INSTRUCTIONS

GEK-45329A

SUPERSEDES GEK-45329

OFFSET MHO RELAY

TYPE CEB13C

GENERAL ELECTRIC

CONTENTS

OFFSET MHO RELAY

TYPE CEB13C

DESCRIPTION

The Type CEB13C relay is a three-phase, single-zone mho distance relay with provisions for offsetting the characteristic. It is a special purpose relay in that it was designed for use in applications where a delta-wye, or wye-delta transformer bank exists between the relay location and the protected line. One CEB13C plus a suitable RPM or SAM timing relay will provide one zone of time delay distance phase fault protection. The relay is not suitable for use as a first zone device.

The Type CEB13C relay includes three targets and a seal-in unit. It is mounted in the size L2 case, the outline and panel drilling dimensions for which are shown in Figure 4. The internal connections for the relay are illustrated in Figure 3.

APPLICATION

The CEB13C relay finds application where a delta-wye, or wye-delta transformer bank exists between the relay and the circuits to be protected. Because of this it is ideally suited for application in unit generator protection schemes to provide back-up protection against faults on the adjacent system that are not cleared by the first line relays.

Figure 5A and 5B illustrate the external ac and dc connections to the CEB13C relay for this type of protection. In this scheme a separate auxiliary tripping relay, device 94, is used to isolate the d-c supply to the back-up relaying from the d-c supply to the generator main breaker. This will make it possible for the relay to shut the generator down in the event that a high voltage bus fault occurs during a loss of d-c supply to the main breaker trip circuit.

Since the CEB13C relay is measuring impedance that is on the remote side of a delta-wye transformer, the actual impedance must be corrected to take this into account. Thus, for the ac connections of Figure 5A the CEB13C relay will see the following impedance:

$$Z = 0.866(Z_T + KZ_L)\left[\frac{V_L}{V_H}\right]^2\left(\frac{\text{CT Ratio}}{\text{PT Ratio}}\right)$$

where:

Z_L = Primary Ohms of line impedance

K = Ratio of current in line (Z_L) to current in the line side of the power transformer. This constant corrects for infeed. (See Figure 6) *

V_L/V_H = Low side to high side voltage ratio of power bank on Taps Used.

Z_T = Power transformer impedance in ohms referred to the high side winding.

The worked example in the section under "Calculation of Settings" illustrates how this equation is used to calculate the desired relay reach setting when it is used to provide back-up protection at a generator for faults on the system side of the step-up transformer.

The Type CEB13C relay may also be used as the carrier-start relay in applications where there is a wye-delta or delta-wye transformer bank between the relay location and line protected by the directional comparison carrier scheme. The external connections shown in Figure 7 are recommended for such an application of the relay. With these connections the response of the relay to external faults in the blocking direction will be the same as if it were connected to CT's and PT's on the line side of the bank which simplifies coordination with the carrier trip relays at the remote end of the protected line.

RATINGS

The Type 12CEB13C(-)A relays are available in either 50 or 60 hertz, 5 amperes and 115 volts. The basic range of ohmic reach is 4 to 20 ohms phase-to-neutral at an angle of maximum torque of 75 degrees lag, which can be adjusted to 60 degrees lag with a reduction to approximately 80 percent of the basic ohmic reach mentioned above. These relays have a reverse offset range of 0-4 ohms phase-to-neutral at 255 degrees lag in 1 ohm increments.

CURRENT CIRCUITS

The 5 ampere rated current circuit has a one second rating of 130 amperes. The 1 ampere rated relay has a one second rating of 25 amperes. Higher or lower currents may be applied for various lengths of time in accordance with the following equation.

$I^2t = K$ 5 ampere relay K=16,900/1 second

1 ampere relay K= 625/1 second

Where: I = Applied current in amperes

T = Time in seconds

POTENTIAL CIRCUITS

The potential circuits of all the 12CEB13C(-)A relays are continuously rated at 115 volts.

CONTACT CIRCUITS

The current-closing rating of the normally open contacts is 30 amperes momentarily for voltages not exceeding 250 volts. The contacts will close and carry continuously 0.3 ampere in circuits up to 250 volts. The contacts are capable of interrupting the continuous rating mentioned previously.

TARGET AND SEAL-IN UNIT COILS

The target and seal-in unit coil ratings are given in TABLE I. These ratings are either AC or DC.

TABLE I

TARGET COIL AND SEAL-IN UNIT COIL RATING

	Target Coil		Seal-In Unit Coil	
	0.2 Amp	2.0 Amp	0.2 Amp	2.0 Amp
Operating Range	0.2-2.0	2-30	0.2-2.0	2-30
Resistance	7	0.1	7	0.13
Carry For Tripping Duty	3	30	5	30
Carry Continuously	0.8	6	0.3	3

The internal connections diagram for the 12CEB13C(-)A relay is shown in Figure 3.

OPERATING CHARACTERISTICS

The offset mho unit is similar to the basic mho unit with the addition of a transactor. The transactor is an air gap reactor with a secondary winding for obtaining the desired voltage at a given primary current without the attendant high burden. Electrical insulation is also obtained. By adding the transactor secondary voltage in series with the terminal voltage and applying the vector sum to the operating unit, the effect is to offset the ohmic characteristic without changing its diameter.

Referring to Fig. 8, the characteristics at 75 and 60 degrees with zero offset are similar to the mho unit characteristic of the Type GCX relay. Curves of Fig. 8 show how the characteristic may be offset in the Type CEB relay. In the carrier-pilot relaying scheme, the connections to the Type CEB relay are reversed so that except for the offset portion OA, its zone of operation lies in the direction opposite to that of the mho unit. It thus covers the line section behind the relay location. Its normally-open contacts close to trip the breaker in third zone time for faults in this section, while its normally closed contacts open to initiate the transmission of carrier.

The characteristic circles may be expanded by reducing the effect of the restraint circuit. This is accomplished by increasing the setting of the adjustable resistor in that circuit.

When zero offset is used, the characteristic circles all pass through the origin. When one ohm offset is used, these circles continue to pass through a common point which has moved to point A in Figure 8.

The direction of the zero offset characteristic can be adjusted from the 75-degree setting, shown by the upper heavy circle of Figure 8, to any angle down to the 60-degree setting, shown by the dashed circle. The variation in minimum ohmic setting with this adjustment is indicated in Table II. This adjustment is made by decreasing the resistance in R_{31} plus R_{41} for the M_{1-2} unit. If no change is made in the setting of R_{61} and if offset is used, the new circle, initially at 60 degrees, for example, will be shifted along a 75-degree line. In order to have the offset along a 60-degree line, the resistance of R_{61} must be reduced.

TABLE II

MINIMUM OHMIC REACH VARIATION

Angle	Frequency	Minimum Ohmic Reach
75	60	3.92 - 4.08
60	60	3.18 - 3.68

No attempt has been made to limit the transient overreach of this relay. The directional action with 2.0 volts, phase-to-phase, is correct from 6 to 60 amperes, when no offset is used.

Figure 15 is an accuracy curve for the 12CEB13C(-)A relay which can be used to determine the magnitude of test current necessary to calibrate the relay without introducing errors. The result of testing at too low a current level will make the relay overreach when placed in service by the percent of underreach produced by the low test currents.

Figure 16 is the static and dynamic characteristic curve for the 12CEB13C(-)A relay. It illustrates the sensitivity of the relay based on $I_{3\phi} \times Z$ setting. Thus, this curve along with the curve of Figure 15 will aid in the calibration of these relays. The dotted portion of the curve shows that under dynamic conditions the memory action of the relay will trip properly for higher fault currents at low voltages where the $I_{3\phi} \times Z$ setting is equal to that shown on the curve.

For the higher basic reach relays, the magnitude of test current is inversely proportional to the lower basic reach relay as shown in Figure 15.

BURDENS

Because of the presence of the transactor in the relay, the ohmic burdens imposed on the currents and potential transformers are not constant, but vary somewhat with the onmic reach, amount of offset, and current. This variation is of little importance to the current transformer, so that a formula for calculating only the potential burden will be given.

CURRENT CIRCUITS

The maximum current burden imposed on each C T with a practical setting of 5 amperes, 115 volts, and 60 cycles is given in Table IIIA.

TABLE IIIA

CURRENT CIRCUIT BURDEN

R	X	Z	WATTS	VARS	VA
.31	.5	.59	7.8	12.5	14.7

TABLE IIIB

POTENTIAL CIRCUIT BURDEN

WATTS	VARS	VA
8.9	4.7	10.1

The potential burden is altered by changing the restraint setting in order to obtain the proper reach, as well as by changing the offset adjustment. The equations below cover the condition of minimum ohmic setting. The burden will be decreased if the ohmic setting is increased.

$W +_j V$ = Volt Ampere Burden on Potential Device or Potential Transformer.

E = Relay Terminal Voltage ($\emptyset$ - $\emptyset$)
I = Relay Current
Z_L = Line-to-Neutral ohms seen by Relay = $\frac{E_{\emptyset - N}}{I}$

Z_0 = Ohmic Offset Setting of Relay
θ = Power Factor Angle of Load
$\emptyset$ = Angle of Offset

$$W +_j V = \frac{E^2}{Z_S} \sqrt{1 + 2\frac{Z_0}{Z_L}\cos(\emptyset - \theta) + \left(\frac{Z_0}{Z_L}\right)^2} \qquad (1)$$

$$\text{where } Z_S - 1160 + j614 + Z_0{}^2 \quad (4.5 \times j74.5) \qquad (2)$$

TABLE IV

Z_0	Z_S
0.25	1160 + j615
0.5	1161 + j618
1	1164 + j628
2	1178 + j672
3	1200 + j744
4	1232 + j844

CALCULATION OF SETTINGS

Assume a system as shown in Figure 6 with the relay supplied from current and potential transformers on the generator side of the step-up transformer. Further assume that the following parameters describe the system:

$$V_L/V_H = 13.8/132$$

$$Z_L = 0.81 \angle 80° \text{ ohms per mile}$$

$$Z_T = 10\% \text{ on } 100{,}000 \text{ KVA base at 86 deg. lagging.}$$

From the Application Section, the impedance seen by the relay for a fault on the high voltage system is:

$$Z_{relay} = 0.866\ (Z_T + KZ_L) \left[\frac{V_L}{V_H}\right]^2 \left(\frac{\text{CT Ratio}}{\text{PT Ratio}}\right)$$

It will be noted that three auxiliary PT's will be required. These should have a winding ratio of 120/69 volts so that when they are connected in delta-wye, the ratio of the line-to-line voltages on the primary and secondary of the auxiliary PT's will be 1:1.

On the system described above, the ratio of the main potential transformers would be:

$$\text{PT Ratios} = 14{,}400/120 = 120/1$$

Assume that the generator CT ratio is 5000/5 which is a reasonable rating for CT's used on a 100,000 KVA, 13.8 KV unit:

$$\text{CT Ratio} = 5000/5 - 1{,}000$$

The primary ohms of the transformer (Z_T) referred to the 132 KV side may be obtained from the following equation:

$$Z_T = \text{Per Unit Impedance}\ \frac{(KV)^2}{\text{MVA Base}}$$

$$Z_T = 0.10\ \frac{(132)^2}{100} = 17.4 \text{ ohms}$$

Assume now that it is desired for the CEB to reach no further than 30 miles out from the high voltage bus on any of the three circuits under any condition of infeed from the other two. Thus:

$$Z_L = 30 \times 0.81 \angle 80° = 24.3 \text{ primary ohms}$$

Assume that a fault study indicates that the minimum value of infeed under any reasonable system conditions will result in K being no smaller than 1.2. Thus,

$$K = 1.2$$

(It should be noted that on a radial system, K will be equal to 1.0. In order to be absolutely certain that the relay does not reach beyond the desired distance under any conditions on any system, K should be assumed equal to 1.0.)

From the above equation the relay should be set with a forward reach of:

$$Z_{relay} = 0.866\ [17.4 \angle 86° + 1.2\ (24.3 \angle 80°)] \left(\frac{13.8}{132}\right)^2 \left(\frac{1000}{120}\right)$$

$$Z_{relay} = (40.2 \angle 82.1°)\ (0.01093)\ (8.34)$$

$$Z_{relay} = 3.67 \angle 82.1° \text{ secondary ohms}$$

Thus, the relays should be set with a forward reach of about 3.7 ohms at 82 degrees. However, in applications of this kind some people prefer to set the relay with offset in order to obtain some additional back-up protection for faults in the leads between the generator and the transformer. If this is the case, it is suggested that the relay be set with 2 ohms offset.

CONSTRUCTION

MHO UNIT

The relay has three units, each unit being on offset mho unit; i.e., it has a circular impedance characteristic similar to that of the basic mho unit except that it is offset so as to encircle the origin of the impedance diagram instead of passing throught it. The schematic connections for this unit are shown in Figure 9. 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 for zero offset at pickup is therefore:

$$T = 0 = EI \cos(\emptyset - \theta) - KE^2$$

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

$\emptyset$ is the power factor angle

K is a design constant

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

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

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.

TRANSACTOR

The relay has three offset mho units. The offset is provided by the voltage drop across a transactor in the current circuit in conjunction with an element which is otherwise simply a mho unit. Transactor is the name given to a reactor which has a secondary winding with a step-up ratio to provide more reactance with less burden on the current circuit. Taps on the secondary winding provide a selection of offset of o, 1, 2, 3, and 4 for the 4 ohm transactor and o, 5, 10, 15, and 20 ohms for the 20 ohm transactor.

CONTACT CLEANING

For cleaning relay contacts, a flexible burnishing tool should be used. This consists of a flexible strip of metal with an etched-roughened surface resembling in effect a superfine file. The polishing action is so delicate that no scratches are left, yet it will clean off any corrosion throughly and rapidly. Its flexibility insures the cleaning of the actual points of contact. Do not use knives, files, abrasive paper or cloth of any kind to clean relay contacts.

RECEIVING, HANDLING AND STORAGE

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

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

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

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

There should be approximately 1/64 inch end play in the shafts of the rotating structures. The lower jewel screw bearing should be screwed firmly in place, and the top pivot locked in place by its set screw.

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

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

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

All contact surfaces should be clean.

CAUTION: Every circuit in the drawout case has an auxiliary brush; this is the short one in the case (not on the cradle) which the connection plug or test plug should engage first. On every current circuit or other circuit with a shorting bar, make sure these auxiliary brushes are bent high enough to engage the connection plug or test plug before the main brushes in the case do, as otherwise the CT secondary circuit may be opened (where one brush touches the shorting bar) before the circuit is completed from the plug to the other main brush,

A cutaway view of the case, cradle blocks, and connection plug is shown in Figure 10.

INSTALLATION PROCEDURE

LOCATION

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

MOUNTING

The relay should be mounted on a vertical surface. The outline and panel drilling dimensions are shown in Figure 4.

CONNECTIONS

The internal connections of the CEB52A relay are shown in Figure 3. An elementary diagram of typical external connections is shown in Figure 7.

VISUAL INSPECTION

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

MECHANICAL INSPECTION

Recheck the six adjustments mentioned under Mechanical Inspection of the section on ACCEPTANCE TESTS.

ACCEPTANCE TESTS

Immediately upon receipt of the relay, an INSPECTION AND ACCEPTANCE TEST should be made to insure that no damage has been sustained in shipment and that the relay calibrations have not been disturbed. If the examination or test indicates that readjustment is necessary, refer to the section on SERVICING.

VISUAL INSPECTION

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

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

MECHANICAL INSPECTION

1. It is recommended that the mechanical adjustment in Table V be checked.
2. There should be no noticeable friction in the rotating structure of the units.
3. Make sure control springs are not deformed and spring convolutions do not touch each other.
4. With the relay well leveled in its upright position the contacts of all three units must be open. The moving contacts of the units should rest against the backstop.
5. The armature and contacts of the seal-in unit should move freely when operated by hand. There should be at least 1/32" wipe on the seal-in contacts.
6. Check the location of the contact brushes on the cradle and case blocks against the internal connection diagram for the relay.

TABLE V

CHECK POINTS	OM UNITS
Rotating Shaft End Play	.010 - .015 Inch
Contact Gap	.015 - .030 Inch
Contact Wipe	.003 - .005 Inch

ELECTRICAL CHECKS - OM UNITS

Before any electrical checks are made on the mho units the relay should be connected as shown in Figure 11 and be allowed to warm up for approximately 15 minutes with the potential circuit alone ener-
* gized at rated voltage. The units were warmed up prior to factory adjustment and if rechecked when cold will tend to underreach by 3 or 4 percent. Accurately calibrated meters are of course essential.

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

Test connections for checking correct OM unit operation are shown in Figure 11.

* Indicates revision

(a). Control Spring Adjustment

Be sure that the relay is level in its upright position. Leave the relay connected as shown in Figure 11 and leave the restraint taps in the 100% position.

Use the following procedure in checking each unit. With the current set at 5 amperes and the voltage across relay voltage studs at 115 volts, set the phase shifter so that the phase angle meter reads the value shown in Table VI for the unit being tested, that is so current lags voltage by an angle equal to the angle of maximum torque of the unit. Now reduce the voltage to the low test voltage, and reduce the current to about 1 ampere. Gradually increase the current until the contacts of the unit just close. This should occur between the current listed in Table VI or adjust the control spring.

TABLE VI

Test Unit	Fig. 11 Connect. A	B	C	D	V Pot. Cir. Test Voltage	Lag	I Oper
Ø1-2	13	14	3	4	1.20	75°	5.4- 6.0
Ø2-3	15	16	5	6	1.20	75°	5-4 6.0
Ø3-1	17	18	7	8	1.20	75°	5-4 6.0

(b) Ohmic Reach

* With the relay still connected as shown in Figure 11, make connections shown in Table VII and set the phase shifter so that the phase-angle meter reads the angle shown in the table for the unit to be checked.

Now set the voltage to the value shown in Table VII and increase the current gradually until the normally open contacts of the unit just close. This should occur within the limits shown in Table VII.

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

The relays are normally shipped from the factory with the basic minimum reach adjustment of the units. The offset tap should be set at zero ohms.

TABLE VII

4 ohm ØN tested @8.0 ØØ

To Test Unit	Fig.11 Connections A	B	C	D	V Pot. Cir. Test Voltage	ØΔ Lag	I Oper
1-2	13	14	3	4	115	75°	13.97-14.8
2-3	15	16	5	6	115	75°	13.97-14.8
3-1	17	18	7	8	115	75°	13.97-14.8

Adjust R11 for Ø1-2 unit

Adjust R12 for Ø2-3 unit

Adjust R13 for Ø3-1 unit

* Indicates revision

20 ohm ØN tested @ 40 ohms ØØ

Test Unit	Fig. 11 Connections A	B	C	D	V Pot. Cir. Test Voltage	Ø Lag	I Oper
Ø1-2	13	14	3	4	115	75°	2.8-3.0
Ø2-3	15	16	5	6	115	75°	2.8-3.0
Ø3.1	17	18	7	8	115	75°	2.8-3.0

100 ohms ØN tested @ 200 ohms ØØ

Test Unit	Fig 11 Connections A	B	C	D	V Pot. Cir. Test Voltage	Ø Lag	I Oper
Ø1-2	13	14	3	4	115	75°	.56-.59
Ø2-3	15	16	5	6	115	75°	.56-.59
Ø3-1	17	18	7	8	115	75°	.56-.59

(c) Angle of Maximum Torque

* For checking the angle of maximum torque the connections of Figure 11 will be used, and with the voltage set at the value shown in Table VIII for the unit to be checked.

In checking the mho units the following procedure would be used. First set the phase shifter so that the phase-angle meter reads 45° lag. Note that while the phase angle is being set, the current should be at 5 amperes and the voltage shown in Table VIII. Increase the current slowly until the mho unit picks up. The pickup current should be within the limits shown in the table. Now reset the phase angle at 105° lag and again check the current required to pick up the mho unit. This current should fall within the same limits as for the 45° lag check.

TABLE VIII

Test Unit	V Pot. Cir. Test Voltage	Ø Set Deg. Lag	I Oper 8Ω Ø-Ø	I Oper 40Ω ØØ	I Oper 200Ω ØØ
Ø1-2	115V	45 & 105	16.1-17.1	3.2-3.42	.644-.684
Ø2-3	115V	45 & 105	16.1-17.1	3.2-3.42	.644-.684
Ø3-1	115V	45 & 105	16.1-17.1	3.2-3.42	.644-.684

Adjust R31 & R41 for the Ø1-2 unit

Adjust R32 & R42 for the Ø2-3 unit

Adjust R33 & R43 for the Ø3-1 unit

Note that the two angles used in the previous check, i.e., 105° and 45° are 30° away from the angle of maximum torque. An examination of the OM unit impedance characteristic in Fig. 8 shows that the ohmic reach of the unit should be the same at both 105° and 45° and should be 0.866 times the reach at the angle of maximum torque.

* Indicates revision

(d) Offset Check

* With the relay connected as shown in Figure 11, make connections and settings shown on Table IX and set the phase shifter so that the phase-angle meter reads the angle shown in the table for the unit to be checked.

Reduce the voltage to the value shown and increase the current gradually until the normally open contacts of the unit just close. This should occur within the current limits shown in Table IX.

TABLE IX

Offset Ohms ØN	Test Conn. Ohms	V Pot. Cir. Test Voltage	X set @ Deg. Lag	I Oper
0	0	55V	255°	60+
1	2	55V	255°	24.75-30.25
2	4	55V	255°	12.37-15.12
3	6	55V	255°	8.25-10.08
4	8	55V	255°	6.18- 7.56
5	10	115V	255°	10.35-12.65
10	20	115V	255°	5.17- 6.32
15	30	115V	255°	3.45- 4.21
20	40	115V	255°	2.58- 3.16

Adjust R61 for the Ø1-2 unit
Adjust R62 for the Ø2-3 unit
Adjust R63 for the Ø3-1 unit

CLUTCH ADJUSTMENT

The clutch on each unit is adjusted by means of the steel collar at the upper end of the rotating shaft. The clutch should slip at a torque corresponding to approximately 50 grams applied at the contact normal to the contact arm. To adjust the clutch, loosen the set screw in the collar, rotate the collar on the shaft through the number of half turns (there is a groove for the set screw on the shaft) necessary to obtain the correct pressure. Moving the collar down increases the clutch pressure. Then lock in place by means of the set screw which should be inserted into the hole of the collar which is in front of the groove in the shaft.

ELECTRICAL TESTS - TARGET SEAL-IN UNIT AND TARGETS

The target seal-in unit has an operating coil tapped at 0.2 or 2.0 amperes. The target coils have a rating of 0.2 or 2.0.

The relay is shipped from the factory with the tap screw in the 2.0 ampere position. The operating point of the targets can be checked by connecting from D-C source (+) to stud 11 of the relay and from stud 1 through an adjustable resistor and ammeter back to (-). Connect a jumper from stud 12 to stud 1 also so that the seal-in contact will protect the OM unit contacts. Then close the OM 1-2 unit contact by hand and increase the D-C current until the seal-in unit operates. It should pick up at tap value or slightly lower. Do not attempt to interrupt the D-C current by means of the OM contacts.

When the target/seal-in unit is picked up open the OM 1-2 unit contact and the target should remain picked up. Reduce the current and the unit should drop out above 30 percent of its rating.

Connect the above mentioned D-C to studs 1-9 to check the pickup of the OM 1-2 and OM 2-3 targets. They should pickup at 85% or less of their ratings. Close OM 1-2 and OM 2-3 contacts.

Connect the D-C to studs 1-10 to check the pickup of the OM 3-1 target. This should be as mentioned above. Close OM 1-2 and OM 3-1 contacts.

PERIODIC CHECKS AND ROUTINE MAINTENANCE

In view of the vital role of protective relays in the operation of a power system it is important that a periodic test program be followed. It is recognized that the interval between periodic checks will vary depending upon environment, type of relay and the user's experience with periodic testing. Until the user has accumulated enough experience to select the test interval best suited to his individual requirements it is suggested that the points listed under INSTALLATION PROCEDURE be checked at an interval of from one to two years.

ELECTRICAL TESTS

DRAWOUT RELAYS GENERAL

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

POWER REQUIREMENTS GENERAL

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

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

Similarly, relays requiring dc control power should be tested using dc and not full wave rectified power. Unless the rectified supply is well filtered, many relays will not operate properly due to the dips in the rectified power. Zener diodes, for example, can turn off during these dips. As a general rule the dc source should not contain more than 5% ripple.

SERVICING

FIELD TESTS

The relay should receive a periodic mechanical inspection with an electrical test to check the reach of each of the units at one point on the circle diagram. For this inspection and these tests refer to the INSTALLATION SECTION of this book.

RECALIBRATION TESTS

Pickup

The pickup current at maximum torque is determined from the equation:

$$I = \frac{E}{2Z} \quad (7)$$

(using the connections of Figure 13) where E is the relay terminal voltage and Z is the required ohmic reach, phase-to-neutral.

The procedure in making the pickup adjustment should be:

1. Determine the required diameter of the impedance characteristic circle. This equals the sum of the desired backward reach (offset) and the desired forward reach.

2. With zero offset, adjust the reach to the diameter which has been determined; this means setting pickup current according to equation (7) above. Pickup current is adjusted by varying the restraint circuit resistors, R_{11}, R_{12}, or R_{13}. (See Figure 1).

3. Set the offset tap plug in the appropriate tap.

Angle of Maximum Torque

If it is necessary to change the maximum torque angle of the units, this is done by changing the resistance of R_{31} plus R_{41} for unit M_{1-2} etc. An increase in this resistance will increase the maximum torque angle. In making this adjustment the relay should be connected according to Figure 13 so the maximum torque angle can be checked after each adjustment.

Transactor Adjustment

The angular setting of the transactor for the M_{1-2} unit can be changed to match any change in the angular setting of the operating element by means of the resistance R_{61}. The test circuit of Fig. 11 should be used and two ohmic characteristic curves similar to Figure 8 plotted, one with offset, and one without offset. Draw the best circle approximating each of the curves and mark the position of their centers. A line joining the centers gives the angle of the offset. To decrease the angle, turn R_{61} to the left.

When checking the ohmic characteristic curve in the offset direction, applying sufficiently low voltages so that excessive currents are not necessary to cause the unit to pick up. High currents not only cause the unit to overheat but give erroneous results due to transactor saturation (saturation occurs at approximately 60 amperes).

INSTALLATION OF RENEWAL PARTS

All stationary contact parts can be installed directly in place by removing the appropriate screws.

The jewel screw can be removed from each unit by means of an offset screw driver or an end wrench. When turning a jewel screw into place, special precautions should be taken to prevent damage to the phosphor bronze bearing surface at the top of the shaft, as the shaft is raised by the jewel screw.

To replace a moving contact arm, control spring, or clutch friction washers from the two lower units, or the clutch friction washers from the top unit, require more time and care.

By removing the middle unit from the relay, the unit becomes accessible, and at the same time provides access to the bottom unit. The top unit can be made accessible by removing the two screws holding the front of the molded inner block to the top of the cradle and tilting up the front of the inner block.

To remove the middle unit: dismount the tap block and swing it outside of the cradle. This permits access to the four splices of the current leads to the unit. Open these splices, tagging all leads carefully. Trace each of the four leads from the polarizing and restraining coils to their points of connections, tagging carefully. Remove the lead from the stationary contact block, and the lead from stud two. Pull the four potential leads and the moving contact lead (to stud two) through to the front of the relay. Remove the four screws holding the unit's mounting plate to the cradle strap and draw the unit from the cradle with R_{42} still mounted to its top bearing support.

When removing the shaft structure, the outer turn of the spiral spring should first be unsoldered from its slot in the supporting post mounted on the adjusting arm. Then after removing the two screws holding the top bearing support to the supporting posts on either side of the unit, the top bearing support (with its rheostat still mounted on the right side) should be pried straight up off its dowel pins, taking the upper pivot and spring adjusting arm with it. Exercise caution that the pivot does not mar the bearing surface inside the shaft and that the dowel pins are not bent. With the top bearing support placed aside, the entire cup and shaft with its clutch and contact assembly can be withdrawn from the magnetic structure of the unit. In order to disengage the moving contact from the stationary contact structure, the stationary contact structure can be dismounted from the two posts at the sides of the unit and worked free of the moving contact.

CAUTION: Ease the cup out very gently to avoid scratches in the soft aluminum surface. Protect the parts from dust and chips while disassembled.

Loosen the set screw in the steel collar at the top of the shaft and remove the collar. The various parts of the clutch and contact structure will then slide off the shaft.

To reassemble, reverse the procedure. Considerable care is necessary in soldering the spiral springs so that neighboring turns do not touch. Do all forming of the spirals near the mounting post and do not make any bend sharper than 1/32 inch radius. A stamp on the back of the upper contact support and one of its supporting posts indicates the proper position of the support on the dowels.

The ohmic offset of the mho unit may be varied from 0-4 or 0-20 (depending on the relay model) by changing the tap setting of the offset tap block.

The setting of each mho unit, defined as the diameter of its ohmic characteristic, becomes equal to the ohmic reach plus the offset. The phase-to-neutral setting (with no offset) may be calculated from equations (3) and (4) when the angular settings of the operating element and the transactor are the same.

$$Z\ (\text{setting}) = Z_R + Z_0 \qquad (3)$$

$$Z_R = \frac{Z_L^2 + Z_0\ Z_L \cos(\theta - \phi)}{Z_0 + Z_L \cos(\theta - \phi)} \qquad (4)$$

where Z_L = Desired ohmic reach at angle
If the angle θ and ϕ are different

Z_0 = Ohmic offset

Z_R = Ohmic reach at angular setting of unit

θ = Angular setting of unit

ϕ = Angle of the line

CALIBRATION

To eliminate the errors which may result from possible instrument inaccuracies a test circuit has been selected which requires no instruments for checking the reach and maximum torque angles. Such a circuit is shown in Figure 12. In Figure 12, R_S + X_S is the source impedance, S_F is the fault switch and R_L + X_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 percent and 1 percent steps so that the line impedance R_L + X_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.

For convenience in field testing the fault switch and tapped autotransformer of Figure 12 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
- Voltmeter
- Ammeter
- Test Plugs

To check the calibration of the mho units it is suggested that the test box Cat. No. 102L201, test reactor (Cat 6054975), and test resistor (Cat. 615B546) be arranged with the type XLA test plugs as shown in Figure 13. This circuit is similar to that shown in Figure 12 except that the source impedance R_S + X_S is replaced by the load box which controls the level of the fault current and produces the source voltage drop.

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 impedance and the relay angle of maximum reach. Twice the relay reach at the angle of the test reactor impedance is:

$$2\ Z\ (\text{Relay}) = 2\ Z\ (\text{p-n}) \cos\ (\theta - \phi) \qquad (5)$$

where ϕ is the angle of the test reactor impedance, θ is the relay angle of maximum reach and Z p-n is actual relay reach, phase-to-neutral. The test-box autotransformer percent tap for the mho-unit pickup is given by:-

$$Z\ \text{tap} = \frac{2Z\ \text{Relay}}{Z_L}\ (100) \qquad (6)$$

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 4 ohms (p-n) minimum at a maximum torque angle of 75 degrees. In determining the reactor tap setting to use it may be assumed that the angle of the test impedance is 80 degrees. From the above, twice the relay reach at the angel of the test-reactor impedance is:-

$$2Z\ \text{Relay} = 2\ \frac{4}{1.0}\ \cos\ (80-75) = 7.97\ \text{ohms}$$

Therefore, use the reactor 12 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 X shows the angles for each of the reactor taps.

TABLE X

TAP	ANGLE	COS (θ - Ø)
24	88	0.973
12	87	0.976
6	86	0.980
3	85	0.984
2	83	0.989
1	81	0.994
0.5	78	0.988

From Table VI it is seen that the angle of the impedance of the 12 ohm tap is 87 degrees. Therefore:

$$2Z \text{ relay} = 2 \frac{4}{1.0} \cos (87 - 75) = 7.82 \text{ ohms}$$

The calibration curve for the portable test reactor should again be referred to in order to determine the exact reactance of the 12 ohm tap at the current level being used. For the purpose of this illustratio assume that the reactance is 12.2 ohms. Since the angle of the impedance of the 12 ohm tap is 87 degrees, the impedance of this tap may be calculated as follows:-

$$Z_L = \frac{X_L}{\cos 3} = \frac{12.2}{.9986} = 12.217$$

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:-

$$Z \text{ tap} = \frac{7.82}{12.2} \times 100 = 64\%$$

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 preset in such a manner that when used with 12 or 6 ohm taps of the specified test reactor, impedance at 60° and 30° respectively will be available for checking the mho unit reach at the 60° and 30° positions. The mho-unit reach at the zero-degree position may be checked by using the calibrated test resistor alone as the line impedance. The calibrated test reactor is supplied with a data sheet which gives the exact impedance and angle for each of the combinations available. The test-box autotransformer percent tap for pickup at a particular angle is given by:-

$$\% \text{ tap} = \frac{2 Z (p-n) \cos (75°-A)}{Z_L}$$

where "A" is the angle of the test impedance (Z_L), Z_L is the 60°, 30° or zero degree impedance value. As in the case of the previous tests, the load box which serves as a 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 angle of maximum reach of the mho unit as indicated above, there are two factors to keep in mind which affect the accuracy of the results. First, when checking the mho unit at angles of more than 30° off the maximum reach position, the error becomes relatively large with phase-angle error.

Second, the effect of the control spring should be considered when testing a mho unit since it 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 mho 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 torque will be low, making the control spring torque no longer negligible. The result of the control spring at low polarizing voltage is to cause the reach to the mho unit to be reduced.

CLUTCH

The clutch on each unit should slip at a torque corresponding to approximately 50 grams applied at the contact normal to the contact arm.

CONTACTS

The relay contact circuits should be given an electrical test by closing each of the mho unit contacts by hand.

OVERALL TESTS

Overall tests on current transformer polarities, relay connections and wiring can be made on the complete installation. Referring to Figure 14, a check of the indicated phase angle meter readings will indicate that the relay is receiving the proper voltages and currents from the connections to the current and potential transformers for the conventional connections shown in Figure 5.

RENEWAL PARTS

It is recommended that sufficient quantities of renewal parts be carried in stock to enable the prompt replacement of any that are worn, broken, or damaged.

When ordering renewal parts, address the nearest Sales Office of the General Electric Company, specify quantity required, name of the part wanted, and the complete model number of the relay for which the part is required.

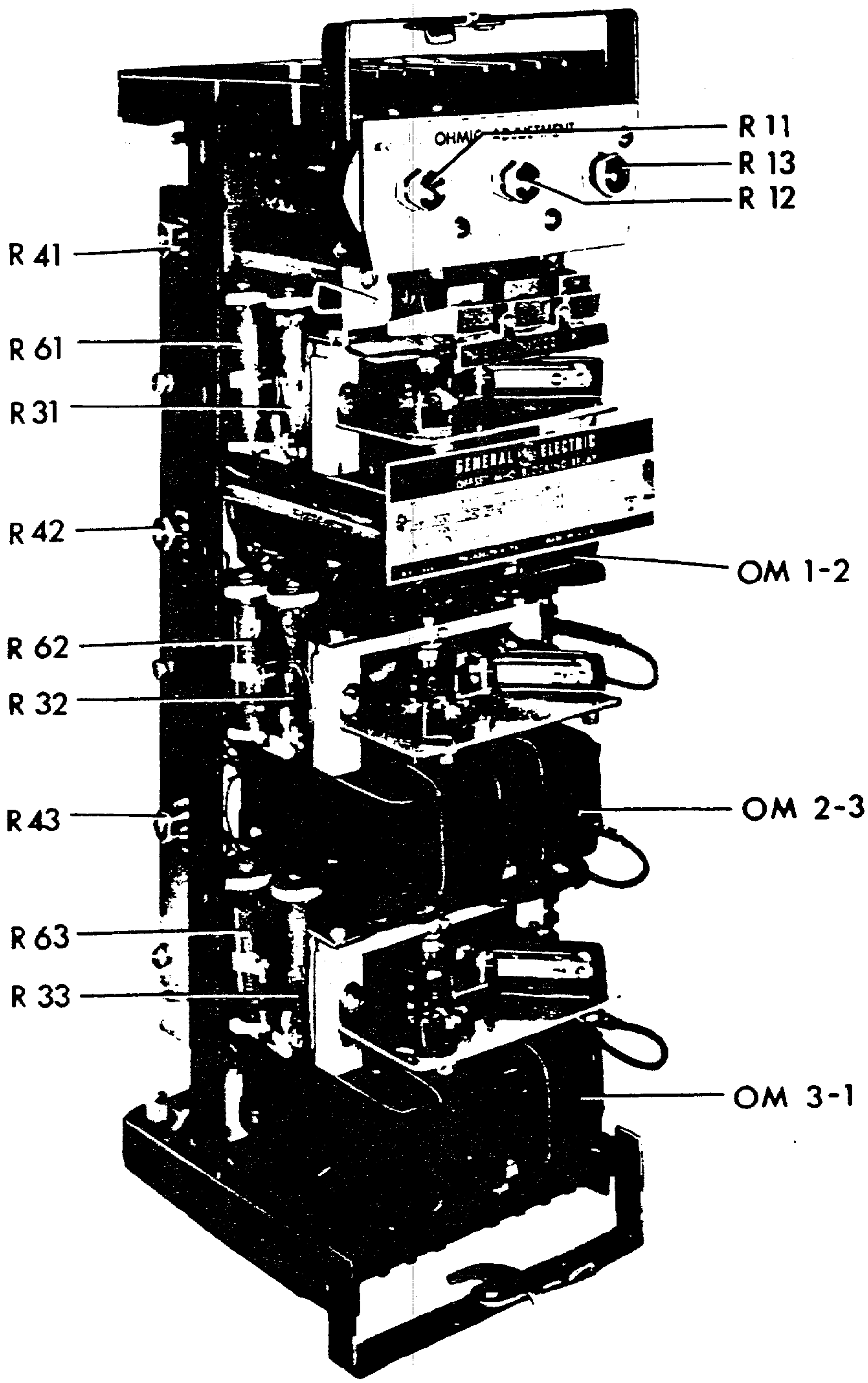


FIG. 1 (8042654) RELAY OUT OF CASE (FRONT VIEW)

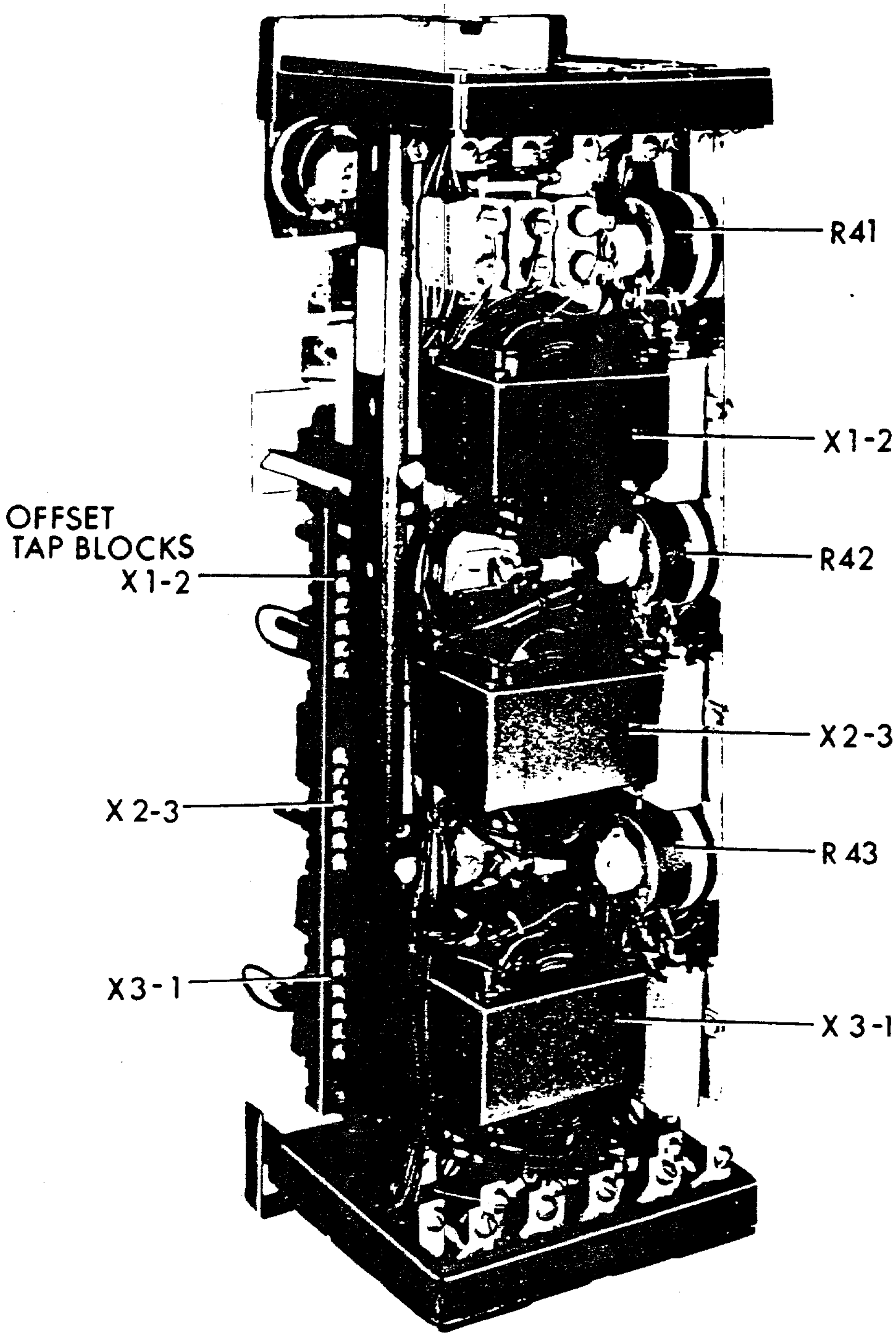
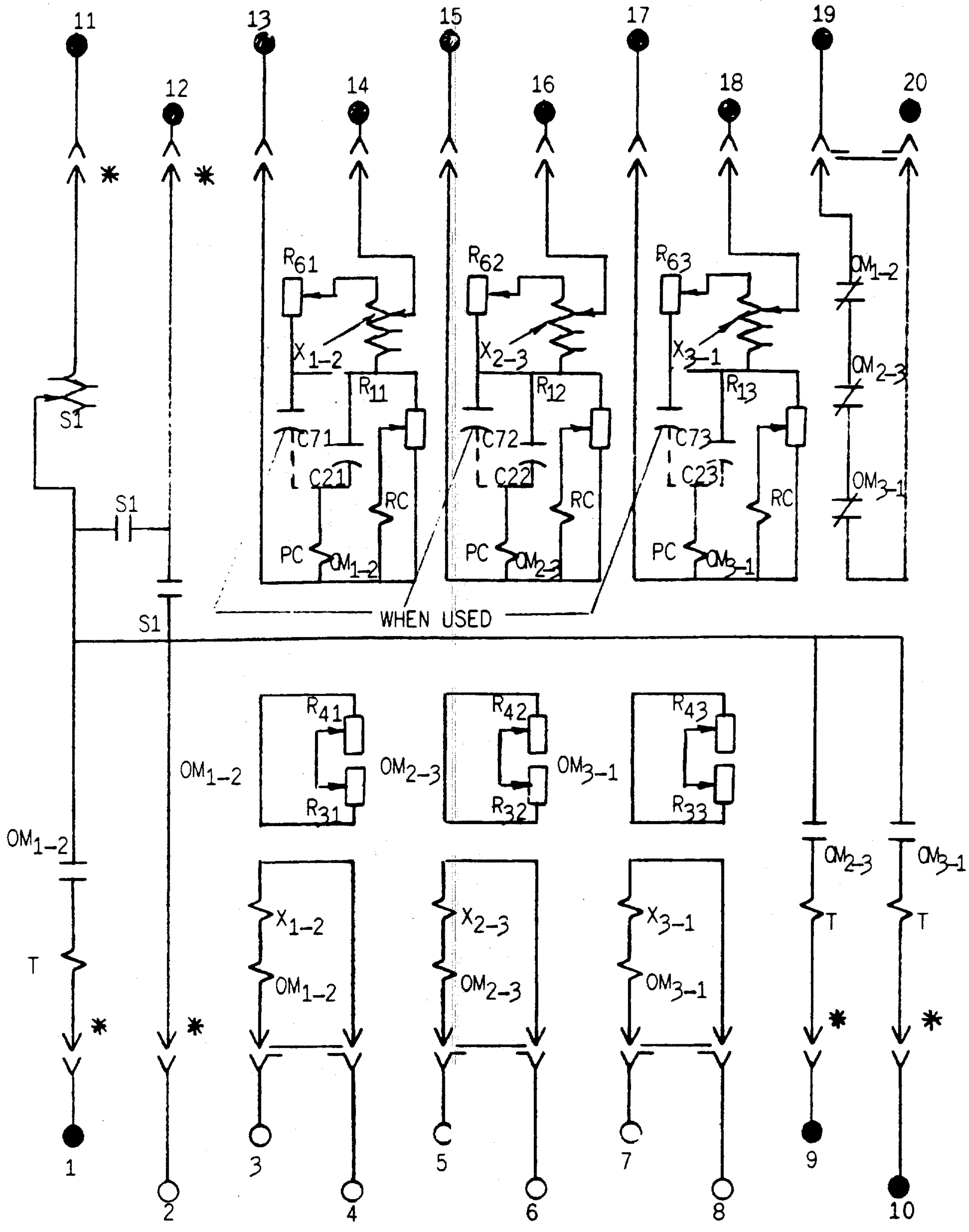


FIG. 2 (8042656) RELAY OUT OF CASE (REAR VIEW)

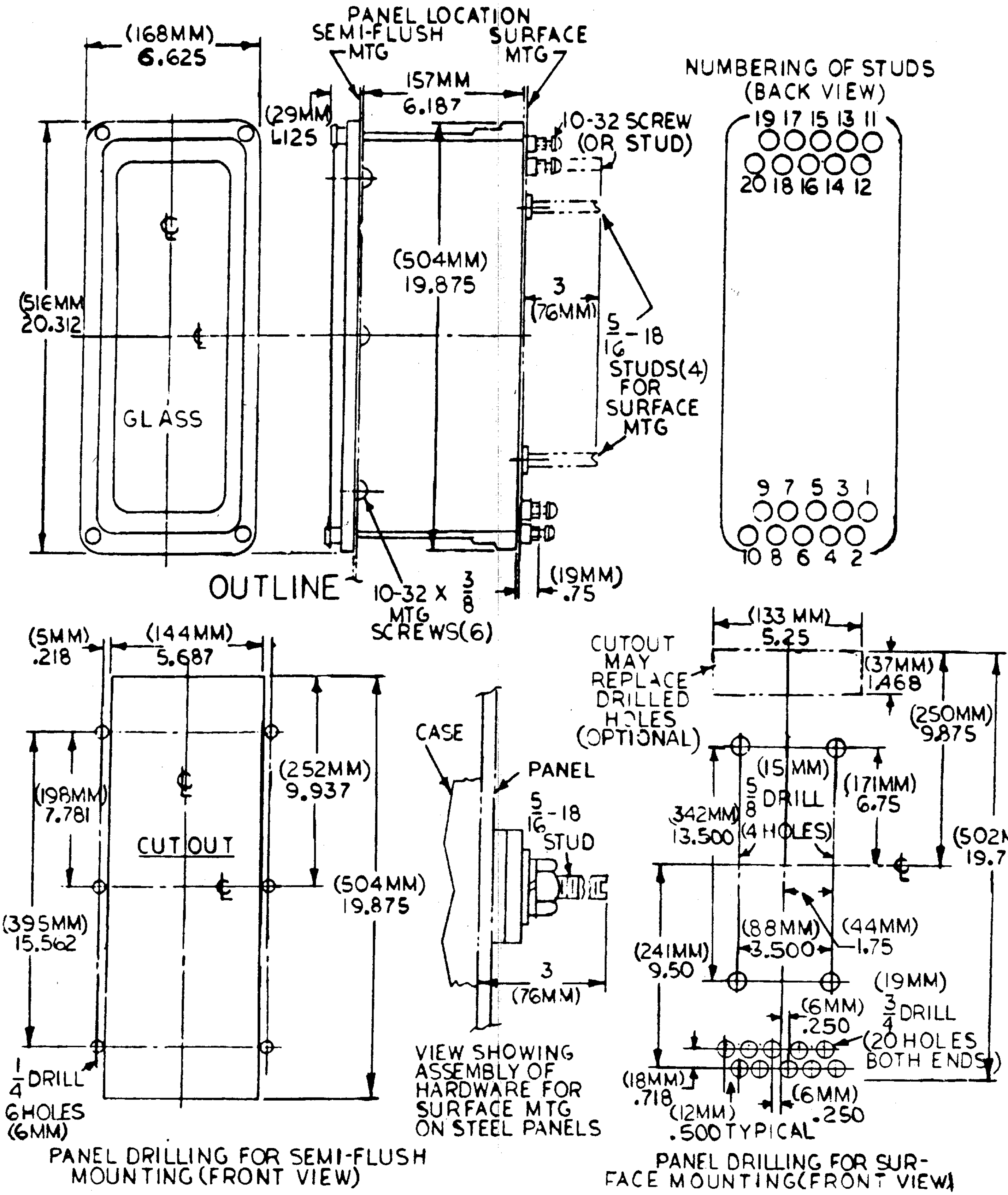


OM_{1-2} = TOP UNIT
OM_{2-3} = MIDDLE UNIT
OM_{3-1} = BOTTOM UNIT

X_{1-2} TOP TRANSACTOR
X_{2-3} MIDDLE TRANSACTOR
X_{3-1} BOTTOM TRANSACTOR

* = SHORT FINGERS
PC = POLARIZING COIL
RC = RESTRAINT COIL

FIG. 3 (0178A9093-0) INTERNAL CONNECTIONS DIAGRAM FOR THE 12CEB13C(-)A RELAY



* FIG. 4 (6209276-3) OUTLINE AND PANEL DRILLING DIAGRAM FOR THE 12CEB13C(-)A RELAY

* Indicates revision

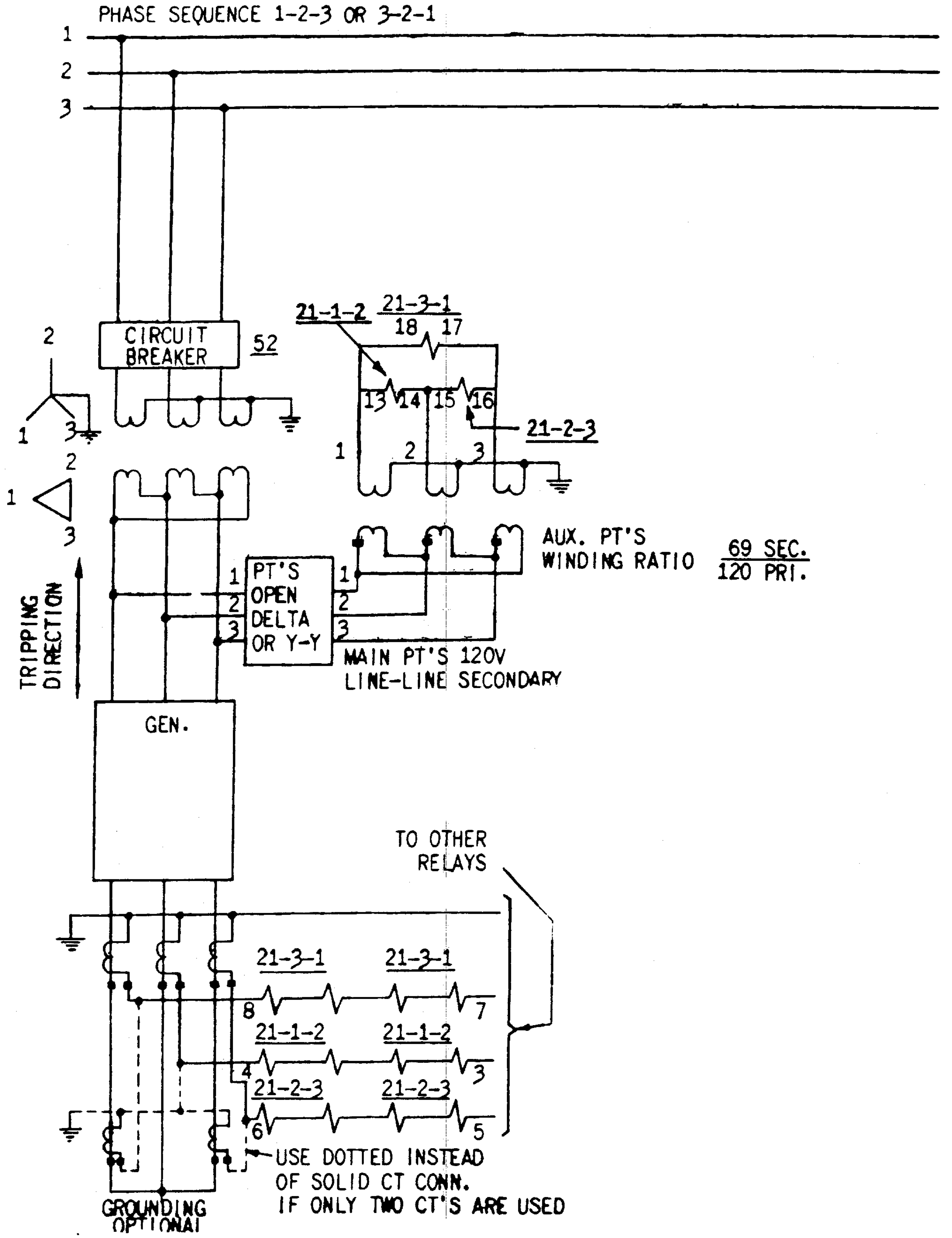


FIG. 5A (0104A8515-1 SH. 1) TYPICAL EXTERNAL CONNECTIONS FOR THE 12CEB13C(-)A AND THE 12PRM13A(-)A THE 12RPM13A(-)A FOR BACK-UP PROTECTION OF UNIT GENERATOR AGAINST SYSTEM FAULTS

LEGEND		
DEVICE NO.	DEVICE TYPE	FUNCTION
21	CEB12C	BACK-UP DISTANCE RELAY
94	HGA14AM OR AL	AUXILIARY TRIPPING RELAY
86	HEA	LOCKOUT RELAY
62	RPM13A, 13B OR 13D	TIMING RELAY

TABULATION OF DEVICES		
TYPE	INT. CONNS.	OUTLINE
CEB13C	403A148	K-6209276
RPM13A	K-6375892-125V K-6375893-250V	K-6209271
HEA		
HGA14AL	377A139	377A139
HGA14AM	6400533	6400533

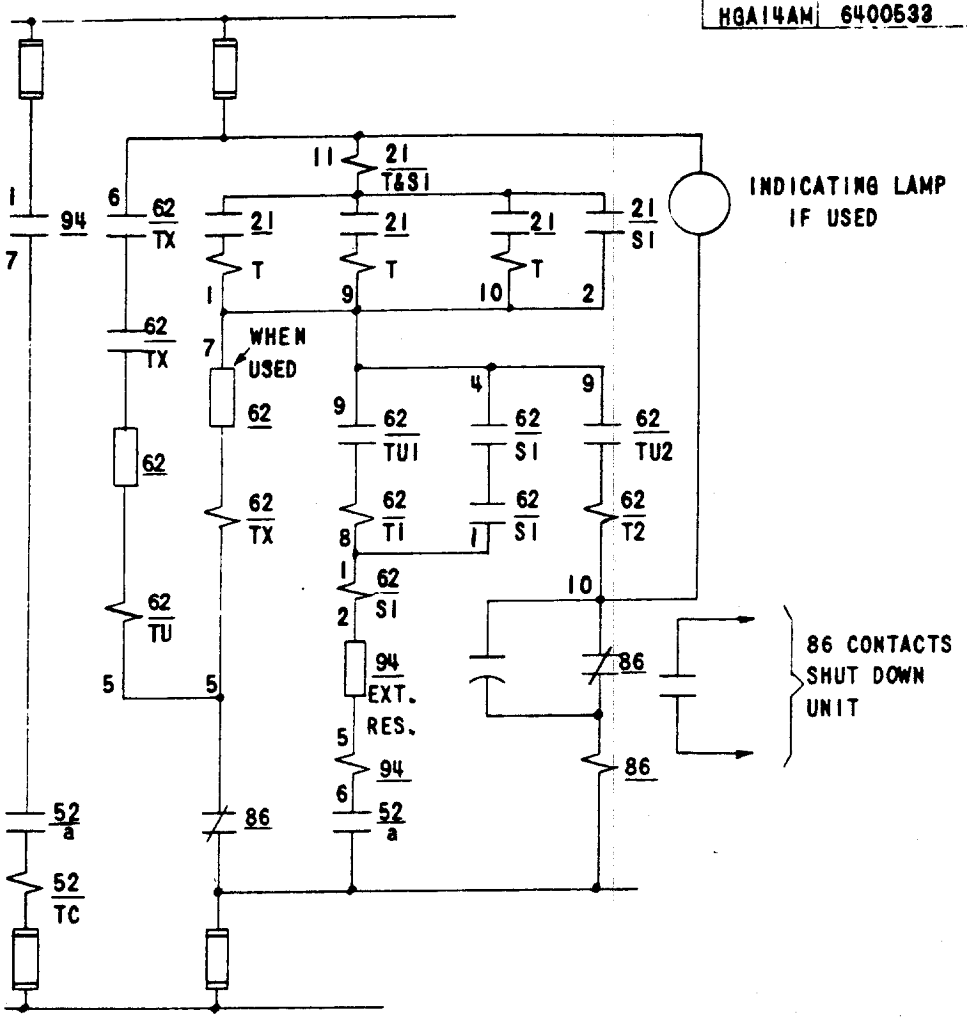
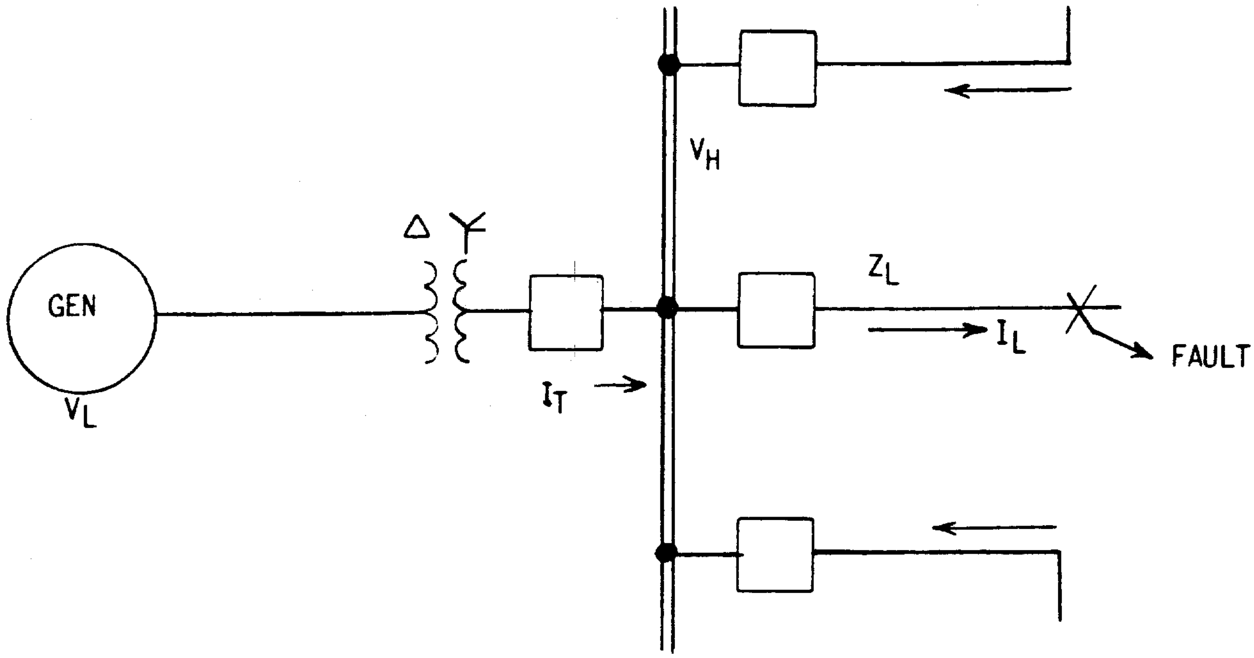


FIG. 5B (0104A8515-0 SH. 2) TYPICAL EXTERNAL CONNECTIONS FOR THE 12CEB13C(-)A AND THE 12RPM13A(-)A FOR BACK-UP PROTECTION OF UNIT GENERATOR AGAINST SYSTEM FAULTS



$$K = \frac{I_L}{I_T}$$

FIG. 6 (0165A7772-1) TYPICAl HIGH-VOLTAGE BUS IN GENERATING STATION

*THESE RELAY CONNECTIONS APPLY FOR ALL DELTA-WYE & WYE-DELTA TRANSFORMER CONNECTIONS, IT IS ONLY NECESSARY THAT THE PHASE 1 VOLTAGE ON THE RELAY SIDE EITHER LEAD OR LAG THE PHASE 1 VOLTAGE ON THE OTHER SIDE OF THE BANK BY 30°. THE PHASE DESIGNATIONS SHOWN ON THIS DWG. APPLY WHEN RELAY SIDE LAGS BY 30°. WHEN RELAY SIDE LEADS BY 30° SEE TABLE I.

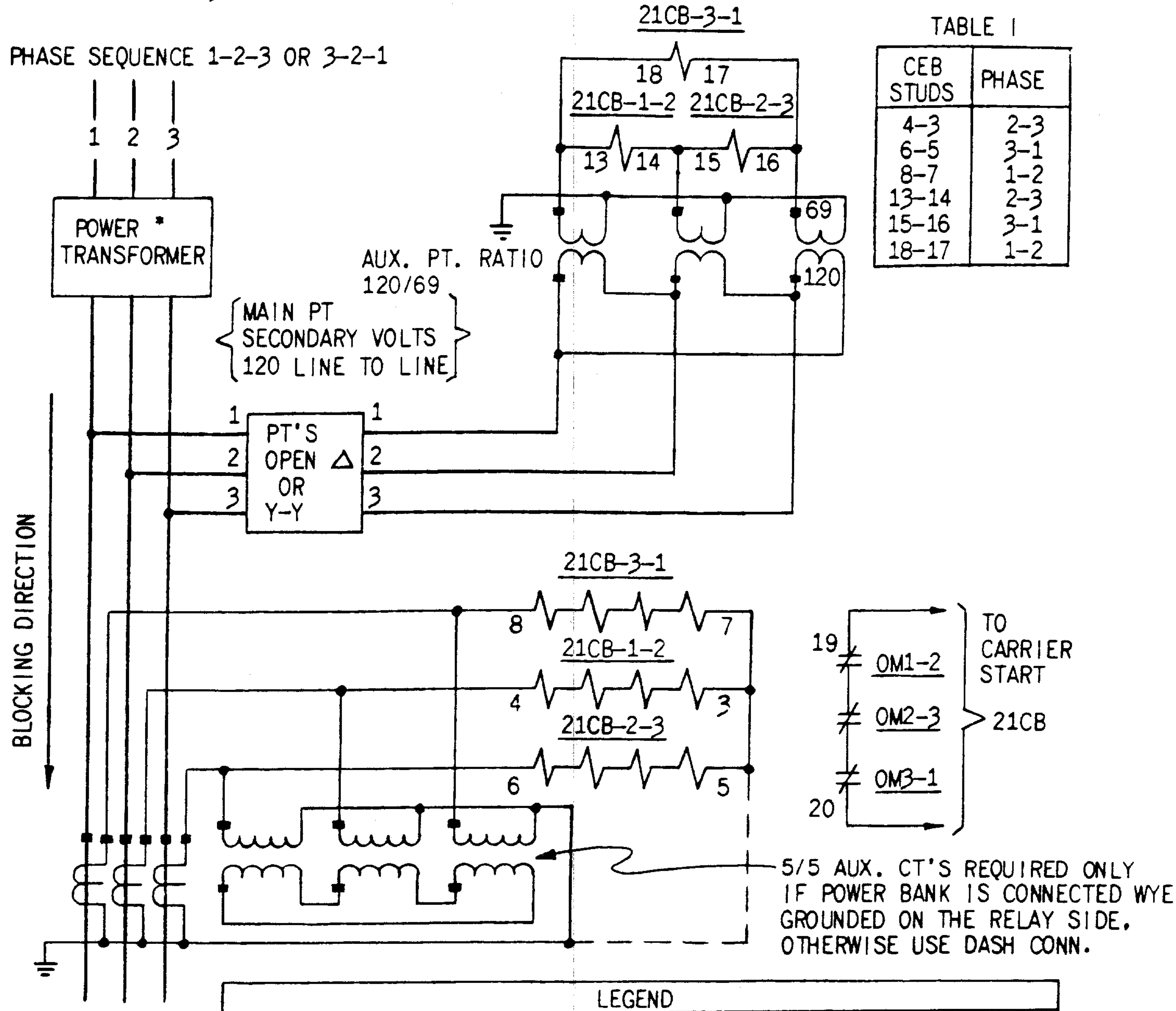


TABLE I

CEB STUDS	PHASE
4-3	2-3
6-5	3-1
8-7	1-2
13-14	2-3
15-16	3-1
18-17	1-2

LEGEND		
DEVICE NO.	DEVICE TYPE	DESCRIPTION
21CB	CEB13C	MHO CARRIER START RELAY

TABULATION OF DEVICES		
TYPE	INT. CONNS.	OUTLINE
CEB13C	403A148	K-6209276

FIG. 7 (0403A103AA-1) TYPICAL EXTERNAL CONNECTIONS FOR THE 12CEB13C(-)A RELAY AS A START CARRIER RELAY

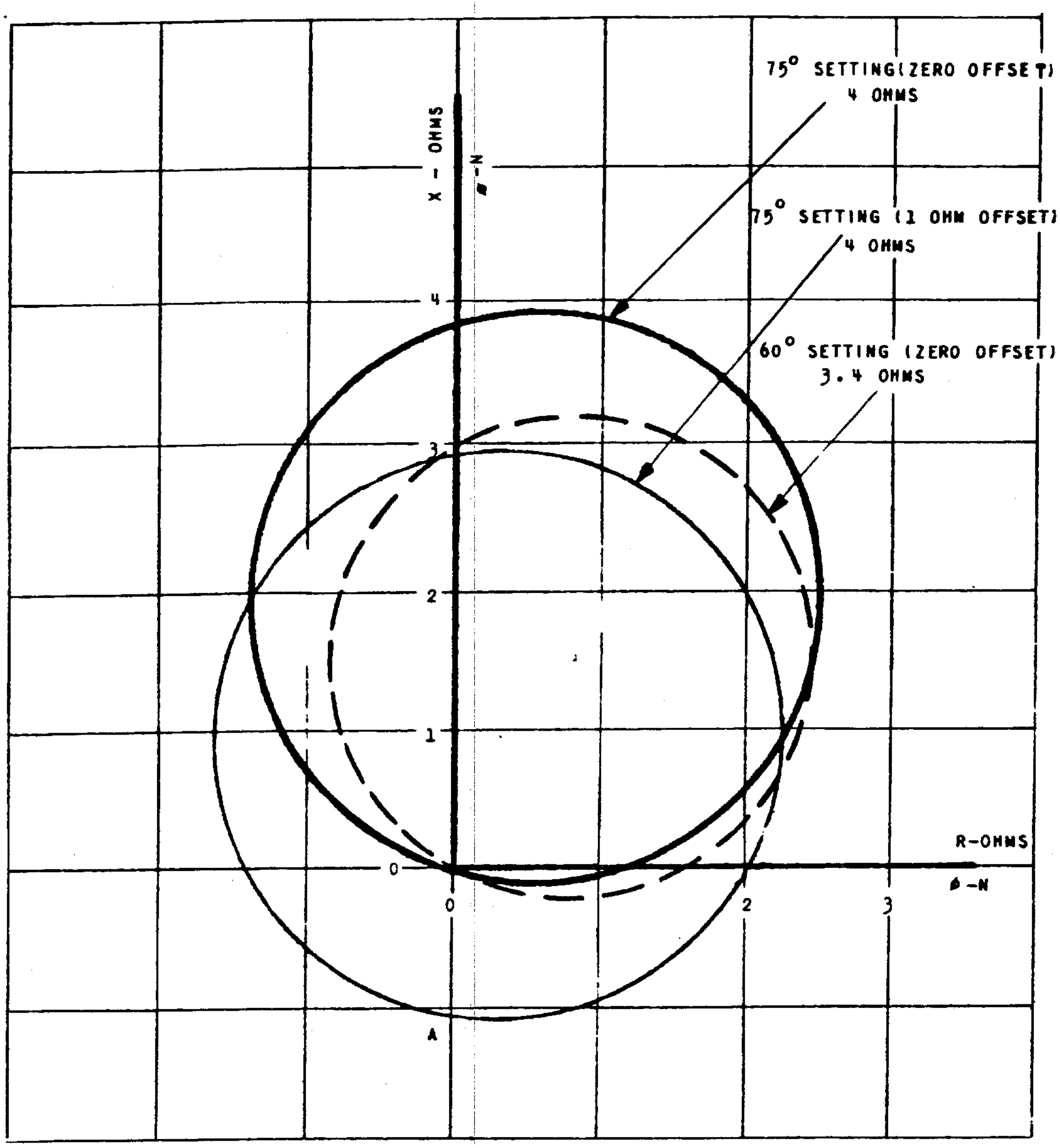


FIG. 8 (0362A671-1) IMPEDENCE CHARACTERISTIC OF THE TYPE 12CEB13C(-)A RELAY

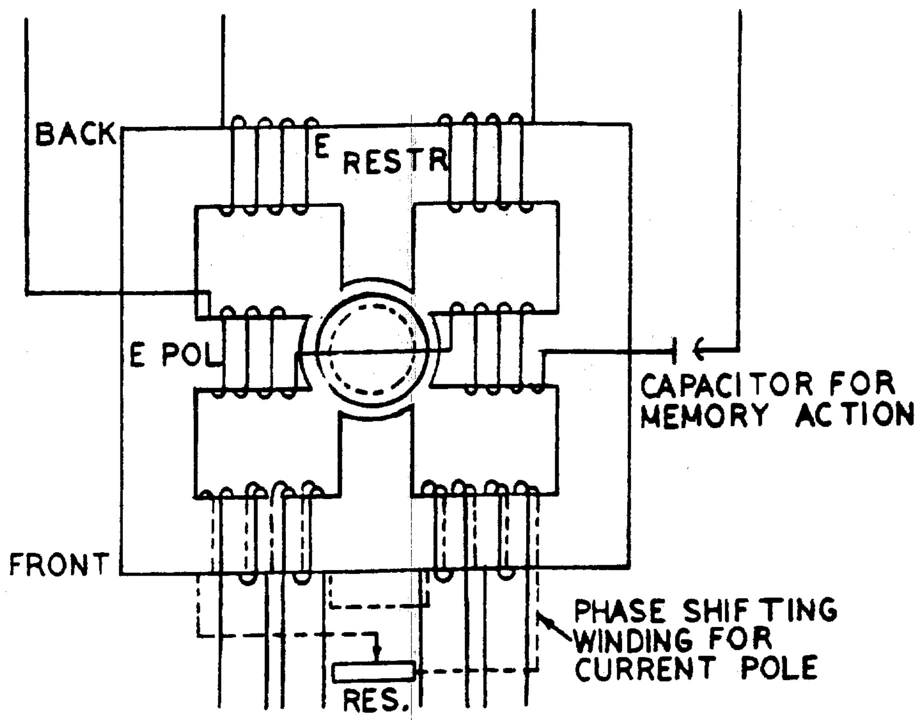
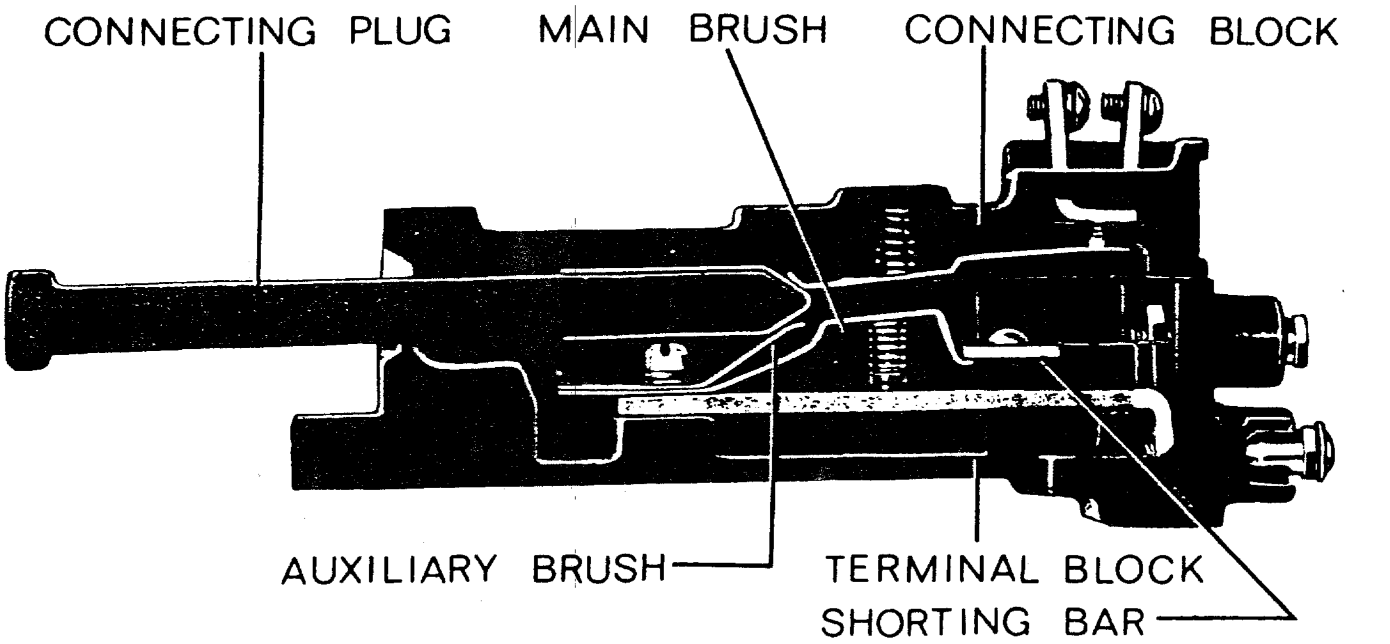
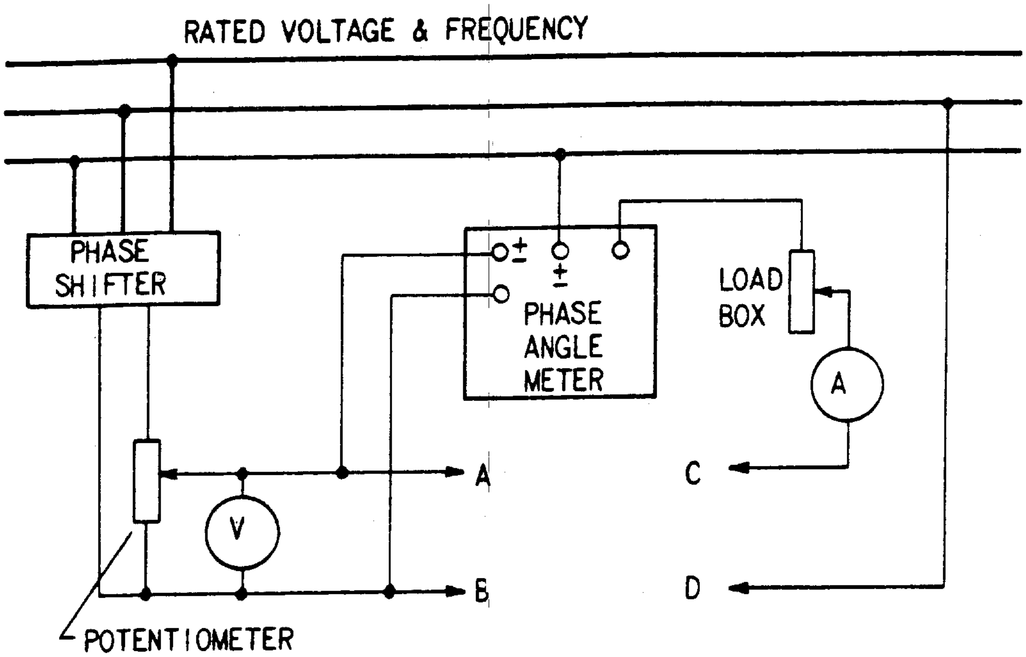


FIG. 9 (0257A8361-0) SCHEMATIC DIAGRAM OF THE UNIT USED IN THE 12CEB13C(-)A RELAY



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

FIG. 10 (8025039) CROSS SECTION OF THE DRAWOUT CASE AND CRADLE SHOWING THE POSITION OF THE AUXILIARY BRUSH AND SHORTING BAR.



TO TEST UNIT	CONNECT LEADS TO TERMINAL			
	A	B	C	D
1-2	13	14	3	4
2-3	15	16	5	6
3-1	17	18	7	8

FIG. 11 (0403A149-0) TEST CONNECTIONS FOR THE CEB13C(-)A RELAYS.

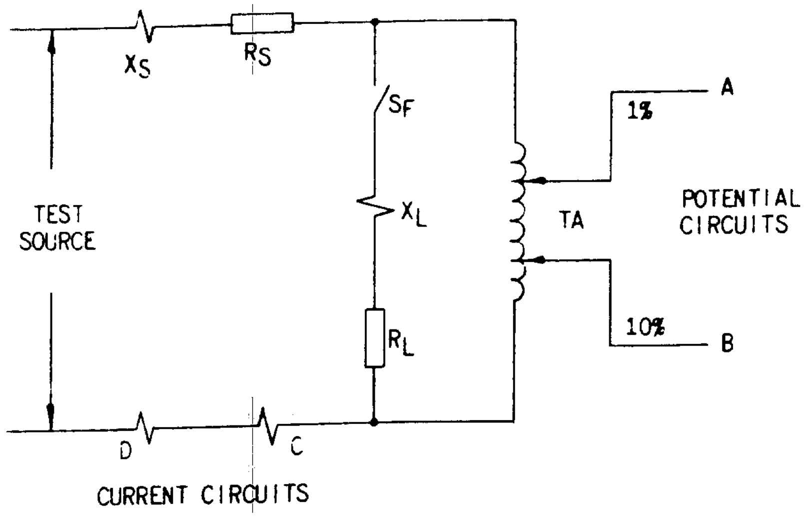
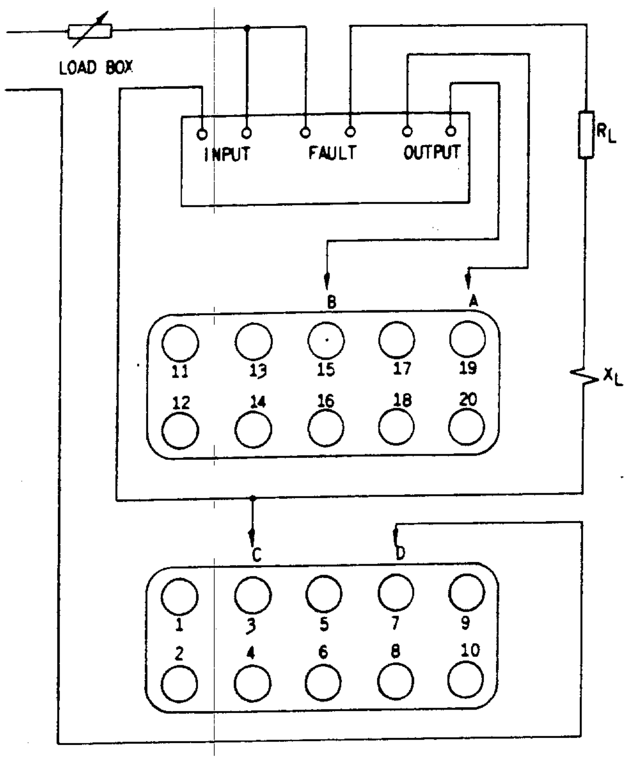
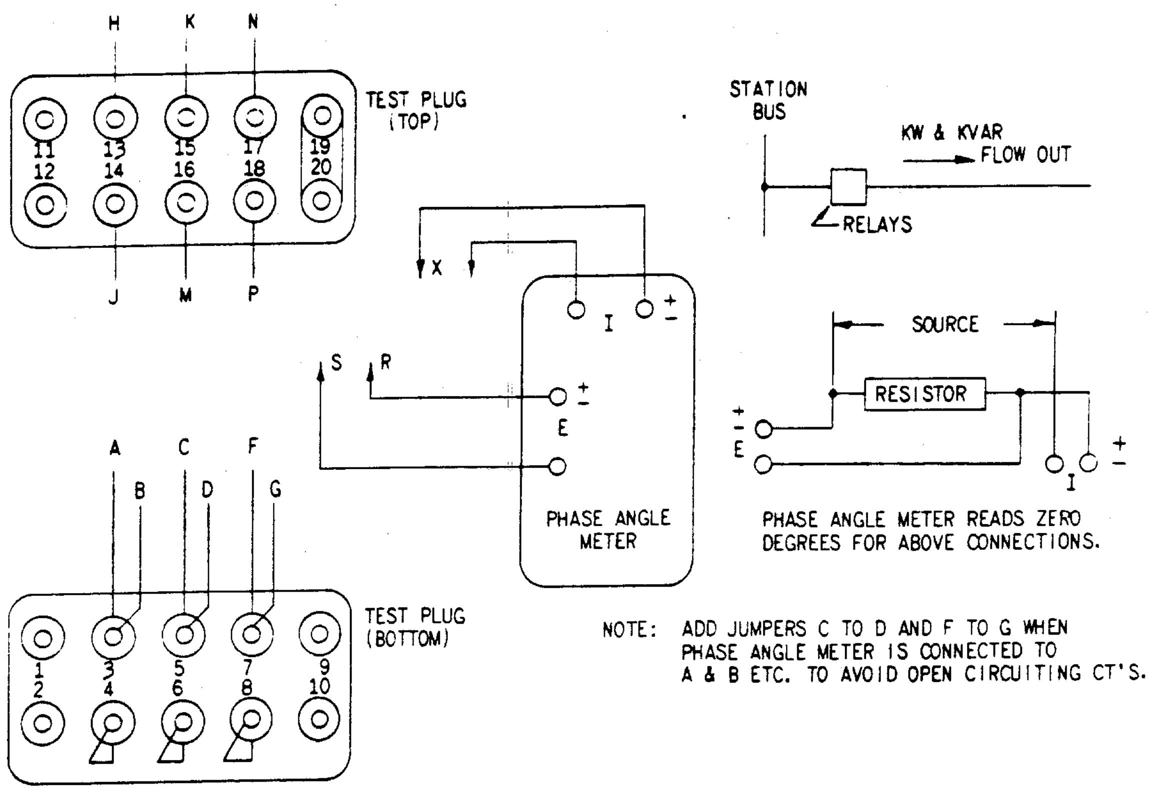


FIG. 12 (0459A299-0) SCHEMATIC TEST CONNECTIONS FOR 12CEB13C(-)A RELAYS.



TO TEST UNIT	CONNECT LEADS TO RELAY TERMINALS				JUMPER TERMINALS
	A	B	C	D	
TOP	13	14	3	5	4 & 6
MIDDLE	15	16	5	7	6 & 8
BOTTOM	17	18	7	3	8 & 4

FIG. 13 (0459A298-0) SCHEMATIC TEST CONNECTIONS WITH XLA13A TEST PLUGS FOR THE 12CEB13C(-)A RELAYS.



CAUTION: BEFORE MAKING THESE TESTS IT IS ESSENTIAL TO ESTABLISH THAT THE KW AND KVAR METERS ARE PROPERLY CONNECTED IN THE CT AND PT CIRCUITS.

	POWER FACTOR ANGLE (DEG. LEAD) →	PROPER READING FOR PHASE SEQUENCE 1-2-3							
		0-45	45-90	90-135	135-180	180-225	225-270	270-315	315-360
	KW AND KVAR DIRECTIONS 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
RELAY CONNECTIONS	R TO H AND S TO J X TO B AND Y TO A	330-15	15-60	60-105	105-150	150-195	195-240	240-285	285-330
	R TO K AND S TO M X TO D AND Y TO C	330-15	15-60	60-105	105-150	150-195	195-240	240-285	285-330
	R TO N AND S TO P X TO G AND Y TO F	330-15	15-60	60-105	105-150	150-195	195-240	240-285	285-330
		PROPER READING FOR PHASE SEQUENCE 1-3-2							
	R TO H AND S TO J X TO B AND Y TO A	30-75	75-120	120-165	165-210	210-255	255-300	300-345	345-30
	R TO K AND S TO M X TO D AND Y TO C	30-75	75-120	120-165	165-210	210-255	255-300	300-345	345-30
	R TO N AND S TO P X TO G AND Y TO F	30-75	75-120	120-165	165-210	210-255	255-300	300-345	345-30

THE VOLTAGE CONNECTIONS TO R AND S OF THE PHASE ANGLE METER ARE FOR THE CONDITION WHEN THE CEB13B IS USED TO START CARRIER FOR FAULTS IN THE NON-TRIPPING DIRECTION. WHEN THE CEB13B IS USED AS A BACKUP RELAY IN THE TRIPPING DIRECTION, THE CONNECTIONS TO R AND S SHOULD BE INTERCHANGED.

THE ABOVE RANGES OF PHASE ANGLE METER READINGS ARE THE ANGLES BY WHICH THE CURRENT LEADS THE VOLTAGE WITH THE DESCRIBED CONDITIONS OF POWER (KW) AND REACTIVE POWER (KVAR) FLOW WITH THE STATION BUS CONSIDERED AS THE REFERENCE IN ALL CASES.

CORRECTIONS SHOULD BE MADE FOR METER ERRORS ON LOW CURRENTS, INHERENT IN SOME PHASE ANGLE METERS.

FIG. 14 (0264B452-0) TEST CONNECTIONS FOR OVERALL TESTS ON THE 12CEB13C(-)A RELAYS

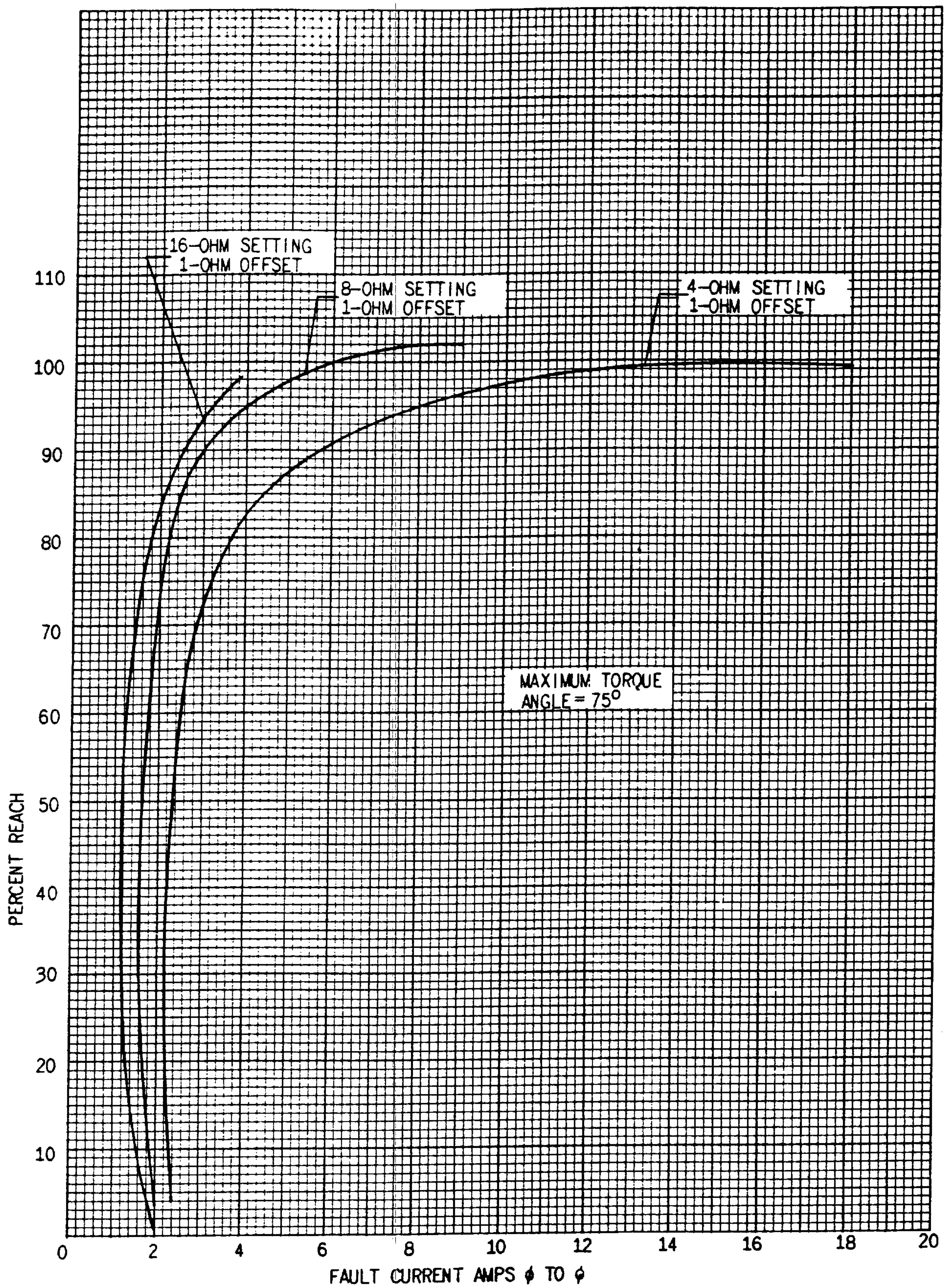


FIG. 15 (0104A8524-0) ACCURACY CURVES AT THE ANGLE OF MAXIMUM TORQUE AND ONE OHM OFFSET FOR THE 12CEB13C(-)A RELAY.

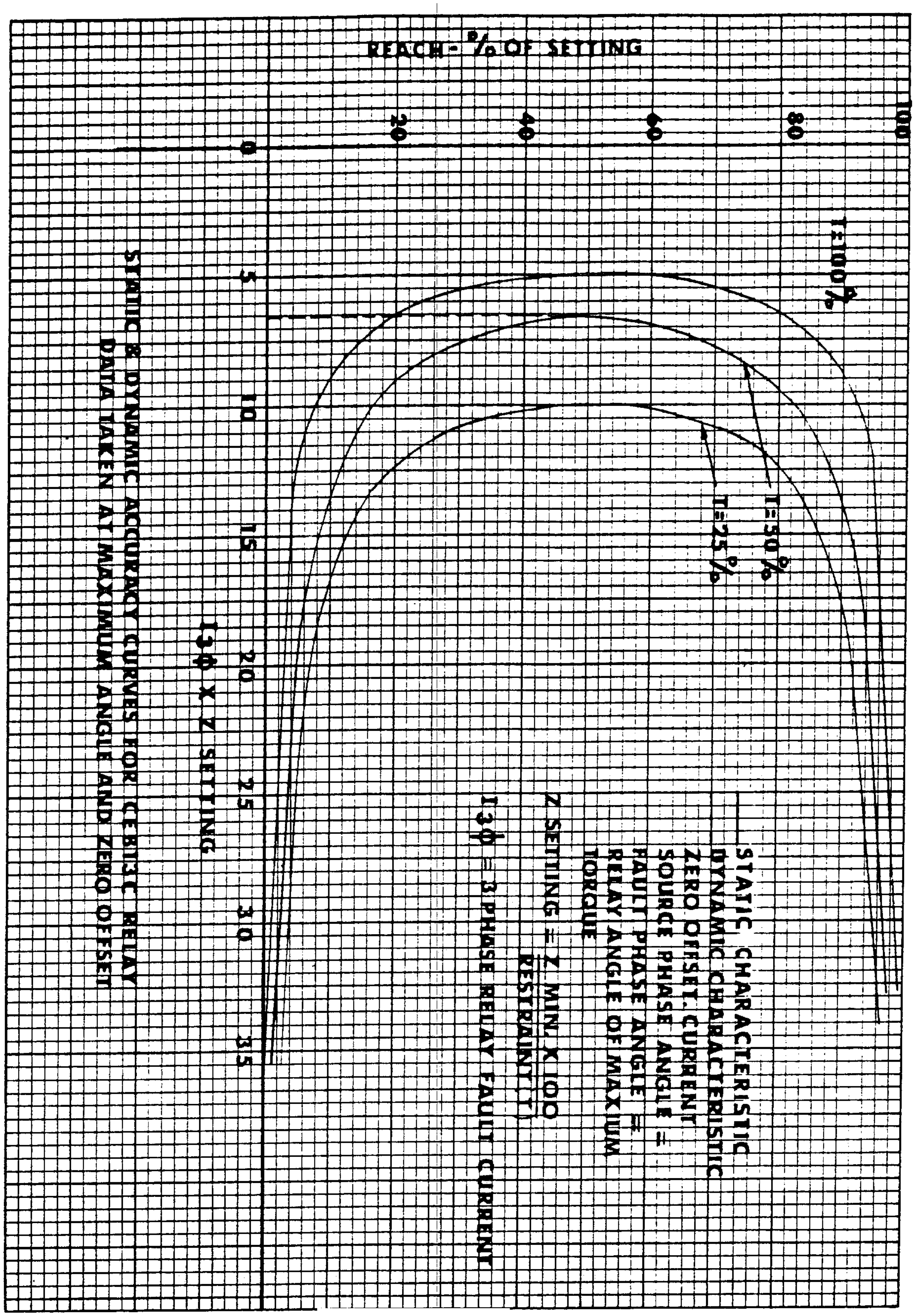


FIG. 16 (0257A8581-0) STATIC AND DYNAMIC CHARACTERISTIC CURVE FOR THE 12CEB13(-)A RELAY

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