INSTRUCTIONS GEH-2043B

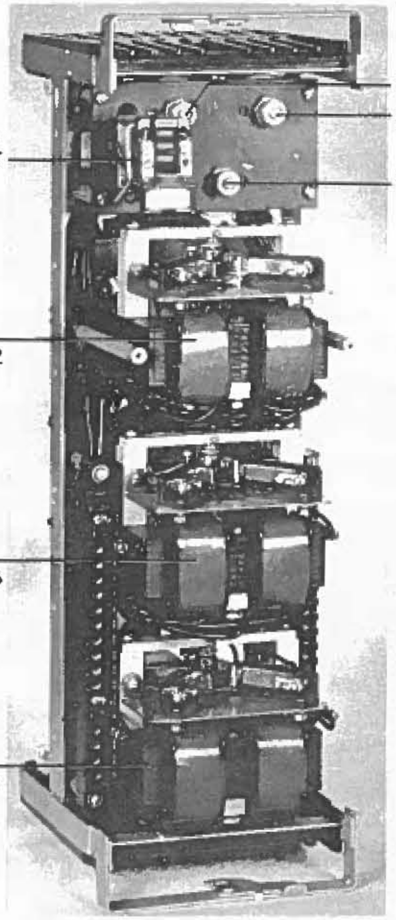
OFFSET MHO DISTANCE RELAY

TYPE CEB17A

POWER SYSTEMS MANAGEMENT DEPARTMENT

GENERAL ELECTRIC

PHILADELPHIA, PA.



A. Front View

T2	o
10	o
8	o
6	o
4	o
2	o
0	o
90	o
80	o
70	o
60	o
50	o
T10	o
40	o
30	o
20	o
10	o
0	o

Left and Right

B. Numbering Details of Tap Blocks (Front View)

Fig.1(8028587) Front View

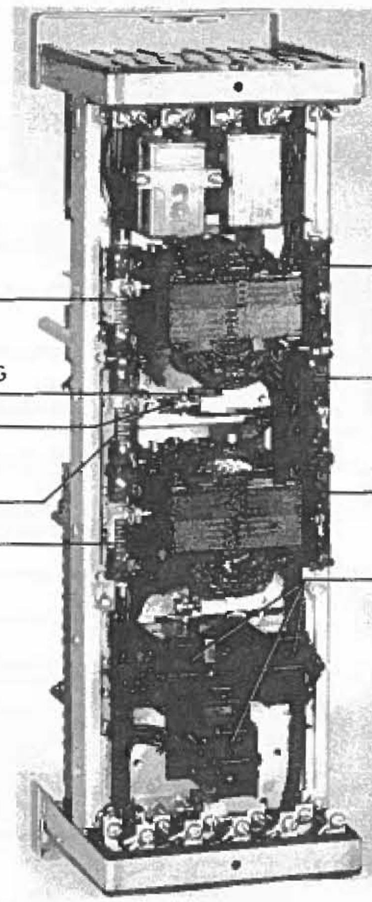


Fig.1(8028586) Back View

C. Back View

Fig. 1 Offset Mho Distance Relay Removed from Case - CEB17A

OFFSET MHO DISTANCE RELAY
TYPE CEB17A

DESCRIPTION

INTRODUCTION

The CEB17A relay is a three-phase, high-speed, single-zone directional mho distance relay with provisions for offsetting the characteristic a fixed amount. It is constructed of three single-phase units in one L_2 case with facilities for single-phase testing. One target and seal-in unit provides indication of operation for all three units. The transient overreach characteristics of the CEB17A have not been limited to the point where it is suitable for use as a first-zone relay. This relay was designed primarily for use in directional comparison relaying schemes.

APPLICATION

The CEB17A was specifically designed for application as a carrier starting relay in directional comparison relaying schemes. To serve this purpose the relay is equipped with normally closed contacts as well as with normally open contacts. Since many original straight distance terminals are later converted into directional comparison terminals, the CEB17A should be used as the third-zone unit in straight distance applications to facilitate possible future conversion.

The offset feature should always be used when the relay is employed to start carrier or when it is required to operate in conjunction with some time delay for zero voltage faults.

The CEB17A relay and its companion zone packaged relays may be combined in several different ways for use in straight distance and directional comparison relaying schemes. Fig. 9 illustrates how the CEB17A, CEY15A, CEY16A and RPM21D relays may be employed for three-zone directional distance protection of transmission circuits against all multi-phase faults. Separate ground fault relays are required for single-phase-to-ground faults. Fig. 8 shows how these same relays plus ground relays and the necessary auxiliaries are combined in a directional comparison carrier relaying scheme.

OPERATING CHARACTERISTICS

MHO UNIT

The mho unit without offset has an 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 offset shifts the circle 0.5 ohm (phase-to-neutral ohms) at an angle of 90° lead (see Fig. 3).

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, and can be determined from the equation:

$$\text{OHMIC REACH} = \frac{Z_{min} \quad \cos(\emptyset - \theta) \times 100}{(\text{OUTPUT TAP})}$$

Where:

Output tap	=	T_{10} plus T_2 tap setting.
Z_{min}	=	Mho unit minimum phase-to-neutral ohmic reach at the maximum torque angle used.
θ	=	Mho unit angle of maximum torque.
$\emptyset$	=	Phase angle of the line.

For a 3-30 ohm mho unit set with 100 per cent input tap, 100 per cent output tap, and 75 degree angle of maximum torque, the reach of the mho unit would be three ohms if the line phase angle were 75 degrees, current lagging voltage.

At reduced voltage, the ohmic value at which the mho unit will operate may be somewhat lower than its calculated value. This "pullback" or reduction in reach, is shown in Fig. 2 where the change in relay reach for a constant tap setting is expressed as a function of the three phase fault current. The mho unit will operate for all points to the right of the curves. The static curves of Fig. 2 were determined by tests performed with no voltage supplied to the relay before the fault was applied.

The mho unit without offset 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 10 and 60 amperes. For faults in the non-tripping direction, the contacts will remain open at zero volts and between 0 and 60 amperes.

* Denotes change since superseded issue

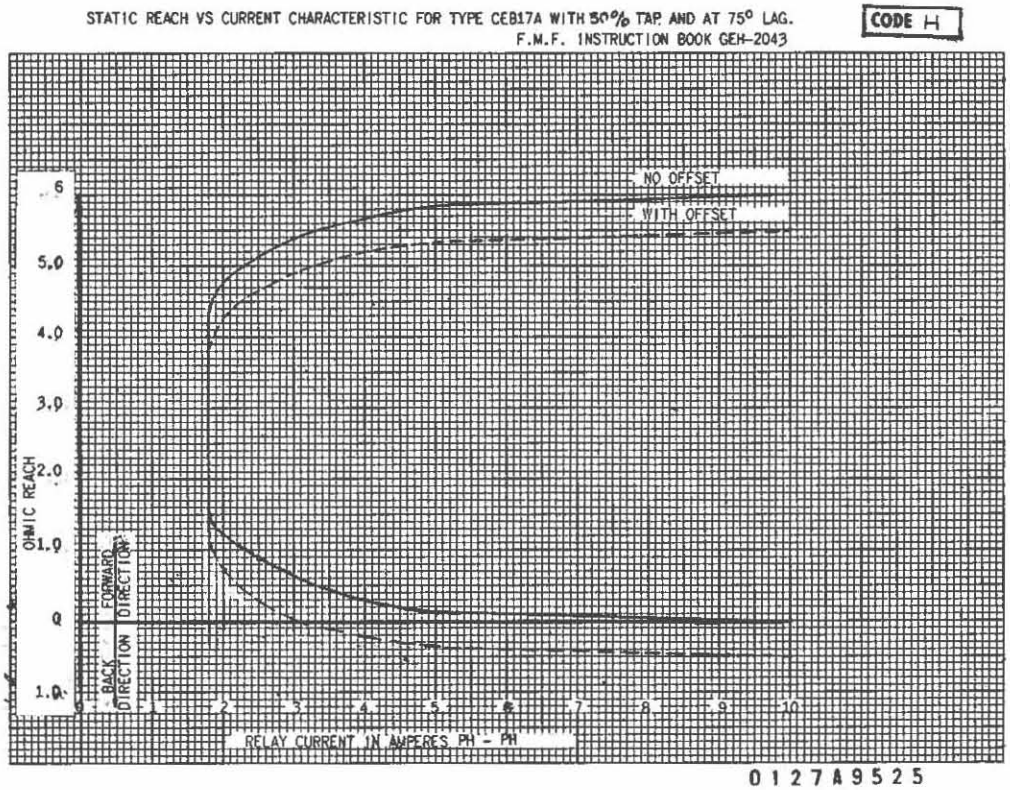


Fig. 2(0127A9525-3)

Fig. 2 Static Reach vs. Current Characteristic with 50% Tap Setting and Maximum Torque Angle at 75° Lag

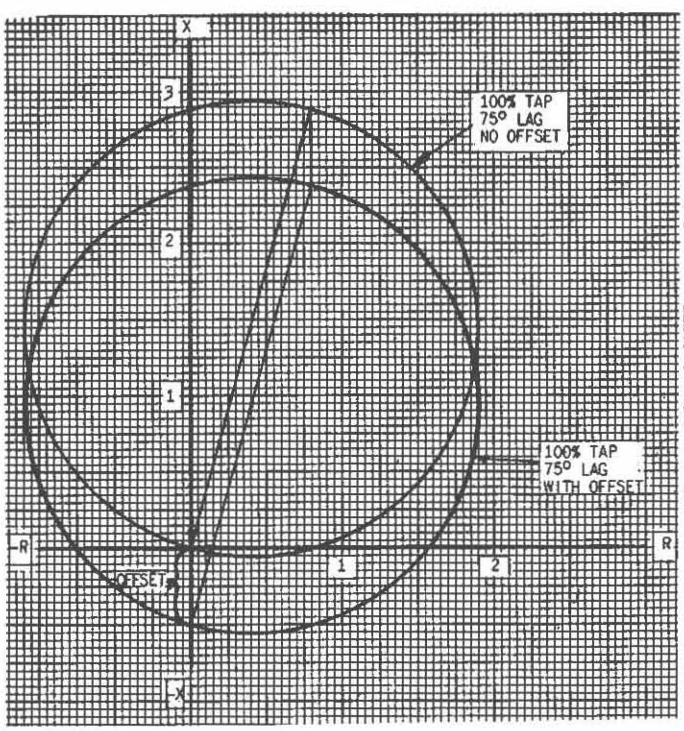


Fig. 3 (0127A9528-0)

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

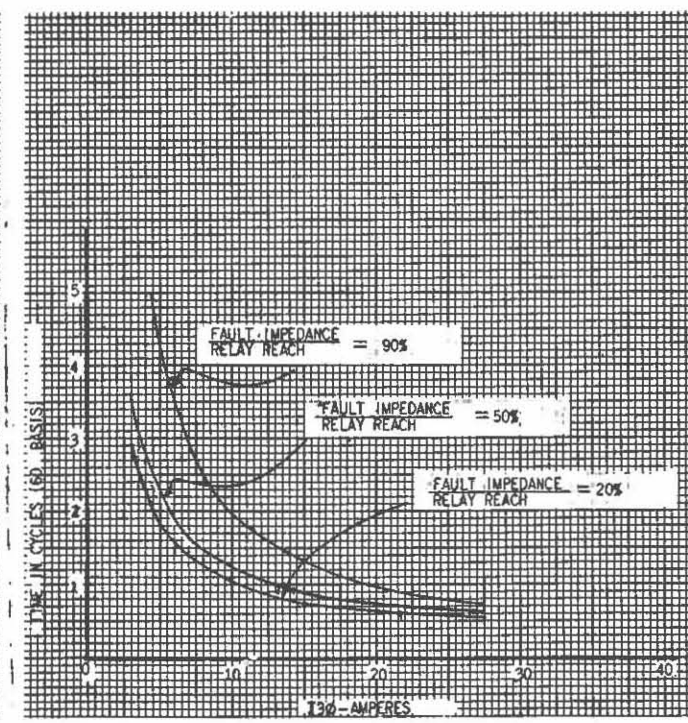


Fig.4(0127A9522-0)

Fig. 4 Typical Time-Current Characteristics with 86% Tap Setting. (Time to close normally open contact).

The speed of operation of the mho unit is 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. Typical time data are presented in Fig. 4 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 T_2 is screwed into one of the 2% taps and the lead marked T_{10} 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 CEB17A relay is rated 115 volts, 5 amperes and the mho unit has an ohmic reach that is adjustable from 3 to 30 ohms at 75° lag. The mho unit can also be adjusted to have maximum torque at 60° lag. When adjusted for 60° lag the mho unit has an ohmic reach of 2.5 to 25 ohms. The mho unit characteristic can be shifted by 0.5 ohm by connecting the transactor in the circuit. The angle of shift of the circle due to the transactor is at 90° lead.

The one second thermal rating of this relay is 300 amperes.

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 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 ampere to 2.0 amperes at the minimum control voltage. This 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 ohm resistance of the target seal-in coil does not cause excessive voltage drop. 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 I

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.

BURDENS

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

TABLE II

CURRENT CIRCUIT BURDENS

	WATTS	VARS	VOLT AMPS
Without Offset	0.90	0.95	1.30
With Offset	2.30	1.75	2.90

The maximum potential burden imposed on each potential transformer at 115 volts and 60 cycles is 14.2 watts, 9.2 vars, 16.9 volt amps.

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:

$$\text{Watts} = 8.25 + \left[\frac{\text{Tap Setting}}{100}\right]^2 (5.95)$$

$$\text{Vars} = \left[\frac{\text{Tap Setting}}{100}\right]^2 (9.20)$$

GENERAL CONSTRUCTION

The mho units of the CEB17A relay are of the four pole induction cylinder construction. The schematic connections for this unit are shown in Fig. 5. 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 (without offset) is therefore:

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

where E is the 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 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.

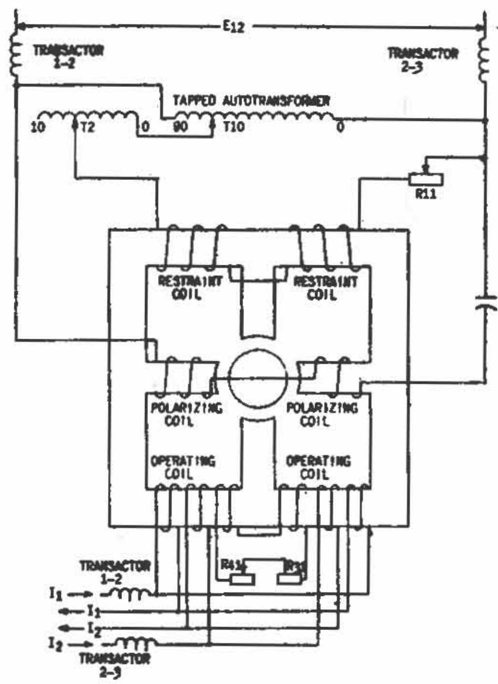


Fig. 5 Schematic Connections of the Mho Unit

Fig. 5(0127A9520-0)

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 circuit.

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

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.

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 unit should operate freely by hand.

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

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

MHO UNITS

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

There should be approximately 0.003-0.006 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 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.

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.

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 is shown in Fig. 15.

CONNECTIONS

The internal connection diagram for the relay is shown in Fig. 7. Typical wiring diagras are given in Figs. 8 and 9.

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.

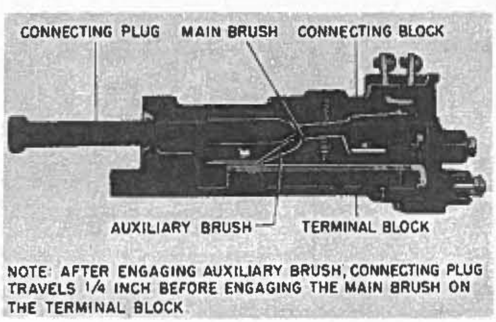


Fig. 6 Cross Section of Drawout Case showing Position of Auxiliary Brush

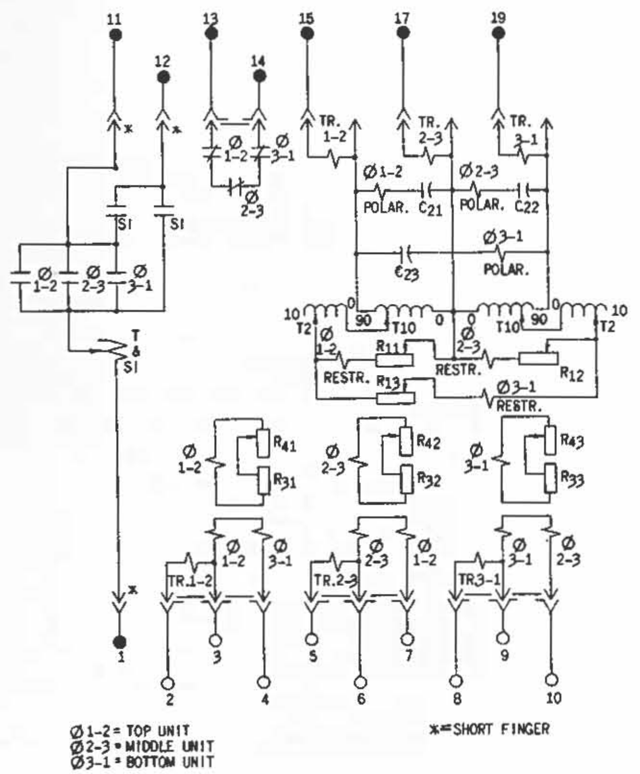


Fig. 7 Internal Connection Diagram for CEB17A Relay (Front View)

Fig. 6 (8025039)

Fig. 7 (0127A9413-0)

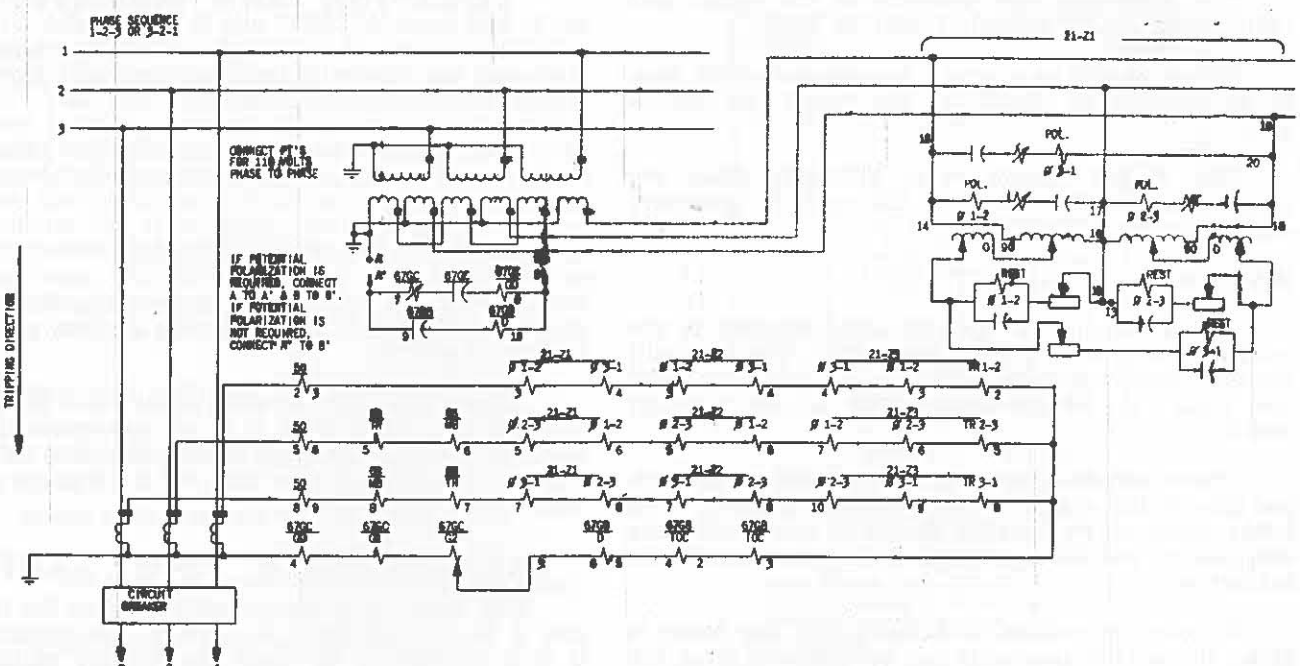


Fig.8(702IB8IBA Sht.1-0)

Fig. 8 Typical Elementary Diagram Showing CEB17A Relay When

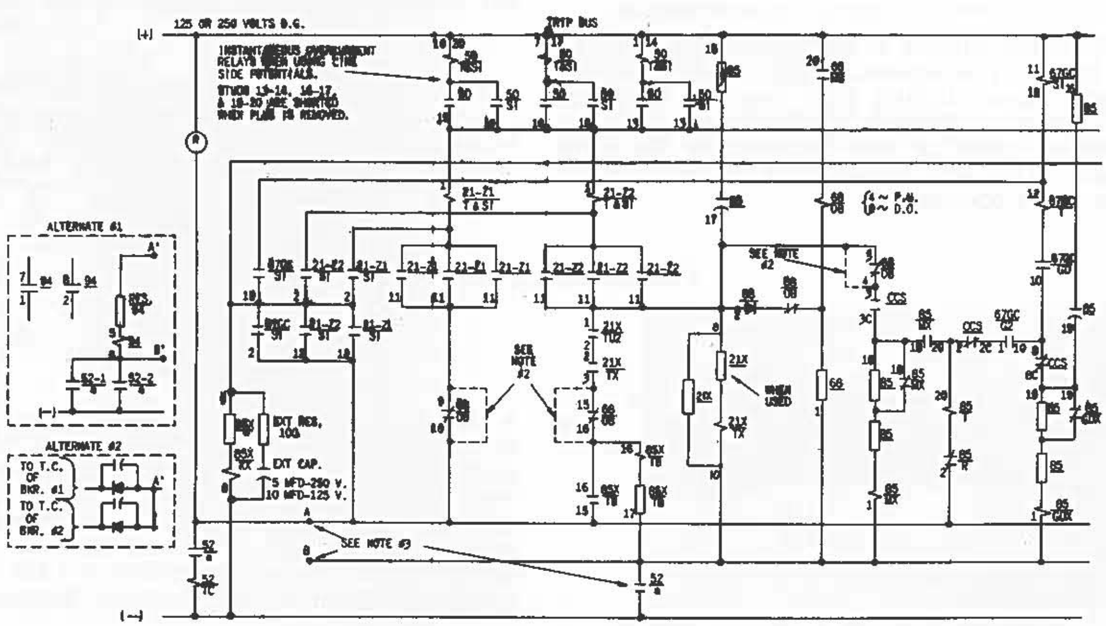
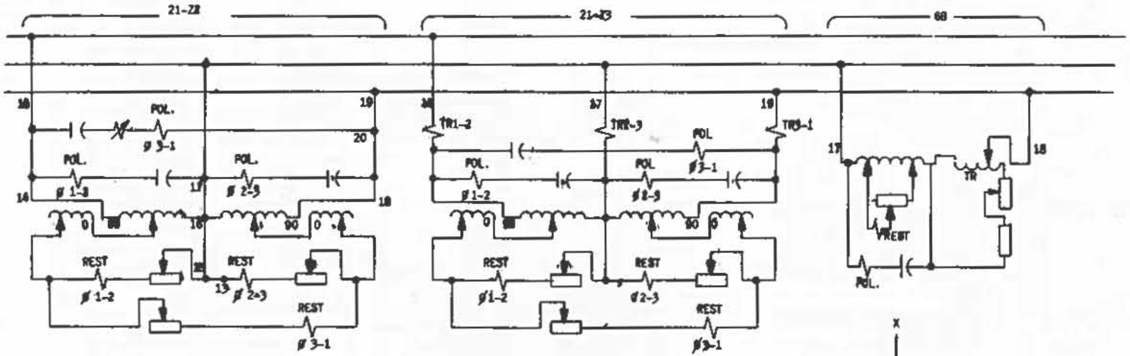
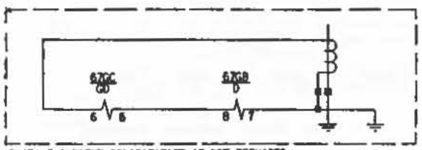


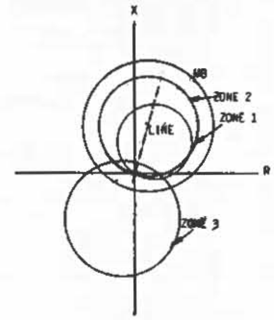
Fig.8(702IB8IBA Sht.2-1)

Fig. 8 Continued

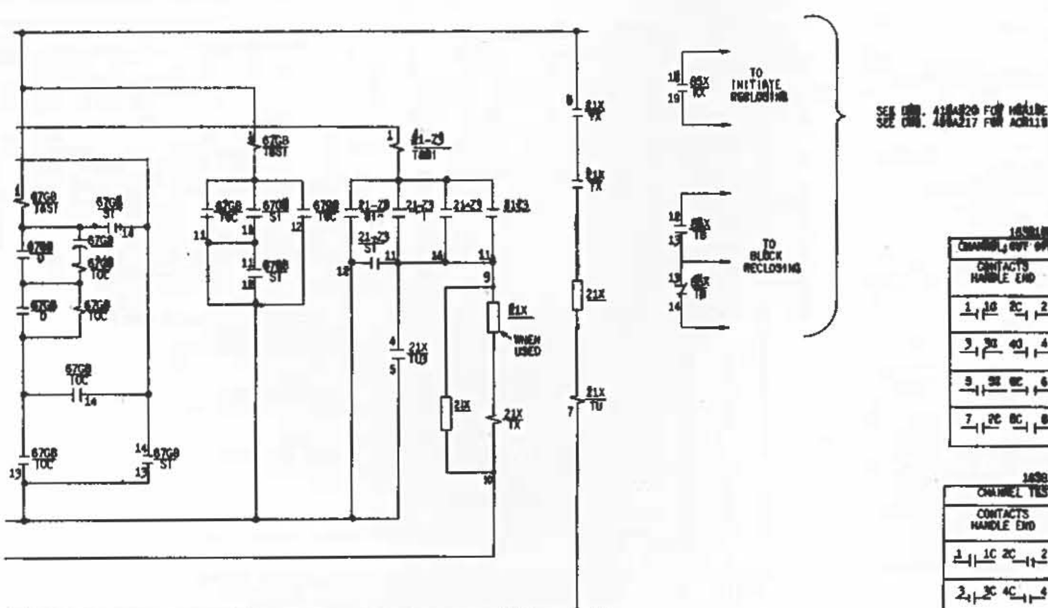




OMIT IF CURRENT POLARIZATION IS NOT REQUIRED



Used in a Directional Comparison Carrier Relaying Scheme



CHANNEL CUT OFF SWITCH (OCS)

CONTACTS HANDLE END		BACK VIEW	
		OFF	ON
1 1C 2C 2	1		X
	2		X
3 3C 4C 4	3		X
	4		X
5 5C 6C 6	5	X	
	6	X	
7 7C 8C 8	7		X
	8		X

CHANNEL TEST SWITCH (TS)

CONTACTS HANDLE END		BACK VIEW			
		SEND	NOR	REC.	R.S.
1 1C 2C 2	1		X		
	2		X		
3 3C 4C 4	3		X	X	X
	4	X	X	X	
SPRING RETURN TO NORMAL					

Fig. 8 Continued

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.
		TR 1-2	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
67GC	CLPG12B		CARRIER GROUND DIRECTIONAL RELAY
		G1	CARRIER GROUND BLOCKING UNIT
		G2	CARRIER GROUND TRIPPING UNIT
		GD	CARRIER GROUND DIRECTIONAL UNIT
		GDIX	AUXILIARY TO CONTINUE GROUND BLOCKING
		SI	SEAL-IN
		T	TARGET
67GB	JBCG52E OR JBCG54E		GROUND DIRECTIONAL OVERCURRENT RELAY
		D	DIRECTIONAL UNIT
		IOC	INSTANTANEOUS UNIT
		TOC	TIME DELAY UNIT
		T&SI	TARGET & SEAL-IN
94	HGA14AM or AL		AUXILIARY TRIPPING RELAY
68	CEB12B		OFFSET MHO OUT-OF STEP BLOCKING RELAY
		MB	MHO BLOCKING UNIT
		TR	TRANSACTOR
		OB	AUXILIARY TO MHO BLOCKING UNIT
85			CARRIER CURRENT AUXILIARY RELAY
		R	RECEIVER RELAY OPERATING COIL
		RH	RECEIVER RELAY HOLDING COIL
		GDX	AUXILIARY TO GD
		MX	AUXILIARY TO 21-Z2
85X	NAA22A		CARRIER AUXILIARY RELAY
		KX	RECLOSURE INITIATING UNIT
		TB	RECLOSURE BLOCKING UNIT
		RA	RECEIVER ALARM UNIT
CCS	SB1		CHANNEL CUT OFF SWITCH
TS	SB1		CHANNEL TEST SWITCH

TABULATION OF DEVICES			
TYPE OR DESCRIPTION		INTERNAL CONNS.	OUTLINE
CEY15A		0127A9412	K-6209276
CEY16A		0127A9418	K-6209276
CEB17A		0127A9413	K-6209276
RPM21D	125V	0127A9440	K-6209270
RPM21D	250V	0127A9441	K-6209270
PJC31C		K-6375726	K-6209272
CLPG12B		418A899	K-6209276
JBCG52E (INVERSE)		418A868	K-6209276
JBCG54E(VERY INVERSE)		418A869	K-6209276
HGA14AM(BACK CONN)		K-6400533	K-6400533
HGA14AL(FRONT CONN)		377A139	377A139
CEB12B		377A103	K-6209274
SCA11AB		418A997	K-6209272
NAA22A		K-6400699	K-6209272
CHANNEL CUT OFF SWITCH	SB1	1638188211	116A190
CHANNEL TEST SWITCH	SB1	1638188499	116A190
WILLIAM.DO-91(FLUSH)			K-6948606
WILLIAM. MODEL 301 (SURFACE)			376A914
TELEPHONE JACK			K-6400578
WHITE LAMP			K-6151144
RHEOSTAT (RES. SIG. TEST)			418A774
TRIP RECTIFIER (102L218 G2)	125V		104A8584
TRIP RECTIFIER (102L218 G4)	250V		104A8584

NOTE 1 - WHEN CARRIER & TRIPPING VOLTAGES ARE THE SAME, THESE CIRCUITS MAY BE SUPPLIED FROM EITHER THE CARRIER CONTROL BUS OR THE TRIP BUS. OTHERWISE CONNECT TO TRIP BUS.

NOTE 2 - IF OUT OF STEP BLOCKING OF TRIPPING IS NOT DESIRED, MAKE DASH CONNECTIONS AS SHOWN.

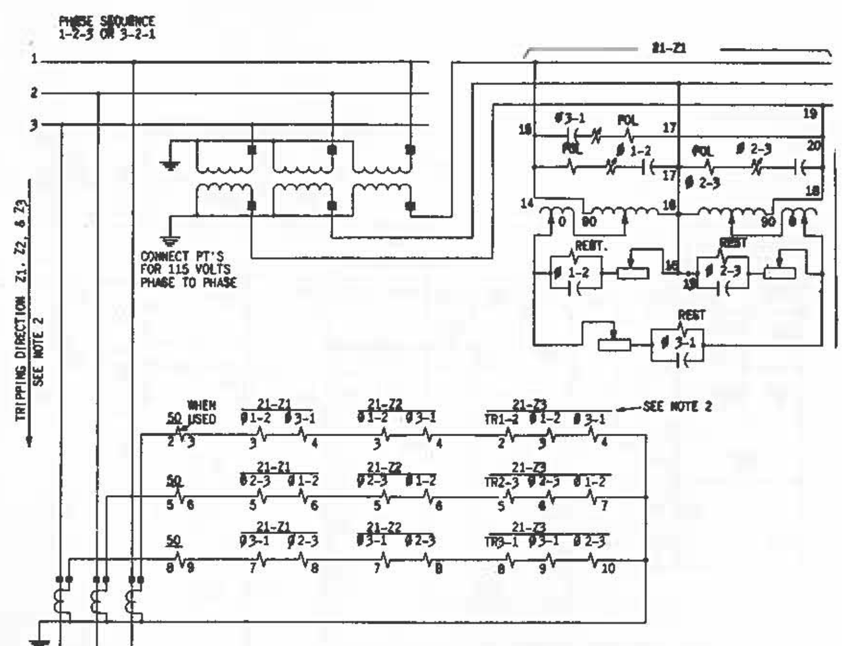
NOTE 3 - IF TRIPPING ONLY ONE BREAKER, MAKE CONNECTIONS AS SHOWN. IF USING AUXILIARY TRIPPING RELAY (94) TO TRIP TWO BREAKERS, USE CONNECTIONS SHOWN IN ALTERNATE #1 BY CONNECTING A TO A' & B TO B'. REPLACE 52/a WITH 52-1/a & 52-2/a. IF RECTIFIERS ARE USED TO TRIP TWO BREAKERS, USE ALTERNATE CONNECTION #2. CONNECT A' TO A & REPLACE 52/a WITH 52-1/a & 52-2/a IN PARALLEL.

Fig. 8 Continued

Fig. 8(7021B81BA Sht. 3-0)

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	125V	0127A9440	K-6209270
RPM21D	250V	0127A9441	K-6209270
PJC31C		K-6375726	K-6209272
HGA14AM (BACK CONNS.)		K-6400533	K-6400533
HGA14AL (FRONT CONNS.)		377A139	377A139
TRIP RECTIFIER (102L218G2)	125V		104A8584
TRIP RECTIFIER (102L218G4)	250V		104A8584



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

Fig. 9 Typical External Connection Diagram of CEB17A

Fig.9(7381B21AA-1)

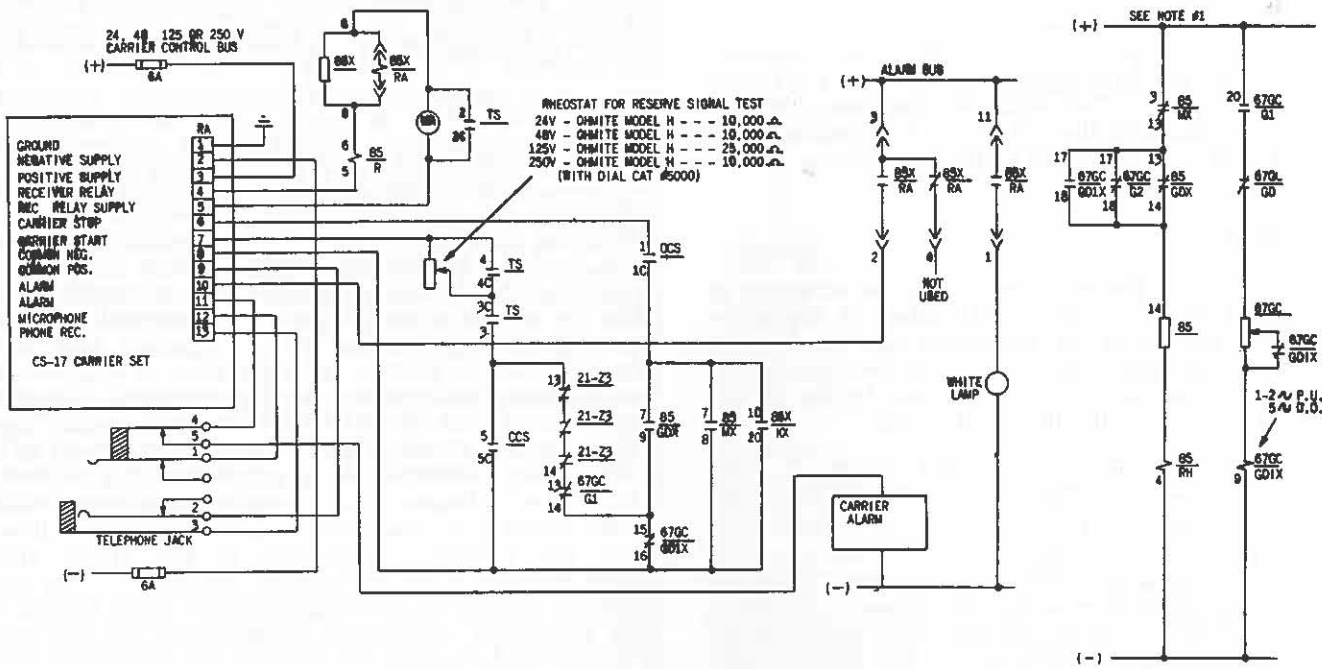
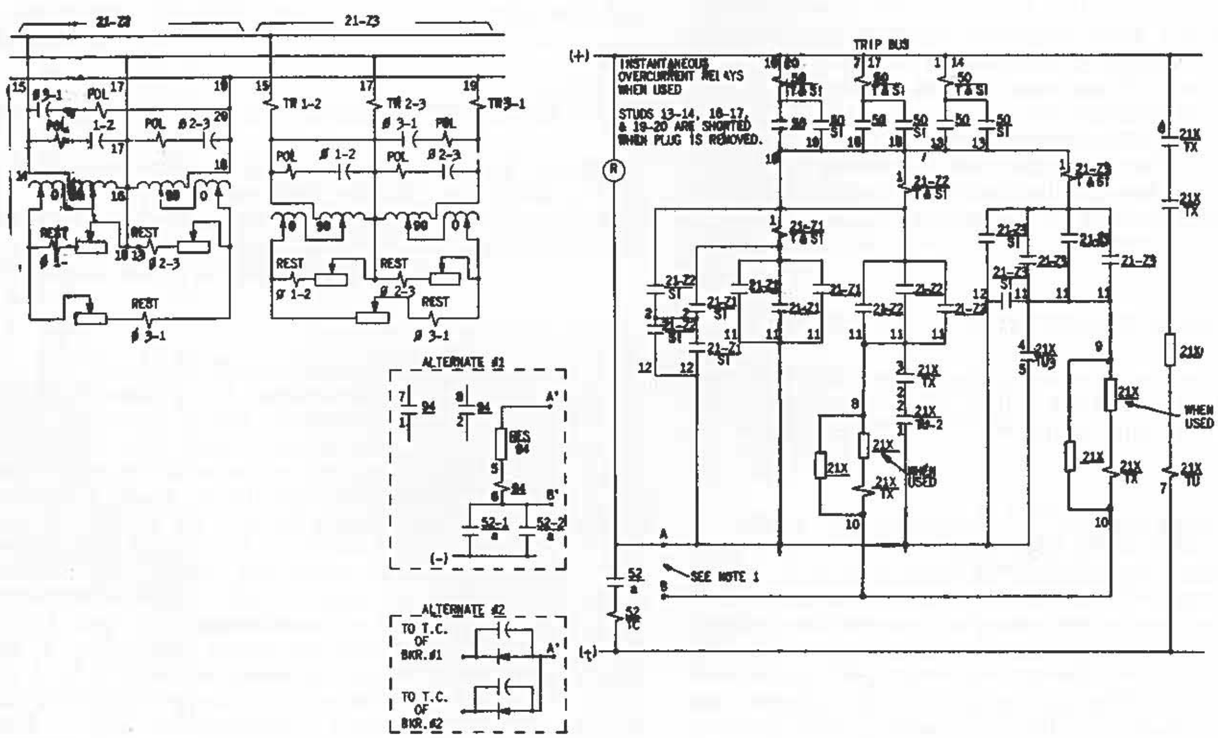


Fig. 8 Continued



Showing Three-zone Directional Distance Protection

MHO UNITS

Angle of Maximum Torque

The relay is calibrated at the factory to have maximum torque at 75° lag. If maximum torque at 60° lag is desired the relay can be readjusted as described in RECALIBRATION section under SERVICING.

Ohmic Reach

The reach of the mho units can be adjusted in two per cent steps by the positioning of the auto-transformer 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 T_{10} and T_2 tap leads to the proper taps. The lower tap leads marked T_{10} (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 T_2 should be connected to one of the two percent taps in the upper section of the tap block. The sum of the tap to which the T_{10} lead is connected and the tap to which the T_2 lead is connected should equal the calculated tap setting. For example a tap setting of 86% is made by connecting the T_{10} lead to the 80% tap and the T_2 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

Jumper Studs 15 to 17 to 19.

The control spring is adjusted so that the left contact will just close when 3.25 ampere ± 10% flow in the current coils with the connections in Table III.

TABLE III
CONNECTIONS FOR CONTROL SPRING ADJUSTMENT

UNIT	TOP	MID.	BOT.
Current in Stud	2	5	8
Current out Stud	5	8	2
Jumper Studs	4-7	7-10	4-10

TARGET AND SEAL-IN UNIT

The choice of tap on the target and seal-in unit is described under RATINGS. To change this tap, the spare screw above the left contact 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. 10, 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. 8 or 9.

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. 10 shows the proper connections for one make of phase angle meter.

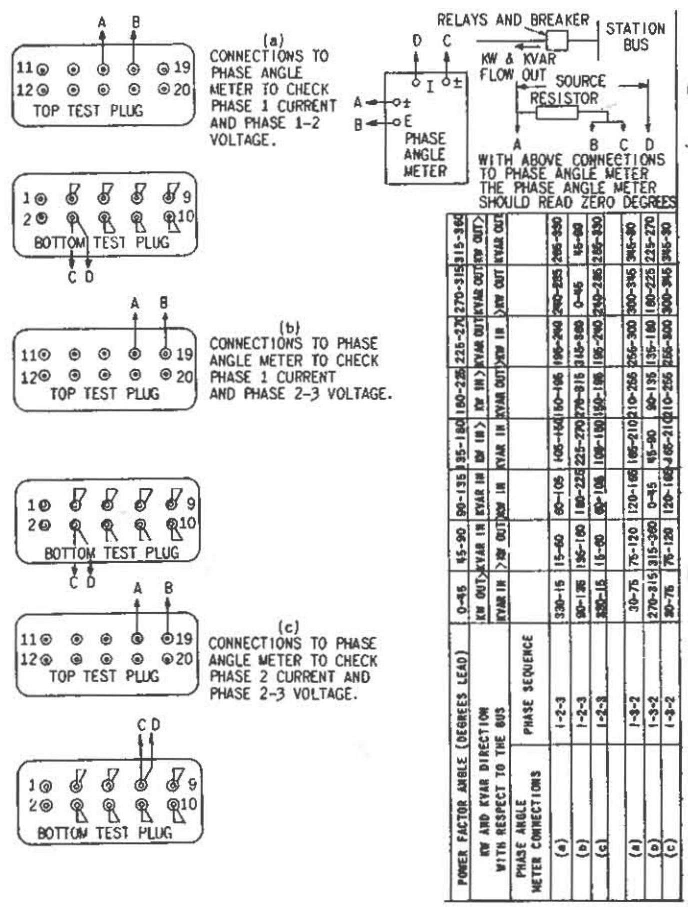


Fig. 10 (0127A9519-0)

Fig. 10 Test Connections for Checking External Connections to CEB17A Relay

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 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. 2.

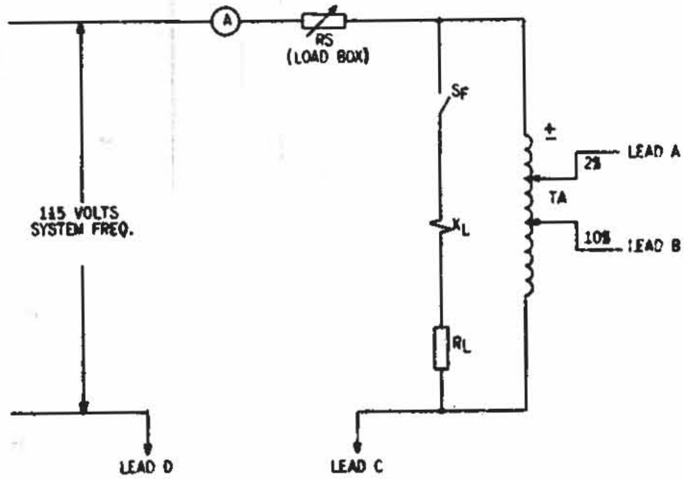
A shorter test which will check for most of the possible open circuits in the AC portion of the relay is as follows: Remove the lower connection plug disconnecting the current circuits. All units should have strong torque to the right when full voltage is applied.

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 has been briefly discussed. 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. 11. In Fig. 11, 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.



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	15	17	3	6	4-7-10
MIDDLE	Ø 2-3	17	19	6	9	4-7-10
BOTTOM	Ø 3-1	19	15	9	3	4-7-10

Fig. 11 Test Connections for Checking Ohmic Pickup of Mho Units

Fig. 11 (0127A9518-0)

For convenience in field testing the fault switch and tapped autotransformer of Fig. 11 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. The relay reach at the angle of the test reactor impedance is:

$$2Z \text{ Relay} = 200 \frac{Z_{\text{min. ohms}}}{\text{OUTPUT TAP}} \cos(\phi - \theta)$$ where ϕ is the angle of the test reactor impedance, θ is the relay angle of maximum reach, and "OUTPUT TAP" 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 at a maximum torque angle of 75 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:

$$2Z \text{ relay} = 200 \times \frac{3}{100} \cos(80-75) = 5.98 \text{ ohms}$$

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 IV shows the angles for each of the reactor taps.

TABLE IV

TAP	ANGLE ϕ	COS (ϕ - 75)
24	88	0.974
12	87	0.978
6	86	0.982
3	85	0.985
2	83	0.990
1	81	0.995
0.5	78	0.999

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

$$2Z \text{ relay} = 200 \times \frac{3}{100} \cos(86-75) = 5.89 \text{ ohms}$$

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:

$$\% = \frac{5.89}{6.1} (100) = 96.5\% \text{ (use 96\% TAP)}$$

Fig. 2 should be checked to determine that the test current used is high enough so that the characteristic is not off 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:

$$\% \text{ Tap} = \frac{200 Z_{min} \cos(\phi - \theta)}{(Z_L)(\text{OUTPUT TAP})} \times 100$$

Where ϕ is the angle of maximum torque of the unit, θ is the angle of the test impedance (Z_L), Z_L is the 60 degree, 30 degree or zero degree impedance value taken from the calibrated resistor data sheet and "OUTPUT TAP" 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.

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. 11. The fault resistor R_L 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 of 10-60 amps with 1.5 volts applied across the potential circuit.

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 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 set reach in secondary ohms at angle of maximum torque (θ).

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

SAMPLE CALCULATIONS

Consider one terminal of a two terminal 69 kv transmission line 17.3 miles long having a phase to neutral impedance

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

$$Z_{prim} = 17.3\,(0.14 + j\,0.80) = 2.4 + j\,13.9 \text{ ohms total}$$

PT Ratio = 69,000/115 = 600/1

CT Ratio = 600/5 = 120/1

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

$$Z_{sec} = (2.4 + j\,13.9)\,\frac{120}{600} = 0.48 + j\,2.78 \text{ ohms}$$

$$Z_{sec} = 2.82\ \angle 80.2^{\circ} \text{ ohms}$$

Assume that the CEB17A is to be used to provide 3rd zone protection in the forward direction and it is desired to set the forward reach for 6.0 ohms at an angle of 80.2° degrees. This setting having been arrived at after due consideration was given to coordination with the phase relays on adjacent circuits and taking current infeed into account.

Case I - No offset required

With the angle of maximum torque of the relay set at 75 degrees, the percent tap setting required is obtained from the equation on page 5.

$$\text{OUTPUT TAP} = \frac{100\ (3.0)\cos(80.2 - 75)}{6.0}$$

$$= 49.8 \text{ percent}$$

Set the output tap at 50 percent

Case II - Offset required

Since the offset setting is along the reactance axis on the R-X diagram, it is easiest to arrive at the proper tap setting by means of a graphical solution as outlined below:

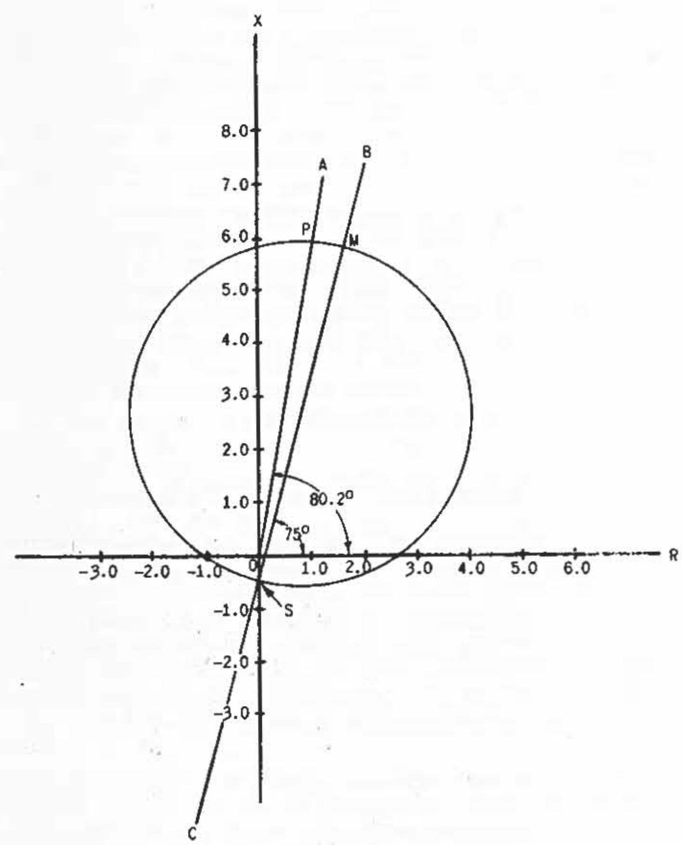


Fig. 12 Graphical Solution To Determine Proper Tap Setting When Mho Unit is Offset

Fig. 12(0127A9443-0)

1. Draw the R-X diagram as in Fig. 12.

2. Draw line $\overline{OA}$ at the impedance angle of the line and measure off the length to be protected. In this case it is 6.0 ohms.

3. Through the point S, representing the offset, which in this case is (R = 0, X = -0.5, draw the line $\overline{BC}$ at the angle of maximum torque for which the relay is set. In this case it is 75 degrees.

4. By trial and error draw a circle which has its center on line $\overline{BC}$ and which passes through both points P and S. This circle represents the desired setting.

5. Measure the diameter of the circle $\overline{SM}$. In this case it measures 6.55 ohms.

6. The desired OUTPUT TAP setting in percent is given by the following equation:

$$\text{OUTPUT TAP} = \frac{(100)\ (\text{Minimum Reach})}{\text{Desired Diameter}}$$

$$\text{OUTPUT TAP} = \frac{(100)\quad(3.0)}{6.55} = 45.8 \text{ percent}$$

Set the OUTPUT TAP for 46 percent.

MAINTENANCE

PERIODIC TESTS

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 increasing arcing and deterioration of the contacts. Abrasive paper or cloth may leave minute particles on 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 normally open contacts of the mho unit should have an .050 - .065 inch gap. Fig. 13 illustrates the mho unit contact adjustments required to obtain proper operation. The gaps should be set by suitable thickness gages.

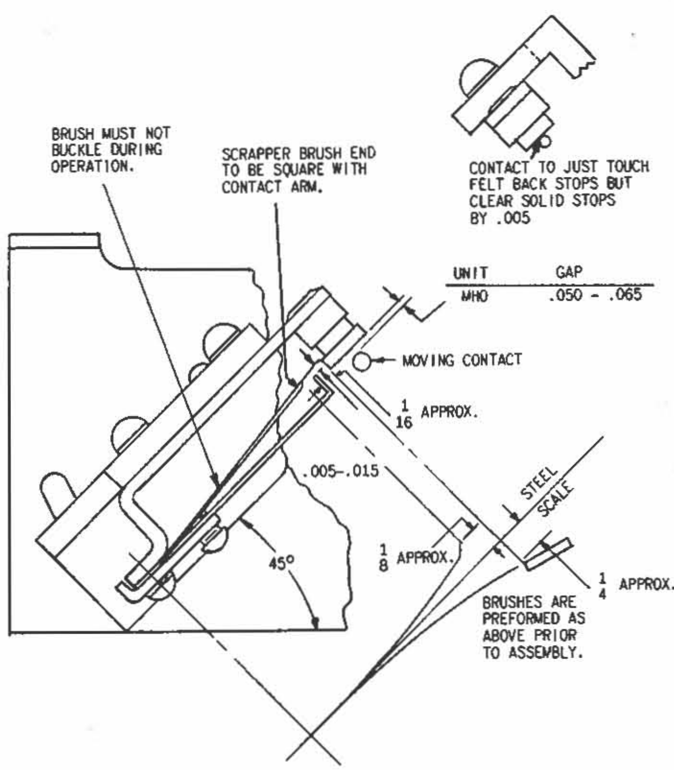


Fig. 13 Contact Adjustment (Normally Open) of CEB17A Relay

b. Control Spring Adjustment

This adjustment is the same as given under the INSTALLATION section.

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. 14A 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.

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

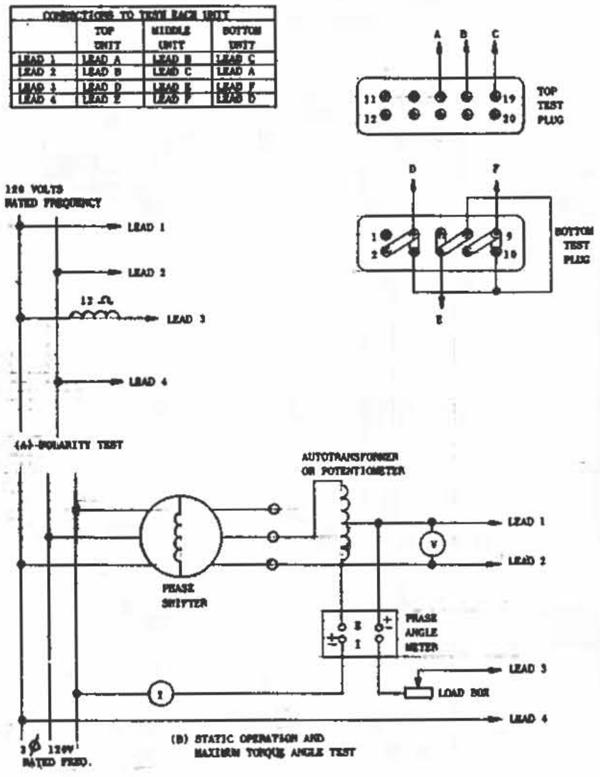


Fig. 14 Test Connections For Checking Correct Mho Unit Operation for CEB17A Relay

e. Directional

To check the directional action of the mho unit, the connections of Fig.14B should be used. Set the mho unit's taps on 100 per cent. With the connections of Fig. 14B 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 of 10 to 60 amps. With the current connections at the relay terminals as shown in Fig. 14B, voltage removed from the relay, and the relay potential terminals shorted the normally open contact of the mho unit should 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 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. 14B. 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. 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. 14B corresponds to the phase-to-phase impedance, and is double the phase-to-neutral or relay impedance, Z. If the contact does not close at the correct current, the setting of the resistor R_{11}, R_{12}, or R_{13} should be changed.

If angular settings are to be checked, use the connections of Fig. 14B 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 normally open 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. If the angle of maximum torque is not correct it can be corrected by adjusting R_{41}, R_{42}, or R_{43} depending on whether it is the top, middle, or bottom unit being adjusted.

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.

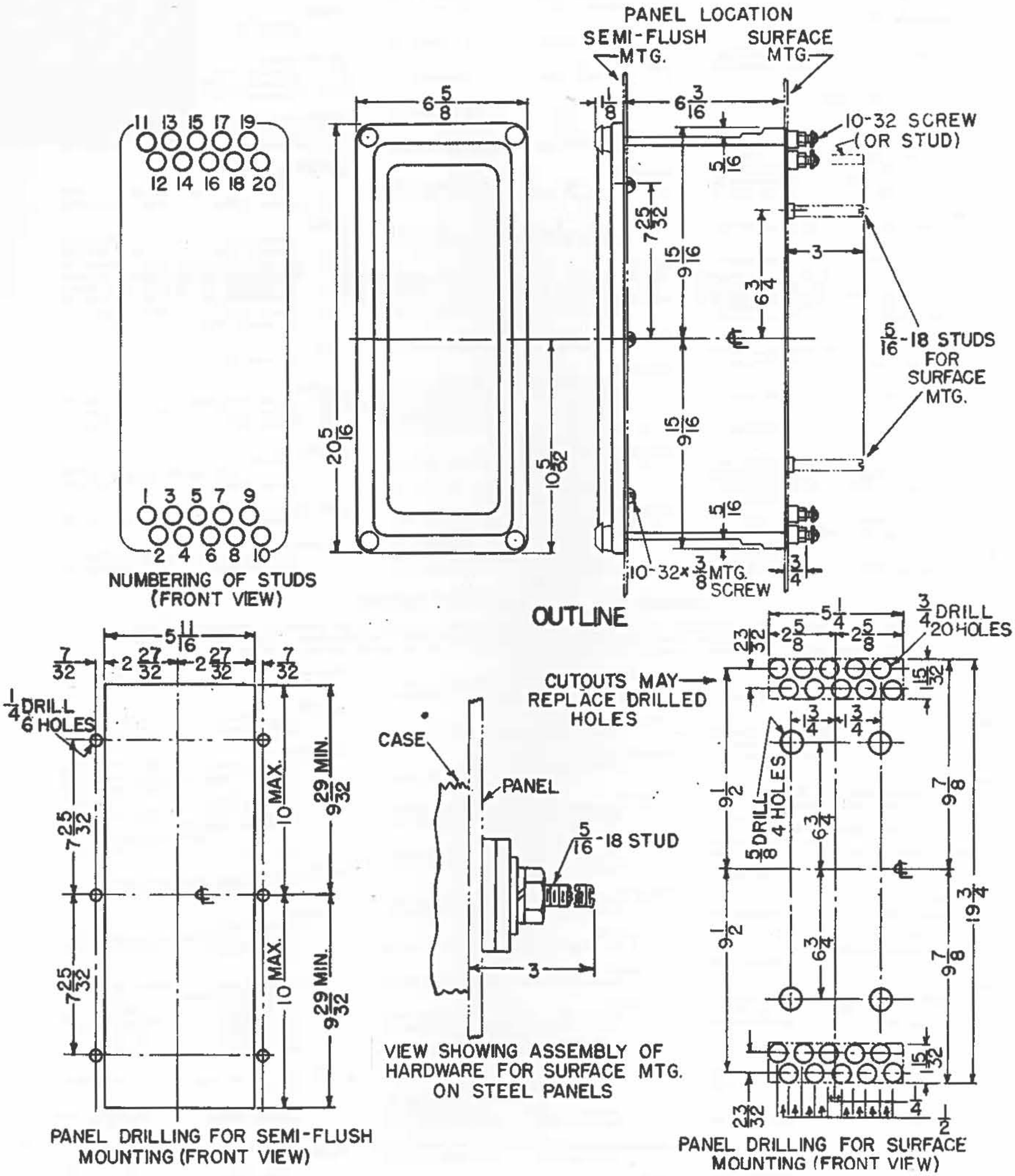


Fig. 15 (6209276-1)

Fig. 15 Outline and Panel Drilling Diagram for CEB17A Relay

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