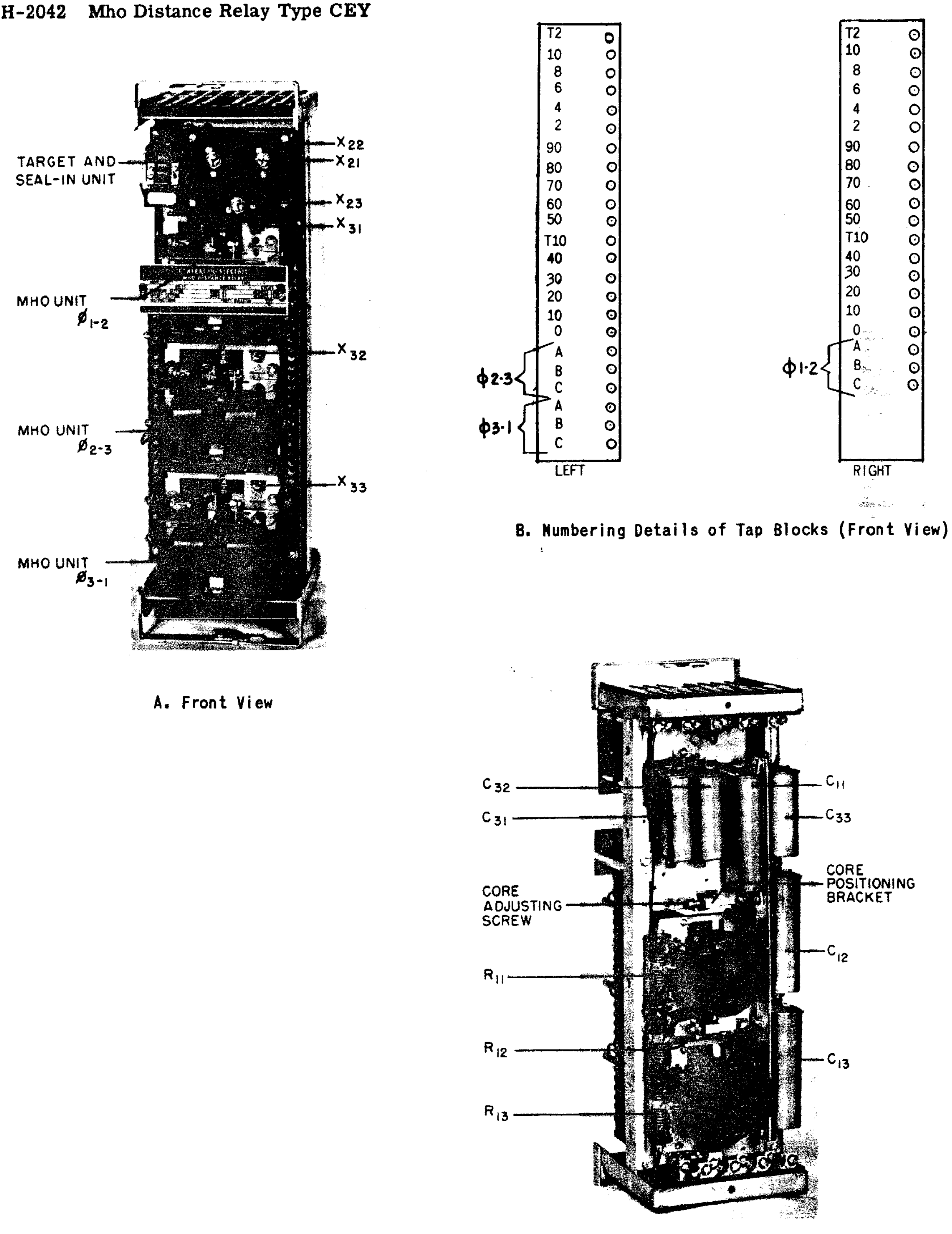
INSTRUCTIONS

GEH-2042A
SUPERSEDES GEH-2042
HANDBOOK 7244

MHO DISTANCE RELAY

Type
CEY15A

POWER SYSTEMS MANAGEMENT DEPARTMENT
GENERAL ELECTRIC



A. Front View

B. Numbering Details of Tap Blocks (Front View)

C. Back View

Fig. 1 Mho Distance Relay - CEY15A

MHO DISTANCE RELAY
CEY15A

DESCRIPTION

INTRODUCTION

The CEY15A relay is a three-phase high-speed single-zone mho directional distance relay. It is constructed of three single-phase units in one L2 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 CEY15A relay will provide complete one-zone protection for three-phase, phase-to-phase and double phase-to-ground faults.

APPLICATION

The CEY15A relay, because of its low transient overreach 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. It is also very well suited as a first-zone tripping relay in any scheme.

When applying this relay for the protection of a given circuit, it is generally advantageous to select the highest ohmic range that can be set for 80 percent of the line impedance. This is true because the forms with the higher ranges operate at a higher torque level.

There is one exception to this general rule and it is related to arc resistance. The 0.75-7.5 ohm relay has maximum torque angles of 45/60 degrees. When arc resistance is a serious factor, such as on short lines, the 45 degree angle of maximum torque offers the advantage that it can accommodate considerably more arc resistance than the units having higher maximum torque angles. This fact may make it desirable, at times, to use the 0.75 ohm relay where a 1.0 ohm relay could have been used on the basis of line impedance alone.

Since all forms of the CEY15A relay have two angles of maximum torque available, a consideration of which angle to use may arise. It is suggested that the transient overreach characteristics of the relay, as given in Figs. 5 and 6, be consulted before an angle of maximum torque is selected for use.

The CEY15A and its companion zone packaged (one 3-phase zone per relay) relays may be combined in many ways for use in many different schemes including straight distance protection, directional comparison carrier protection, permissive overreaching, permissive and direct underreaching, transfer tripping and miscellaneous backup schemes. Fig. 14 illustrates the external connections to the CEY15A relay when used in conjunction with a CEY16A, CEB17A and an RPM21D for three-zone protection of a transmission circuit against all multi-phase faults.

OPERATING CHARACTERISTICS

MHO UNIT

The mho unit has a circular impedance characteristic that passes through the origin of an R-X diagram, and whose center lies on the angle of maximum torque line. The Type CEY mho units are available with the ratings shown in Table I.

The minimum ohmic reach is obtained by setting the taps on the autotransformer on 100%. The ohmic reach can be increased by reducing the autotransformer setting, thereby reducing the percentage of the terminal voltage supplied to the restraint circuit. The diameter of the mho unit circular characteristic is the ohmic reach of the unit at the angle of maximum torque. At any other torque angle, the

TABLE I

Factory Setting Unless Otherwise Specified		Other Settings Available by Changing Tap for Max. Torque Angle	
Ohmic Range	Angle of Max. Torque	Ohmic Range	Angle of Max. Torque
0.75 - 7.5	45°	0.56 - 5.6*	60°
1-10	60°	0.75 - 7.5*	75°
2-20	60°	1.5 - 15 *	75°
3-30	60°	2.3 - 23 *	75°

* These values may vary ± 5% from above value unless restraint resistor is readjusted.

ohmic reach may be determined from the equation:

$$\text{OHMIC REACH} = \frac{Z_{min} \ \text{COS} \ (\phi - \theta) \ 100}{(\text{OUTPUT TAP})}$$

Where:

Output tap = T10 plus T2 tap setting.
Z_{min} = Mho unit minimum phase-to-neutral ohmic reach (Given on relay nameplate).
θ = Mho unit angle of maximum torque.
ϕ = Phase angle of the line.

For a 3-30 ohm mho unit set with 100 per cent output tap, and 60 degree angle of maximum torque, the reach of the mho unit would be three ohms if the line phase angle were 60 degrees, current lagging voltage.

Fig. 2 and 3 show typical relay characteristics for both the $45^\circ/60^\circ$ relay and the $60^\circ/75^\circ$ relay.

At reduced voltage, the ohmic value at which the mho unit will operate may be somewhat lower than its calculated value. The "pullback" or reduction in reach, is shown in Fig. 4 where the percentage change in relay reach for a constant tap setting is expressed as a function of the three phase fault current, $I_{3\phi}$, and the relay reach setting $Z_{setting}$. The mho unit will operate for all points to the right of the curves. The static curves of Fig. 4 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. These dynamic curves illustrate the effect of the mho unit memory action which maintains the polarizing voltage on the unit for a few cycles after 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 Fig. 4. A zero voltage fault must 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. Fig. 4 shows the mho unit, under static conditions, will not see a fault at zero percent of the relay setting regardless of the tap setting or the $I_{3\phi} Z_{setting}$ product. However, under dynamic conditions when the memory action is effective, Fig. 4 shows that a mho unit with a 100 percent tap setting will pick up if the $I_{3\phi} Z_{setting}$ product is greater than three (3). This means, therefore, that a 3 ohm relay with a 100 percent tap setting, or a $Z_{setting}$ of 3, will pick up if the three phase fault current, $I_{3\phi}$, is greater than 1 ampere.

The mho unit is carefully adjusted to have correct directional action under steady-state low voltage and current conditions. For faults in the tripping direction at the angle of maximum torque of the mho unit, the 3 ohm unit with a 100 per cent tap setting will close its contacts at 1.5 volts and between 1.5 and 60 amperes. For faults in the non-tripping direction, the contacts will remain open at zero volts and between 0 and 60 amperes. The minimum closing current for the other mho unit ranges is inversely proportional to the ratio of the unit's minimum reach to the 3 ohm unit reach.

Since the Type CEY15A relay is connected to trip instantaneously, the operation of the mho unit under the transient system conditions present at the

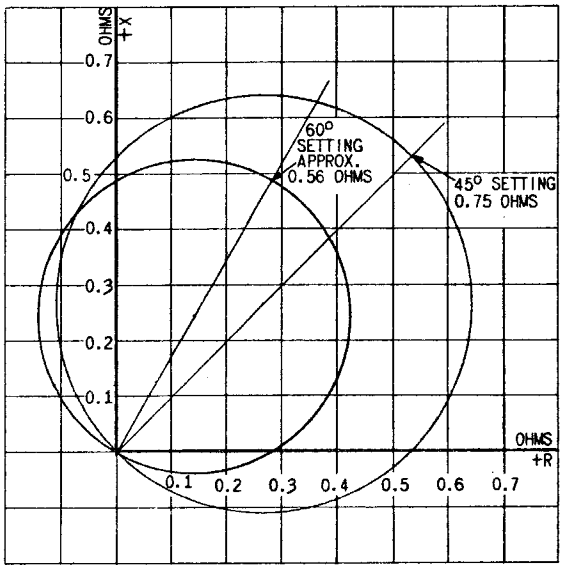


Fig. 2 Minimum Static Operating Characteristics of The 0.75 Ohm Mho Unit

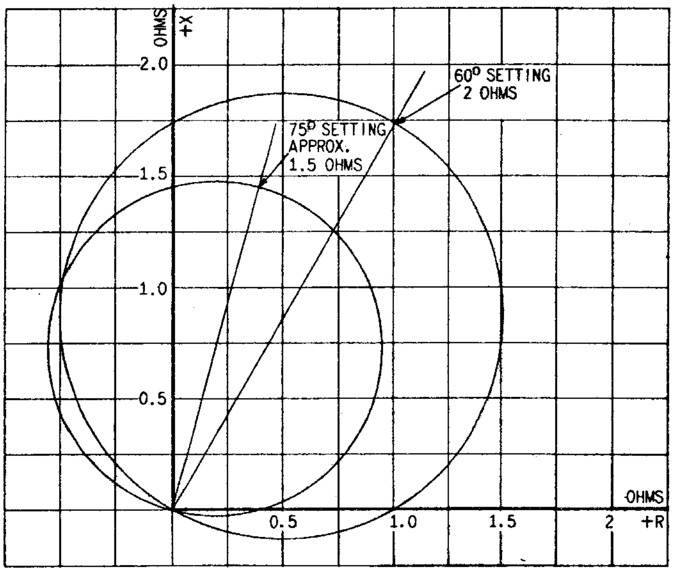


Fig. 3 Minimum Static Operating Characteristics of The 2 Ohm Mho Unit

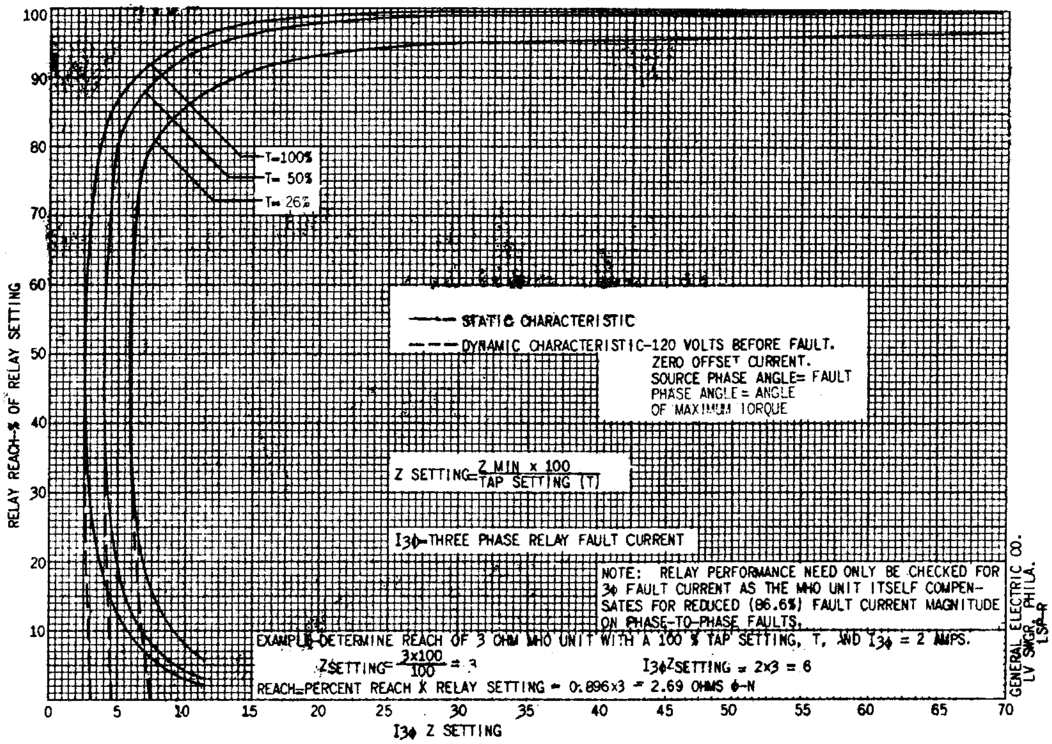


Fig. 4 (0127A7965-1)

Fig. 4 Static and Dynamic Accuracy Curves of Type CEY Mho Unit. Data taken for Phase-To-Phase Fault at Mho Unit Angle of Maximum Torque

inception of a fault is important. Transient overreach is the tendency of the mho unit, under transient system conditions, to close its contacts momentarily for a fault impedance greater than its impedance setting. The magnitude of the mho unit's transient overreach is directly proportional to the degree of asymmetry in the fault current, and is also related to the circuit angle, (the angle of the system from the point of the fault to the source of generation). Maximum transient overreach is obtained when the fault occurs at that instant in either half of the cycle which produces maximum asymmetry, or maximum DC offset of the fault current wave. If the fault occurs midway between these two instants, there is no offset current, and hence, no transient overreach. Figs. 5 and 6 show the maximum transient overreach of the Type CEY15A mho unit as a function of the circuit angle.

The speed of operation of the mho unit is similarly a function of the instant in the cycle at which the fault occurs. It is also necessarily a function of the angle of the fault impedance, the magnitude of the fault impedance, the magnitude of the fault current, the angle of the circuit, and the tap setting and angle of maximum torque of the mho unit. The time data are presented in Figs. 7, 8, 9 and 10 in terms of these variables. Maximum operating times are obtained when the fault occurs at that instant in the cycle which produces zero DC offset current.

TAPPED AUTOTRANSFORMER

The ohmic reach of the mho unit may be adjusted by means of taps on the autotransformer. The autotransformer is tapped in two percent steps from zero to one hundred per cent, and these taps are brought to the two tap blocks. The tap setting is the sum of the tap settings made on one tap block. The lead marked T2 is screwed into one of the 2% taps and the lead marked T10 is screwed into one of the 10% taps.

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:

$$\text{OUTPUT TAP} = \frac{(100)\ (\text{MIN. OHMS}) \cos(\phi - \theta)}{Z}$$

The minimum ohms of the mho unit can be found on the relay nameplate.

For a numerical example of the relay tap settings, refer to the CALCULATIONS section of this book.

RATINGS

The CEY15A relay is rated 115 volts, 5 amperes. The mho units are available in four ratings. For

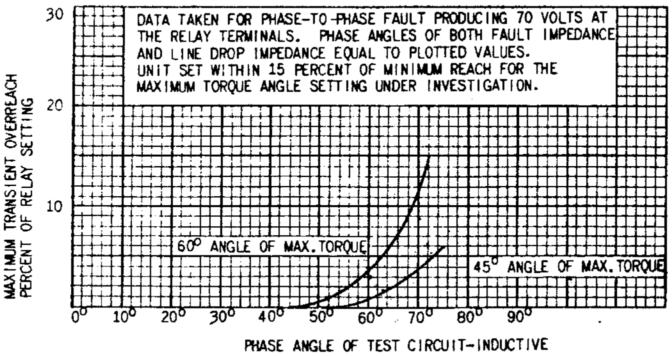


Fig. 5 Maximum Transient Overreach of 45°/60° Mho Unit

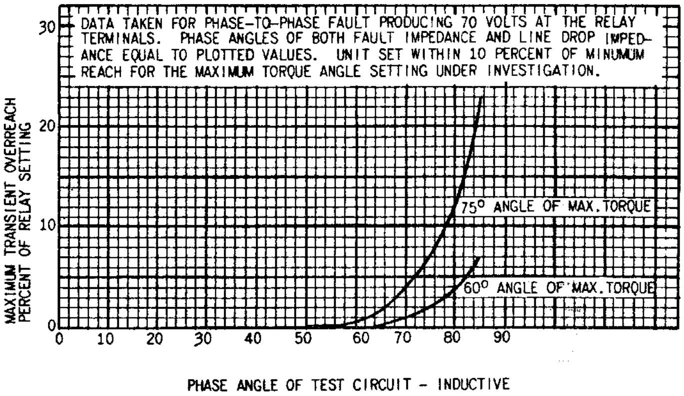


Fig. 6 Maximum Transient Overreach of 60°/75° Mho Unit

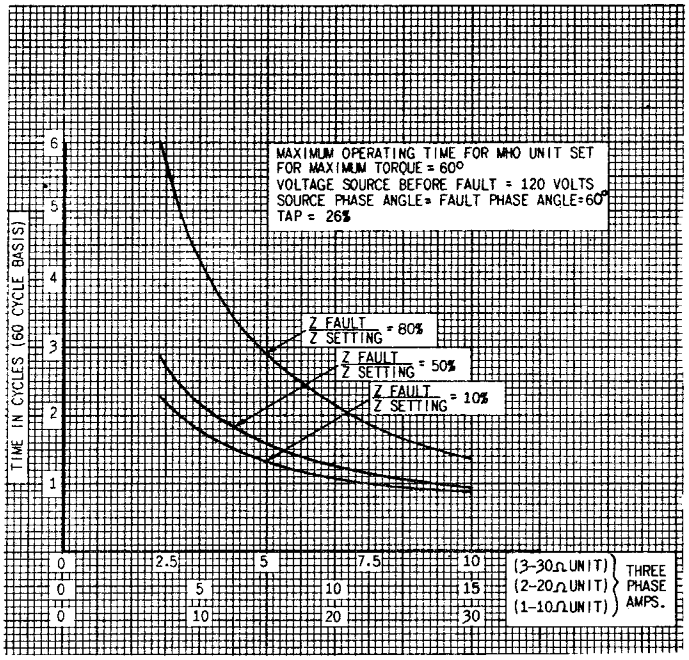


Fig. 7 Maximum Time-Current Characteristics of Mho Unit with 60° Max. Torque Angle and 26% Tap Setting

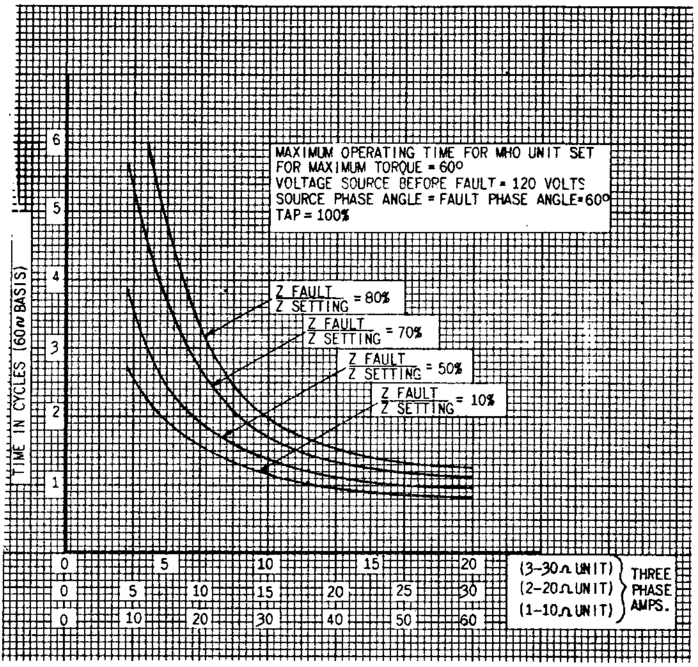


Fig. 8 Maximum Time-Current Characteristics of Mho Unit with 60° Max. Torque Angle and 100% Tap Setting

short lines where arc resistance may be a factor a mho unit is available with maximum torque that can be set for 45° lag or 60° lag. This unit has an ohmic range of 0.75 - 7.5 ohms if set for 45° or 0.56 - 5.6 ohms if set for 60°. For longer lines there are mho units that can be set for maximum torque at 60° lag or 75° lag. The ohmic reach of these units are 1-10, 2-20, or 3-30 if set for 75° lag.

The trip circuit of the relay will close and carry momentarily 30 amperes DC. The breaker trip circuit however, should always be opened by a circuit breaker auxiliary switch or other suitable means, because the relay contacts cannot interrupt the trip coil current. If the tripping current should exceed 30 amperes it is recommended that an auxiliary tripping relay be used.

The combination target and seal-in unit has a dual rating of 0.6/2.0 amperes. The tap setting used on the target and seal-in unit is determined by the current drawn by the trip coil. The 0.6 ampere tap is used with trip coils which operate on currents ranging from 0.6 amperes to 2.0 amperes at the minimum control voltage. They may also be used with trip coils drawing as much as 30 amperes if the voltage drop caused by the trip current flowing through the 0.6 ohms resistance of the target seal-in coil is not excessive. The 0.6 ampere target seal-in tap can carry 30 amperes for one half second without overheating. The 2.0 ampere target seal-in tap can be used with all trip coils that draw more than 2.0 amperes at minimum control voltage and will carry 30 amperes for 4 seconds without overheating.

TABLE II

TARGET AND SEAL-IN UNIT

	2 Amp Tap	0.6 Amp Tap
DC Resistance	0.13 ohms	0.6 ohms
Minimum Operating	2.0 amps	0.6 amps
Carry Continuously	4.0 amps	1.2 amps
Carry 30 Amperes for	4.0 sec.	0.5 sec.

The one second thermal ratings of this relay are listed in Table III.

TABLE III

SHORT TIME RATINGS

OHMIC RANGE (OHMS)	1-SEC. RATING (AMPS)
0.75 - 7.5	500
1 - 10	500
2 - 20	500
3 - 30	300

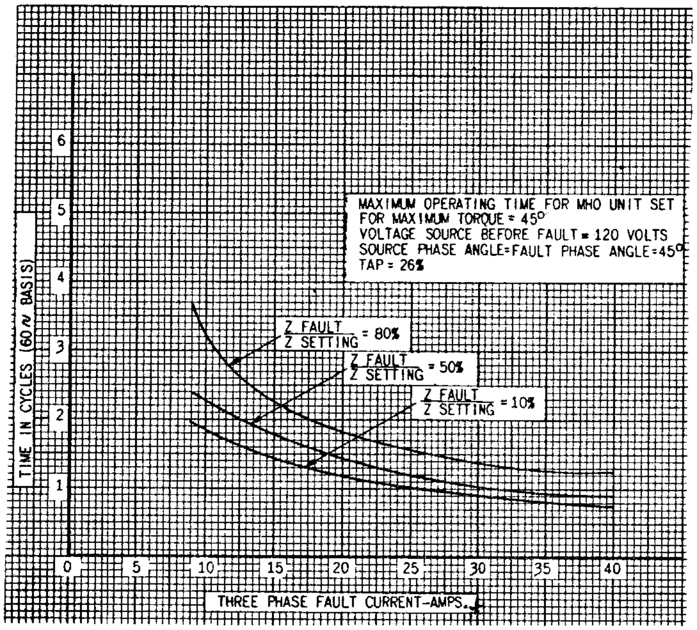


Fig. 9 Maximum Time-Current Characteristics of Mho Unit with 45° Maximum Torque Angle and 26% Tap Setting

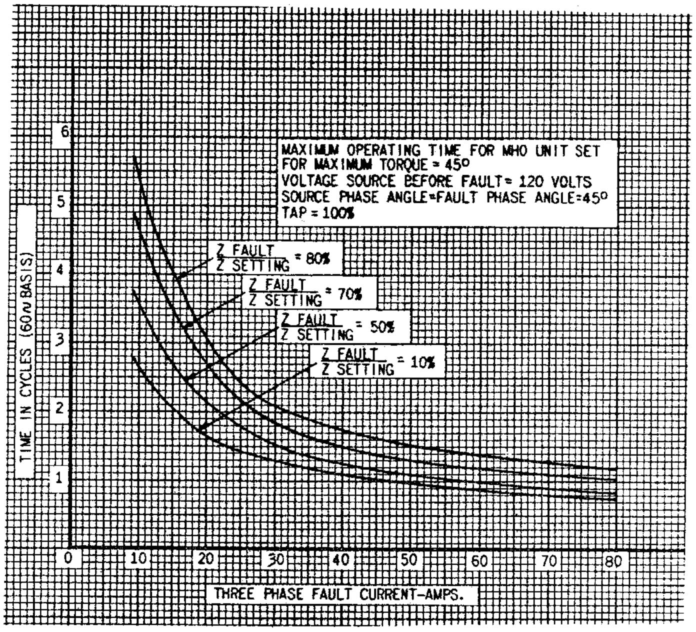


Fig. 10 Maximum Time-Current Characteristics of Mho Unit with 45° Maximum Torque Angle and 100% Tap Setting

BURDENS

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

TABLE IV

CURRENT BURDEN

Mho Unit Rating	Watts	Vars	Volt Amps
0.75 at 45°	0.25	0.05	0.25
1.0 at 60°	0.36	0.10	0.39
2.0 at 60°	0.68	0.40	0.80
3.0 at 60°	0.98	0.90	1.30

The maximum potential burden imposed on each potential transformer at 115 volts and 60 cycles is listed in Table V.

TABLE V

POTENTIAL BURDEN

Max Torque Angle	Watts	Vars	Volt Amps
45°/60°	12.2	-5.7*	14.1
60°/75°	12.9	-4.0*	13.5

* Leading Reactive Power (Current Leading Voltage)

The potential burden of the mho unit is altered by changing the restraint tap setting in order to choose the proper reach. The burden for any set of conditions can be computed by using the equations below:

For 45° /60° relays

$$\text{Watts} = 8.0 + \left[\frac{\text{Tap Setting}}{100}\right]^2 (4.2)$$

$$\text{Vars} = -4.7 - \left[\frac{\text{Tap Setting}}{100}\right]^2 (1.0)$$

For 60°/75° Relays

$$\text{Watts} = 8.4 + \left[\frac{\text{Tap Setting}}{100}\right]^2 (4.5)$$

$$\text{Vars} = -3.0 - \left[\frac{\text{Tap Setting}}{100}\right]^2 (1.0)$$

GENERAL CONSTRUCTION

The mho units of the CEY15A relay are of the four pole induction cylinder construction. The schematic connections for this unit are shown in Fig. 11. The two side poles, energized with phase-to-phase voltage, produce the polarizing flux which interacts with the flux produced in the back pole energized with a percentage of the same voltage to produce the restraint torque in the relay. The flux produced in the front pole, energized with the two line currents associated with the phase-to-phase voltage used, interacts with the polarizing flux to produce the operating torque. The torque equation at pickup is therefore:

$$\text{Torque} = 0 = EI\cos(\phi - \theta) - KE^2$$

where E is th phase-to-phase voltage

I is the delta current e.g. $(I_1 - I_2)$

θ is the angle of maximum torque of the relay.

ϕ is the power factor angle

K is a design constant

Dividing through by E^2 and transposing reduces the equation to:

$$Y\cos(\phi - \theta) = K$$

Thus, the relay will pick up at a constant component of admittance at a fixed angle depending upon the maximum torque angle of the unit, hence the name mho unit.

The mho unit contacts are of the fine silver for low contact resistance and are of the ideal design of two cylinders at right angles, which provides a point contact without using an actually pointed contact. To protect the contacts from damage caused by high operating torques under short circuit conditions, a felt clutch is provided between the shaft and the contact arm.

A combination target and seal-in unit is mounted at the top of the relay and is connected in series with the tripping circuits.

Fig. 1, shows the locations of the component parts of the relay visible when the relay is removed from its case.

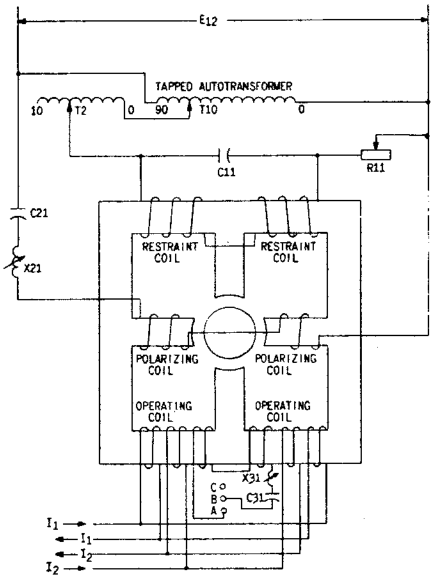


Fig. 11 Schematic Connections of Mho Units in CEY15A Relay

INSTALLATION

RECEIVING

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

Reasonable care should be exercised in unpacking the relay in order that none of the parts are injured or the adjustments disturbed.

If the relays are not to be installed immediately, they should be stored in their original cartons in a place that is free from moisture, dust and metallic chips. Foreign matter collected on the outside of the case may find its way inside when the cover is removed and cause trouble in the operation of the relay.

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.

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 0.003-.006 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.

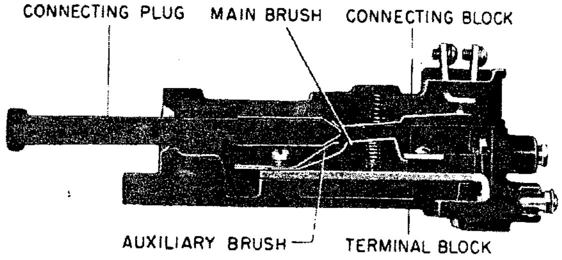
All nuts and screws should be tight, with particular attention paid to the tap plugs.

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

The contact surfaces should be clean.

The moving contact backstops should be clean. The backstops should be wiped clean at regular intervals with a cloth moistened with carbon tetrachloride solution.

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.



NOTE: AFTER ENGAGING AUXILIARY BRUSH, CONNECTING PLUG TRAVELS 1/4 INCH BEFORE ENGAGING THE MAIN BRUSH ON THE TERMINAL BLOCK

Fig. 12 Cross Section of Drawout Case showing Position of Auxiliary Brush

Fig. 12 (8025039)

LOCATION AND MOUNTING

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

The relay should be mounted on a vertical surface. The outline and panel drilling diagram is shown in Fig. 22.

CONNECTIONS

The internal connection diagram for the relay is shown in Fig. 13. A typical wiring diagram is given in Fig. 14.

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 gauge copper wire or its equivalent.

ADJUSTMENTS AND TESTS

The relay is properly calibrated at the factory and it is not advisable to disturb the adjustments. If it is necessary to check the factory calibration of the units or to change the calibration, refer to the MAINTENANCE section of this book where detailed instructions are given under the SERVICING subsection.

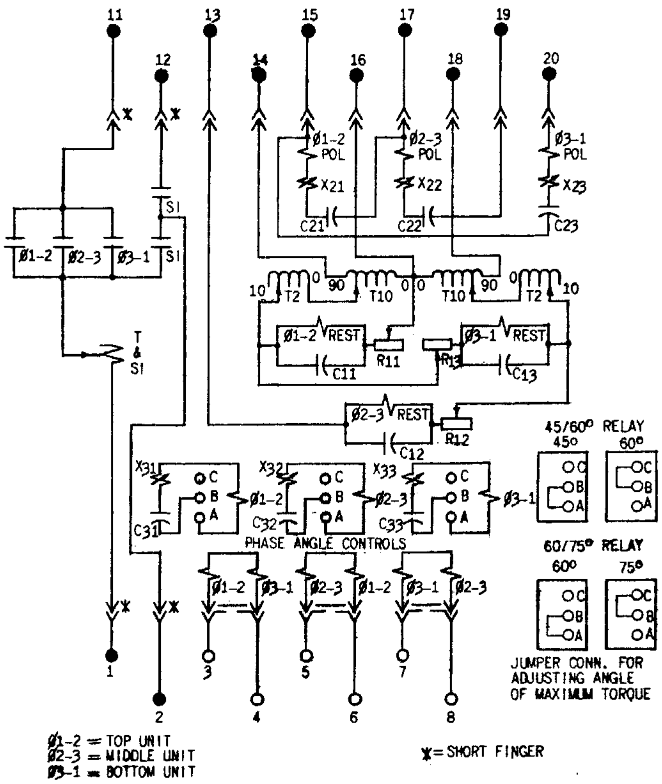


Fig. 13 Internal Connection Diagram of The CEY15A Relay (Front View)

MHO UNITS

Angle of Maximum Torque

The connection for the jumpers to the A, B and C taps on the tap blocks determine the angular setting of the mho unit. The proper connections are shown in Fig. 13.

Ohmic Reach

The reach of the mho units can be adjusted in two per cent steps by the positioning of the autotransformer tap leads on the relay tap blocks. To determine the proper tap setting of the mho units, a procedure similar to that outlined in the CALCULATIONS section should be followed.

The calculated tap settings are made by connecting the T10 and T2 tap leads to the proper taps. The lower tap leads marked T10 (on each tap block) should be connected to one of the 10 percent taps in the lower half of the tap blocks. The upper tap lead (on each tap block) marked T2 should be connected to one of the two percent taps in the upper section of the tap blocks. The sum of the tap to which the T10 lead is connected and the tap to which the T2 lead is connected should equal the calculated tap setting. For example a tap setting of 86% is made by connecting the T10 lead to the 80% tap and the T2 lead to the 6% tap. The same tap setting must be made on both the right hand and left hand tap blocks.

CAUTION: Examine the tap blocks with great care to make sure the tap lead terminals do not come in contact with adjacent terminals, tap hole shoulders, mounting screw heads, the case or other grounded parts. This may cause a portion of the tapped autotransformer to be shorted or grounded, the result from this being eventual failure of the transformer. The transformer tap leads should be placed horizontally on the tap block with the leads coming out rather than in toward the relay.

Spring Adjustment

The rotating structure of the mho units 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 using the control spring adjusting arm at the top rear of the unit. First loosen the set screw on the front of the top pivot support, and rotate the control spring adjusting arm so as to return the contact arm to the backstop, but without supplying enough torque so that the contact would move beyond this position if the stationary contact or backstop were removed. Tighten the set screw permitting approximately .003 - .006 inch end play to the shaft.

TARGET AND SEAL-IN UNIT

The choice of tap on the target and seal-in unit is described above under RATINGS. To change this tap, the spare screw above the left contacts should be inserted into the vacant tap on the right-hand contact, and the other screw removed and placed in the spare position. Do not leave screws in both taps on the right-side of the unit.

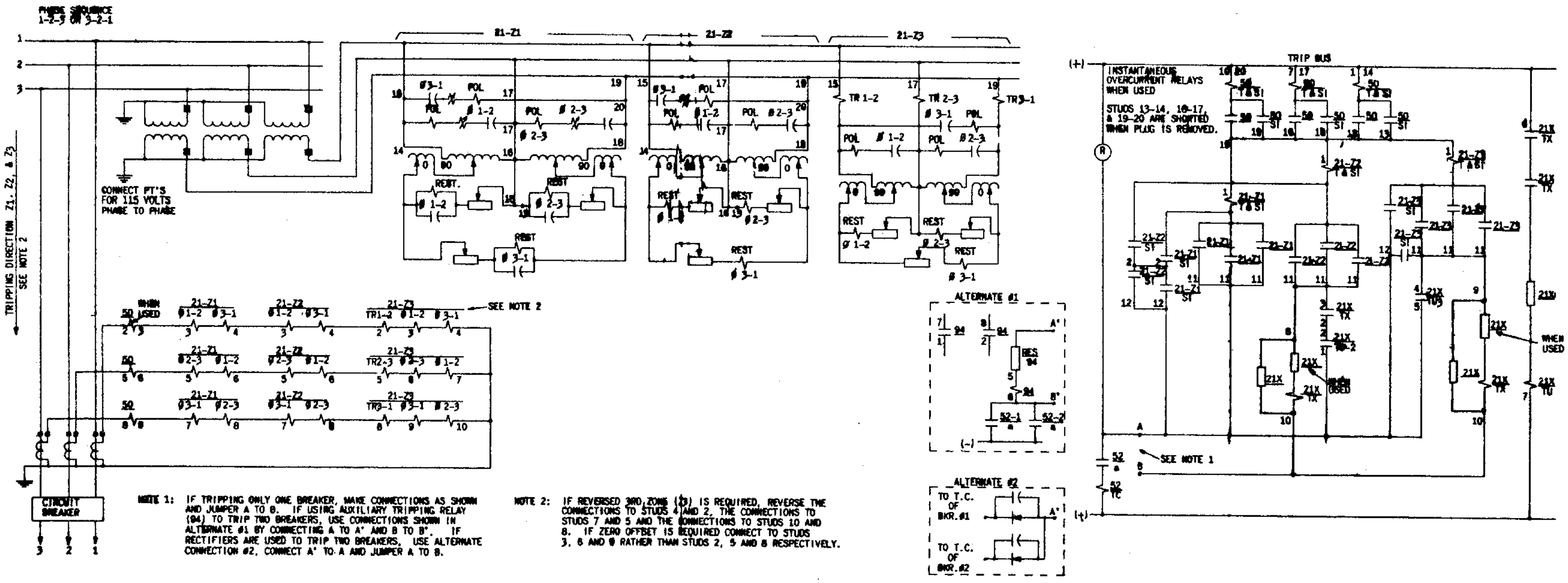
OVERALL TESTS

Overall tests on current transformer polarities, potential transformer polarities, relay connections, and wiring can be made on the complete installation. Referring to Fig. 15, a check of the indicated phase angle meter reading will indicate that the relay is receiving the proper voltages and currents if the relay is connected as shown on the typical external connections, Fig. 14.

To completely check the connection it is necessary to make all three tests ("a", "b", and "c") and if the proper phase angle reading is obtained in all three tests, then the three mho units are receiving the proper voltages and currents. The phase angle meter should be checked using a resistor to determine the correct connection to the phase angle meter to get a zero degree reading. The connections shown in the upper right hand corner of Fig. 15 shows the proper connections for one make of phase angle meter.

If sufficient power is flowing into the protected section an approximate check on calibration can be made. This check can be relied on only if the ammeters and wattmeters, or power factor meters are connected to a separate set of current and potential transformers from which the relays are connected, or the connection from the current transformers and potential transformers are known to be right as far as the ammeters, wattmeters and power factor meters are concerned. It is necessary to know this since the reading of the ammeter, wattmeter, and power factor meter will be used to

Fig. 14(7381B21AA-0)



NOTE 1: IF TRIPPING ONLY ONE BREAKER, MAKE CONNECTIONS AS SHOWN AND JUMPER A TO B. IF USING AUXILIARY TRIPPING RELAY (94) TO TRIP TWO BREAKERS, USE CONNECTIONS SHOWN IN ALTERNATE #1 BY CONNECTING A TO A' AND B TO B'. IF RECTIFIERS ARE USED TO TRIP TWO BREAKERS, USE ALTERNATE CONNECTION #2, CONNECT A' TO A AND JUMPER A TO B.

NOTE 2: IF REVERSED 3RD ZONE (Z3) IS REQUIRED, REVERSE THE CONNECTIONS TO STUDS 4 AND 2, THE CONNECTIONS TO STUDS 7 AND 5 AND THE CONNECTIONS TO STUDS 10 AND 8. IF ZERO OFFSET IS REQUIRED CONNECT TO STUDS 3, 6 AND 9 RATHER THAN STUDS 2, 5 AND 8 RESPECTIVELY.

LEGEND			
DEVICE NO.	DEVICE TYPE	INCL. ELEM.	DESCRIPTION
21-Z1	CEY15A		3 PHASE - 1st ZONE MHO RELAY
		ϕ 1-2	PHASE 1-2 UNIT ETC.
		T & SI	TARGET & SEAL-IN
21-Z2	CEY16A		3 PHASE -2nd ZONE & CARRIER TRIP MHO RELAY
		ϕ 1-2	PHASE 1-2 UNIT ETC.
		T & SI	TARGET & SEAL-IN
21-Z3	CEB17A		3 PHASE-3rd ZONE & CARRIER START MHO RELAY
		ϕ 1-2	PHASE 1-2 UNIT ETC.
		TR1-2	PHASE 1-2 TRANSACTOR ETC.
		T & SI	TARGET & SEAL-IN
21X	RPM21D		TIMING RELAY
		TU	TIMING UNIT
		TX	AUXILIARY FOR TIMING UNIT
50	PJC31C		INSTANTANEOUS PHASE FAULT DETECTOR
		T & SI	TARGET & SEAL-IN
94	HGA14AM	OR AL	AUXILIARY TRIPPING RELAY

TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INTERNAL CONNECTIONS	OUTLINE
CEY15A		0127A9412	K-6209276
CEY16A		0127A9418	K-6209276
CEB17A		0127A9413	K-6209276
RPM21D	125 V	0127A9440	K-6209270
RPM21D	250 V	0127A9441	K-6209270
PJC31C		K-6375726	K-6209272
HGA14AM (BACK CONNS.)		K-6400633	K-6400633
HGA14AL (FRONT CONN.)		377A139	377A139
TRIP RECTIFIER (102L218 G-2)	125 V		104A8564
TRIP RECTIFIER (102L218 G-4)	250 V		104A8564

Fig. 14 Typical External Connection Diagram For The CEY15A Relay

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 Fig. 4. For example the 0.75 to 7.5 ohm unit set for 100% tap and 45° has a 0.75 ohm reach. At 5 amperes the $I_{3\phi} Z_{setting} = 5 \times 0.75 = 3.75$. From Fig. 4 the reach of the unit will be approximately 81% of normal reach or $0.81 \times 0.75 = 0.606$ ohms. The same unit set for 26% would have a reach ($Z_{setting}$) of $0.75/0.26 = 2.88$ ohms. At 5 amperes $I_{3\phi} Z_{setting} = 5 \times 2.88 = 14.4$. From Fig. 4 the reach would be approximately 91% or a reach of $0.91 \times 2.88 = 2.62$ ohms.

A shorter test which will check for most of the possible open circuits in the AC portion of the relay is as follows: Remove the lower connection plug disconnecting the current circuits. 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.

ELECTRICAL CHECK TESTS ON THE MHO UNITS

The manner in which reach settings are made for the mho unit is briefly discussed in the introduction of these instructions. It is the purpose of the electrical tests in this section to check the ohmic pickup at the settings which have been made for a particular line section.

To eliminate the errors which may result from possible instrument inaccuracies a test circuit has been selected which requires no instruments to determine the fault impedance. The ammeter is used only to determine the magnitude of the fault current. Such a circuit is shown in Fig. 16. In Fig. 16 R_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, TA, which is across the fault switch and line impedance is tapped in 10 per cent and 1 per cent steps so that the line impedance $R_L + jX_L$ may be made to appear to the relay very nearly 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.

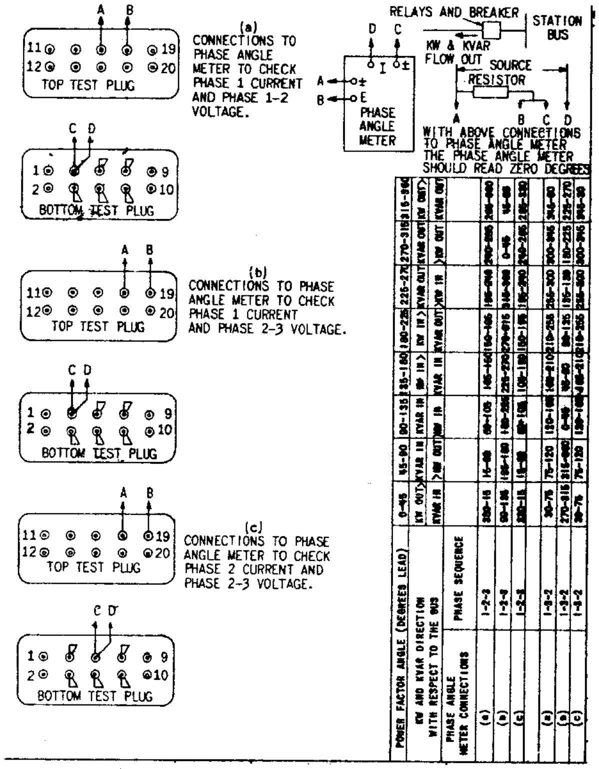
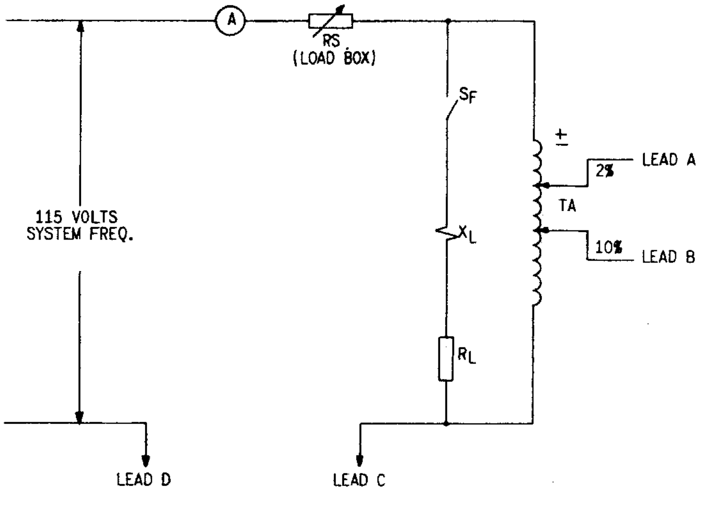


*Fig. 15 Overall Test Connections For Checking of External Wiring to Relay



UNIT LOCATION	UNIT	CONNECT LEAD TO RELAY STUDS AS FOLLOWS				JUMPER RELAY STUDS
		LEAD A	LEAD B	LEAD C	LEAD D	
TOP	ϕ 1-2	14-15	13-16-17	3	5	4-6-8
MIDDLE	ϕ 2-3	13-16-17	18-19-20	5	7	4-6-8
BOTTOM	ϕ 3-1	18-19-20	14-15	7	3	4-6-8

Fig. 16 Test Connections For Checking Ohmic Pickup of Mho Units

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* Denotes change since superseded issue.

For convenience in field testing the fault switch and tapped autotransformer of Fig. 16 have been arranged in a portable test box, Cat. 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 GEI-38977.

Other equipment required includes:

Load Box
Tapped Test Reactor
Tapped Test Resistor
Ammeter
Test Plugs

Since the reactance of the test reactor may be very accurately determined from its calibration curve, it is desirable to check relay pickup with the fault reactor alone, due account being taken of the angular difference between the line reactance, X_L, and the relay angle of maximum reach. The line reactance, X_L, selected should be the test reactor tap nearest above twice the mho unit reach with account being taken of the difference in angle of the test reactor tap impedance and the relay angle of maximum reach. From Fig. 17 it is seen that twice the relay reach at the angle of the test reactor impedance is:

$2Z \text{ Relay} = 200 \frac{Z \text{ min. ohms}}{T} \cos(\phi - \theta)$ where ϕ is the angle of the test reactor impedance, θ is the relay angle of maximum reach, and T is the voltage restraint tap setting. The test-box autotransformer percent tap for the mho-unit pickup is given by:

$$\% \text{ tap} = \frac{2Z \text{ Relay}}{Z_L}(100)$$

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 60 degrees. In determining the reactor tap setting to use, it may be assumed that the angle (ϕ) of the test reactor impedance is 80 degrees. 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 80 degrees. Table VI shows the angles for each of the reactor taps.

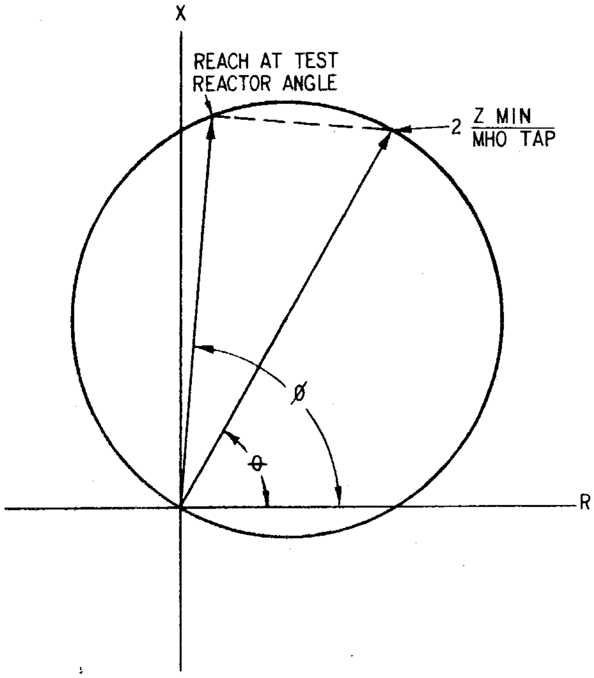


Fig. 17 Diagram Showing Reach of Mho Unit at Angle of Test Reactor

Fig. 17(362A625-4)

TABLE VI

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 VI it is seen that the angle of the impedance of the 6 ohm tap is 86 degrees. Therefore:

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

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 86 degrees, the impedance of this tap may be calculated as follows:

$$Z_L = \frac{X_L}{\sin 86} = \frac{6.1}{.9976} = 6.115$$

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:

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

Fig. 4 should be checked to determine that the test current used is high enough so that the characteristic is not off the calculated value because of low current.

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 12 and 6 ohm taps of the specified test reactor, impedances at 60 degrees and 30 degrees respectively will be available for checking the mho-unit reach at the 60 degree and 30 degree positions. The mho-unit ohmic reach at the zero-degree 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 which gives the exact impedance and angle for each of the combinations available. The test-box autotransformer per cent tap for pickup at a particular angle is given by:

$$\% \text{ Tap} = \frac{200 Z_{min} \quad \cos(\emptyset - \theta)}{T \; Z_L} \qquad 100$$

wher θ is the angle of maximum torque of the unit, $\emptyset$ is the angle of the test impedance (Z_L), Z is the 60 degree, 30 degree or zero degree impedance value taken from the calibrated resistor data sheet and T is mho unit restraint tap setting. As in the case of the previous tests, the load box which serves as 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 degrees off the maximum reach position, the error becomes relatively large with phase angle error. This is apparent from Fig. 17 where it is seen, for example, at the zero-degree position that a two or three degree error in phase angle will cause a considerable apparent error in reach.

In addition to the above test on the mho units, they may also be checked for directional action with the test box circuits as shown in Fig. 16. The fault resistor RL may be zero and the test reactor should be set on the 0.5 ohm tap. With connections made as shown, the mho unit contacts should close over the current range as specified in Table VII with 1.5 volts applied across the potential circuit.

TABLE VII

Minimum Ohmic Reach	.75	1	2	3
Minimum Amperes Maximum Amperes	8 60	6 60	3 60	2 60

TRIP CIRCUIT

If possible, the relay contact circuits should be given an electrical test in place by closing each mho unit contact successively by hand and allowing trip current to pass through the contacts and the target and seal-in unit. The target should promptly appear.

SETTINGS

The mho unit is usually set to reach 80 to 90 per cent of the protected line section. The setting used will depend on how accurately the line impedance is known as well as the overreach characteristic, as given in Figs. 5 and 6. Also important is the phase angle of the protected line section relative to the angle of maximum torque of the relay and the effects of arc resistance.

Referring to Fig. 18 which illustrates the characteristic of the mho unit set for a 45 degree angle of maximum torque, $\overline{OB}$ represents the protected line and $\overline{OA}$ is 90 per cent of $\overline{OB}$. Thus, the relay is set to protect 90 per cent of the protected line on 1st zone. If the arc resistance for a fault at A is given by $\overline{AC}$, then the impedance as seen by

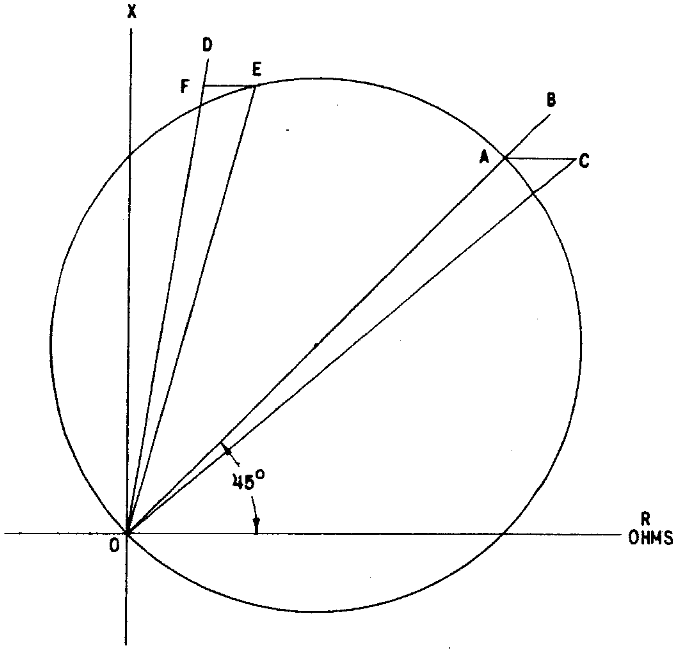


Fig. 18 Effect of Arc Resistance on Impedance as seen by Mho Units

the relays at $\overline{0}$ for such a fault would be $\overline{OC}$. This is outside of the relay 1st zone characteristic and would be tripped by second zone.

If the protected line has an impedance that plots to the left of the crest of the mho circle, such as $\overline{OD}$, then the effect of fault resistance $\overline{FE}$ for a fault at $\overline{F}$ is to bring the total impedance into the tripping circle causing the relay to overreach slightly. This situation can result with the 45 degree setting only when the line impedance angle is greater than 67.5 degrees; with the 60 degree setting only when the line impedance angle is greater than 75 degrees. If such a situation is encountered, the relay reach setting may be reduced enough to compensate for it. With a 75 degree angle of maximum torque setting this effect will be very small and may well be neglected.

It is not recommended that any attempt be made to take advantage of arc resistance to justify a longer 1st zone reach setting, because certain faults will have very little arc resistance and for this condition the relays may reach too far. The reach of the relay at any given impedance angle in terms of its reach at the set angle is given by the following expression:

$$Z_R = Z_M \cos\ (\phi - \theta)$$

where:

θ = maximum torque angle of relay

ϕ = angle of impedance to the fault.

Z_M = relay reach in secondary ohms at angle of maximum torque (θ).

Z_R = relay reach in secondary ohms at impedance angle (ϕ).

SAMPLE CALCULATIONS

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

$$Z_{prim} = 0.14 + j\ 0.80 \text{ ohms per mile}$$

$$Z_{prim} = 50\ (0.14 + j\ 0.80) = 7 + j\ 40 \text{ ohms total}$$

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

CT Ratio = 600/5 = 120/1

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

$$Z_{sec} = (7.0 + j\ 40.0)\ \frac{120}{2000} = 0.42 + j\ 2.4 \text{ ohms}$$

$$Z_{sec} = 2.43\ \underline{\angle 80.5^{o}} \text{ ohms}$$

Assume that the CEY15A is to be used to provide first zone protection and it is desired to set the relay to protect 90 percent of the line.

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

For this application the highest suitable range is 2-20 ohms. Thus, the 2 ohm relay will be selected. Since the transient overreach must be limited in this case, the 60 degree angle of maximum torque setting will be used. Connect jumper between A & B on angle of maximum torque terminal block.

The ohmic reach equation, given in the section under OPERATING CHARACTERISTICS - TAPPED AUTO TRANSFORMER, is used.

$$\text{Output Tap} = \frac{(100)\ (\text{Minimum Ohms})\ \text{Cos}\ (\phi - 0)}{Z}$$

Minimum Ohms = 2.0

$Z = Z_{sec} = 2.19$

$\phi = 80.5^{o}$

$\theta = 60^{o}$

$$\text{Output Tap} = \frac{(100)\ (2.0)\ \text{Cos}\ (80.5-60)}{2.19}$$

$$\text{Output Tap} = \frac{200\ \text{Cos}\ (20.5)}{2.19}$$

Output Tap = 85.5

Set T10 on 80 and set T2 on 6.

Since the line impedance angle, ϕ, is greater than 75 degrees, the situation illustrated in Fig. 18 exists. However, a graphical construction to scale will indicate that in this case the maximum possible "overreach" due to arc resistance will be about 1 per cent. This may be neglected or the calculated tap setting could be increased by about 1 percent. In this case a tap setting of 86 per cent appears adequate.

MAINTENANCE

PERIODIC TESTING

An operation test and an inspection of each relay unit and seal-in unit are recommended at least once every six months. The inspection of the relay should be made as outlined in the INSPECTION subsection of the INSTALLATION section. The check tests should be those described in the ELECTRICAL CHECK TESTS subsection of the INSTALLATION section. These check tests may be made very quickly if the test box autotransformer settings for each relay terminal are determined ahead of time. In that case, it is only necessary to insert the test plugs in each relay in succession and observe relay contact operation when the fault switch is closed. Frequent CALIBRATION tests are not considered necessary since the calibration of the relay does not change appreciably with time. If it is found that the relay does not check test correctly, recalibration may be made according to the procedures set forth under SERVICING in this section.

CONTACT CLEANING

For cleaning the 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 corroded material will be removed rapidly and thoroughly. The flexibility of the tool insures the cleaning of the actual points of contact.

Fine silver contacts should not be cleaned with knives, files, or abrasive paper or cloth. Knives or files may leave scratches which increase arcing and deterioration of the contacts. Abrasive paper or cloth may leave minute particles of insulating abrasive material in the contacts and thus prevent closing.

The burnishing tool described is included in the standard relay tool kit obtainable from the factory.

SERVICING

MHO UNIT

a. Contact Adjustment

The contacts of the mho unit should have an 0.030-0.035 inch gap when open, and should have no wipe beyond that due to the compressibility of the felt backstop. Fig. 19 illustrates the mho unit contact adjustments required to obtain proper operation. The gaps should be set by suitable thickness gages.

b. Control Spring Adjustment

After the CEY relay has been mounted in its test stand, the control spring of the mho unit should be adjusted so that the moving contact will just return to the right backstop when the relay is de-energized. It should be set so that if the backstop were removed, the moving contact would not move further to the right. This adjustment should be made by using the control spring adjusting arm at the top rear of the mho unit. First loosen the set screw on the front of the top pivot support, and then rotate the control spring adjusting arm so as to return the contact arm to the backstop. Tighten the set screw permitting 0.003-.006 inch end play to the shaft. The clutch should then be slipped mechanically and the reset position of the contact observed. This test should be repeated, and the control spring adjusted so that the moving contact will return to the backstop for all cup positions.

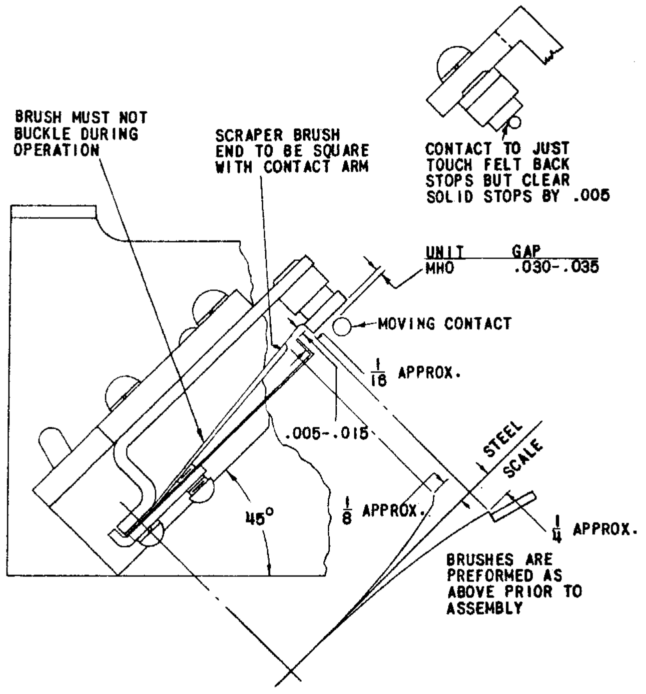


Fig. 19 Mho Unit Contact Adjustments

c. Clutch Setting

The clutch of the mho unit is set to slip when a force of from 45 to 55 grams is applied to the moving contact assembly at the moving contact.

The clutch on the mho unit is adjusted by means of the steel collar at the upper end of the rotating shaft. To adjust the clutch, loosen the set screw in the collar, rotate the collar on the shaft through the number of half turns necessary to obtain the correct pressure. Moving the collar down increases the clutch pressure. The collar should then be locked by means of the set screw which seats itself in a groove provided on the shaft. Care should be taken to seat the set screw in this groove rather than tighten it against the threaded shaft.

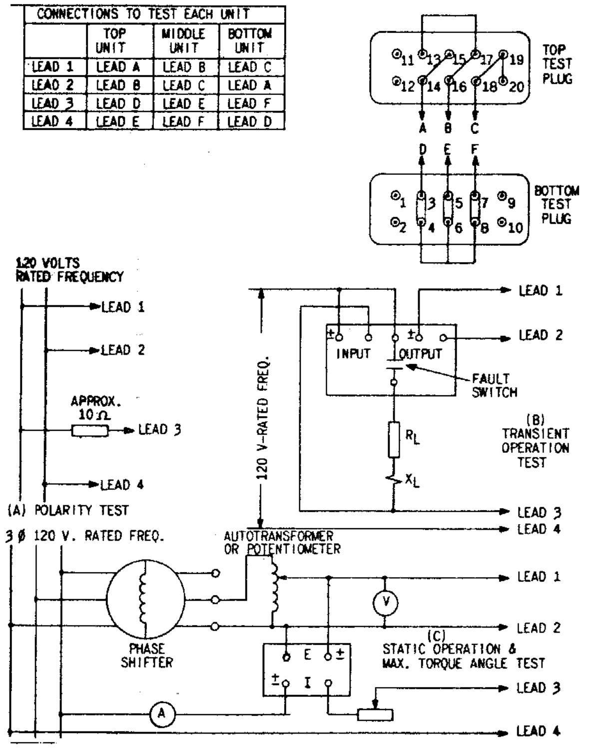
d. Polarity

To check the polarity of the mho unit, the connections of Fig. 20A may be used. With these connections and the mho unit taps on 100 per cent, the mho unit contacts should remain open. The correct polarity for the mho unit is indicated by the closing of the left-hand contact of the mho unit when the T2 tap leads are removed from the autotransformer tap blocks.

e. Directional

To check the directional action of the mho unit, the connections of Fig. 20C should be used. Set the mho unit taps on 100 per cent. With the connections of Fig. 20C adjust the phase shifter to the angle of maximum torque. With 1.5 volts applied to the potential circuit, the mho unit contact should be closed over the range given in Table VII under ELECTRICAL CHECK TESTS. With the current connections at the relay terminals reversed from that shown in Fig. 20C, remove voltage from the relay terminals and then short circuit them. The contact of the mho unit should then remain open from 0 to 60 amperes.

If the mho unit fails to perform properly at these high current levels, the inner stator, or core, should be adjusted to the left or right a small amount. To accomplish this, first loosen the hex head nut in the bottom rear of the mho unit. This nut clamps the core positioning bracket. Once this nut is loosened, the core can be moved from side



CONNECTIONS TO TEST EACH UNIT			
	TOP UNIT	MIDDLE UNIT	BOTTOM UNIT
LEAD 1	LEAD A	LEAD B	LEAD C
LEAD 2	LEAD B	LEAD C	LEAD A
LEAD 3	LEAD D	LEAD E	LEAD F
LEAD 4	LEAD E	LEAD F	LEAD D

Fig. 20 Test Connections for Checking Correct Mho Unit Operation

to side by means of the core adjusting screw mounted on the rear of the mho unit mounting plate. This adjusting screw is accessible from the right side of the relay. If the mho unit contact fails to close at the high current level, turn the core adjusting screw slightly clockwise. If the mho unit contact fails to open properly at the high current level, turn the core adjusting screw slightly counter-clockwise. After an adjustment of the screw in either direction, back it off slightly in the opposite direction to relieve tension on the screw.

f. Recalibration

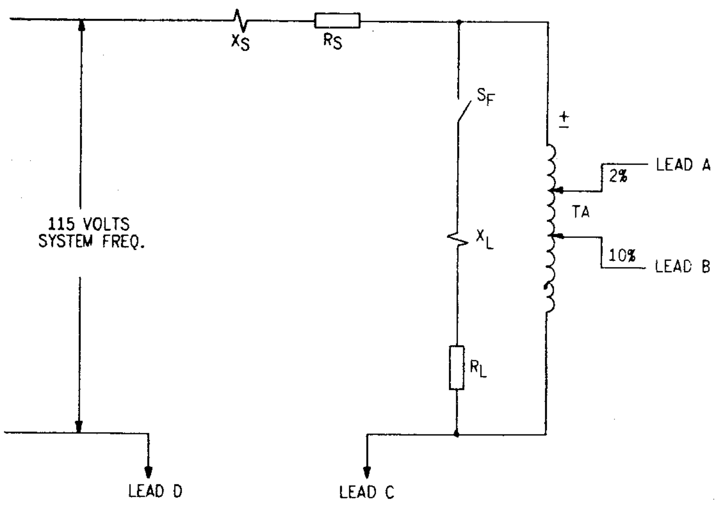
Before pickup or phase angle checks are made, the mho unit should be allowed to heat up for approximately 15 minutes energized with rated voltage alone. When cold the relay tends to underreach by 3 or 4 per cent. If the relay is permitted to warm up, the error due to temperature will be less than one per cent.

If the pickup of the mho unit is to be calibrated by test, use the connections of Fig. 20C. Carefully calibrated meters are an absolute necessity if the relay calibration tests are to be carried out successfully. Set the mho unit calculated reach, Z, by means of the taps. Set the angle tap to the desired angle of maximum torque. Adjust the voltage to the desired level. When setting low values of impedance, it is advisable to use approximately 55 volts to avoid excessive currents. Adjust the phase angle to the angle of maximum torque of the mho unit. Increase the current to determine the mho unit pickup current. The impedance calculated from the ratio of the voltage and current readings with the connections of Fig. 20C corresponds to the phase-to-phase impedance, and is double the phase-to-neutral or relay impedance Z_R. If the contact does not close at the correct current, the setting of the rheostat, R_{11}, R_{12}, or R_{13} should be changed.

If angular settings are to be checked, use the connections of Fig. 20C with about 55 volts on the relay, and current sufficiently high to cause the contacts to close over a span of 90 degrees or more. Turn the phase shifter and find the two values of phase angle at which the contacts will just close (always taking the reading as contacts move from open to closed position), maintaining the same voltage and current when both angles are read. The angle midway between these two values is the angular setting of the unit, or its angle of maximum torque. This test should be made first with the taps set to connect "B" to "C" on the tap blocks. If the angle of maximum torque is not correct it can be corrected by adjusting X_{21}, X_{22}, or X_{23}, depending on whether it is the top, middle, or bottom unit being adjusted. The taps should then be changed to connect "A" to "B" and the angle of maximum torque determined again. If this angle of maximum torque is not correct, it can be corrected by adjusting X_{31}, X_{32}, or X_{33} depending upon whether it is the top, middle, or bottom unit being adjusted.

TRANSIENT TESTS

If a test is desired showing the operation of the relay under transient conditions, the circuit shown in Fig. 20B or Fig. 21 should be used. The impedance measured by the relay is $R_L + jX_L$. This should be approximately equal in magnitude



UNIT LOCATION	UNIT	CONNECT LEAD TO RELAY STUDS AS FOLLOWS				JUMPER RELAY STUDS
		LEAD A	LEAD B	LEAD C	LEAD D	
TOP	φ1-2	14-15	13-16-17	3	5	4-6-8
MIDDLE	φ2-3	13-16-17	18-19-20	5	7	4-6-8
BOTTOM	φ3-1	18-19-20	14-15	7	3	4-6-8

Fig. 21 Test Connections for Checking Transient Overreach of Mho Unit

and phase angle to the secondary impedance from the relay bus to and including the fault to be investigated. Ideally, the impedance of the test bus plus R_S, X_S, and the relay current coils in series, should be equal to the secondary impedance from the internal voltages at the sources of generation behind the relay bus to the relay bus. Ordinarily a test bus can be found of capacity large enough to permit neglecting its impedance. The fault impedance of this test circuit represents phase-to-phase fault impedance and is double the value calculated as the relay setting. A neon lamp in the contact circuit of the mho unit is satisfactory for detecting closure of the contacts. See Figs. 5 and 6 for typical performance characteristics.

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

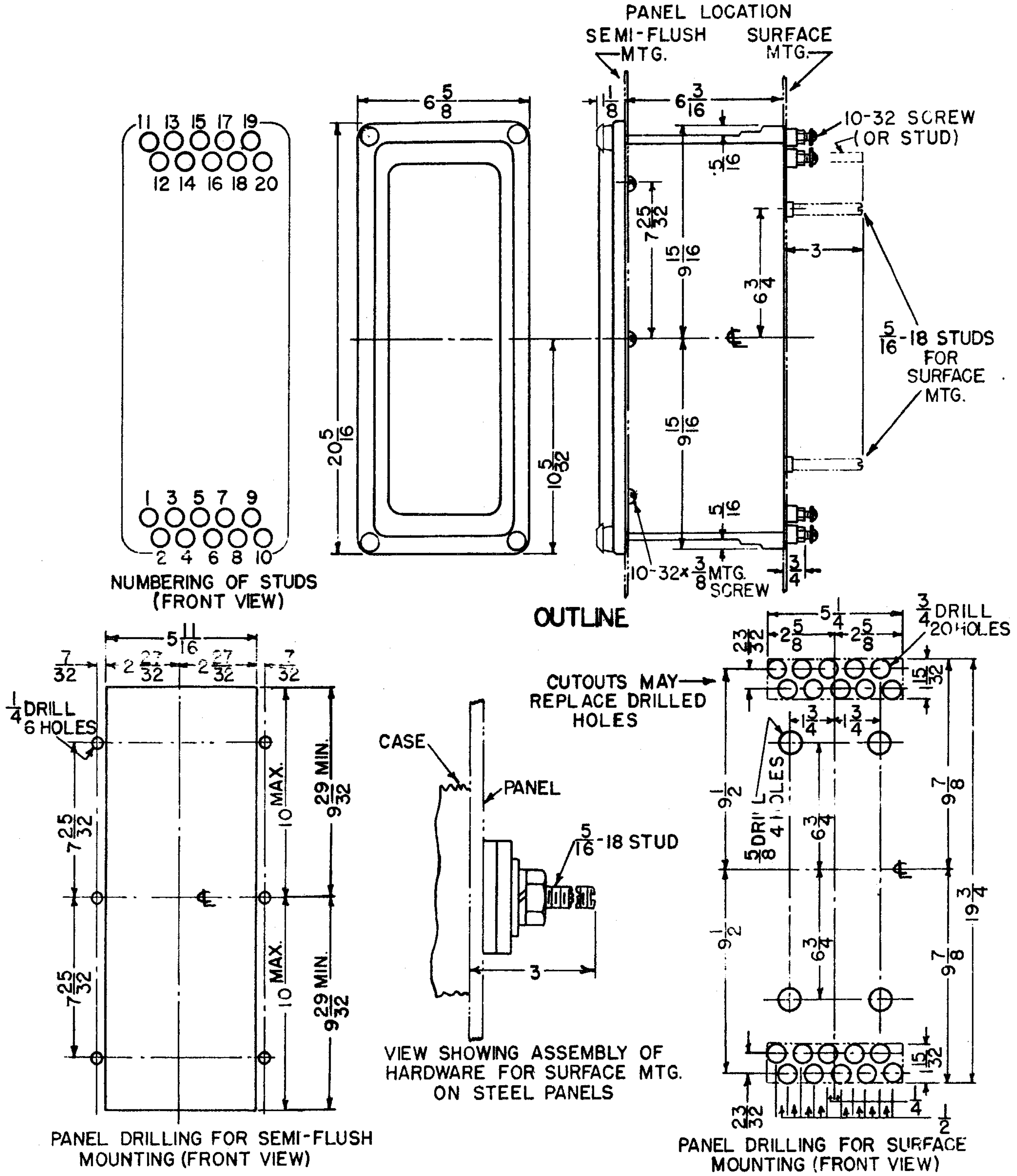


Fig. 22 Outline and Panel Drilling Diagram of CEY15A Relay

Fig. 22 (6209276-1)

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