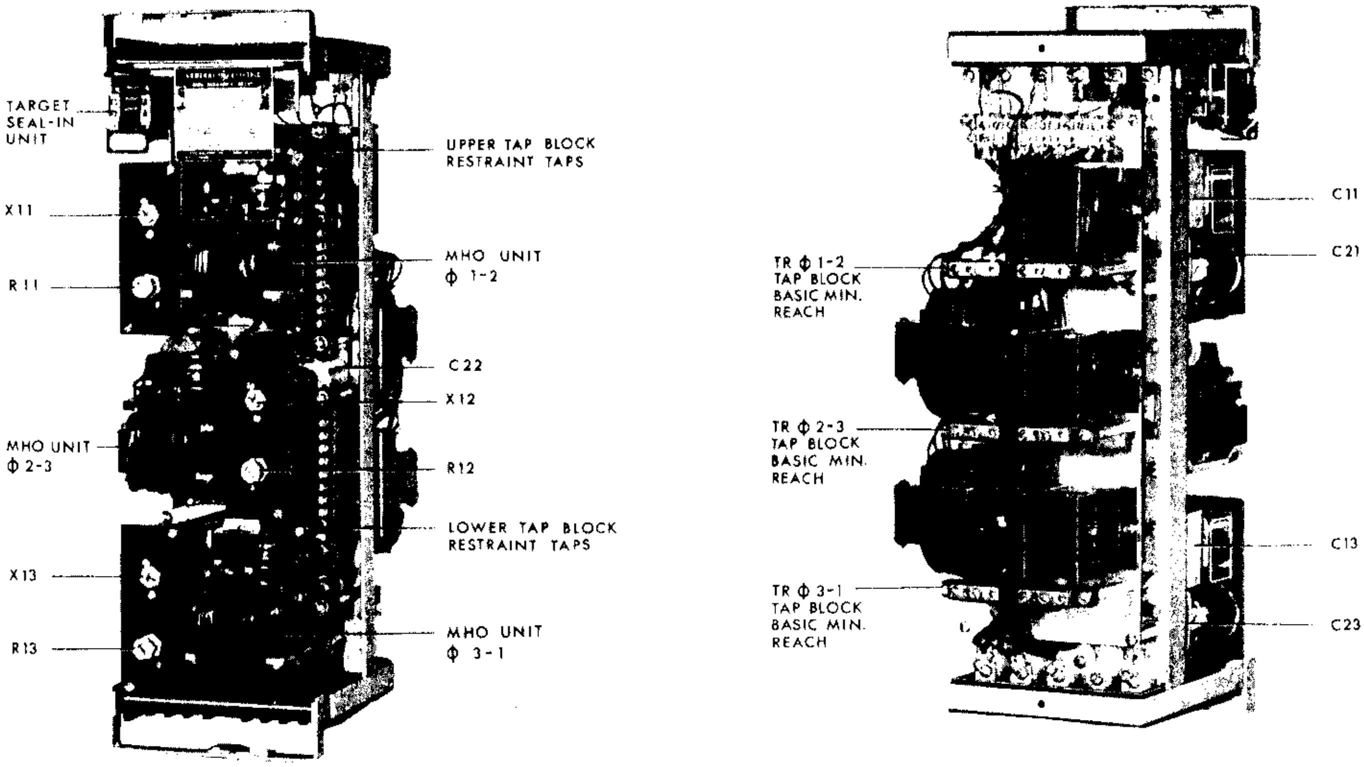
RENEWAL PARTS

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 and name of the part wanted, and give complete nameplate data. If possible give the General Electric requisition number on which the relay was furnished.

LIST OF FIGURES

Since the last edition, Tables IX, X, XII, XIII, and XIV have been expanded, and Figures 3 and 14 have been clarified. The drawing number of Figure 11 has been corrected.



A. Front View (8036549)

B. Back View (8036550)

Figure 1 MHO Distance Relay Type CEY51A

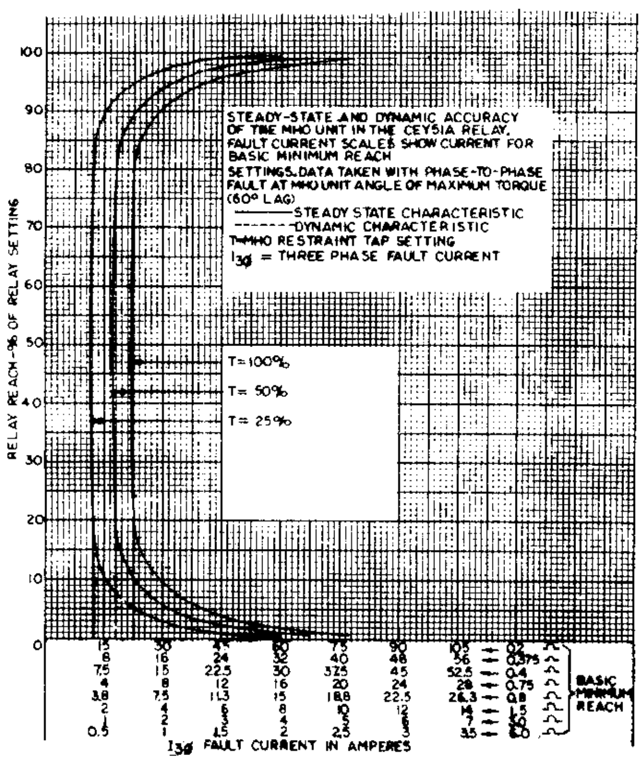
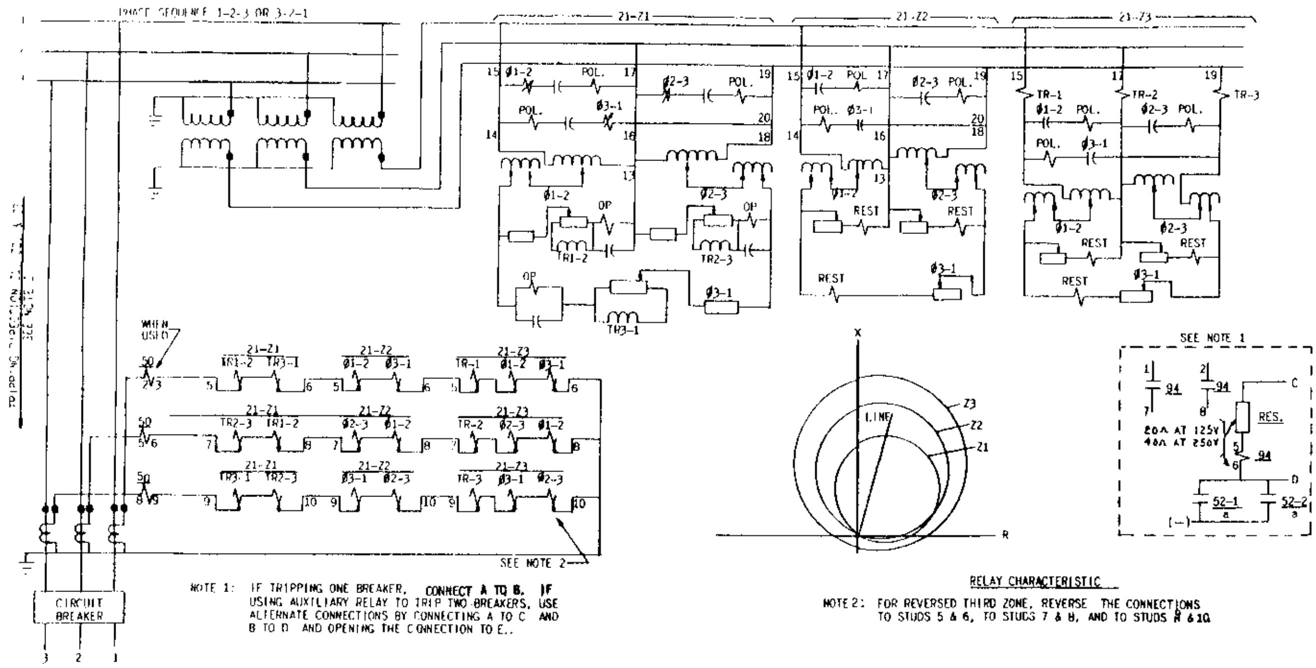
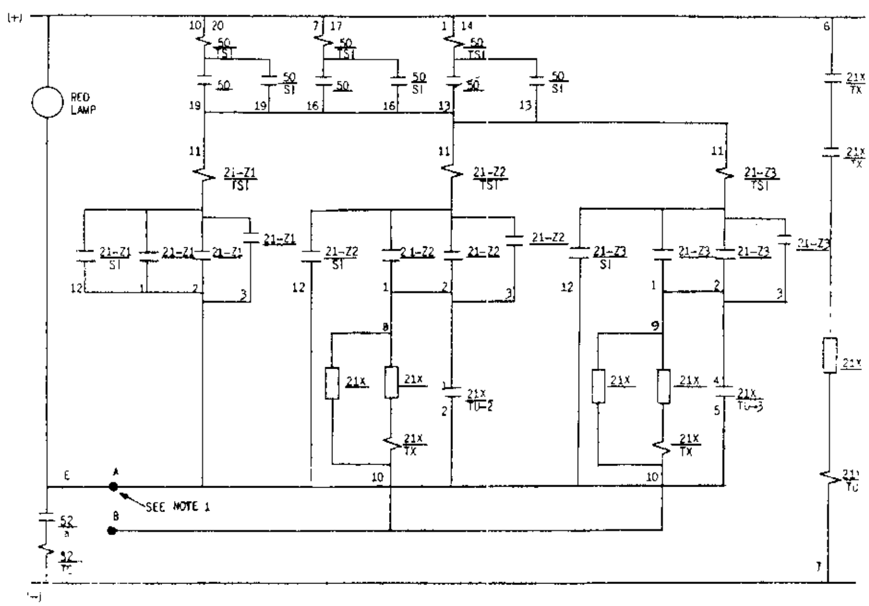


Figure 2 (0195A4989-2) Steady-State and Dynamic-Reach Curves for MHO Unit in the CEY51A Relay

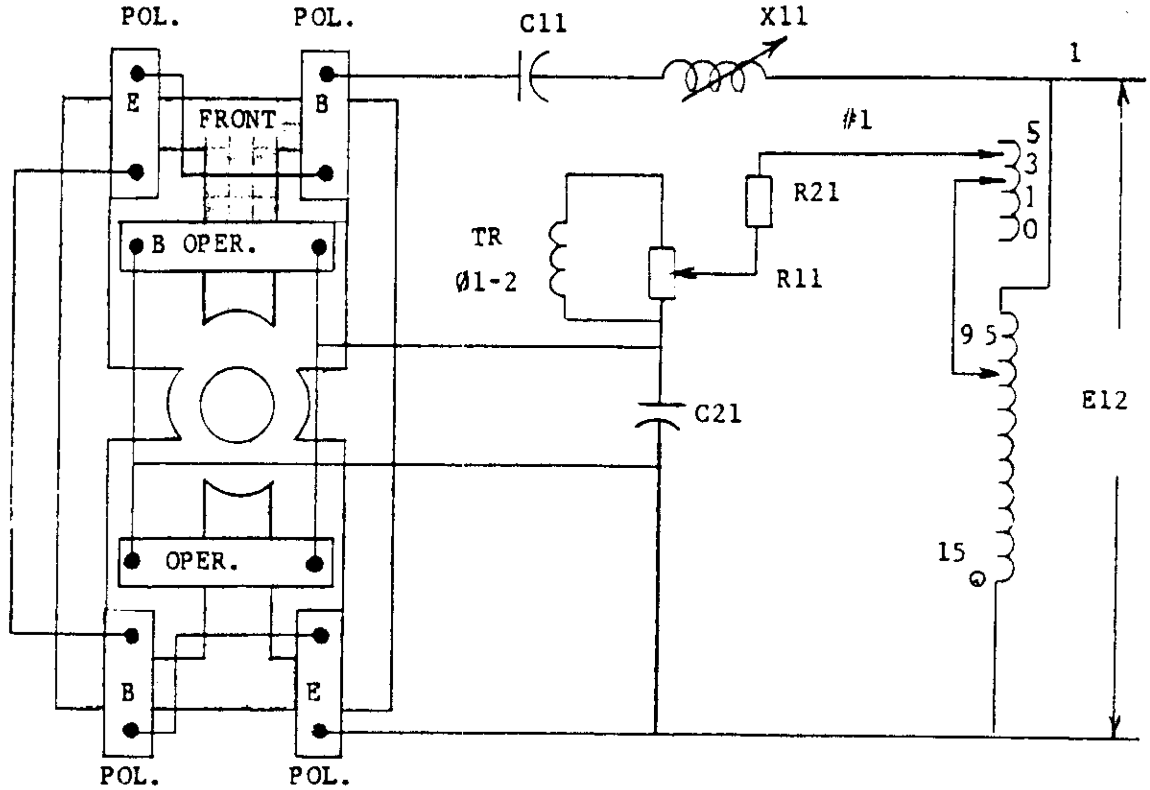




LEGEND			
DEVICE NO.	DEVICE TYPE	INCL. ELEM.	DESCRIPTION
21-Z1	CEY51A		3 PHASE-1ST. ZONE MHO RELAY
		Ø 1-2	PHASE 1-2 UNIT ETC.
		TR1-2	PHASE 1-2 TRANSACTOR ETC.
		T & SI	TARGET & SEAL-IN UNIT
21-Z2	CEY52A		3 PHASE-2ND ZONE MHO RELAY
		Ø 1-2	PHASE 1-2 UNIT ETC.
		T & SI	TARGET & SEAL-IN UNIT
21-Z3	CEB52A		3 PHASE-3RD ZONE OFFSET MHO RELAY
		Ø 1-2	PHASE 1-2 UNIT ETC.
		TR-1	PHASE 1 TRANSACTOR ETC.
		T & SI	TARGET & SEAL-IN UNIT
21X	RPM21D		TIMING RELAY
		TU	TIMING UNIT
		TX	AUXILIARY TO TIMING UNIT
50	PJC31C		INSTANTANEOUS PHASE FAULT DET.
		T & SI	TARGET & SEAL-IN UNIT
94	HGA14	AM or AL	AUXILIARY TRIPPING RELAY

TABULATION OF DEVICES		
TYPE OR DESCRIPTION	INTERNAL CONNS.	OUTLINE
CEY51A	0178A7132	0168A7336
CEY52A	0178A7133	0178A7336
CEB52A	0178A7134	0178A7336
RPM21D	0127A9440	K-6209271
PJC31C	K-6375726	K-6209272
HGA14AM (BACK CONNS.)	K-6400533	K-6400533
HGA14AL (FRONT CONNS.)	377A139	377A139

Figure 3 (0116B9309-5) Typical External-Connection the CEY51A Relay



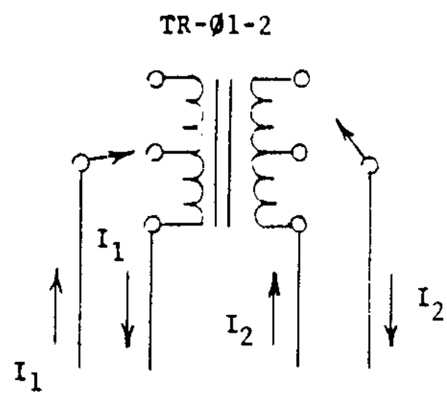


Figure 4 (0195A4986-1) Schematic Connections of MHO Units in the CEY51A Relay (Top View)

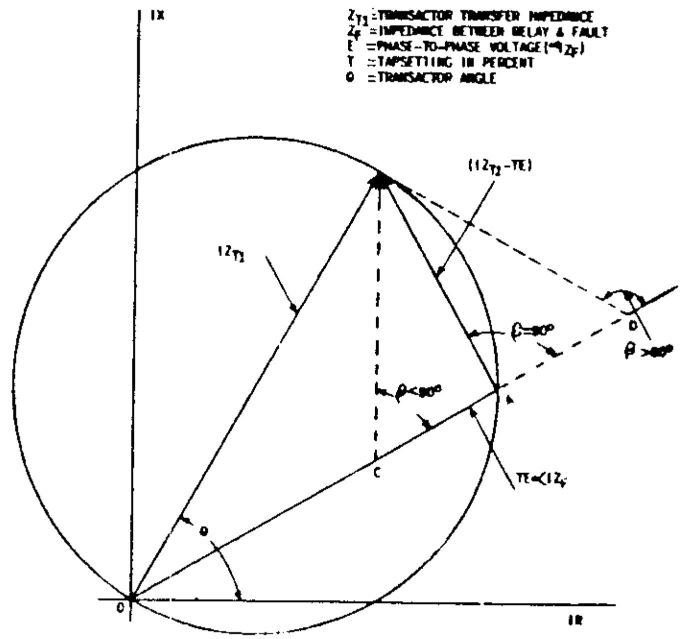


Figure 5 (0195A4987) Graphical Representation of MHO-Unit Operating Principle

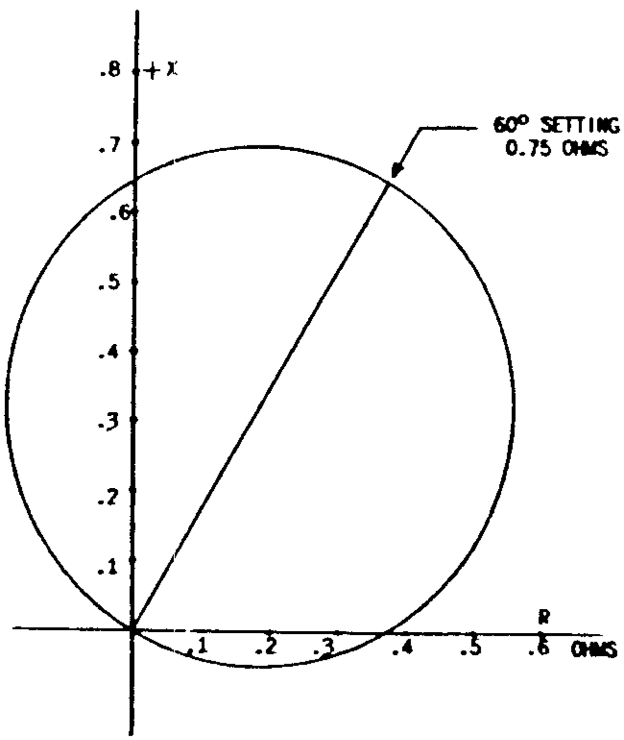


Figure 6 (0195A4988) Steady-State Impedance Characteristic of the MHO Unit in the CEY51A Relay

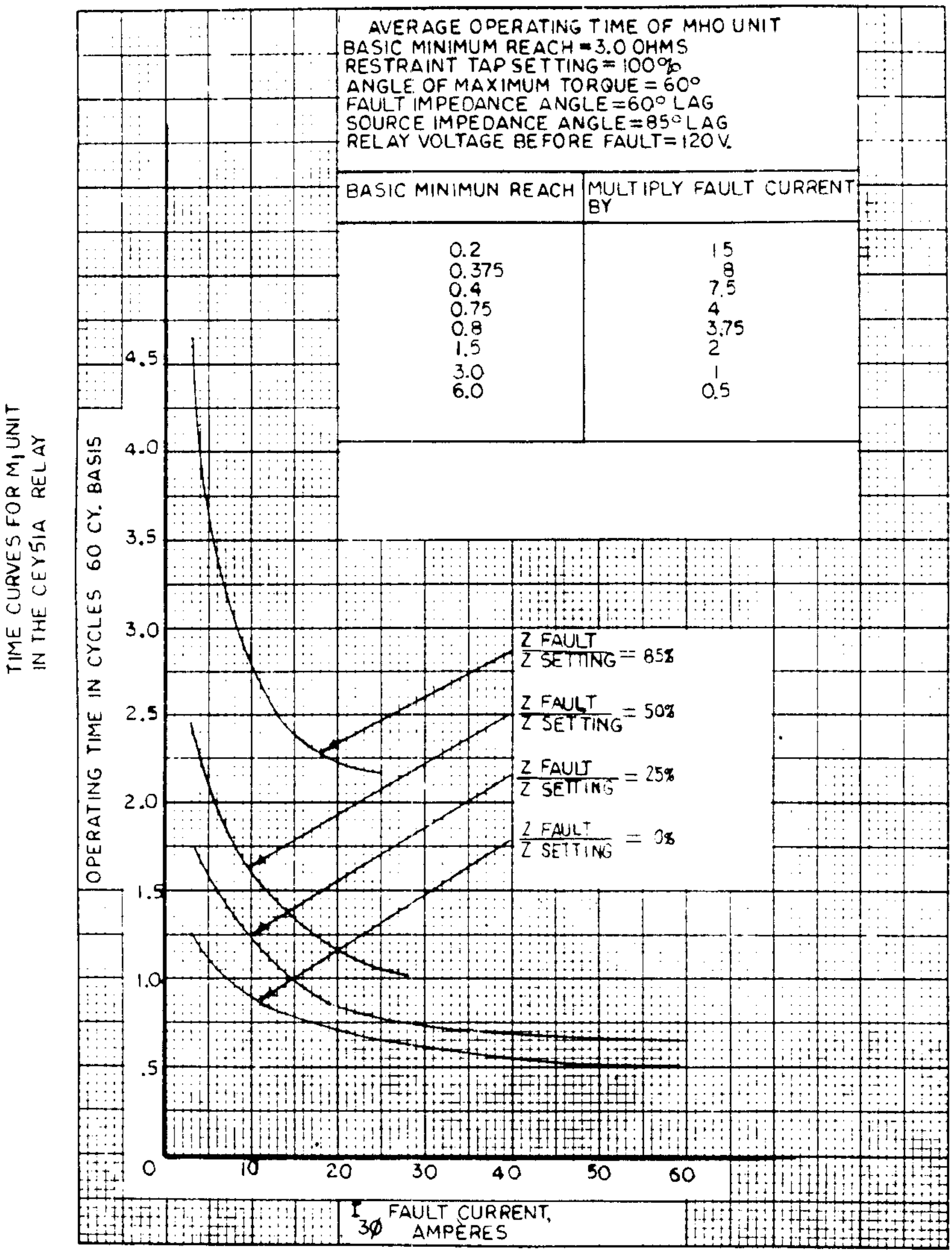


Figure 7 (0195A4990-1) Average-Operating-Time Curves of the MHO Unit in the CEY51A Relay

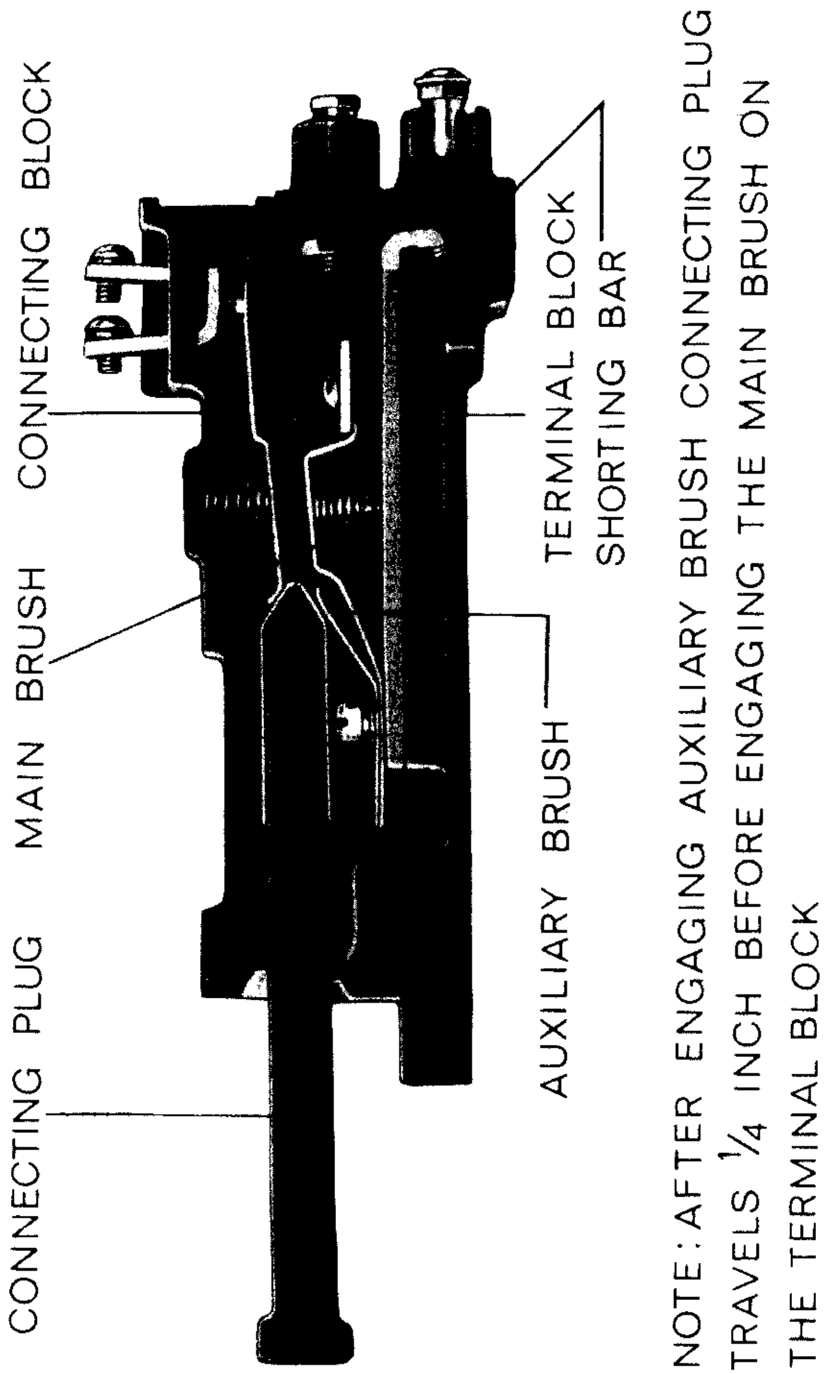


Figure 8 (8025039) Cross Section of Case and Cradle Block, Showing Auxiliary Brush and Shorting Bar

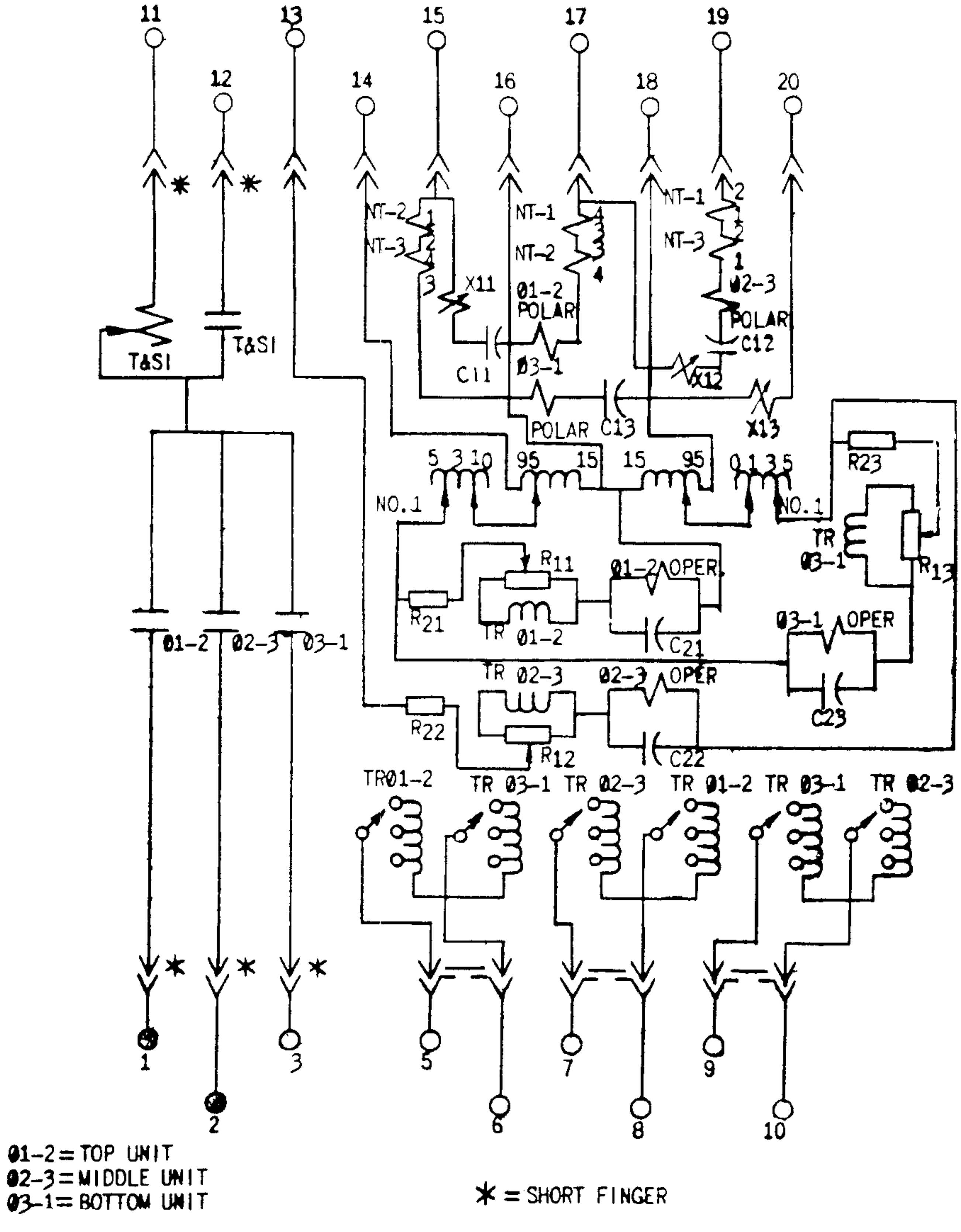
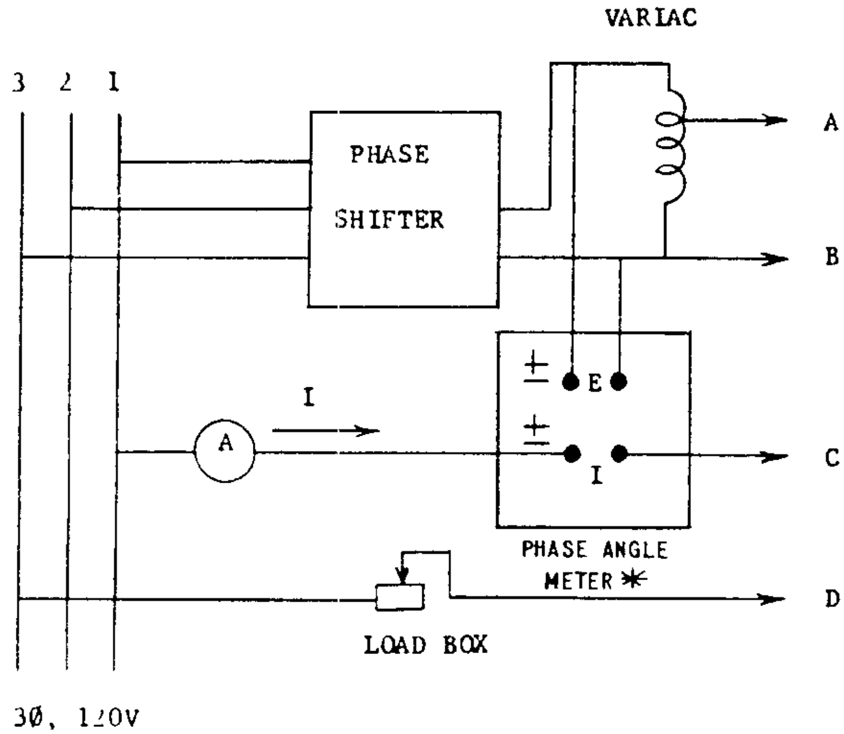


Figure 9 (0178A7132-1) Internal-Connection Diagram of the CEY51A Relay (Front View)



* = PHASE ANGLE METER READS THE ANGLE THAT THE CURRENT LEADS THE VOLTAGE.

UNIT LOCATION	UNIT	CONNECT LEAD TO RELAY STUDS AS FOLLOWS				JUMPER RELAY STUDS
		LEAD A	LEAD B	LEAD C	LEAD D	
TOP	Ø1-2	14-15	13-16-17	5	7	6-8-10
MIDDLE	Ø2-3	13-16-17	18-19-20	7	9	6-8-10
BOTTOM	Ø3-1	18-19-20	14-15	9	5	6-8-10

Figure 10 (0195A4991-1) Test Connections for Checking the Correct MHO-Unit Operation

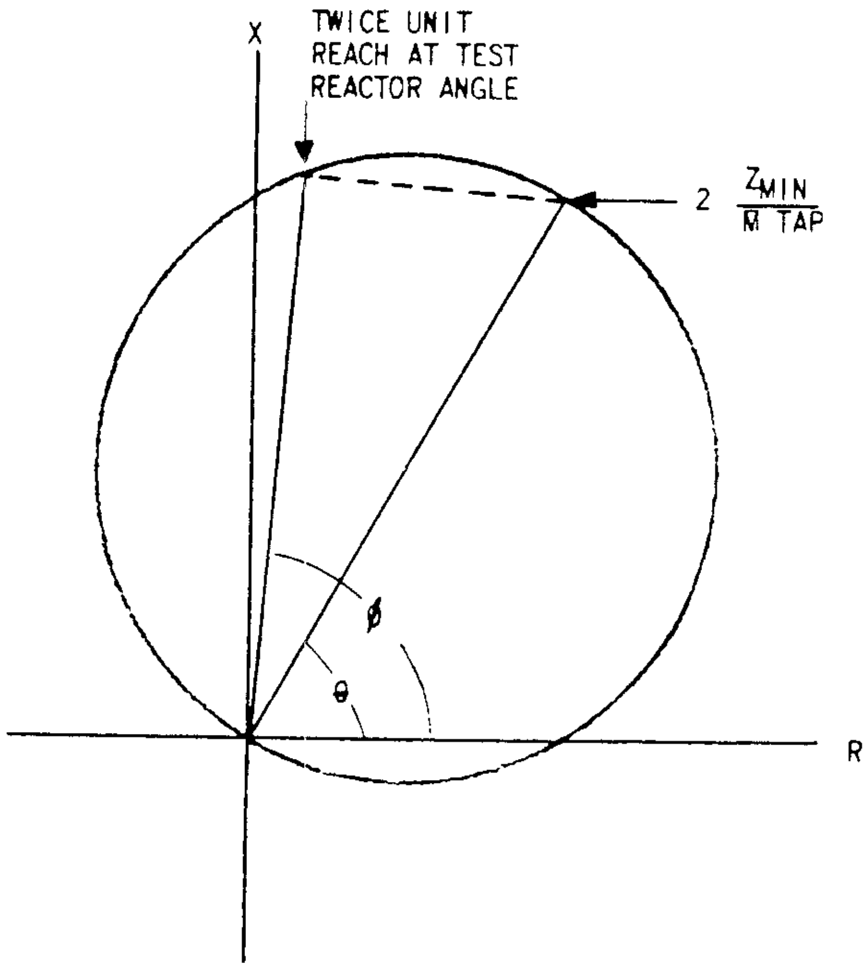
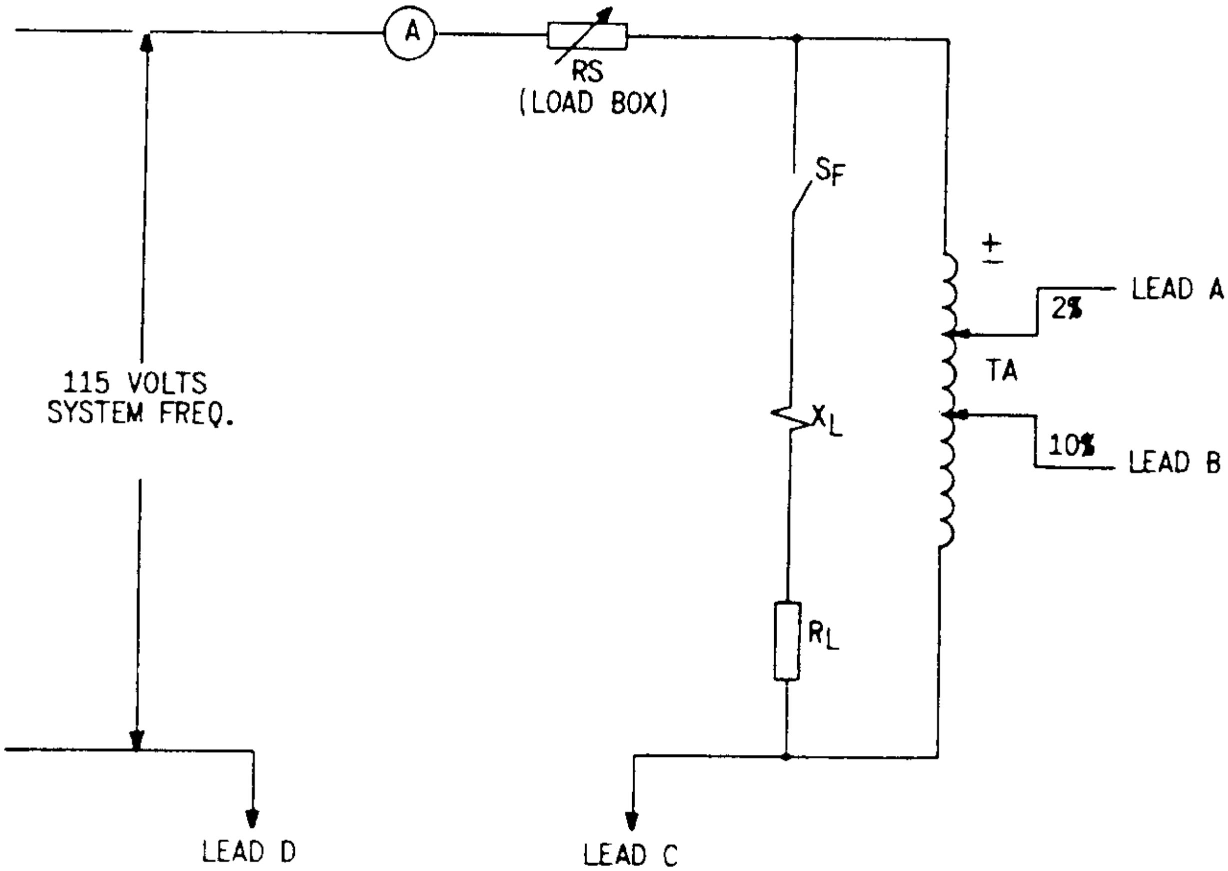
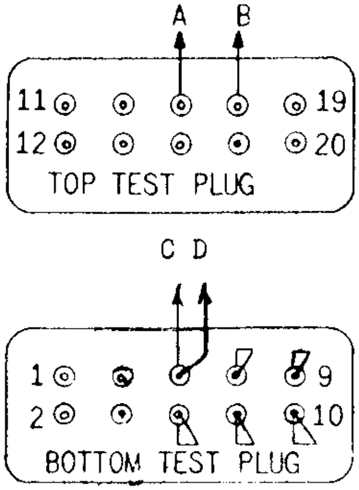


Figure 11 (0195A4992) Diagram Showing Reach of the MHO Units at Angle of Test Reactor

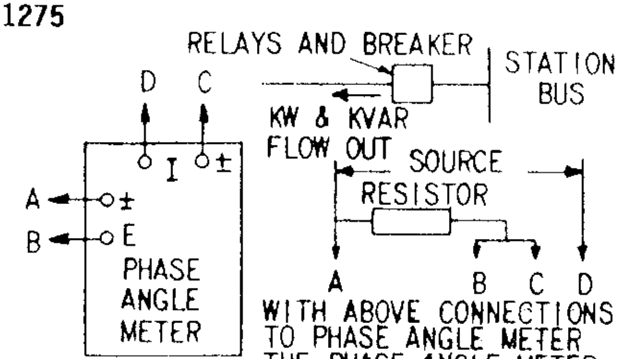


UNIT LOCATION	UNIT	CONNECT LEAD TO RELAY STUDS AS FOLLOWS				JUMPER RELAY STUDS
		LEAD A	LEAD B	LEAD C	LEAD D	
TOP	Ø 1-2	14-15	13-16-17	5	7	6-8-10
MIDDLE	Ø 2-3	13-16-17	18-19-20	7	9	6-8-10
BOTTOM	Ø 3-1	18-19-20	14-15	9	5	6-8-10

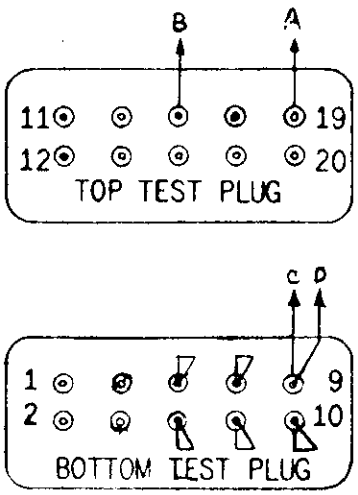
Figure 12 (0195A4994) Mho-Unit Test Connections



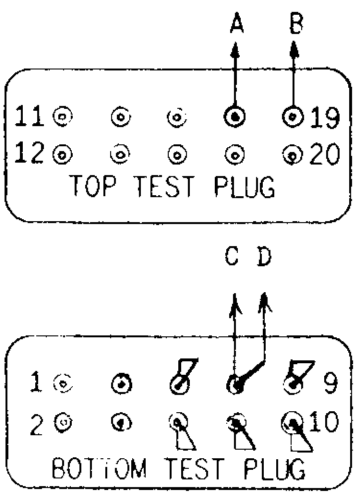
(a)
CONNECTIONS TO PHASE ANGLE METER TO CHECK PHASE 1 CURRENT AND PHASE 1-2 VOLTAGE.



WITH ABOVE CONNECTIONS TO PHASE ANGLE METER THE PHASE ANGLE METER SHOULD READ ZERO DEGREES



(b)
CONNECTIONS TO PHASE ANGLE METER TO CHECK PHASE 3 CURRENT AND PHASE 3-1 VOLTAGE.



(c)
CONNECTIONS TO PHASE ANGLE METER TO CHECK PHASE 2 CURRENT AND PHASE 2-3 VOLTAGE.

POWER FACTOR ANGLE (DEGREES LEAD)		0-45	45-90	90-135	135-180	180-225	225-270	270-315	315-360
KW AND KVAR DIRECTION WITH RESPECT TO THE BUS		KW OUT / KVAR IN	KVAR IN / KW OUT	KVAR IN / KW IN	KW IN / KVAR IN	KW IN / KVAR OUT	KVAR OUT / KW IN	KVAR OUT / KW OUT	KW OUT / KVAR OUT
PHASE ANGLE METER CONNECTIONS	PHASE SEQUENCE								
(a)	1-2-3	330-15	15-60	60-105	105-150	150-195	195-240	240-285	285-330
(b)	1-2-3	330-15	15-60	60-105	105-150	150-195	195-240	240-285	285-330
(c)	1-2-3	330-15	15-60	60-105	105-150	150-195	195-240	240-285	285-330
(a)	1-3-2	30-75	75-120	120-165	165-210	210-255	255-300	300-345	345-30
(b)	1-3-2	30-75	75-120	120-165	165-210	210-255	255-300	300-345	345-30
(c)	1-3-2	30-75	75-120	120-165	165-210	210-255	255-300	300-345	345-30

Figure 13 (0195A4993 [1]) Overall Test Connections for Checking of External Wiring to Relay

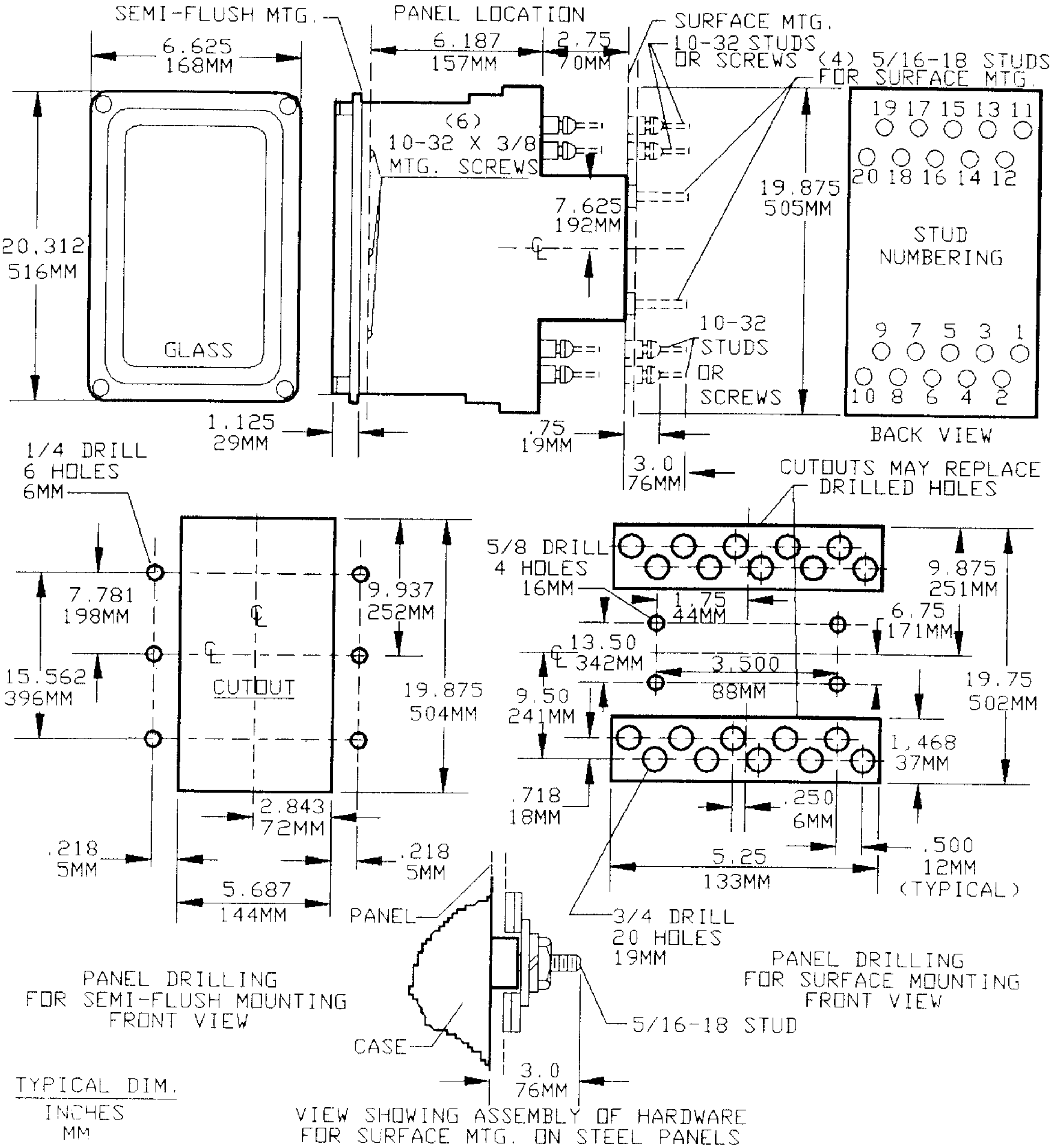


Figure 14 (0178A7336 [6]) Outline and Panel-Drilling Dimensions for Relay Type CEY51A

Protection and Control

(1/95) (1000)

GE Technology Center
205 Great Valley Parkway
Malvern, Pennsylvania 19355-1337