INSTRUCTIONS

GEH-2037 A

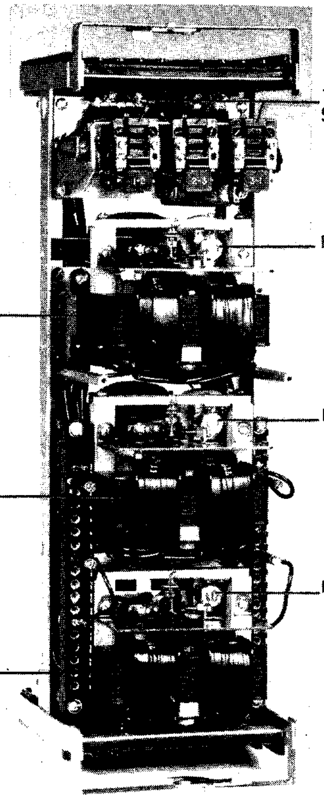
OFFSET MHO RELAY

Type CEB16A

POWER SYSTEMS MANAGEMENT DEPARTMENT

GENERAL ELECTRIC

PHILADELPHIA, PA.

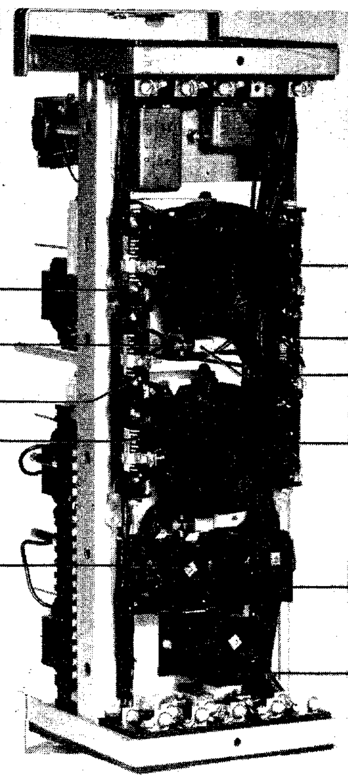


(8025952) A. Front View

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. Tap Block Numbering Details



(8025953) C. Back View

Fig. 1 CEB16A Relay Removed From Case

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NOTES

OFFSET MHO RELAY

TYPE CEB16A

DESCRIPTION

The CEB16A 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. Three target seal-in units provide indication of operation for each unit individually. The transient overreach characteristics of the CEB16A relay have not been limited to the point where it is suitable for use as a first-zone relay. This relay was specifically designed for use with time delay to provide one zone of transmission line back-up protection for three-phase, phase-to-phase and double-phase-to-ground faults.

APPLICATION

The CEB16A was specifically designed for use with time delay as a single-zone back-up relay on transmission circuits. It may be connected for either zero offset or some small offset. When the relay is required to operate in conjunction with time delay for zero voltage faults, it is necessary to use the offset setting. The angle of maximum torque of the CEB16A is adjustable over a range of about 15 degrees. When this relay is employed to protect short lines where arc resistance may be appreciable, it is suggested that the 45 degree angle of maximum torque setting be used. This setting will accommodate more arc resistance than higher maximum torque angle settings. Fig. 14 illustrates how the CEB16A may be used in conjunction with an RPM21D timing relay.

When applying this relay for the protection of a given circuit, it is generally advantageous to select the highest ohmic range that will permit the desired setting. This is true because the forms with the higher ranges operate at a higher torque level.

OPERATING CHARACTERISTICS

OM UNIT ZERO OFFSET

With zero offset connections the characteristics of the OM unit are similar to the characteristics of the basic mho unit.

The OM unit has a circular impedance characteristic that passes through the origin of the R-X diagram, and whose center lies on the angle of maximum torque line.

The minimum operating characteristics of the OM unit are shown in Fig. 2. The angle of maximum torque of the OM unit is continuously adjustable from 45 to 60 degrees, current lagging voltage.

The relay is factory calibrated so that the 45 degree angle of maximum torque setting has a minimum diameter of 2.0 or 3.0 ohm, phase-to-neutral, when the terminal voltage is supplied directly to the OM unit restraint circuit (100% tap setting). When the angle of maximum torque of the OM unit is set at 60 degrees its minimum ohmic reach increases by approximately 8 percent.

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 OM unit circular characteristic is the ohmic reach of the unit, and can be determined from the equation:

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

Where:

OUTPUT TAP = T10 plus T2 tap setting.

Z_{min} = OM unit minimum phase-to-neutral ohmic reach - Given on relay nameplate.

θ = OM unit angle of maximum torque.

ϕ = Phase angle of the line.

At reduced voltage, the ohmic value at which the OM unit will operate may be somewhat lower than its calculated value. This "pullback" or reduction in reach, is shown in Fig. 3 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 OM unit will operate for all points to the right of the curves. The static curves of FIG. 3 were determined by tests performed with no voltage supplied to the relay before the fault was applied. Under dynamic conditions, (rated voltage of 115 volts supplied to the relay before the fault), for a zero voltage fault the OM unit will operate for all fault currents above two amperes.

The OM 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 OM unit, the unit with a 100 per cent tap setting will close its contacts at 1.15 volts and between 6 and 60 amperes. For faults in the nontripping direction, the contacts will remain open at zero volts and between 0 and 60 amperes. The zero volt test means no voltage applied to the potential circuit and with the potential studs of the unit short circuited.

The directional action test was made using the connections of Fig. 21B. With these connections the relay characteristic is as shown in Fig. 2.

Under transient conditions the OM unit has a tendency to close its contact momentarily for a fault impedance greater than its impedance setting. This tendency is called transient overreach and is a function of the degree of asymmetry in the fault current wave, and the circuit angle (The angle of the system from the point of the fault to the source of generation).

For normal CEB16A applications, transient overreach is of no significance since the OM unit does not perform a precise measuring function.

The speed of operation of the OM 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 current, the angle of the circuit, and the tap setting and angle of maximum torque of the OM unit. The time data are presented in Figs. 4 to 9 inclusive 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. Conversely, mimimum operating times are obtained when the fault occurs at that instant in the cycle which produces maximum DC offset currents.

OM UNIT WITH OFFSET

When the offset connections are made the circular characteristic is moved approximately 0.2 ohm along the X-axis as shown by the dashed lines in Figs. 10A and 10B. With offset connections the relay is adjusted at the factory to operate at any current above 8 amperes for a zero voltage fault.

TAPPED AUTOTRANSFORMER

The ohmic reach of the OM units may be adjusted by means of taps of the two (open delta-connected) autotransformers which are brought out to the two tap blocks. The autotransformer taps provide reach adjustment in two percent steps from zero to one hundred percent. The ohmic reach of all three OM units is set by making identical connections on both tap blocks. The tap setting of each unit is the sum of the T2 and T10 settings on either tap block.

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:

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

The minimum ohms of the OM 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 CEB16A relay is rated continuously at 115 volts, 5 amperes, 60 cycles. The relay is available in ohmic ranges of 0.5 - 5.0 and 2.0 - 20 ohms, phase-to-neutral. The reach of the OM units can be adjusted in two percent steps. Two fixed selections of offset are available: (1) zero offset, (2) 0.2 secondary phase-to-neutral ohms at 90 degrees, current leading voltage. The angle of maximum torque of the OM unit is continuously adjustable from 45 to 60 degrees, current lagging voltage. The reach of the OM unit is rated on the basis of its 45 degree angle of maximum torque setting.

The one second thermal rating of the current circuits of these relays is 260 amperes.

The trip circuit of the relay will close and carry monentarily 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 connot interrupt tripping current. If the tripping current should exceed 30 amperes it is recommended that an auxiliary tripping relay be used.

Each combination target seal-in unit has a dual rating. Two different combinations are available: (1) 0.2/2.0 and (2) 0.6/2.0 amperes. The tap setting used on the target seal-in unit is determined by the current drawn by the trip coil. The 0.2 or 0.6 ampere tap is used with trip coils which operate on currents ranging from 0.2 to 2.0 amperes or 0.6 to 2.0 amperes respectively 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 7.5 (0.2 amp tap) or 0.6 (0.6 amp tap) ohm resistance of the target seal-in coil does not cause excessive voltage drop. The 0.2 and 0.6 ampere seal-in tap can carry 10 and 30 amperes respectively for one half second without overheating. The 2.0 and 0.6 ampere seal-in tap can carry 10 and 30 amperes respectively 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 four seconds without overheating.

TABLE I

TARGET AND SEAL-IN UNIT RATINGS

	2 Amp Tap	0.6 Amp Tap	0.2 Amp Tap
DC Resistance	0.13 ohma	0.6 ohms	7.5 ohms
Mimimum Operating	2.0 amps	0.6 amps	0.2 amps
Carry Continuously	4.0 amps	1.2 amps	0.4 amps
Carry 30 amperes for	4.0 sec	0.5 sec	+

\+ This tap will carry 10 amperes for one half second.

BURDENS

The maximum current burdens imposed on each CT with a practical setting at 5 amperes, 115 volts and 60 cycles are listed in Table III. The Burden was measured under phase-to-phase, fault conditions which yields higher burden readings than balanced three-phase conditions.

TABLE III

CURRENT BURDEN

OHMIC RANGE		R (Ohms)	X (Ohms)	Z (Ohms)	VA (Volt-Amps)
WITHOUT OFFSET	0.5 - 5	0.007	0.001	0.007	0.18
	2 - 20	0.012	0.012	0.017	0.43
	3 - 30	0.018	0.018	0.023	0.58
WITH OFFSET	0.5 - 5	0.015	0.012	0.020	0.50
	2 - 20	0.024	0.023	0.033	0.83
	3 - 30	0.029	0.029	0.046	1.15

The maximum potential burden imposed on each P.T. with a practical setting at 115 volts, 5 amperes, 60 cycles for the o.5, 2 and 3 ohm OM units is listen in TABLE IV.

TABLE IV

WATTS	VARS	VOLT AMPERES
14.6	4.5	15.3

The potential burden of the OM unit is altered by changing the restraint tap setting in order to choose the proper reach.

The burden for any set conditions can be computed by using the equations below:

$$\text{Watts} = 8.6 + \left[\frac{\text{Tap Setting}}{100}\right]^2 6.0$$

$$\text{Vars} = 2.4 + \left[\frac{\text{Tap Setting}}{100}\right]^2 6.9$$

CONSTRUCTION

The OM units of the CEB16A 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 poles 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:

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

where E is the phase-to-phase voltage

I is the delta current $(I_1 - I_2)$

θ is the angle of maximum torque of the relay.

ϕ is the power factor angle

K is the design constant

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

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

Thus the relay will pickup at a constant component of admittance at a fixed angle depending upon the maximum torque angle of the unit, hence the name mho unit. When the offset is provided, the basic name is redesignated as OM unit.

The OM 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. 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.

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 the relay, an examination should be made for any damage sustained during shipment. If injury or damage resulting from rough handling is evident, a claim should be filed at once with the transportation company and the nearest Sales Office of the General Electric Company notified promptly.

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 the section or under the MAINTENANCE section.

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

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

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

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

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

OM UNITS

The OM units are properly calibrated at the factory and it is not advisable to disturb the calibration. If it is desirable to check the factory calibration, refer to the ELECTRICAL CHECK TESTS subsection of the INSTALLATION section.

The reach of the OM unit can be adjusted in two per cent steps by proper positioning of the autotransformer tap leads (T_{10} & T_{12}) on both (right & left) tap blocks. The angle of maximum torque of the relay is set at 45 degrees, current lagging voltage and may be set at 60 degrees, current lagging voltage by test. For angle of maximum torque setting procedure refer to Recalibration (Page) under MAINTENANCE.

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 OM 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 0.010 to 0.015 inch end play to the shaft.

TARGET SEAL-IN UNITS

The choice of tap on the target 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 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 OM 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 OM unit at low currents. This effect is shown in Fig. 3

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 OM UNITS

The manner in which the OM unit tap settings are determined is described in the CALCULATIONS section, and the manner in which the tap settings are made is discussed in the ADJUSTMENTS subsection of the INSTALLATION section. It is the purpose of the electrical test in this section to check the factory calibrations of the OM unit and/or the ohmic pickup of the OM unit (no offset) at the settings which have been made for a particular line section.

a. OM Unit Test Equipment

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 + jXL 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 + jXL 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.

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

IMPORTANT: The test resistor has a one minute current rating of 10 amperes. Excessive currents should not flow through this resistor for extended periods of time.

b. Testing OM Unit

NOTE: Before making pickup or phase-angle checks, the OM unit should be allowed to heat up for approximately 15 minutes energized with rated voltage alone.

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

$$2Z_{Relay} = 2 \frac{100\ Z_{min.}}{} \cos(\theta - \phi)$$

Where ϕ is the angle of the test reactor impedance and θ is the relay angle of maximum reach. The test box autotransformer percent tap for the OM unit pickup is given by:

$$\%\ tap = \frac{2Z_{Relay}}{Z_L} \times (100)$$

As an illustration of the above instructions, the percent tap required on the test box autotransformer to check an OM unit (no offset) that has been factory calibrated for a 2 ohm minimum reach and 60 degree angle of maximum torque will be calculated. 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:

$$2Z_{Relay} = 2 \frac{200}{100} \cos(80-60) = 3.6 \text{ ohms}$$

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:

$$Z_L = \frac{X_L}{\sin 86} = 6.115$$

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 OM unit contacts (on offset) with the fault switch closed is:

$$\% = \frac{3.6}{6.1} (100) = 59\%$$

If the ohmic pickup of the OM unit checks correctly according to the above, the chances are that the angle of the characteriatic 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 OM unit reach at the 60 degree positions. The OM 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. It should not be necessary to check the ohmic pickup at more than two impedance angles to ascertain the accuracy of the angle of maximum torque setting. These two points and the origin would then define the circular characteristic of the OM unit under test.

When checking the angle of maximum reach of the OM unit as indicated above, there are two vactors to keep in mind which affect the accuracy of the results. First, when checking the OM unit at angles of more than 30 degrees of 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. Secondly, the effect of the control spring should be considered since the OM unit can only have a perfectly circular characteristic when the control spring torque is negligible. For any normal level of polarizing voltage, the control spring may be neglected but in testing the unit as indicated above it may be necessary to reduce the test box autotransformer tap setting to a point where the voltage supplied to the unit may be relatively low, This reduces the torque level since the polarizing as well as the restraint will be low with the result being that the control spring torque will no longer be negligible. The result of the control spring at low polarizing voltages is to cause the reach of the OM unit to be somewhat reduced.

TRIP CIRCUIT

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

SETTINGS

The reach setting of the CEB16A will generally depend on the line being protected the impedance of the adjacent line sections and the specific scheme of application. 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 with no offset, $\overline{OA}$ represents the reach setting and $\overline{OB}$ is the maximum permissable reach for coordination purposes with adjacent circuits. If arc resistance for a fault at $\overline{A}$ is given by $\overline{AC}$ then the impedance as seen by the relays at $\overline{O}$ for such a fault would be $\overline{OC}$. This is outside of the relay characteristic and would have to be tripped by some other relay with a larger reach setting.

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 at $\overline{E}$ 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. If such a situation is encountered relay reach setting may be reduced enough to compensate for it. With a 60 degree angle of maximum torque setting this effect will prevail only if the line impedance angle exceeds 75 degrees.

The reach of the relay without offset 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

Assume that it is desired to set the CEB16A to reach the equivalent of 5 miles of 69 kv line having a primary impedance

Z_{prim} = 0.14 + j 0.80 ohms per mile with a PT ratio of 69,000/115 and a CT ratio of 600/5.

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

$$Z_{sec} = (0.7 + j\,4.0)\ \frac{120}{600} = 0.14 + j0.8 \text{ ohms}$$

$$Z_{sec} = 0.81 \angle 80^{o}$$

Case I - No offset required

Use the 0.5 - 5.0 ohm relay to obtain the required reach setting. Since the line is short, set the angle of maximum torque at 45 degrees.

From the equation on page 7 the percent tap setting required is:

$$\text{OUTPUT TAP} = \frac{100\ (0.5)\ \text{Cos}\ (80-45)}{0.81} = 50.5 \text{ percent}$$

Set the output tap for 50 percent

Since the line impedance angle, ϕ, is greater than 67.5 degrees, the situation illustrated in Fig. 18 exists. A graphical construction to scale will indicate that in this case the maximum possible "overreach" due to arc resistance will be about 6 percent. If desired, this may be compensated for by setting the relay with a tap setting of:

$$\text{OUTPUT TAP} = (1.06)\ (50.5) = 53.5 \text{ percent}$$

Set the OUTPUT TAP for 54 percent.

Case II - Offset Required

Use the o.5 - 5.0 ohm relay to obtain the required reach setting. Set the angle of maximum torque at 45 degrees. 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:

1. Draw R-X diagram as in Fig. 19.

2. Draw line $\overline{OA}$ at the impedance angle of the line and measure off the length to be protected ($\overline{OP}$). In this case it is 0.81 ohms.

3. Through the point S, representing the offset, which in this case is (R = 0, X = - 0.2), draw the line $\overline{BS}$ at the angle of maximum torque for which the relay is set. In this case it is 45 degrees.

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

5. Measure the diameter of the circle $\overline{SM}$. In this case it measure 1.25 ohms.

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

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

in this case

$$\text{OUTPUT TAP} = \frac{(100)\ (0.5)}{1.25} = 40 \text{ percent}$$

Set the OUTPUT TAP for 40 percent

It will be noted from Fig. 19, that a small amount of arc resistance can effectively extend the reach of the relay. Thus, with arc resistance in the order of R_{arc} the relay with the given setting will actually see a fault at Q. If this "overreach" is undesirable, then step 4 above could be modified so that the relay characteristic is drawn through points S and N rather than P and S. This will shorten the reach for faults without arc resistance. In general, since this is not a first zone relay a small amount of overreach due to arc resistance may not be objectionable. For the conditions assumed here about 10 percent overreach appears possible. This figure becomes smaller and disappears eventually as the line angle is reduced and or the maximum torque angle of the relay is increased.

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 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 ket obtainable from the factory.

SERVICING

OM UNITS

a. Contact Adjustment

The contacts of the OM unit should have a 0.020 inch gap when open, and should have no wipe beyond that due to the compressibility of the felt backstop. Fig. 2C illustrates the OM unit contact adjustments required to obtain proper operation. The gaps should be set by suitable thickness gages.

b. Control Spring Adjustment

After the CEB16A relay has been mounted in its test stand, the control spring of each unit should be adjusted so that the moving contact will just return to the right backstop when the relay is de-ener-gized. 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 OM 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 0.010 - 0.015 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.

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 OM unit is adjusted by means of the steel collar at the upper end of the rotation 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 by 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. 21A may be used. With these connections, the OM unit taps on taps on 100 per cent, and no offset, the mho unit contacts should remain open.

The correct polarity for the OM unit is indicated by the closing of the left-hand contact of the OM unit when the T2 tap leads are removed from the autotransformer tap blocks.

e. Directional

To check the directional action of the OM unit, the connections of Fig. 21B should be used. Set the OM unit taps on 100 percent. With the connections of Fig. 21B adjust the phase shifter to the 45 degree angle of maximum torque. With 1.15 volts applied to the potential circuit, the OM unit contact should be closed over the range of 6 to 60 amperes. With the current connections at the relay terminals shown in Fig. 21B, voltage removed from the relay, and the relay potential studs shorted, the contact of the OM unit should remain open from 0 to 60 amperes.

If the OM 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 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 OM unit mounting plate. This adjusting screw is accessible from the right side of the relay. If the OM unit contact fails to close at the high current level, turn the core adjusting screw slightly clockwise. If the OM 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

Befor pickup or phase angle checks are made, the OM 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 percent. If the relay is permitted to warm up, the error due to temperature will be less than one percent.

If the pickup of the OM unit (on offset) is to be calibrated by test, use the connections of Fig. 21B. Carefully calibrated meters are an absolute necessity if the relay calibration tests are to be carried out successfully. Set the OM 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 OM unit. Increase the current to determine the OM unit pickup current. The impedance calculated from the ratio of the voltage and current readings with the connections of Fig. 21B 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. 21B with about 55volts 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. If the angle of maximum torque is not correct it can be corrected by adjusting R_{31}, &R_{41},R_{32},&R_{42} or R_{33} & R_{43}, depending on whether it is the top, middle, or bottom 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.

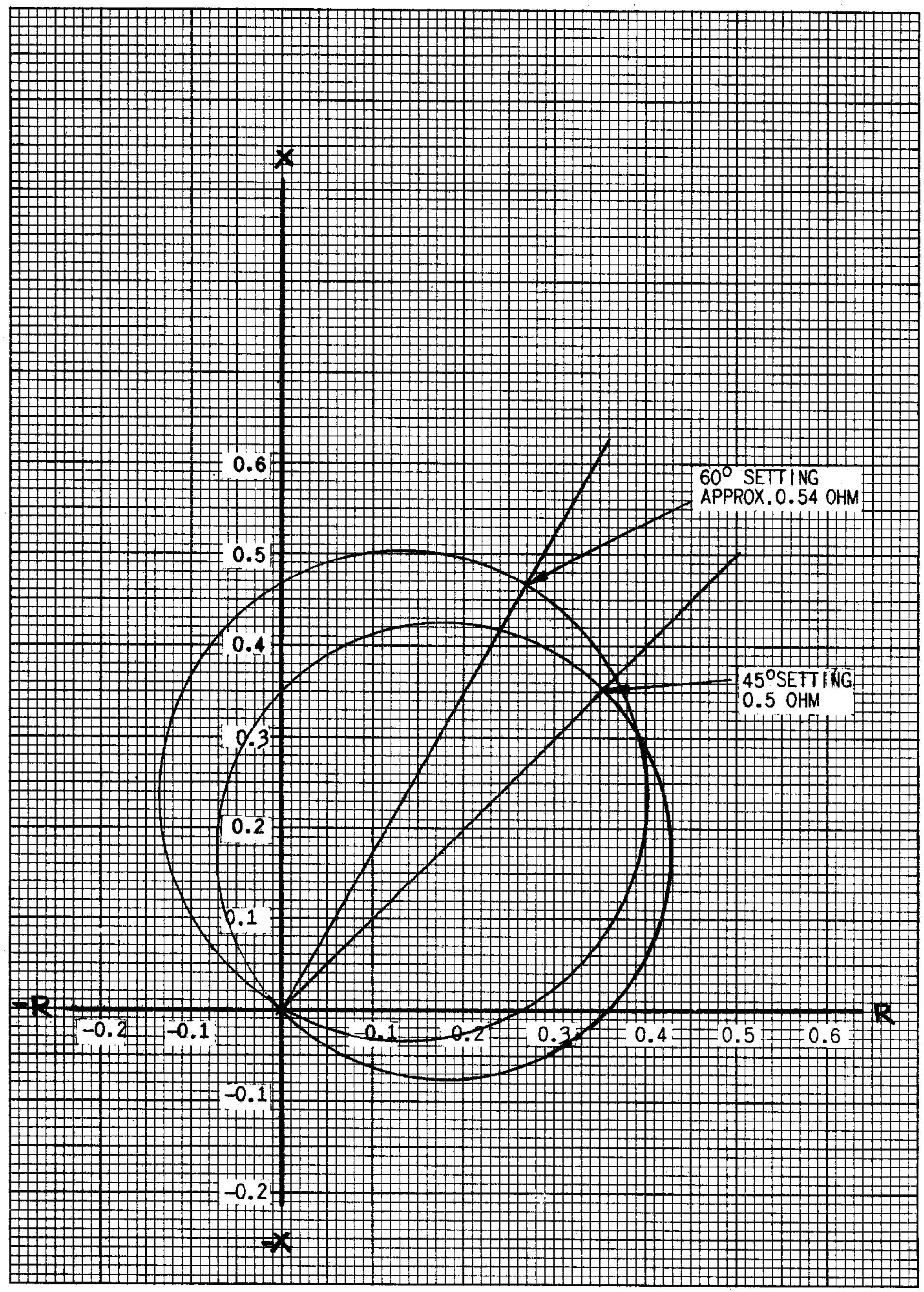


Fig. 2 (0127A9544-0 Sh. 1) Minimum Static Operating Characteristics of 0.5 Ohm Unit - No Offset

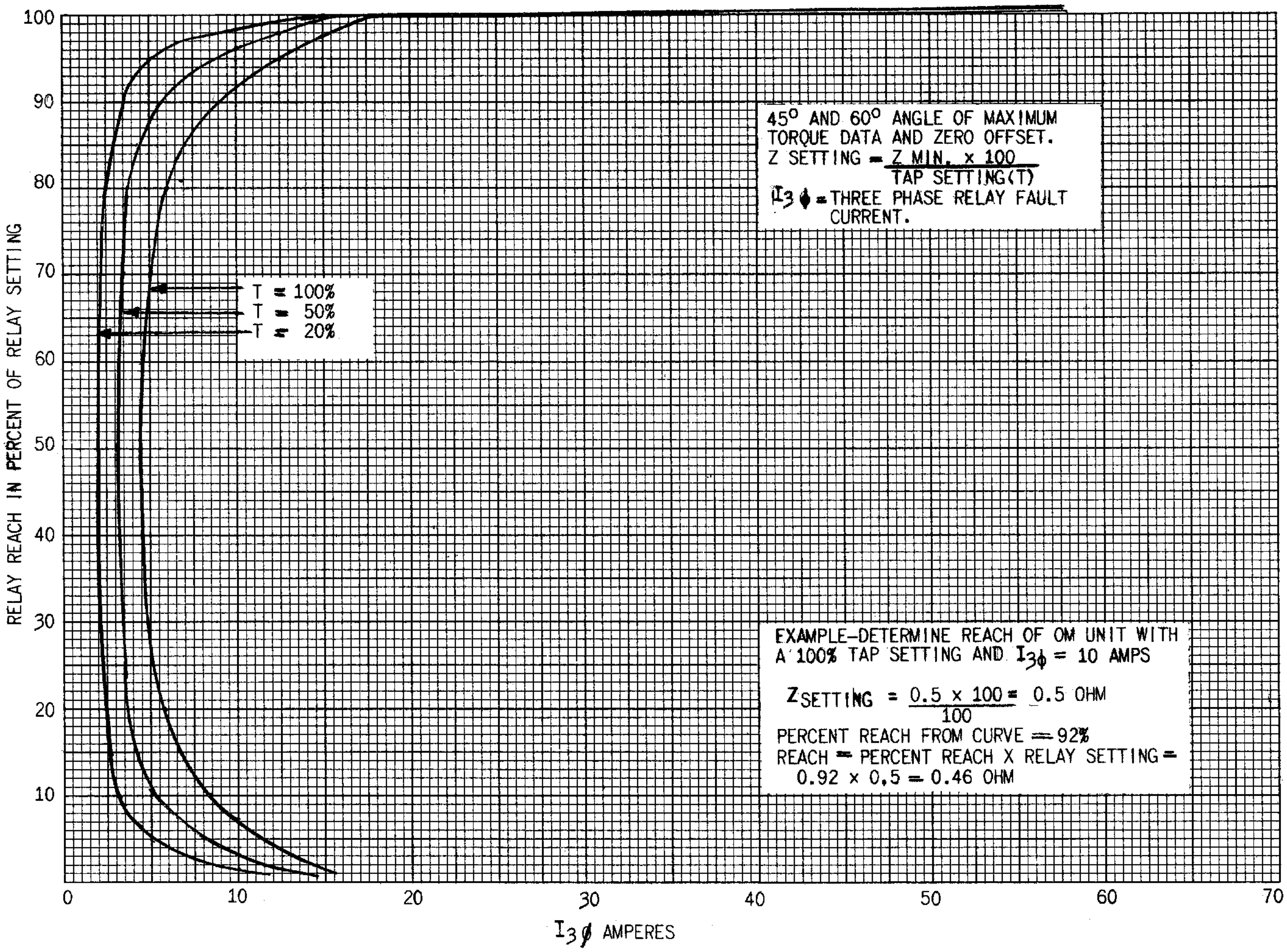


Fig. 3 (0127A9543-0) Static Accuracy Characteristic of 0.5 Ohm Om Unit No Offset

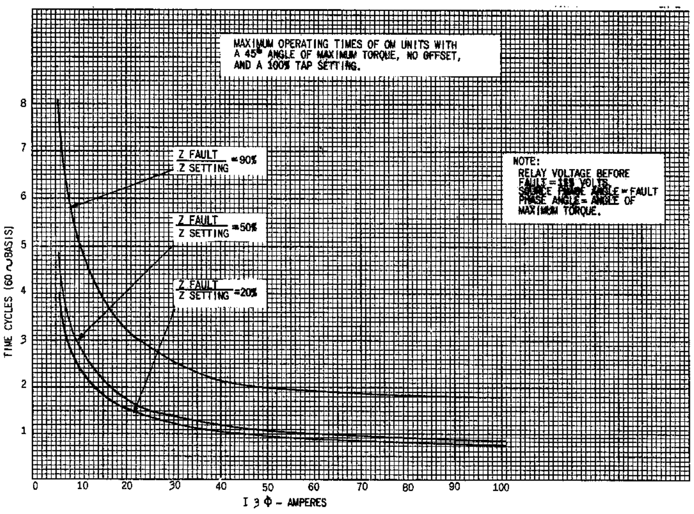


Fig. 4 (0127A9542-0 Sh 1) Maximum Operating Times of Om Unit with 45° Max. Torque Angel, 100% Tap Setting and no Offset

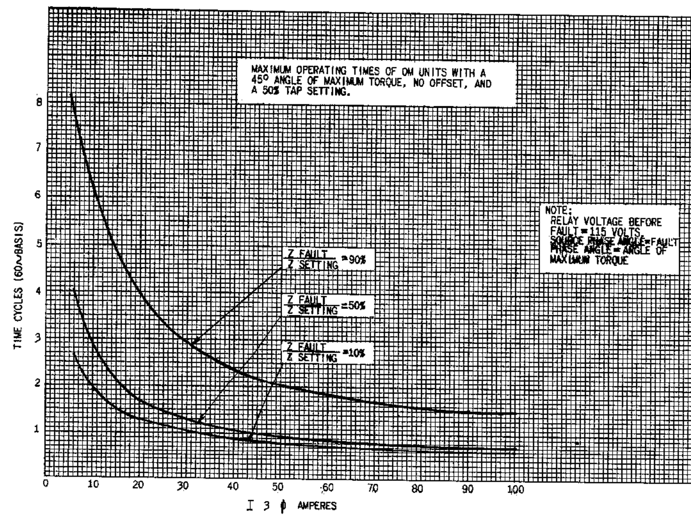


Fig. 5 (0127A9542-0 Sh 2) Maximum Operating Times of Om Unit with 45° Max. Torque, 50% Tap Setting and no Offset.

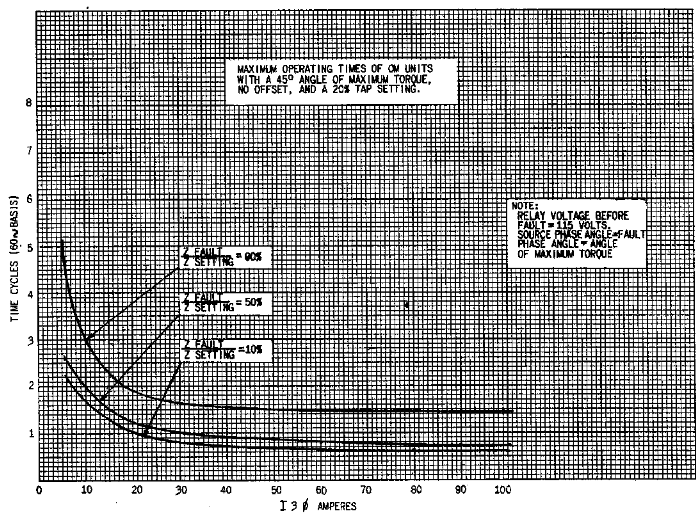


Fig. 6 (0127A9542-0 Sh 3) Maximum Operating Times Max. Torque Angle, 20% Tap Setting and no Offset.

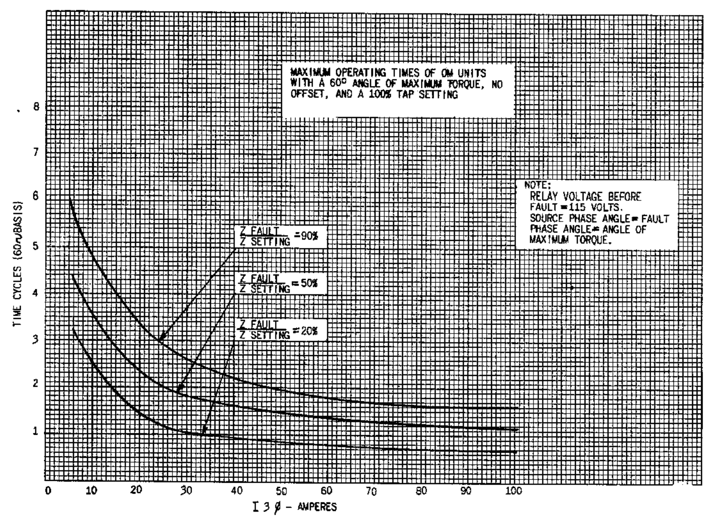


Fig. 7 (0127A9542-0 Sh 4) Maximum Operating Times of Om Unit with a 60° Max. Torque Angle, 100% Tap Setting and no Offset.

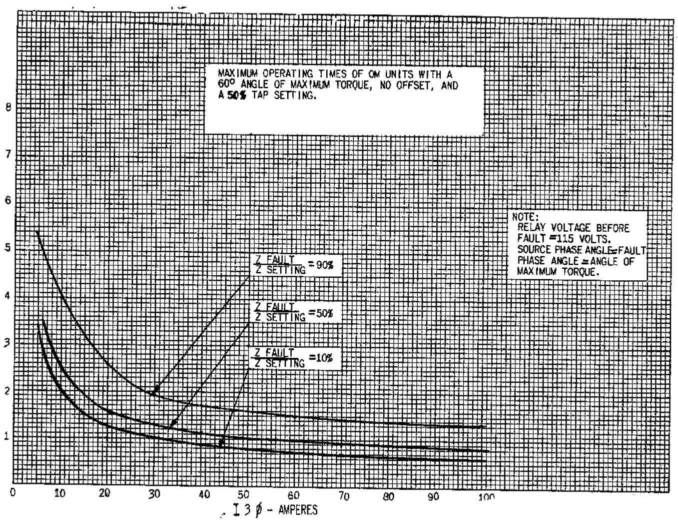


Fig. 8 (0127A9542-0 Sh 6) Maximum Operating Times of Om Unit with A 60° Max. Torque Angle, A 50% Tap Setting and no Offset.

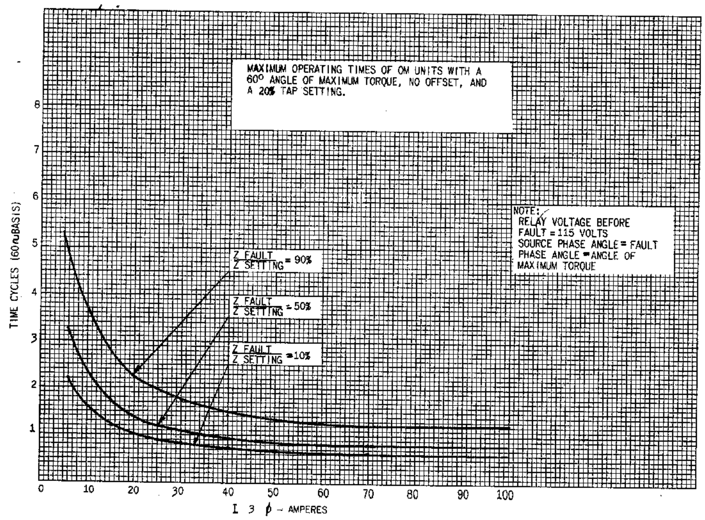


Fig. 9 (0127A9542-0 Sh 5) Maximum Operating Times of Om Unit with A 60° Max. Torque Angle, A 20% Tap Setting and no Offset.

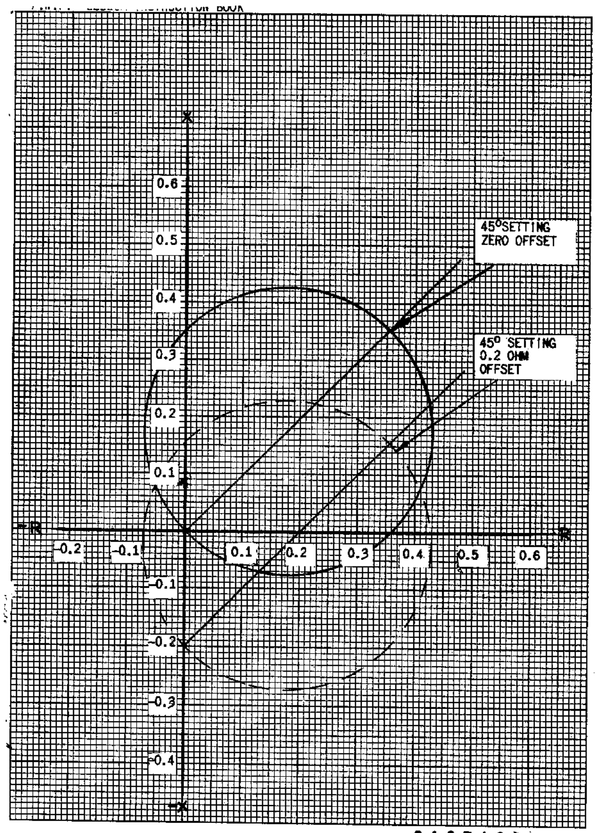


Fig. 10A (0127A9544-0 Sh 2) Minimum Static Operating Characteristics with Offset. 45° Max. Torque Angle.

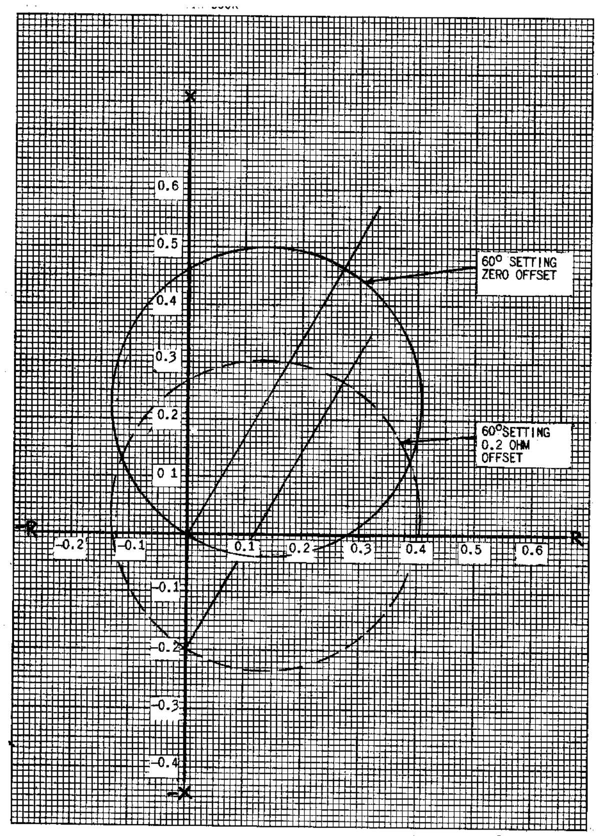


Fig. 10B (0127A9544-0 Sh 3) Minimum Static Operating Characteristic with Offset. 60° Torque Angle.

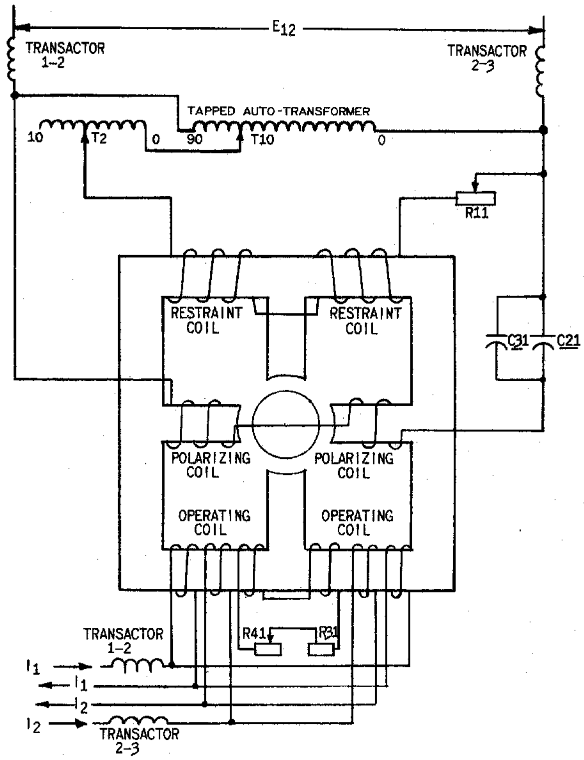
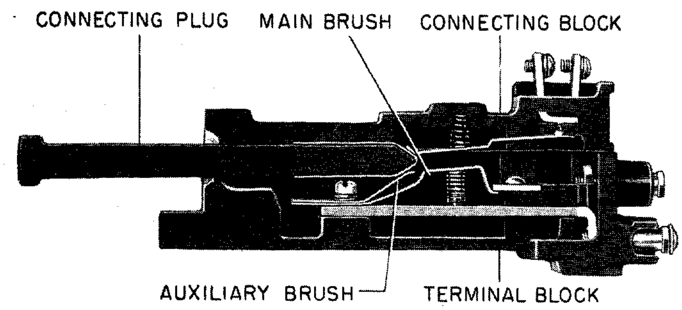


Fig. 11 (0127A9533-0) Schematic Connections of the Om Units in A CEB16A Relay



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

Fig. 12 (8025039) Cross Section of Drawout Case Showing Position of Auxiliary Brush

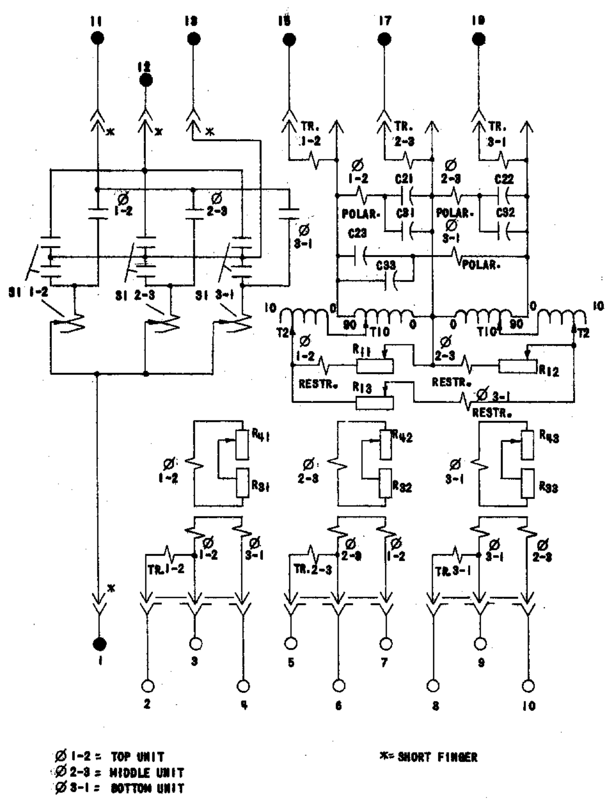


Fig. 13 (0148A8591-1) Internal Connections Diagrams of CEB16A Relay (Front View).

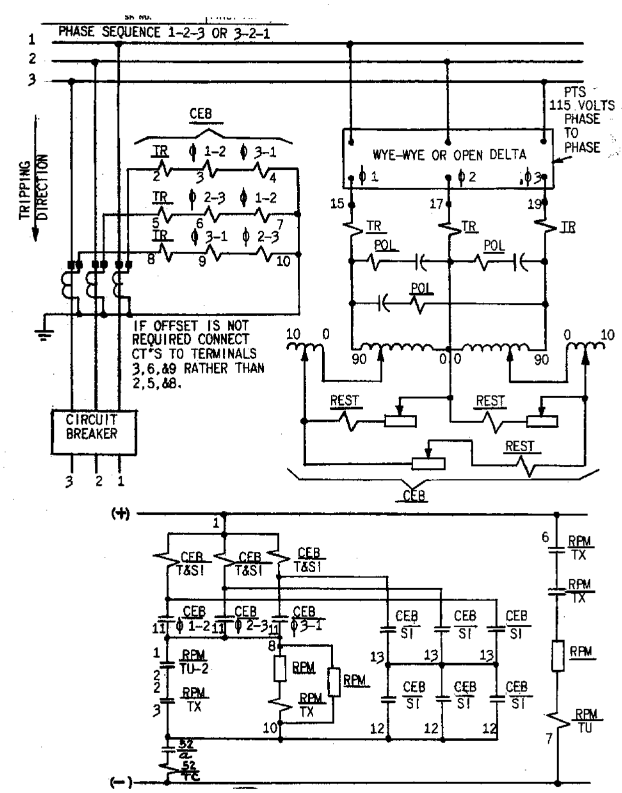
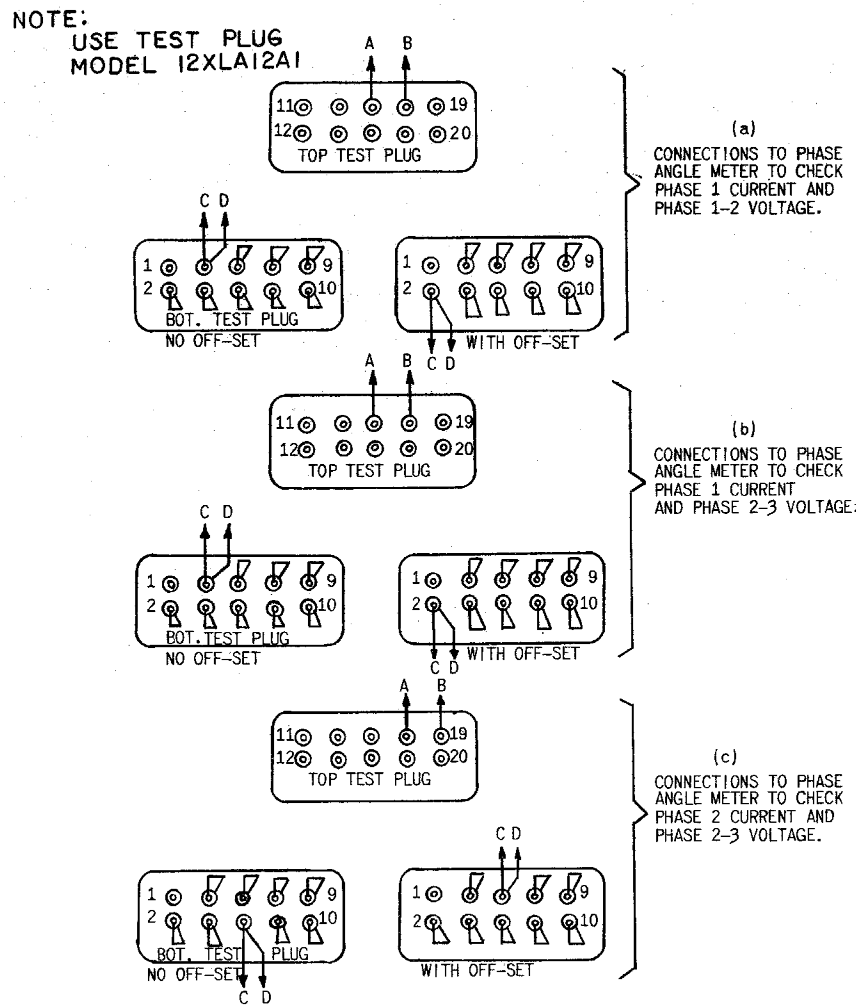
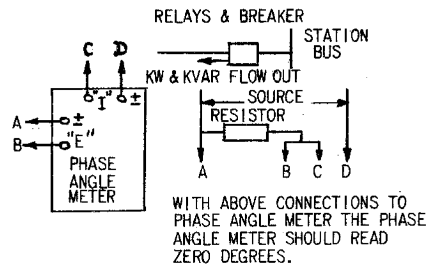


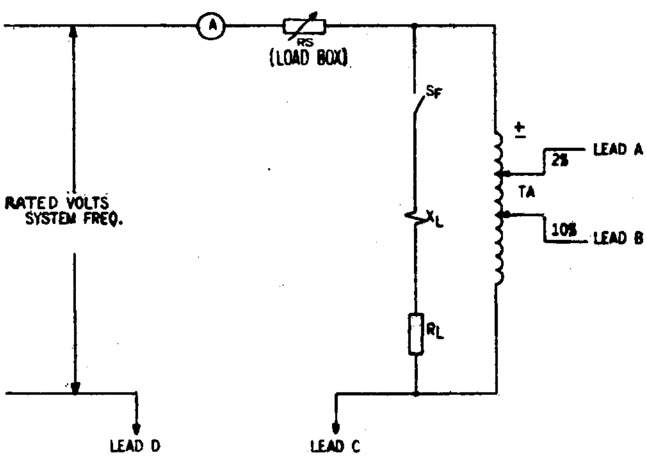
Fig.14 (0127A9513-0) Typical External Connection Diagram of CEB16A Relay and PRM21D Timing Relay.





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

Fig. 15 (0264B470-1) Overall Test Connections For Checking of External Wiring to CEB16A Relay



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. 16 (0127A9518-0) Test Connections for Checking Ohmic Pickup of Om Unit.

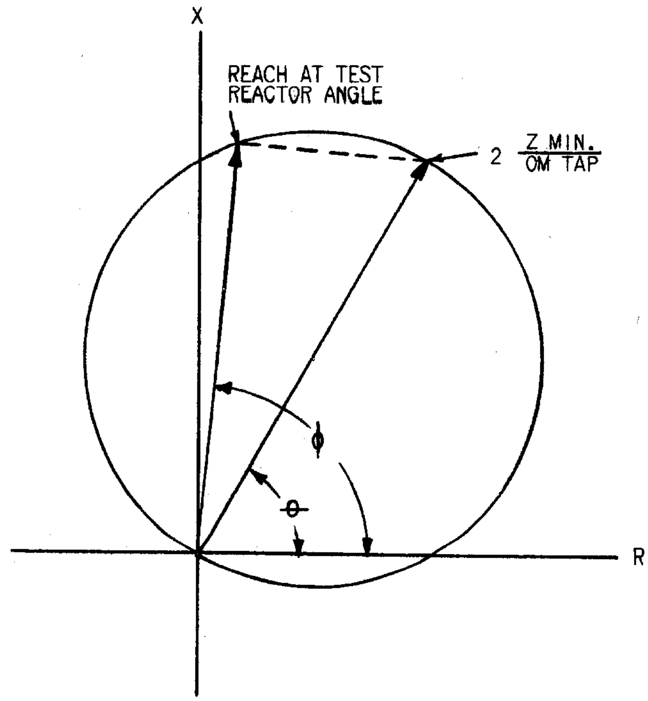


Fig. 17 (0127A9532-0) Reach of Om Unit at the Angle of the Test Reactor.

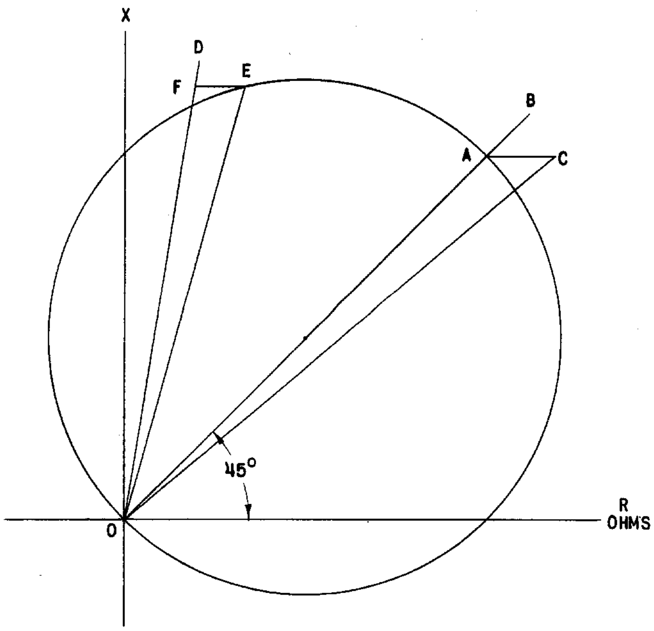


Fig. 18 (0418A957-0) Affect of Arc Resistance on Impedance as Seen by Om Units.

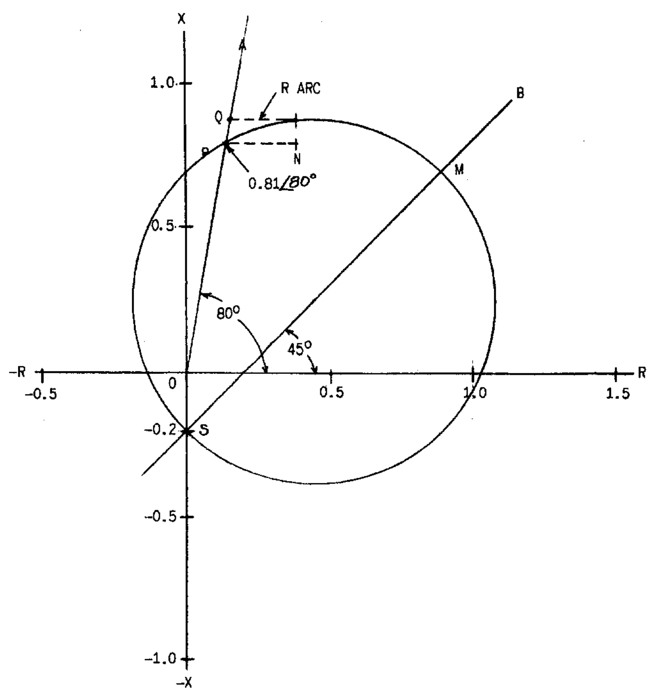


Fig. 19 (0127A9538-0) Graphical Construction of CEB16A Impedance Diagram with 0.2 Ohm Offset.

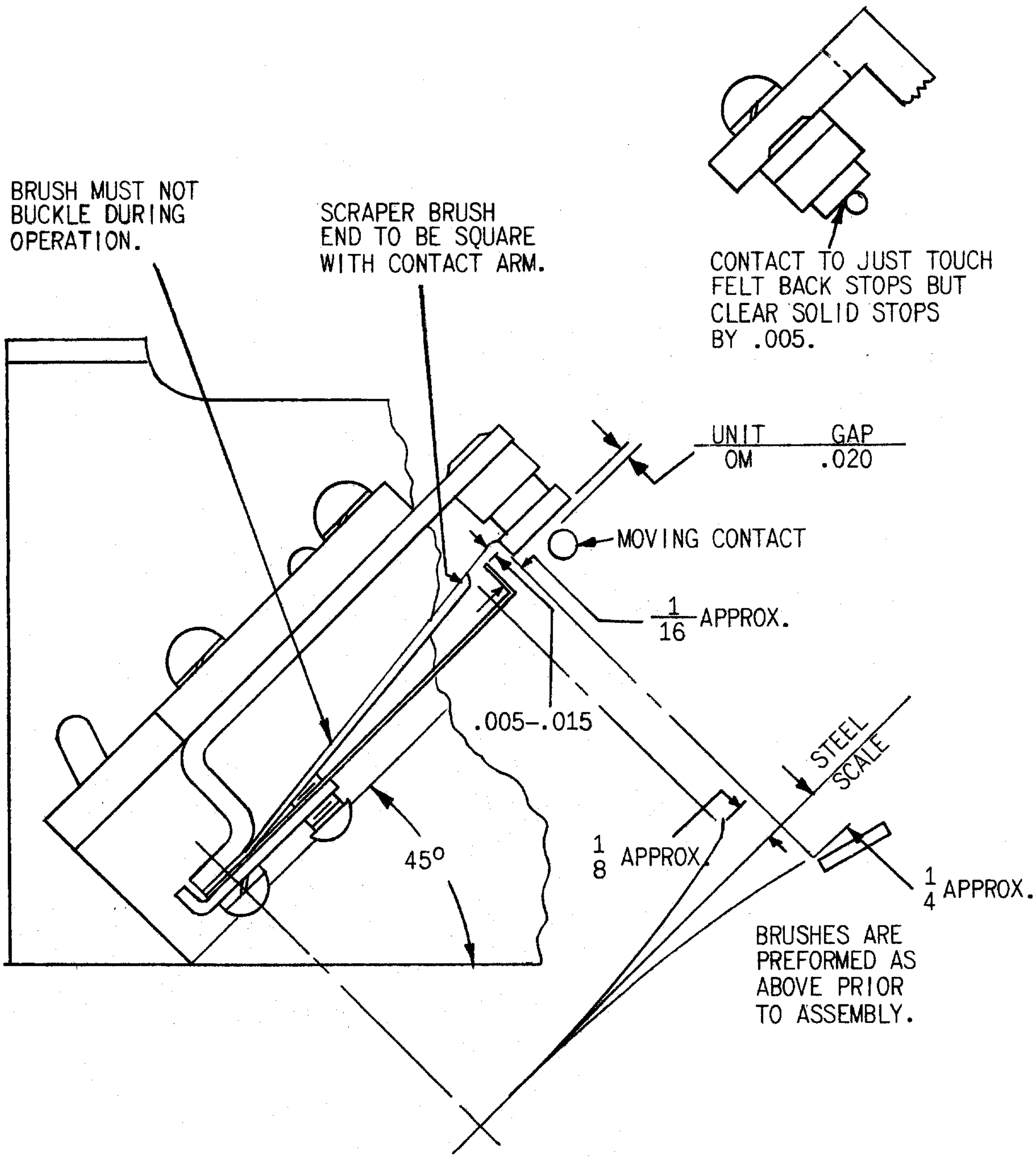
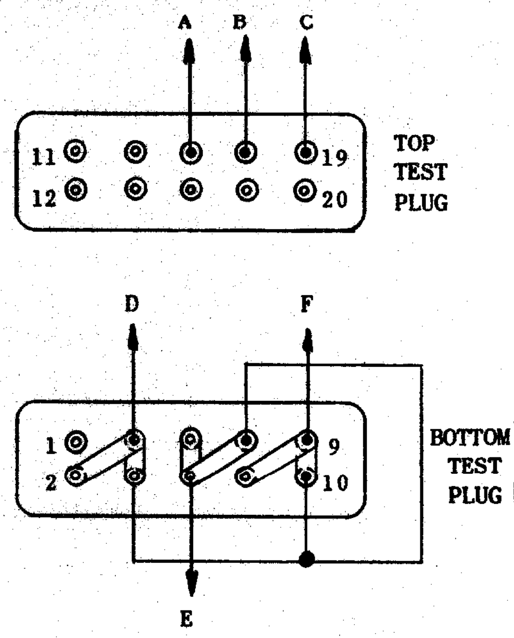
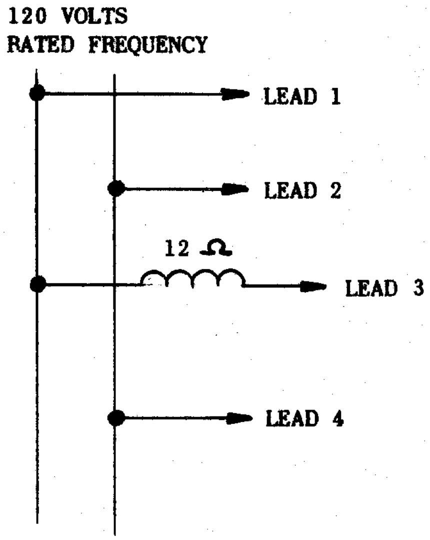


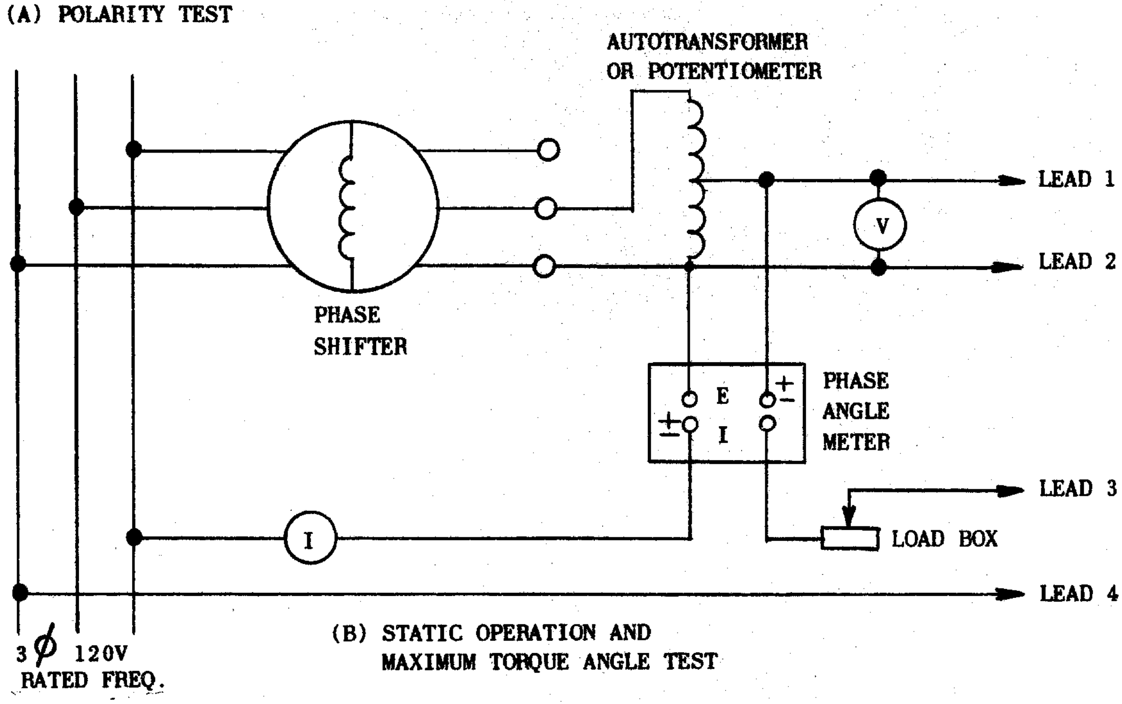
Fig. 20 (0127A9534-0) Om Unit Contact Adjustments

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





(A) POLARITY TEST



(B) STATIC OPERATION AND MAXIMUM TORQUE ANGLE TEST

Fig. 21 (0127A9523-0) Test Connections for Checking Correct Om Unit Operation.

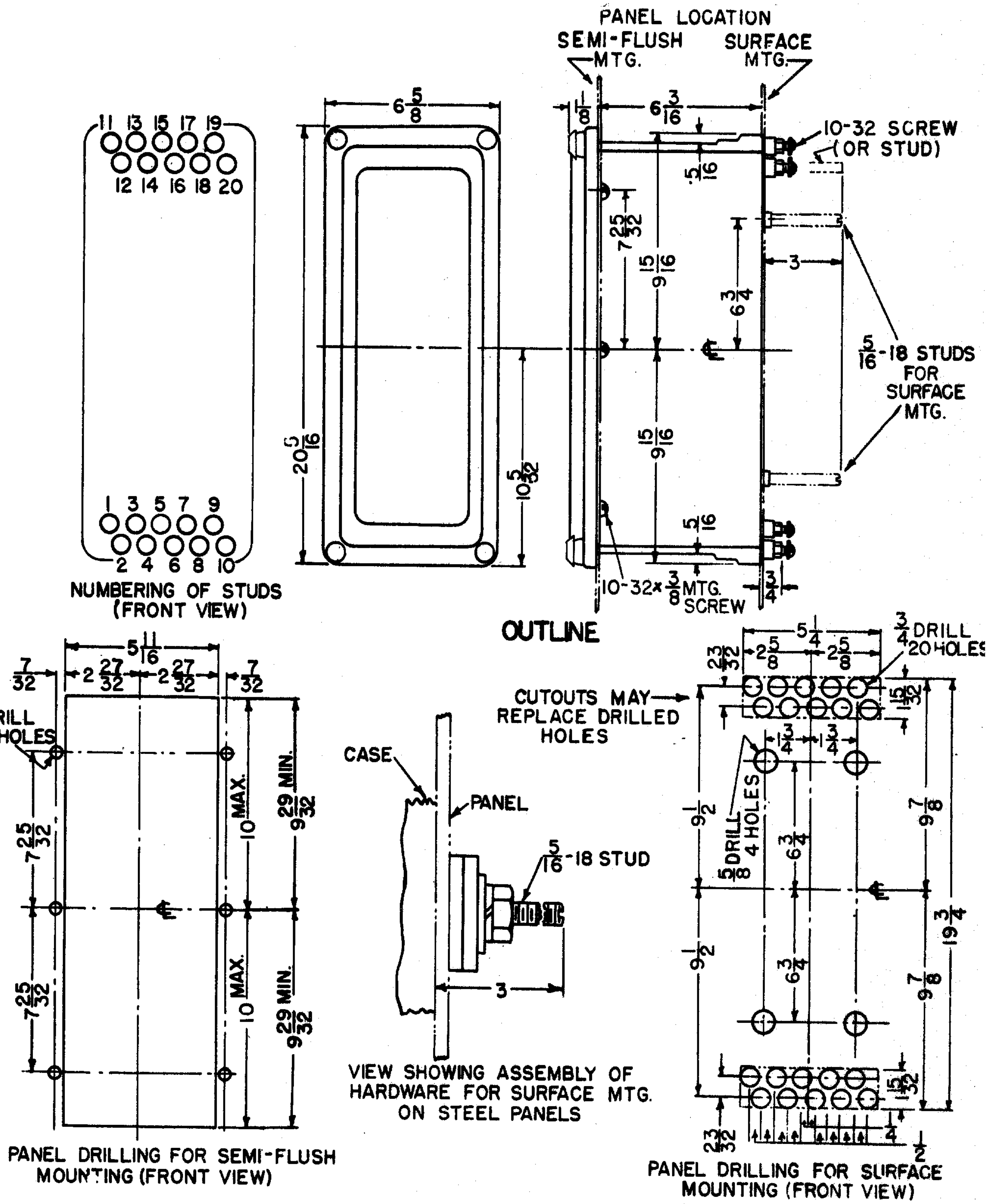


Fig. 22 (06209276-1) Outline and Panel Drilling Diagram of CEB16A Relay.