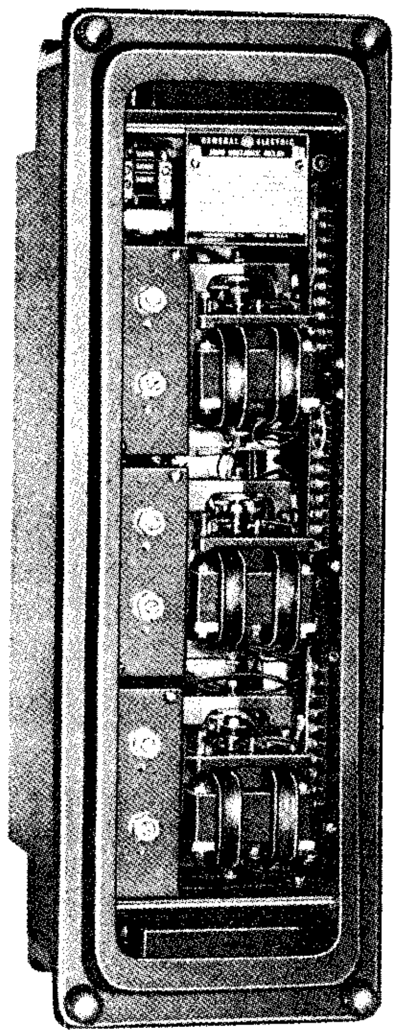
GEK-26423D

INSTRUCTIONS

GROUND DISTANCE RELAY

TYPE CEYG51A



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GROUND DISTANCE RELAY

CEYG51A RELAY

INTRODUCTION

The CEYG51A is a three phase, high speed, single zone, mho type, directional distance ground relay. It consists of three single-phase units in one L2-D case with facilities for testing one unit at a time. One target and seal-in unit provides indication of operation for all three distance units. The transient overreach characteristic of the CEYG51A relay has not been limited to the point where it is suitable for use as a first-zone relay. The relay was specifically designed for use as an overreaching device in directional comparison and transferred tripping schemes. Figure 3 shows the internal connections.

APPLICATION

The CEYG51A ground mho relay is applied as the primary ground relay in directional comparison and permissive overreaching transferred tripping schemes, employing separate primary and separate backup protection.

The ground mho units of the CEYG51A relay are specifically designed to detect single phase to ground faults. To this end they are supplied with quadrature voltage polarization. Thus, the polarizing voltage will be quite high and the relay will have a high operating torque level even on very close in line to ground faults. For this reason, these units are not provided with memory action. These ground mho units will also respond to three phase faults. If this is objectionable, the relay can be made unresponsive to any faults not involving ground simply by adding a non-directional zero sequence fault detector.

The ground mho units are provided with separate current circuits for zero sequence current compensation. A tapped auxiliary current transformer is used to obtain the proper ratio of compensation. When zero sequence current compensation is used, the ground mho unit has essentially the same reach on single phase to ground faults as on three phase faults. If zero sequence compensation is NOT used, the ground mho unit reach is considerably foreshortened on single phase to ground faults. See Appendix I for the minimum permissible reach settings under both conditions.

In directional comparison schemes, two CEYG51A relays connected back-to-back are required at each terminal. These relays operate in conjunction with a carrier channel to provide high speed protection against all single phase to ground faults in the protected line section. One relay acts to stop carrier and trip for internal faults while the other initiates carrier blocking on external faults. If zero sequence current compensation is used on the carrier stopping and tripping units, it should also be used on the carrier starting units. This will facilitate the unit settings and insure that both units that must coordinate will be operating on the same torque level. In any event, the carrier starting unit should be set as sensitively as possible. This will tend to increase security since the presence of a carrier signal will block tripping.

In permissive overreaching transferred tripping schemes, one CEYG51A relay is required at each terminal. It acts as a combined transferred trip initiating and a permissive relay for ground faults in the protected line section.

The choice of whether or not to use sequence current compensation depends upon the protected line length and system conditions. When zero sequence current compensation is NOT used, the ground mho unit reach required may be about 2 to 3 times the positive sequence impedance of the line in order to provide the proper coverage. This then tends to make the ground mho unit more sensitive to operation on load conditions or on power swings. The use of zero sequence current compensation reduces the necessary ground mho unit reach setting to approximately 1.25 times the positive sequence impedance of the line and, thus, minimizes its response to load or power swings. This is true provided there is little or no mutual impedance present from a parallel line.

Whether or not zero sequence current compensation is used, the ground mho units may be subject to incorrect operation on ground faults immediately behind the relay terminals. This will be dependent upon the line impedance and system conditions. It may be necessary to limit the mho unit reach setting in order to avoid this false tripping. Appendix II gives the limiatations of the mho unit reach setting when zero sequence current compensation is NOT used Appendix III gives the limitations of the mho unit reach setting when zero sequence current compensation is used.

The system conditions which require the limitation of the mho unit reach, as described by Appendices II and III, are rather unusual. They occur when the zero sequence current contribution over the line to a fault behind the relay is larger than the positive sequence current contribution.

If the reach of the unfaulted phase units in the non-trip direction is an application limitation, a zero sequence directional overcurrent relay (CFPG16A) may be used to supervise the CEYG51 operation. This will permit tripping only when the fault is in the forward direction. The external connections are shown in Figure 4.

Since the CEYG51A is an extended range relay with three basic minimum reach settings, the best overall performance will be obtained if the highest basic minimum reach tap setting that will accommodate the desired setting is used.

RATINGS

The Type CEYG51A relays covered by these instructions are available with potential circuits rated for operation on wye-wye connected potential transformers which supply secondary voltage of 120 volts phase-to-phase. Current coil ratings and ohmic ranges are as tabulated below:

BASIC MIN. OHMIC REACH (Ø-N OHMS)	RANGE OHMIC REACH (Ø-N OHMS)	CONTIN. CURRENT RATING AMPERES	ONE SEC. CUR. RATING AMPERES
1/2/3	1 - 30	5	225
0.5/1.0/1.5	0.5 - 15	5	225

The ohmic reach is at the angle of maximum torque of 60 degrees lag, and can be adjusted in 5 percent steps by means of a tapped autotransformer.

It will be noted that three basic minimum reach settings are listed for the mho units. Selection of the desired basic minimum reach is made by means of links on terminal boards located on rear of the relay. The positions of the two sets of links, (for each M unit), each identified as A-B determine the minimum ohmic reach setting as follows:

MINIMUM OHMIC REACH SETTING (OHM PHASE-TO-NEUTRAL) = A + B

CONTACTS

The main circuit-closing contacts of the relay will close and carry 30 amperes DC momentarily for tripping duty at control voltages of 250V DC or less. The circuit breaker trip coil should, however, always by opened by an auxiliary switch or other suitable means. If the tripping current exceeds 30 amperes, a tripping relay should be used.

The current carrying rating of the main contacts is determined by the tap setting of the seal-in coil as shown in Table I:

TABLE I

TARGET AND SEAL-IN UNIT			
	2.0 Amp Tap	0.6 Amp Tap	0.2 Amp Tap
D-C Resistance	0.13 Ohms	0.6 Ohms	7 Ohms
Carry Continuously	3.5 Amps	1.0 Amps	0.35 Amps
Carry 30 Amps for	4 Secs.	0.5 Secs.	---------
Carry 10 Amps for	----------	---------	0.2 Secs.

The normally closed contacts between terminals 19 and 20 will close, carry continuously, or interrupt 0.3 amperes in non-inductive circuits up to 250V DC.

OPERATING PRINCIPLES

The mho type units in the CEYG51A relay are of the four-pole induction-cylinder construction (see Fig. 6) with schematic connections as shown in Fig. 3. The two side poles, which are energized by the phase-to-phase voltage in quadrature with the phase-to-neutral voltage of the protected phase, produce the polarizing flux. The flux in the front pole, which is energized by a percentage of the phase-to-neutral voltage of the protected phase, interacts with the polarizing flux to produce restraint torque. The flux in the rear pole, which is energized by the line current of the protected phase, interacts with the polarizing flux to produce operating torque.

The torque at the balance point for the phase A starting unit can, therefore, be expressed by the following equation:

$$\text{Torque} = 0 = KI'_a E'_{bc} \cos(\alpha - 30) - TE'_a E_{bc}' \sin B \qquad (1)$$

where:

K = design constant

E_a' = Phase-A-to-neutral voltage at the relay location

E_{bc}' = Phase B to Phase C voltage ($E_b' - E_c'$) at the relay

I_a' = Phase A current, at the relay location

B = Angle by which E_a leads E_{bc}' (90^0 for balanced 3-phase condition)

T = Restraint tap setting

α = Angle by which I_a' leads E_{bc}'

CHARACTERISTICS

The operating characteristics of the mho units in the CEYG51A relay may be represented on the R-X impedance diagram as shown in Fig. 7. It should be noted that these steady-state characteristics are for rather specific fault conditions described below:

The mho unit has a circular characteristic which passes through the origin of the R-X diagram. The diameter passing through the origin defines the angle of maximum torque of the unit, which occurs when line current (I_a for example) leads the quadrature polarizing voltage (Ebc for example) by 30^o. Since there is essentially no phase shift in the line-to-neutral voltage for a single-phase-to-ground fault, this maximum torque angle (i.e. maximum reach angle) occurs when the line current lags the phase-to-neutral voltage by 60^o, which is the condition represented in Fig. 8.

The diameter of the impedance circle would normally be considered as the ohmic reach of the unit, which would be the basic minimum reach with the E^2 tap leads on 100 percent. However, if the mho unit is not compensated it is not an accurate distance measuring until except on 3-phase faults, or for the special case of single-phase-to-ground faults where the zero-sequence impedance to the fault is equal to the positive sequence impedance to the fault. Instructions are given in Appendices II and III for selecting a reach setting.

The ohmic reach of the mho unit can be extended by reducing the percentage of the fault voltage applied to the restraint circuit, that is by setting the E^2 tap leads on a lower percentage position on the tap block.

$$\text{Ohmic Reach} = \frac{(Z_{min})\ 100}{E^2 \text{ Tap Setting } (\%)} \qquad (5)$$

The ohmic reach obtained from equation (5) assumes that line angle and maximum torque angle are equal (60^o). The reduced reach at line angles other than 60^o can be obtained by multiplying the reach obtained from equation (5) by cos (60-Ø), where Ø is the line angle.

PICKUP

The operating torque will close the contacts when the fault current is in a certain direction and of sufficient magnitude to overcome the restraint torque. The operating torque on 3-phase faults is a maximum for fault currents which lag the unity power factor position by 60 degrees and is reliable down to one percent voltage with currents as tabulated below:

MINIMUM OHMIC REACH SETTING (Ø-N OHMS)	CURRENT RANGE FOR RELIABLE OPERATION
0.5	36 - 60
1	18 - 60
1.5	12 - 60
2	9 - 60
3	6 - 60

On single-phase-to-ground faults the quadrature polarizing potential will remain quite high with the result that the relay will operate at considerably less current than tabulated. For example, with a one percent restraint voltage and 120 volts polarizing the unit will operate with less than 1 ampere operating current for the 3-ohm minimum reach setting.

OPERATING TIME

For typical operating time characteristics see Figure 13A and 13B.

BURDEN

The burden imposed on the potential transformers by the type CEYG51A relay with the restraint tap set at 100 percent is as given below:

Basic Ohms	Rated Freq	Polarizing Circuit V	Polarizing Circuit Watts	Polarizing Circuit Vars	Polarizing Circuit VA	Restraint Circuit Volts	Restraint Circuit Watts	Restraint Circuit Vars	Restraint Circuit VA
1 - 30	60	120	10.1	8.88	13.5	70	2.7	4.0	4.8
0.5 - 15	60	120	10.1	8.88	13.5	70	0.9	1.6	1.8
1 - 30	50	120	8.41	7.38	11.2	70	1.7	3.0	3.4

If the restraint tap is reduced, the burden of the restraint circuit is given by the following equation:

$$VA = Watts \left(\frac{T}{100}\right)^2 + j\ VARS \left(\frac{T}{100}\right)^2$$

where Watts = Restraint circuit watts from table above.
VARS = Restraint circuit Vars from table above.
T = Tap in percent.

The burdens imposed on the current transformers by the current circuits are given below:

Basic Ohms	Rated Freq.	3-4, 5-6, or 7-8 Circuit I	R	X	Z	9-10 Circuit I	R	X	Z
1 - 30	60	5	0.070	0.040	0.080	5	0.210	0.120	0.240
0.5 - 15	60	5	0.007	0.005	0.008	5	0.021	0.013	0.024
1 - 30	50	5	0.058	0.033	0.067	5	0.175	0.100	0.200

NOTE: Above data is for the mho units set on their maximum ohmic reach taps. The burden for the lower reach tap settings will be less than the tabulated burdens.

CALCULATION OF SETTINGS

In applying the relay to a particular line and system, the limitations outlined under APPLICATION frequently do not materialize. Therefore, it is recommended that the initial calculations of 1 and 2 below be followed to determine what final calculations may be necessary and how the relay may be applied.

1. Determine if zero sequence current compensation is required. This will depend upon on evaluation of the necessary mho unit tap settings and the relation of the resulting mho characteristic with the line power loadings and power swings. See Appendix I, equations I_b and I_c.

2. Determine if there is a limitation in the application for incorrect operation on faults behind the relay terminal.

   a. When zero sequence current compensation is NOT used: if Co is equal to or less than C, no further evaluation need be made. See Appendix II, equations IIa, IIb and IIc.

   b. When zero sequence current compensation is used: if (3K' + 1) Co is equal to or less than C, no further evaluation need be made. See Appendix III, equations IIIa, IIIb and IIIc.

   c. If neither a nor b above is applicable, evaluate the equations of either Appendix II or III to determine if it is necessary to use the zero sequence directional overcurrent supervising relay, Type CFPH16A.

The following calculations are made as an example of determining the actual tap settings to be used.

Consider the protected line to be between breakers A and B on the portion of a system shown in Fig. 5.

Assume the following characteristics:

$Z_1' = 24.0 \angle 79^\circ$ primary ohms

$Z_o' = 72.0 \angle 75^\circ$ primary ohms

$Z_{om} = 14.4 \angle 75^\circ$ primary ohms

CT Ratio = 600/5

PT Ratio = 1200/1

$$\text{Secondary Ohms} = \frac{\text{CT Ratio}}{\text{PT Ratio}} \times \text{Primary Ohms}$$

$Z_1' = 2.4 \angle 79^\circ = 0.47 + j2.36$ secondary ohms

$Z_o' = 7.2 \angle 75^\circ = 1.9 + j6.95$ secondary ohms

$Z_{om} = 1.4 \angle 75^\circ = 0.36 + j1.35$ secondary ohms

Checking Appendix I first to establish the maximum tap setting that would still permit the CEYG51A at breaker A to detect a single phase to ground fault (F2) at the remote bus, Equation Ib should be used.

Assume for this fault at F2 that a system study yields the following quantities.

C_o = 0.17

C = 0.20

I_a' = 13.7 secondary amperes based on 600/5 CT's

I_o' = 4.1 secondary amperes

I_o'' = -0.88 secondary amperes based on the protected line CT ratio of 600/5. Note the negative sign because I_o'' flows in the opposite direction in the parallel line (D to C) from that in which I_o' flows in the protected line (A to B).

θ = 79^o

Substituting these values and the values of impedance assumed above into equation Ib of Appendix I, we obtain:

$$T = \frac{K \text{ Cos } (60-79)}{1.25\left[2.4 + \frac{(7.2 - 2.4)(0.17)}{(0.4 + 0.17)} + \frac{(1.4)(-0.88)}{13.7}\right]}$$

T = 0.204K

The value of T could be obtained for all three basic minimum reach settings. However, the highest one should be used. For the three ohm basic reach settings K = 300. Thus, for this basic tap setting the restraint tap T should be no larger than:

T = 0.204K = 61 percent

Consider now a ground fault at F1 immediately behind the relay. Appendix II indicates the approach to calculate the maximum safe reach setting to eliminate the possibility of an incorrect operation on single or double phase to ground faults at this location. Assume that a system study yields the following system constants:

C = 0.27

C_o = 0.11

Z_1 = 0.875 $\angle 82^o$ secondary ohms

Z_o = 1.05 $\angle 78^o$ secondary ohms

Z_o/Z_1 = 1.2

Using the 3 ohm basic minimum tap settings established above and evaluating equations IIa, IIb and IIc of Appendix II, the minimum permissible values of tap setting T are tabulated below.

QUANTITY	VALUE
Z1	0.875 $\angle 82^o$
Z_o	1.05 $\angle 78^o$
Z_o/Z_1	1.2
C_o	0.11
C	0.27
K_s	100
A	123^o
8	82^o
T (Equation IIa)	-10.5 Percent
T (Equation IIb)	-18 Percent
T (Equation IIc)	-14.5 Percent

Since all the values of T in the above table are negative, these equations impose no restrictions on the tap setting for this application. Thus, the relays may be set in the range of 10 to 61 percent.

Since the 61 percent setting will insure that the relay will reach only to the remote bus, a lower setting should be used. It is desirable to set the relay to reach at least 25 to 50 percent beyond the remote terminal. Thus, for 50 percent additional reach the restraint tap setting should be:

$$T = \frac{61}{1.5} = 41 \text{ percent}$$

Set tap on 40 percent

These same calculations should be repeated for the relays at the remote end of the line at terminal B. If the application is for directional comparison carrier, it will also be necessary to determine the settings of the carrier starting CEYG51A relays at both terminals. The carrier start relay settings should be at least 1.25 times the setting of the tripping relay at the remote terminal. This will insure that the carrier starting relay at the rear terminal will outreach the carrier tripping relay at the remote terminal and they will, therefore, coordinate properly. In any event the carrier starting units should be set as sensitively as possible.

In any case, ALWAYS set the relays that must coordinate with each other on the same basic minimum tap setting. Thus, the carrier start CEYG51A relay at terminal B should be set with the same basic minimum reach setting as the tripping CEYG51A relay at terminal A.

If zero sequence current compensation is used, equation Ic should be used instead of equation Ib. Thus, we obtain.

$$K' = \frac{6.95 - 2.36}{3(2.36)} = \frac{4.59}{7.08} = 0.65 \text{ per unit}$$

$$T = 0.33K = 0.33 \times 300 = 99 \text{ percent}$$

For the ground fault F2 immediately behind the relay, use the equation of Appendix III to calculate the maximum safe reach setting when using zero sequence current compensation.

CONSTRUCTION

The Type CEYG51A relay consists of three mho-type, 4-pole induction cylinder units. Each unit has an associated tapped autotransformer for controlling reach and adjustable resistors in the polarizing and restraint circuits for adjustment of angle and basic minimum ohmic reach. Figures 1 and 2 show construction details of the relay. Internal connections of the relay are shown in Figure 3.

The components are mounted on a cradle assembly which can be easily removed from the relay case. The cradle is locked in the case by means of latches at the top and bottom. The electrical connections between the case block and cradle block are completed through a removable connection plug. A separate testing plug can be inserted in place of the connection plug to permit testing the relay in its case. The cover attaches to the case from the front and includes the target reset mechanism and an interlock arm to prevent the cover from being replaced until the connection plug has been inserted.

Outline and panel drilling dimensions are shown in Figure 15.

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

ACCEPTANCE TESTS

Immediately upon receipt of the relay an inspection and acceptance test should be made to insure that no damage has been sustained in shipment and that the relay calibrations have not been disturbed.

VISUAL INSPECTION

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

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

MECHANICAL INSPECTION

It is recommended that the following mechanical adjustments be checked:

1. There should be no noticeable friction in the rotating structure of each unit. The normally closed contacts should be closed when the relay is in the upright position.

2. There should be an end play of from .005 to .015 inches on the shafts of the rotating structures. The lower jewel screw bearing of each unit should be screwed firmly in place, and the pivot at the top of the shaft locked by its set screw.

3. The contact gap on each unit should be approximately .045 to .065 inches. There should be .004 to .012 inch clearance between the stationary contact rod and the solid backstop when the contact is open.

4. The spring windup should be sufficient to cause the normally closed stationary contact to deflect so that it just touches the solid stop when the unit is de-energized.

5. The clutch of each unit should slip when a force of 45 to 65 grams is applied to the moving contact assembly at the moving contact.

6. The armature and contacts of the target and seal-in unit should move freely when operated by hand. There should be a screw in only one of the tap positions on the right stationary contact strip. Operate the armature by hand and check that the target latches in its exposed position before the contacts close. There should be at least 1/32" wipe on the seal-in contacts. With the cover fastened securely in place, check that the target resets positively when the reset button at the bottom of the cover is operated.

7. Check the location of the contact brushes on the cradle and case blocks against the internal connection diagram for the relay. Be sure that the shorting bars are in the proper locations on the case blocks, and that the long and short brushes on the cradle block agree with the internal connection diagram. Figure 11 shows a sectional view of the case and cradle blocks with the connection plug in place. Note that there is an auxiliary brush in each position on the case block. This brush should be formed high enough so that when the connecting plug is inserted it engages the auxiliary brush before striking the main brush. This is especially important in current and other circuits with shorting bars since an improper adjustment of the auxiliary brush could result in a CT secondary circuit being momentarily open circuited.

ELECTRICAL TESTS

It is recommended that the following electrical checks be made immediately upon receipt of the relay.

1. Polarity Check - The following check will insure that the relative polarity of operating, polarizing and restraint circuits of each unit is correct. Each unit can be checked individually using the test connections in Figure 9. With all tap leads removed the connections shown for each unit should cause the contacts of that unit to close. With the E^2 tap of each unit set in the 80 percent position, that unit should develop a strong contact opening torque.

2. Directional Check - The following checks are to determine that each unit has correct directional characteristics. Use the test connections shown in Figure 10. Set the voltages to two volts and set the phase shifter so that the current leads the voltage by 30 degrees with the connections shown. The contacts of each unit should close at some value less than the minimum amperes given in Table III and remain closed as the current is increased to the maximum value given in Table III. The E^2 taps should be on 100 percent for these tests.

TABLE III

OHMIC REACH TAP SETTING	MINIMUM AMPERES	MAXIMUM AMPERES
0.5	32	60
1.0	16	60
1.5	12	60
2.0	8	60
3.0	6	60

Set the phase shifter so that the current leads the voltage by 210 degrees. The contacts of each unit should remain open from zero to 60 amperes.

3. Maximum Torque Angle - The maximum torque angle of the mho-type units can be checked using the connections shown in Figure 10, but with the E^2 tap disconnected. The operating current should be set for 5 amperes, with polarizing voltage at 120 volts.

With the phase shifter set so that operating current leads polarizing voltage by 30°, the left contact of the unit will be closed. Next find the angles on either side of the 30° position which cause the left contact to just open. These are the zero torque angles of the unit. The maximum torque position will be at the bisector of the angle between the two zero torque lines. For example, assume that for a particular unit the left contact just opens at 110° and 310°. The angle of maximum torque will be:

$$\frac{1}{2}(110 + 310) = 210^{\circ}, \text{ ie } 30^{\circ} \text{ lead}$$

The maximum torque angle of the units should be at 30° lead, $\pm 3^{\circ}$. This is the angle by which the operating current leads the polarizing voltage for a particular unit.

4. Pickup Check - The following check is to determine that the ohmic reach of each unit is within ± 14 percent of the minimum reach as given on the nameplate. These checks should be made with the E^2 taps set at 100 percent and the voltage adjusted for the value shown in Table IV for the specific ohmic range and with the relay connected as shown in Figure 10. Set the phase shifter so that current leads voltage by 30 degrees, check that the current required to close the contacts falls within the range shown in Table IV. Resistor R_{11}-R_{12}-R_{13} should not be used to adjust pickup. The resistors are used to make the phase angle of the restraint circuit the same as the phase angle of the polarizing circuit.

TABLE IV

UNIT Ø-N	REACH LINK SETTING	RESTRAINT APPLIED VOLTAGE	POLAR. APPLIED VOLTAGE	PICKUP CURRENT	PHASE ANGLE °LEAD
0.5	0.5	20V	120V	34.4 - 45.6	30°
1.0	1.0	25	120	21.6 - 28.5	30°
1.5	1.5	35	120	20.0 - 26.6	30°
2.0	2.0	35	120	15.0 - 20.0	30°
3.0	3.0	70	120	20.0 - 26.6	30°

5. Compensating Winding Check - The following check is to confirm that the relative polarity of the compensating windings between terminals 9-10, is correct. Use the basic test connections of Figure 10, but connect the current circuits as tabulated in the following:

UNIT	I_1 TO STUD	I_2 TO STUD	JUMPER STUDS
M1	3	10	4 - 9
M2	5	10	6 - 9
M3	7	10	8 - 9

With voltage, E^2 tap, and phase angle set as in the pickup check (4), measure the current required to close the left contact of each unit. The current should be one half the values listed in Table IV.

6. Target Seal-in Unit - With the target in the "down" or unexposed position, check pickup on both taps. Use a DC source with the circuit arranged so that test current through studs 1-11, with M1 contact held closed, can be gradually increased to the pickup point. Pickup current should be tap rating or less. Refer to the section on Target Seal-in Unit Settings under INSTALLATION PROCEDURE for the recommended steps to change the tap setting.

INSTALLATION PROCEDURE

If after the ACCEPTANCE TESTS the relay is held in storage before shipment to the job site, it is recommended that the visual and mechanical inspection described under the section on ACCEPTANCE TESTS be repeated before installation.

The relay should be mounted on a vertical surface in a location which is clean and dry and free from excessive vibration. The outline and panel drilling dimensions are shown in Fig. 15. The internal connections are shown in Fig. 3 and typical external connections are shown in Fig. 4.

RELAY SETTINGS

1. Mho Units

Refer to the section on CALCULATIONS AND SETTINGS for a discussion of suggested procedures for determining the mho unit tap block settings for a specific application.

The reach of the mho units can be adjusted in five percent steps by connecting the tap leads to the proper taps on the tap blocks. The red leads should be connected to one of the 10 percent tap positions of the blocks. The green leads should be connected to one of the two 5% tap positions.

MECHANICAL CHECKS

1. Check the movable contact structures of each unit by hand. There should be no noticeable friction. When the left contact is closed by hand and then released the movable structure should reset to the right and reclose the normally closed contact with the relay completely deenergized.

2. Examine the contact surfaces for signs of tarnishing or corrosion. Fine silver contacts should be cleaned with a burnishing tool, which consists of a flexible strip of metal with an etched, roughened surface. Burnishing tools designed specially for cleaning relay contacts can be obtained from the factory. Do not use knives, files, or abrasive paper or cloth of any kind to clean relay contacts.

3. Operate the target seal-in unit by hand and check that the target latches before the contacts make, and that the contacts have at least 1/32" wipe. With the cover replaced check that the target resets when the reset button is operated.

ELECTRICAL CHECKS

Using the test connections shown in Figure 10 check the relay reach setting as described under ACCEPTANCE TEST - PICKUP CHECK.

PORTABLE TEST EQUIPMENT

The manner in which reach settings are made on the starting units is briefly discussed in the section titled SAMPLE CALCULATIONS FOR SETTINGS. Examples of the calculation of typical settings are given in that section. It is the purpose of the electrical tests in this section to check the starting unit ohmic pick-up settings which have been made for a particular line section.

To eliminate errors which may result from instrument inaccuracies the test circuit shown in schematic form in Fig. 16 for the mho units are recommended. In the figure $R_S + jX_S$ (when used) is the source impedance, S_F is the fault switch, and $R_L + jX_L$ is the impedance of the line section for which the relay is being tested. The autotransformer T_A which is across the fault switch and line impedance is tapped in 10 percent and 1 percent steps so that the line impedance $R_L + jX_L$ may be made to appear to the relay very nearly as the actual line on which the relay is to be used. This is necessary since it is not feasible to provide the portable test reactor X_L and the test resistor with enough taps so that the combination may be made to match any line.

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.

B. TESTING THE MHO UNITS

To check the calibration of the mho unit it is suggested that the test box, test reactor, and test resistor be arranged with Type XLA test plugs as shown in Fig. 18. These connections are similar to the schematic connections of Fig. 16, except that the XLA test plug connections are now included. As noted in the section on CHARACTERISTICS the mho unit provides an accurate distance measurement on ground faults only for the special case where the zero sequence impedance is equal to the positive sequence impedance to the fault. The tests outlined below check the line-to-neutral ohms that the unit would measure under these conditions.

After the mho unit has been set for the desired reach, select a value of test impedance at 60°, that is $R_L + jX_L \underline{/60^o}$, which exceeds the reach setting of the unit by the smallest amount possible. Then using the test circuit of Fig. 18 (note that current limiting impedance X_S and R_S is omitted), turn the test box fault switch S_F to the "ON" position and adjust the selector switches to obtain a balance point. The percent tap setting of the test box autotransformer, which should cause the starting unit to just close its contacts, is given by equation (12).

$$\% \text{ Tap} = \frac{Z_{MU} \cos (60 - \theta)}{Z_L} (100) \qquad (12)$$

where: Z_{MU} = Ohmic reach of the mho unit (See Equation 5 in CHARACTERISTICS section).

Z_L = Test impedance in ohms

θ = Angle of test impedance

The portable test reactor (Cat. No. 6054975) and test resistor (Cat. No. 6158546) are normally sold as a set identified by a calibration curve number shown on the nameplate. The test resistor taps have been set at the factory in conjunction with taps on the associated test reactor to provide a range of impedances at 60° and 30° angles. If one of the 60° impedance values thus obtained is used the angle θ in the above equation will be 60°. If a resistor-reactor tap combination other than those covered by the calibration sheet is used, or if the test reactor is used with some other non-inductive resistance to approximate the 60° impedance, then the actual value of θ should be used in equation 12. The angles of the test reactor at the various nominal tap settings are given in Table VI.

TABLE VI

TEST REACTOR TAP	ANGLE
24	88°
12	87°
6	86°
3	85°
2	83°
1	81°
0.5	78°

As an illustration of the above assume that the 3 ohm basic minimum reach link setting is to be used and that is has been decided to set the E^2 tap on 45 percent. This setting falls within the limits of 10 and 67 percent determined in the example in the section SAMPLE CALCULATIONS OF SETTINGS. Ohmic reach of the starting unit at its 60° angle of maximum torque will then be 6.68 ohms, as determined from equation 5 in the CHARACTERISTICS section.

Using a typical combination of test reactor and test resistor, the 60° impedance closest above this reach setting is 14.4 ohms. The percent tap of the test box autotransformer at which the mho unit contacts will just close can then be calculated as follows from equation (12):

$$\% \text{ Tap} = \frac{6.68 \cos (60^o - 60^o)}{14.4} (100) = 46.3\%$$

The mho unit should therefore theoretically close its contacts at 46 percent and remain open at 47 percent. A range of 40 to 54 percent in the balance point (±14% of the nominal) is satisfactory tolerance for the mho unit.

If the ohmic reach of the mho unit checks correctly according to the above procedure, the angle of maximum torque is probably correct also. The angle can be verified if desired by checking two other points on the mho characteristic of the mho unit. It is suggested that the check be made for a fault impedance angle near 90° by using the test reactor alone, and for a fault impedance of 30° by using the appropriate resistor-reactor combination.

Assume that the nominal 12 ohm reactor tap is used with $R_L = 0$, and that the actual reactance value of this tap is 11.9 ohms. Since the angle of this tap (Table VI) is 87°, the impedance is:

$$Z_L = \frac{X_L}{\cos 3^0} = \frac{11.9}{.993} = 11.95 \text{ ohms}$$

It is obvious from the above that the reactance and impedance can be assumed to be the same for this reactor tap. Actually the difference need only be taken into account on the 3, 2, 1 and 0.5 ohm taps.

The test box autotransformer tap required for the contacts to just close can be determined from equation (12) as follows:

$$\% \text{ Tap} = \frac{6.68 \cos (60 - 87)}{11.9} (100) = 50\%$$

A range of 43 to 57 percent in the balance point indicates acceptable tolerance for the mho unit angle. A similar approach can then be taken using a 30° combination of reactor-resistor taps.

If a four-wire test source is not available, the mho unit characteristic can then be checked using a three-phase, three-wire test source and the test circuit of Fig. 17. Following the same procedure outlined above for the four-wire test circuit the only difference in results if a 30° shift in the mho characteristic. With these connections maximum reach occurs at 90° with 88.6% reach at 60°, and 50% reach at 30°. A mho unit which produces the mho characteristic shown in Fig. 17 for the three-wire connections will produce the mho characteristic shown in Fig. 18 when supplied with normal polarizing, restraining, and operating quantities.

TABLE VII

UNIT	A	B	C	D	E	F
TOP	15	18	16	17	3	4
MID.	16	18	17	15	5	6
BOT.	17	18	15	16	7	8

COMPENSATING WDG

G	H
9	10
9	10
9	10

Check the unit using E and F currents as shown in Table VII above. Then move the E and F leads to G and H connections to check the compensating windings.

SERVICING

If it is found during the installation or periodic tests that the mho unit calibrations are out of limits, they should be recalibrated as outlined in the following paragraphs. It is suggested that these calibrations be made in the laboratory. The circuit components listed below, which are normally considered as factory adjustments, are used in recalibrating the units. These parts may be located from Figure 1 and 2.

R_{11} - M1 unit restraint angle adjustment

R_{21} - M1 unit angle of maximum torque adjustment

R_{12} - M2 unit restraint angle adjustment

R_{22} - M2 unit angle of maximum torque adjustment

R_{13} - M3 unit restraint angle adjustment

R_{23} - M3 unit angle of maximum torque adjustment

NOTE: Before making pickup or phase angle adjustments on the mho units, the unit should be allowed to heat up for approximately 15 minutes energized with rated voltage. Also it is important that the relay be mounted in upright position so that the units are level.

RESTRAINT CIRCUIT ANGLE ADJUSTMENT

The resistors R_{11}-R_{12}-R_{13} are used to make the phase angle of the restraint circuit the same as the phase angle of the polarizing circuit. This is done to improve the transient performance of the unit. To properly adjust R_{11}-R_{12}-R_{13} the following is required.

1. Remove lower connection plug.
2. Adjust control spring so that the contacts float between the two stationary contacts, when the relay is de-energized.
3. Connect studs 15 and 16 to one side of a 70 volt test source. Connect studs 17 and 18 to the other side of the 70 volt test source. Adjust R_{11} until the moving contact on the top unit floats between the two stationary contacts.
4. Connect studs 16 and 17 to one side of the 70 volt test source and studs 15 and 18 to the other side. Adjust R_{12} until the moving contact of the middle unit floats between the two stationary contacts.
5. Connect stud 15 and 17 to one side of the 70 volt test source and studs 16 and 18 to the other side. Adjust R_{13} until the moving contact of the bottom unit floats between the two stationary contacts.

DIRECTIONAL CHARACTERISTIC

If the mho unit fails to perform properly at high current levels as outline under ACCEPTANCE TESTS the inner stator or core must be readjusted. This can be accomplished by means of rotating the core (slightly clockwise or counterclockwise as required to make sure that the contacts close and remain closed within specified currents), with the special core adjusting wrench. (Cat. No. 0178A9455 Pt. 1) (See Fig. 12).

MAXIMUM TORQUE ANGLE

The maximum torque angle of the mho-type units can be checked using connections shown in Fig. 10, but with the E^2 taps disconnected, as outlined in ACCEPTANCE TESTS. If it is found that the angle of maximum torque is outside of limits it can be restored by means of the adjustable resistors, R_{21}, R_{22}. and R_{23} for mho units M1, M2 and M3 respectively.

PICKUP

The pickup or ohmic reach of each unit should be within ±14 percent of the published minimum reach at the angle of maximum torque as checked, in ACCEPTANCE TESTS. On the CEYG51A the adjustable resistors in the restraint circuits (R_{11}, R_{12}, and R_{13}) are used to adjust the angle of the restraint circuit to equal the angle of the polarizing circuit. This is done so that the restraint torque will be proportional to the area of the voltage triangle. Therefore, since the resistors R_{11}, R_{12} and R_{13} are used to set the angle of the restraint circuit, they must not be used to adjust reach.

CLUTCH ADJUSTMENT

The clutch of each unit should slip when a force of 45-65 grams is applied to the moving contact. The cup assembly must be held securely with a special wrench 0246A7916 (1/2 inch wrench, 1/32 inch thick) placed between the front coils and the contact head. The clutch pressure is varied by loosening or tightening the self locking nut (3/8 inch) at the top of the cup shaft.

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 give the General Electric Requisition number on which the relay was furnished.

APPENDIX I

MINIMUM PERMISSIBLE REACH SETTING FOR THE CEYG51A

The CEYG51A relay will measure positive sequence impedance and, therefore, distance on the transmission line accurately on three phase faults. However, on single phase to ground faults, when zero sequence current compensation is NOT used, its reach is foreshortened. If zero sequence current compensation is used, the only remaining variation in unit reach will be due to zero sequence mutual impedance with a parallel line. These factors will be evident from the following equations Ia and Ib. The mho units of the CEYG51A relay must not be compensated for the zero sequence mutual impedance due to a parallel line. This is because reversal mutual in the parallel line could cause the mho unit to operate incorrectly on the protected line.

NO ZERO SEQUENCE CURRENT COMPENSATION

When zero sequence current compensation is NOT used, the effective impedance as seen by the relay on the faulted phase for a single phase to ground fault at the far end of the line is:

$$Z_1' + \frac{(Z_o' - Z_1')C_o}{2C + C_o} + \frac{Z_{om}I_o''}{I_a'} \qquad \text{Ia}$$

where:

Z_1' = Positive sequence impedance of the protected line.

Z_o' = Zero sequence impedance of the protected line.

Z_{om} = Total zero sequence mutual impedance between protected line and parallel line.

I_o'' = Zero sequence current in the parallel line, taken as positive when the current flow in the parallel line is in the same direction as the current in the protected line.

I_a' = Phase A current in the relay.

C = Positive sequence distribution constant I_1'/I_1.

C_o = Zero sequence distribution constant I_o'/I_o.

T = Tap setting in percent.

K = Design Constant

100 for the 1.0 ohm basic minimum tap

200 for the 2.0 ohm basic minimum tap

300 for the 3.0 ohm basic minimum tap

θ = The angle the fault current lags the fault voltage.

To insure that the relay on the faulted phase picks up for a fault at the remote bus, the maximum percent tap setting permissible is:

$$T = \frac{K \cos(60^o - \theta)}{1.25\left[Z_1' + \frac{(Z_o' - Z_1')C_o}{2C + C_o} + \frac{Z_{om}I_o''}{I_a'}\right]} \qquad \text{Ib}$$

If the solution to equation Ib yields a tap value (T) greater than 100 percent, this implies that even the shortest reach setting possible (100 percent tap) will suffice.

The factor 1.25 introducted in equation Ib is a safety factor. In order to extend the reach of the relay beyond the far bus, lower tap settings will be required.

If there is no zero sequence mutual impedance, the last term in the denominator of equation Ib becomes zero. If there is mutual impedance existing between the protected line and several other circuits, this last term becomes:

$$\frac{1}{I_a'} \sum Z_{om} I_o''$$

Note that in this summation, the direction of the zero sequence current flow (I_o'') in each of the parallel circuits must be considered.

All voltages, currents and impedances in the above equations are in terms of secondary quantities based on the CT and PT ratios of the protected line. This applies to I_o'' as well as I_a'.

WITH ZERO SEQUENCE CURRENT COMPENSATION

When zero sequence current compensation is used, the effective impedance as seen by the relay on the faulted phase for a single phase to ground fault at the far end of the line becomes:

$$Z_1' + \frac{Z_{om} I_o''}{I_a' + 3K'I_o'}$$

where:

$$K' = \frac{X_o' - X_1'}{3X_1'}$$

The per unit ratio of zero sequence current to be used for compensation.

To insure that the relay on the faulted phase picks up for a fault at the remote bus, the maximum percent tap setting permissible is:

$$T = \frac{K \operatorname{Cos}(60 - \theta)}{1.25 \left[Z_1' + \dfrac{Z_{om} I_o''}{I_a' + 3K'I_o'} \right]}$$

APPENDIX II

MAXIMUM PERMISSIBLE REACH SETTING FOR THE CEYG51A NO ZERO SEQUENCE CURRENT COMPENSATION

Under some system conditions it is possible during single phase to ground faults in the non-tripping direction that one or the other of the units associated with the unfaulted phase will pick up. Since this can result in a false trip, it is necessary to limit the reach setting of the starting units to prevent them from picking up on reverse faults. Equations IIa and IIb give this limit.

$$T = \frac{K_s (C_o - C)}{Z_1} \operatorname{Cos}(150 - A - \theta) \qquad \text{IIa}$$

$$T = \frac{K_s (C_o - C)}{Z_1} \operatorname{Cos}(A - \theta - 30) \qquad \text{IIb}$$

The system constants in the above equations should be evaluated for a single phase to ground fault in the non-tripping direction at the relay terminals. This fault location is designated as F1 in Figure 5.

T = Minimum permissible tap setting in percent.

C = Positive sequence distribution constant I_1'/I_1.

C_0 = Zero sequence distribution constant I_0'/I_0.

Z_1 = System positive sequence impedance as viewed from the fault.

Z_0 = System zero sequence impedance as viewed from the fault.

θ = The angle of the system positive sequence impedance Z_1.

K_s = Constant depending on the ratio of Z_0/Z_1. See curves on Figure 14.

A = Angle depending on the ratio of Z_0/Z_1. See curves on Figure 14.

The system constants in these equations should be evaluated for a single phase to ground fault in the non-tripping direction at the relay terminals. This fault location is designated as F1 in Figure 5.

Under some system conditions it is possible during double phase to ground faults in the non-tripping direction that the unit on the unfaulted phase will pick up. Since this can result in a false trip, it is necessary to limit the reach setting of the units to prevent them from picking up on reverse double phase to ground faults. Equation IIc gives this limit.

$$T = \frac{K\,(C_0 - C)}{3Z_0}\,\text{Cos}\,(\theta - 60) \qquad \text{IIc}$$

where:

K = Design Constant

100 for 1.0 basic minimum tap

200 for 2.0 basic minimum tap

300 for 3.0 basic minimum tap

θ = The angle of the system zero sequence impedance Z_0.

All other terms are defined above.

Note that C_0 and C in equation IIc have the same values as they have in equations IIa and IIb.

After the values of T have been calculated for equations IIa, IIb and IIc above, the largest of the three values should be selected and then some margin, such as 10% (not 10 percentage points), should be added to this setting. This value of tap setting is then the minimum permissible tap setting for the relay at the terminal under consideration. If any (or all) of the values of T calculated from the three equations is negative, that signifies that the particular equation (or equations) offers no limitation on the minimum permissible tap setting.

Aside from all of the above, the relay should never be set on a tap that is lower than 10 percent.

All voltages, currents and impedances in the above equations are in terms of secondary quantities based on the CT and PT ratios of the protected line.

The effects of arc resistance have not been included in these calculations.

APPENDIX III

MAXIMUM PERMISSIBLE REACH SETTING FOR THE CEYG51A WITH ZERO SEQUENCE CURRENT COMPENSATION

When zero sequence current compensation is used, the equations of Appendix II are modified as follows:

for single phase to ground faults in the non-trip direction:

$$T = \frac{K_s\left[(3K' + 1)\ C_0 - C)\right]}{Z_1} \text{Cos}\ (150\text{-}A\text{-}\theta) \qquad \text{IIIa}$$

$$T = \frac{K_s\left[(3K' + 1)\ C_0 - C)\right]}{Z_1} \text{Cos}\ (A\text{-}\theta\text{-}30) \qquad \text{IIIb}$$

for double phase to ground faults in the non-trip direction:

$$T = \frac{K\left[(3K' + 1)\ C_0 - C)\right]}{3Z_0} \text{Cos}\ (\theta - 60) \qquad \text{IIIc}$$

where:

$$K' = \frac{X_0' - X_1'}{3X_1}$$ The per unit ratio of zero sequence current to be used for compensation.

All other terms are as defined in Appendix II.

If the minimum permissible tap setting including suitable margins as determined from equations IIIa, IIIb, or IIIc above are positive and greater than the maximum permissible tap setting as determined from equation Ic, then it will be necessary to use the zero sequence directional overcurrent supervising relay, Type CFPG16A.

Since the last edition, Figures 4 and 15 have been changed.

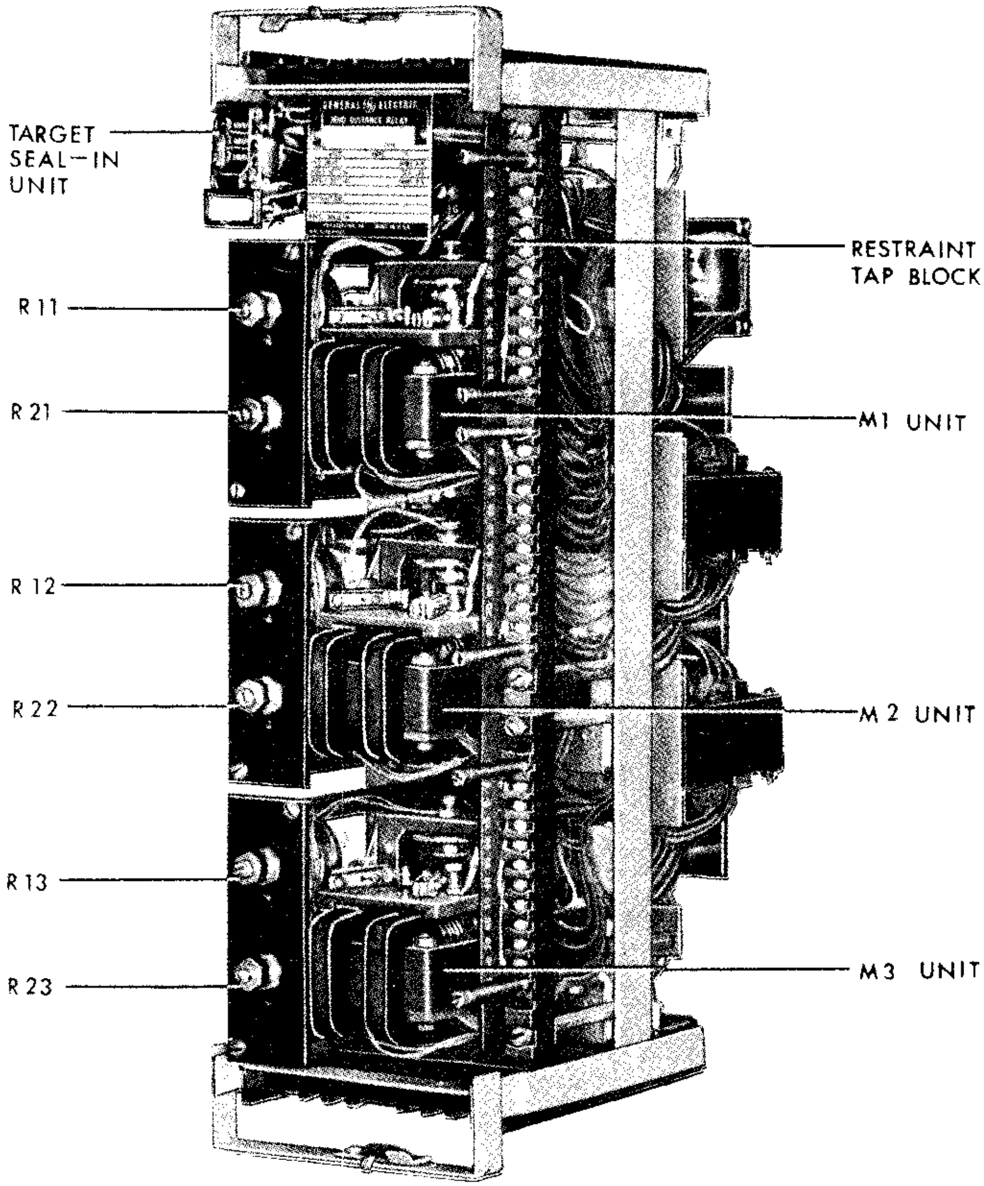


FIG. 1 (8039015) RELAY TYPE CEYG51A OUT OF CASE (3/4 FRONT VIEW)

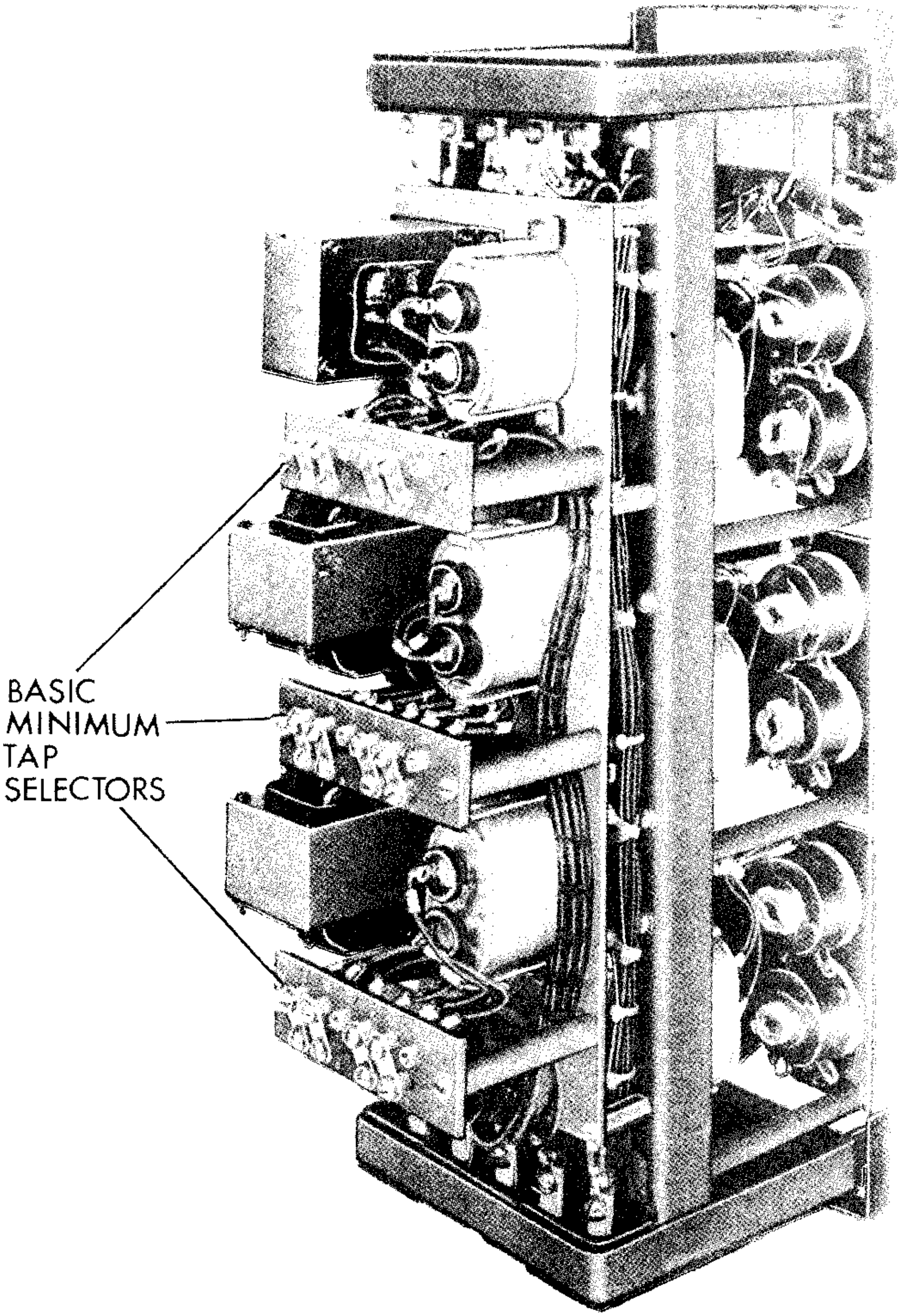
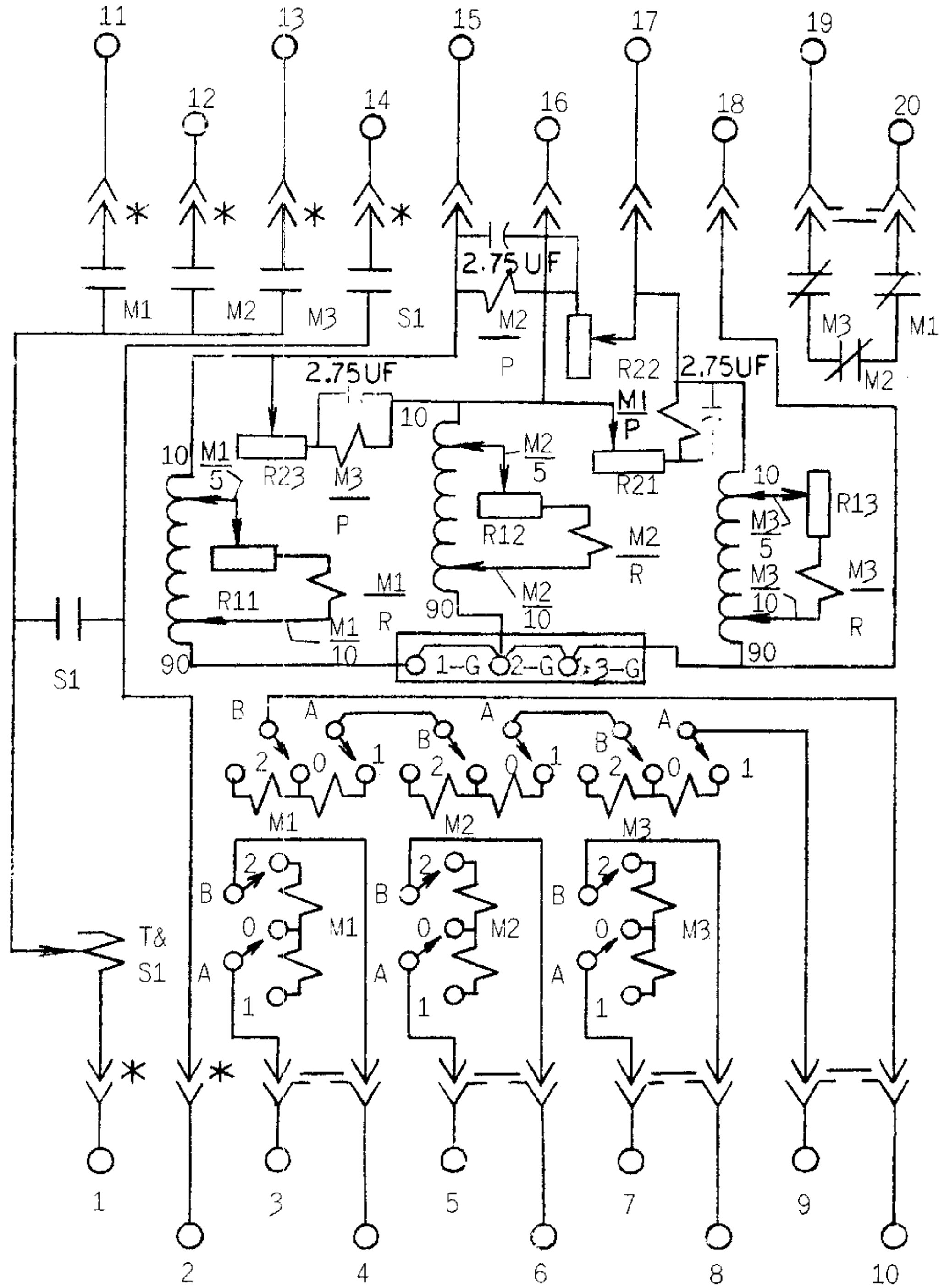


FIG. 2 (8043301) RELAY TYPE CEYG51A OUT OF CASE (3/4 REAR VIEW)



M1=TOP UNIT
M2=MIDDLE UNIT
M3=BOTTOM UNIT

*= SHORT FINGER

FIG. 3 (0178A9106-1) INTERNAL CONNECTIONS DIAGRAM FOR THE CEYG51A RELAY

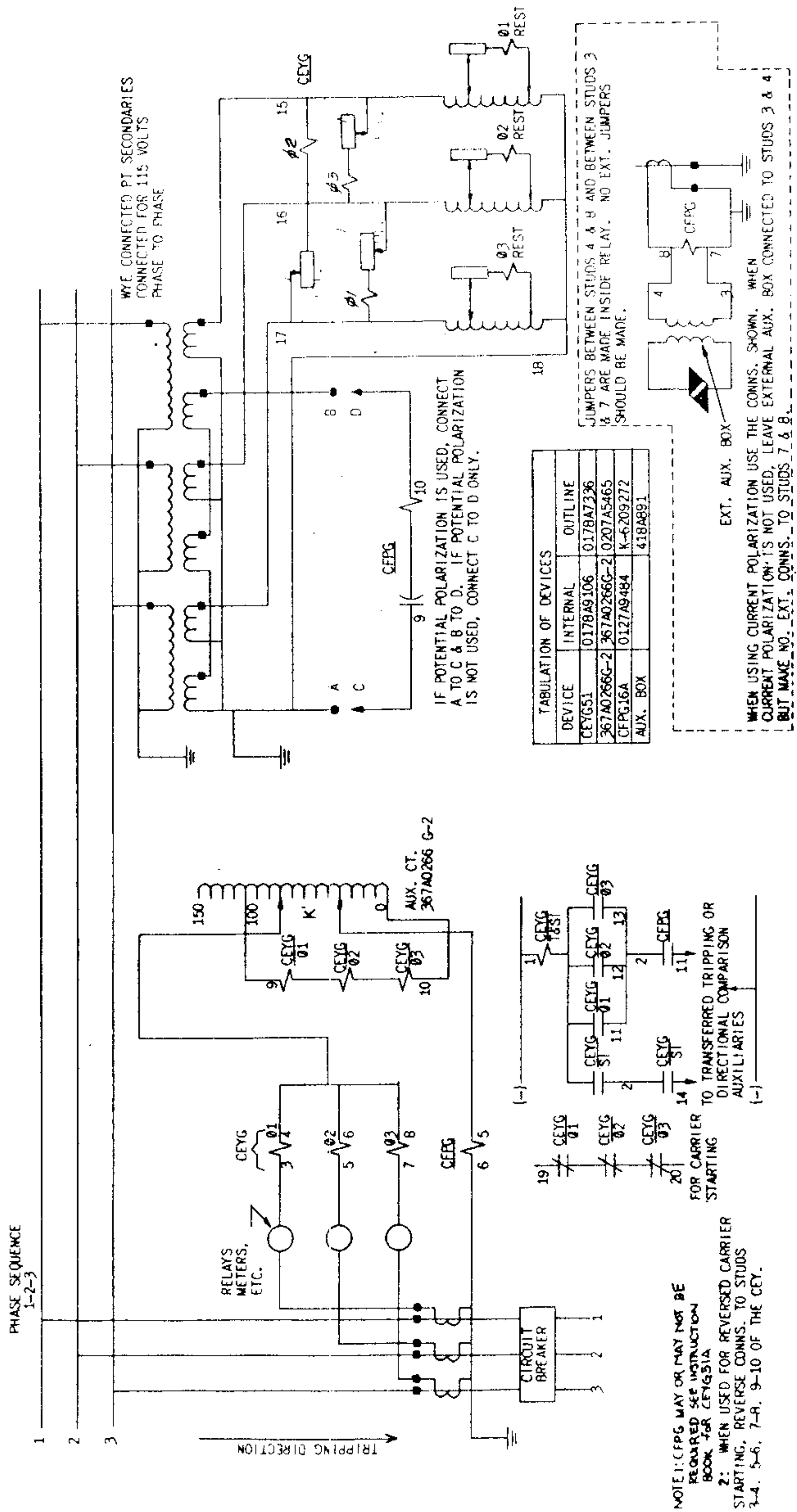


FIG. 4 (0165B2201 [2]) EXTERNAL CONNECTIONS DIAGRAM FOR CEYG51A RELAY

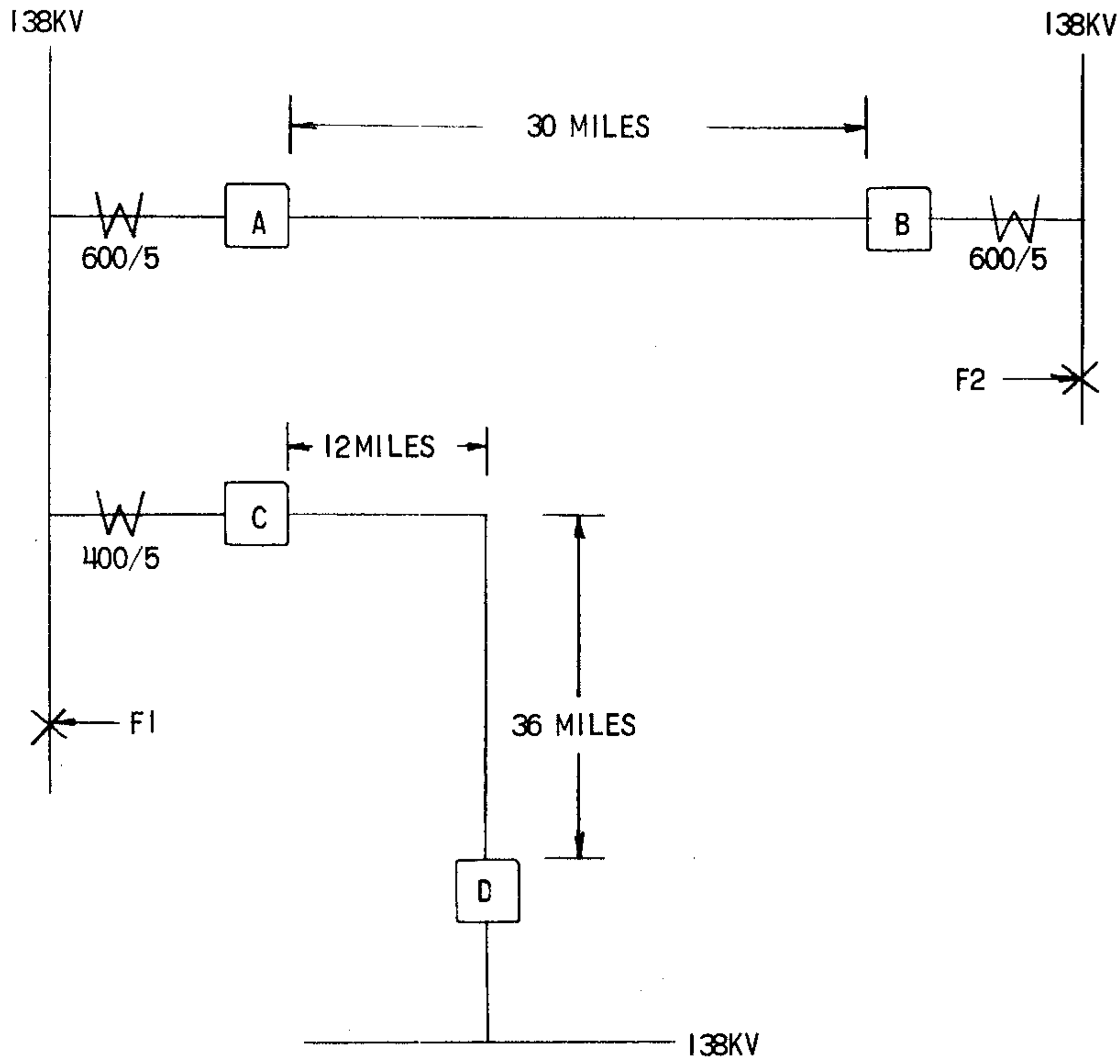


FIG. 5 (0208A5544-0) TYPICAL TRANSMISSION SYSTEM

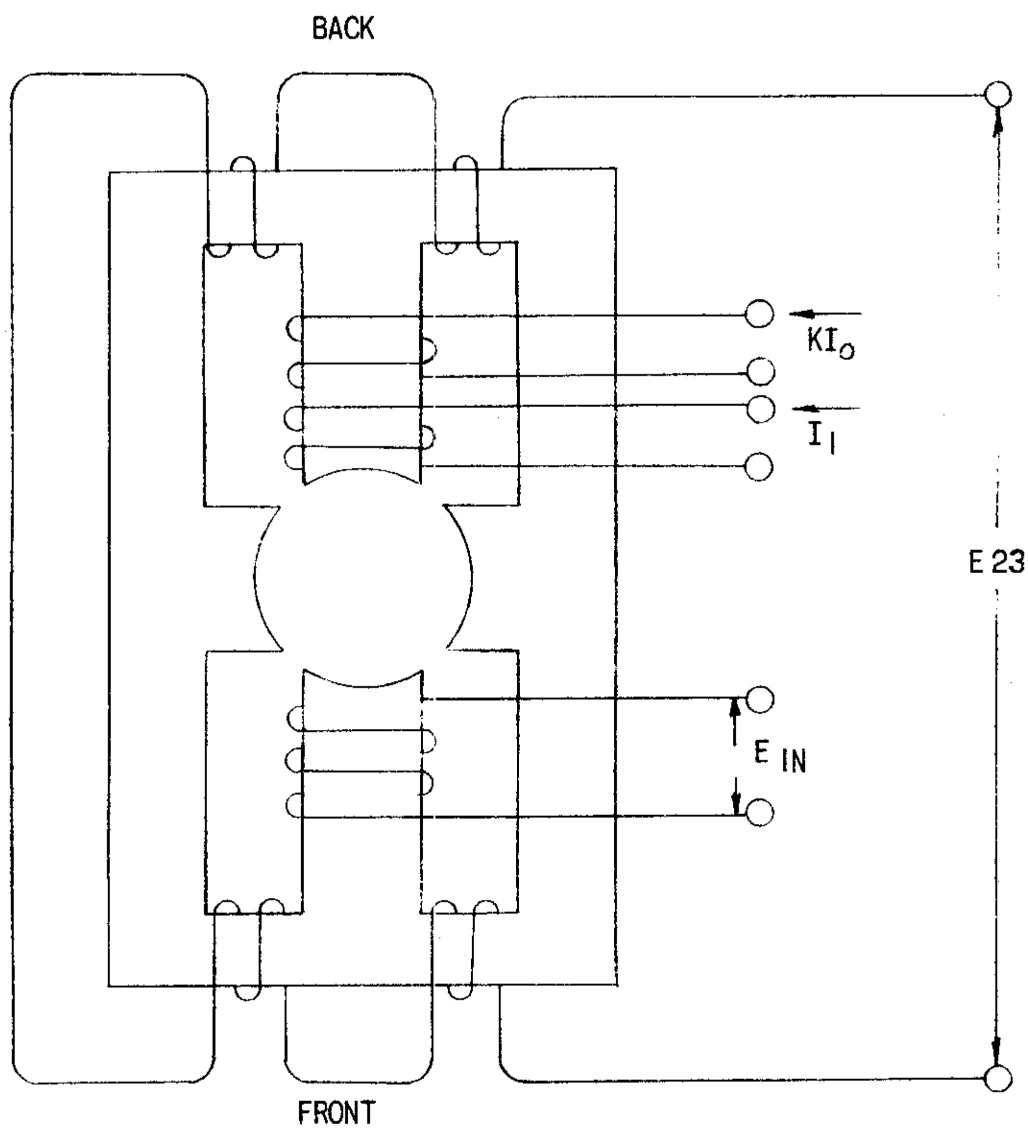


FIG. 6 (0208A5545-0) TYPICAL SCHEMATIC OF MHO UNIT

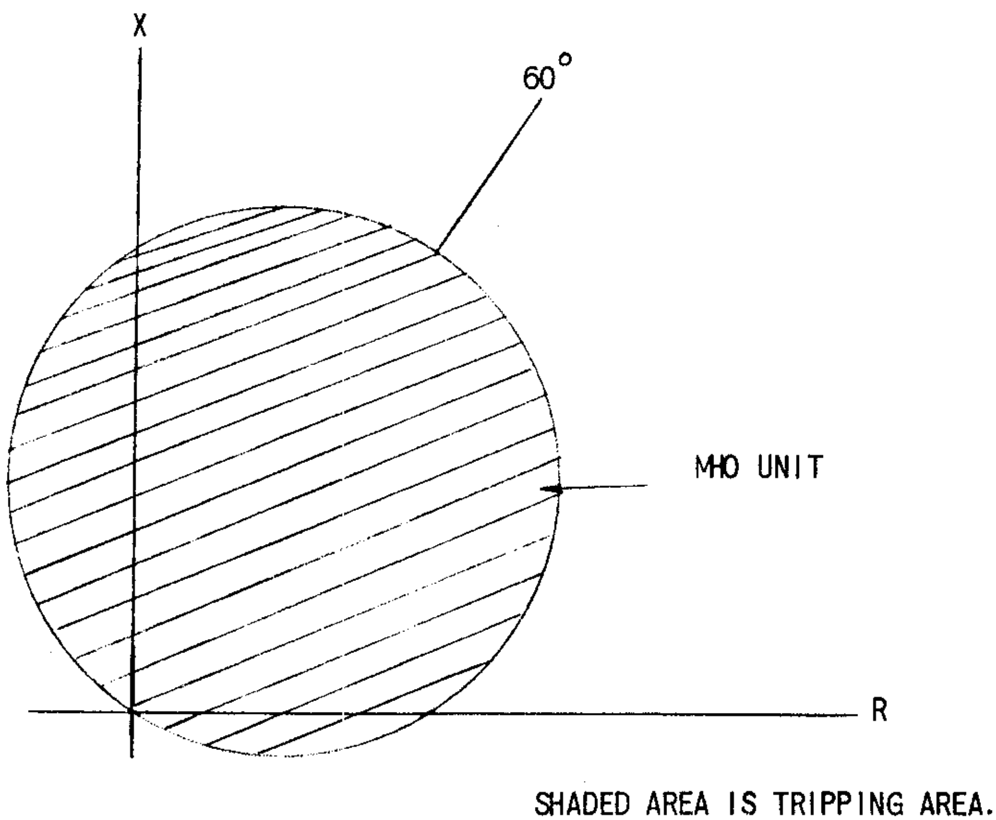


FIG. 7 (0208A5543-0) TYPICAL R-X DIAGRAM OF MHO UNIT

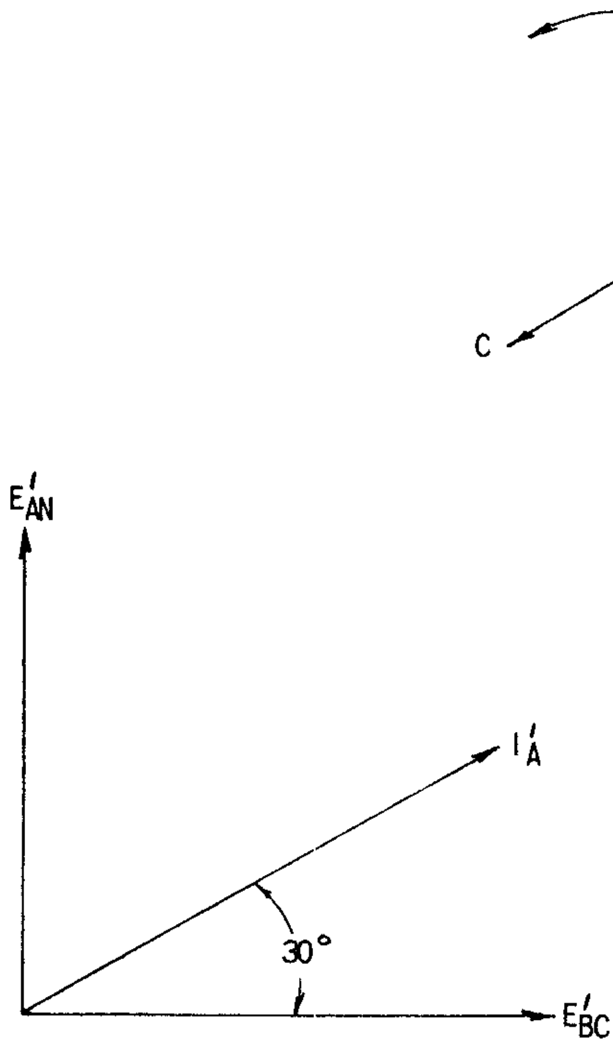
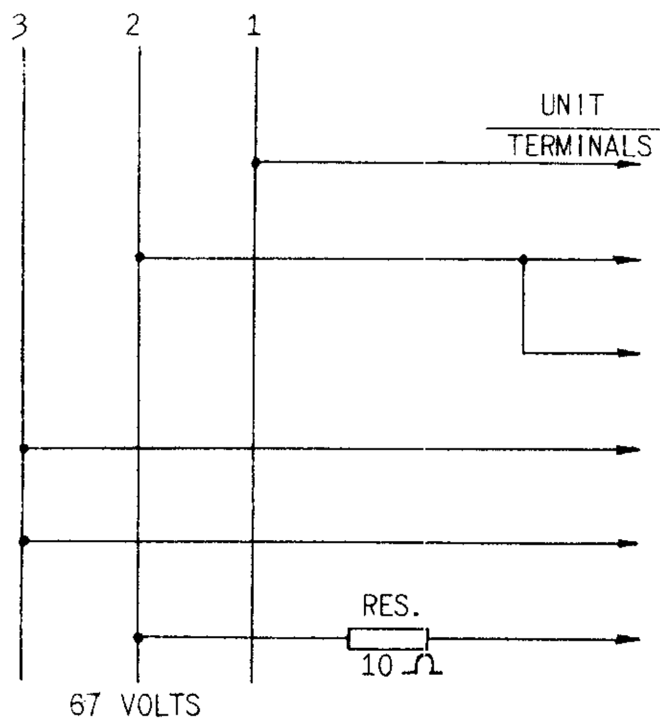


FIG. 8 (0208A5541-0) TYPICAL RELATION OF I'_A, E'_{BC} AND E'_{AN}



M_1	M_1	M_2	M_2	M_3	M_3
15	15	16	16	17	17
18	18	18	18	18	18
16	16	17	17	15	15
17	17	15	15	16	16
4	10	6	10	8	10
3	9	5	9	7	9

POLARITY TEST

FIG. 9 (0127A9562-1) POLARITY TEST

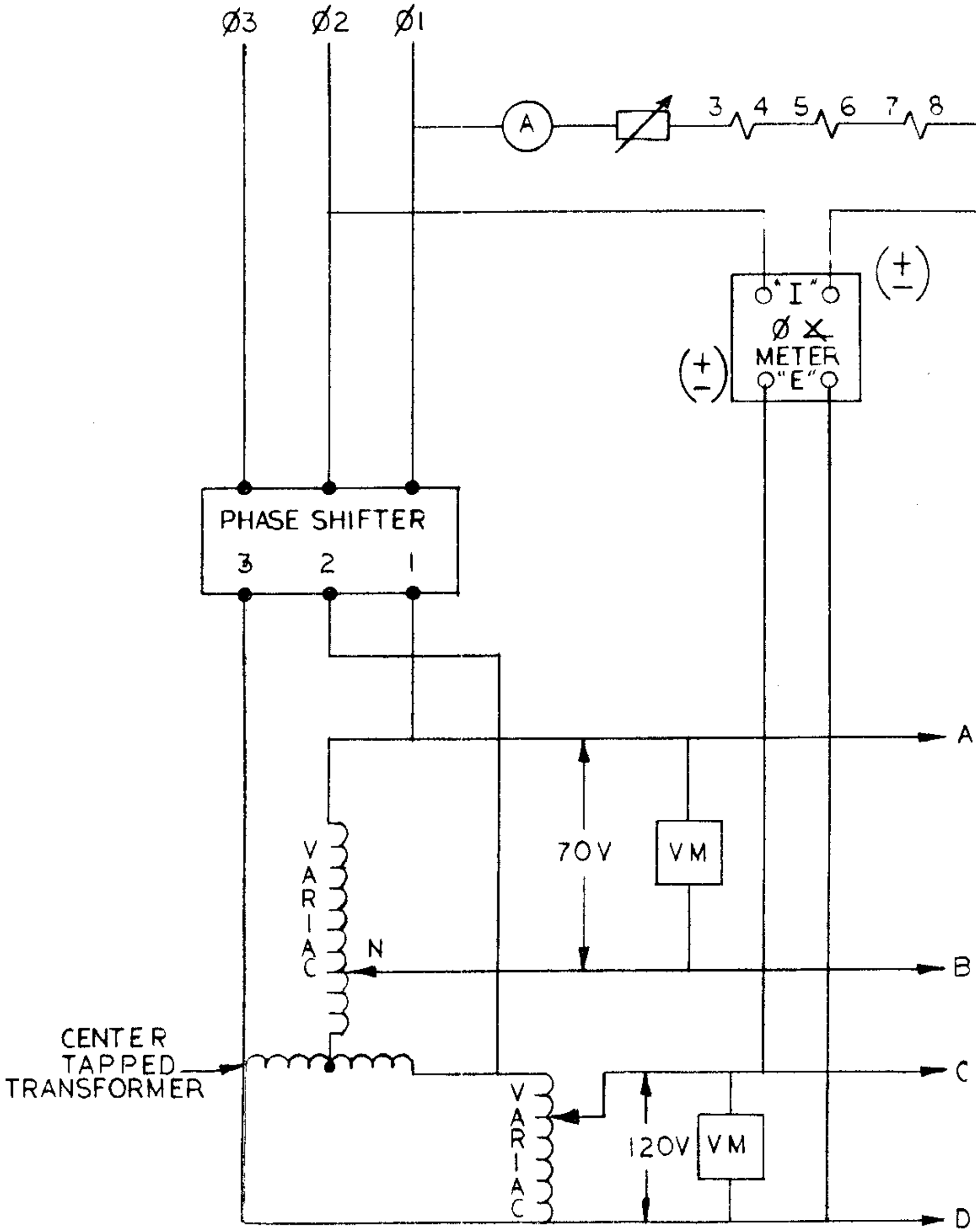
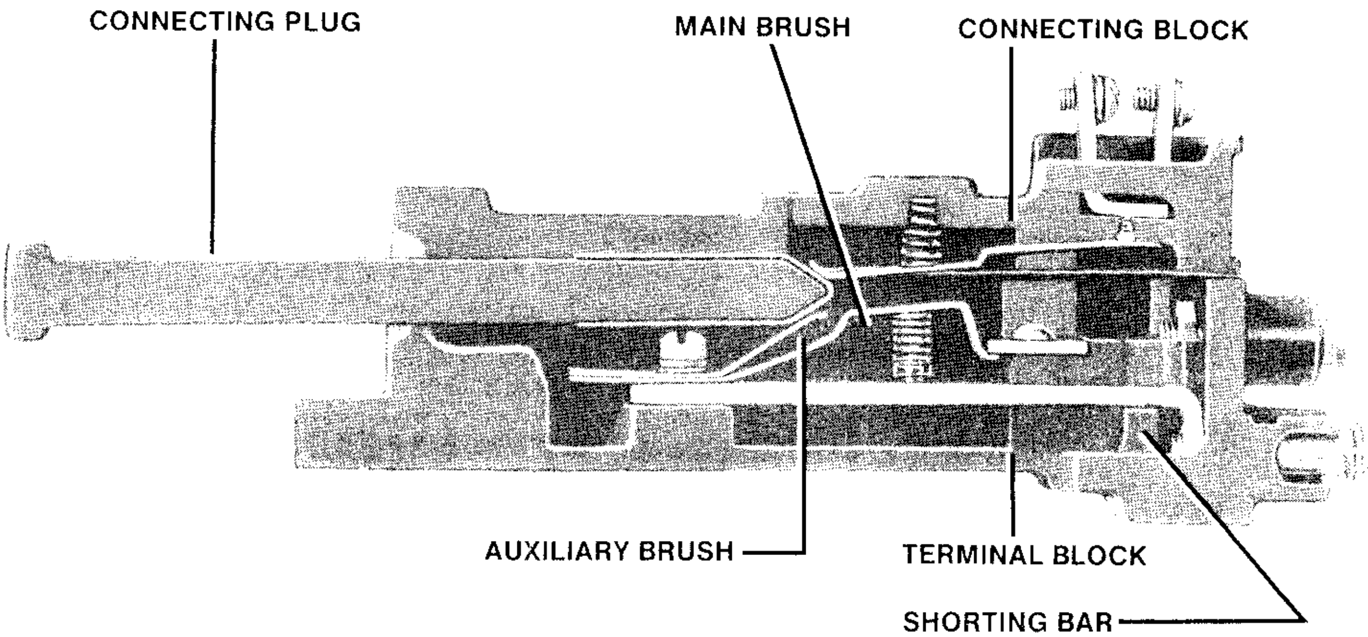


FIGURE 7

FIG. 10 (0195A4970-0 Sh. 4) TYPICAL TEST CONNECTIONS DIAGRAM



NOTE: AFTER ENGAGING AUXILIARY BRUSH CONNECTING PLUG TRAVELS ¼ INCH BEFORE ENGAGING THE MAIN BRUSH ON THE TERMINAL BLOCK.

FIG. 11 (8025039) CROSS SECTION DRAWOUT CASE SHOWING POISITION OF AUXILIARY BRUSH

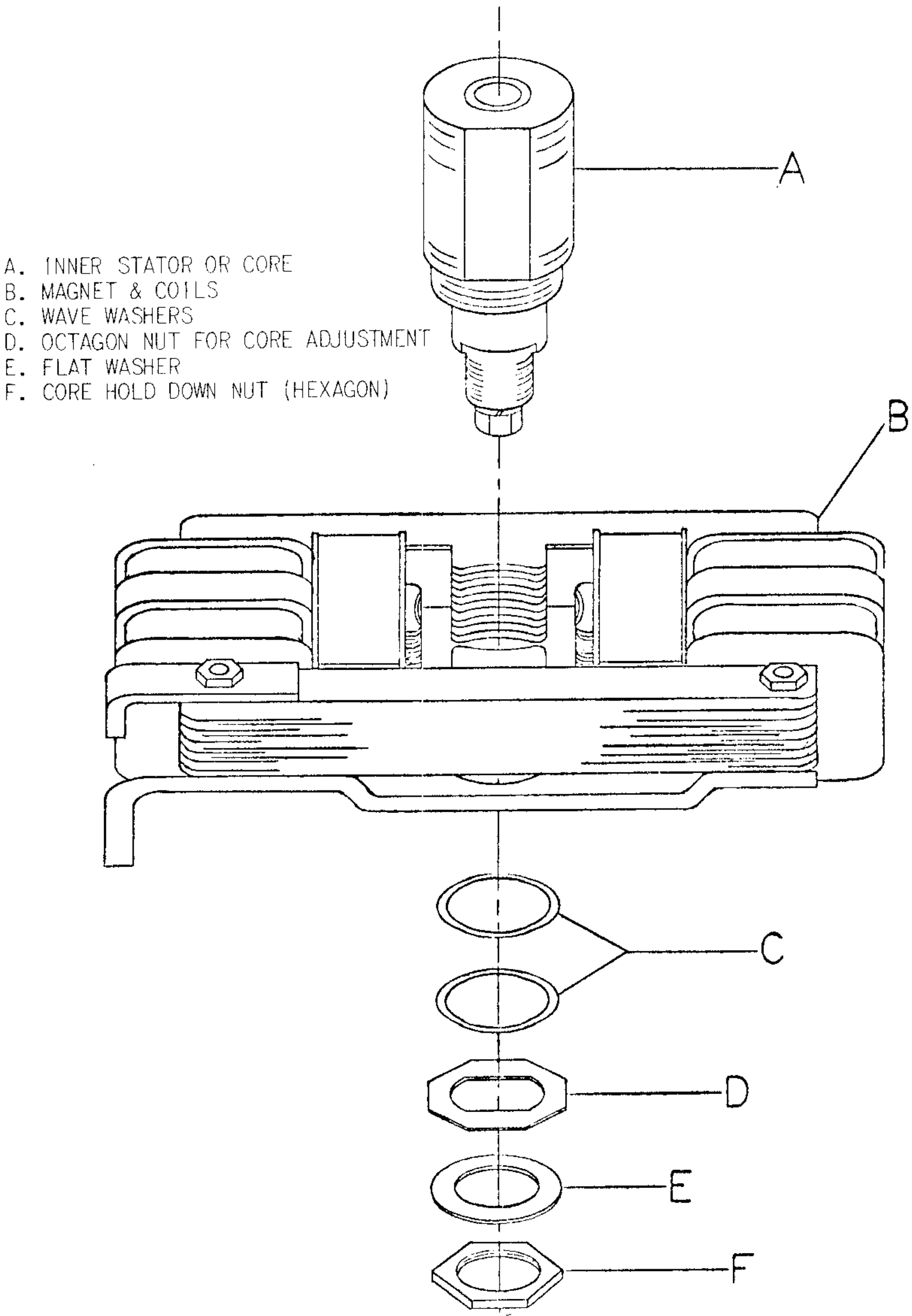


FIG. 12 (0208A3583-0) CORE ADJUSTMENT

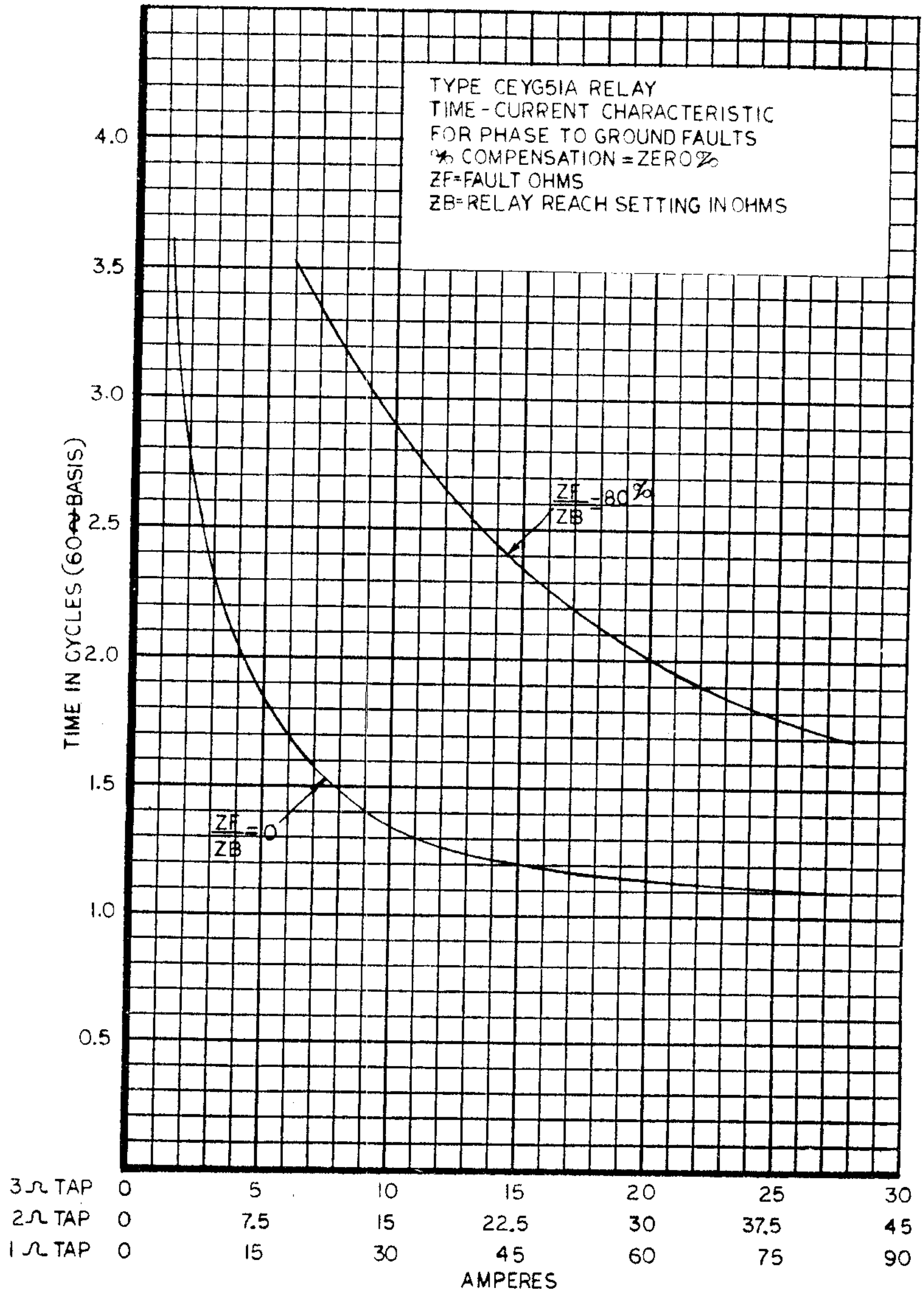


FIG. 13A (0273A9031-0) TYPICAL TIME-CURRENT CHARACTERISTIC WHEN TYPE CEYG51A IS USED WITH ZERO PERCENT COMPENSATION

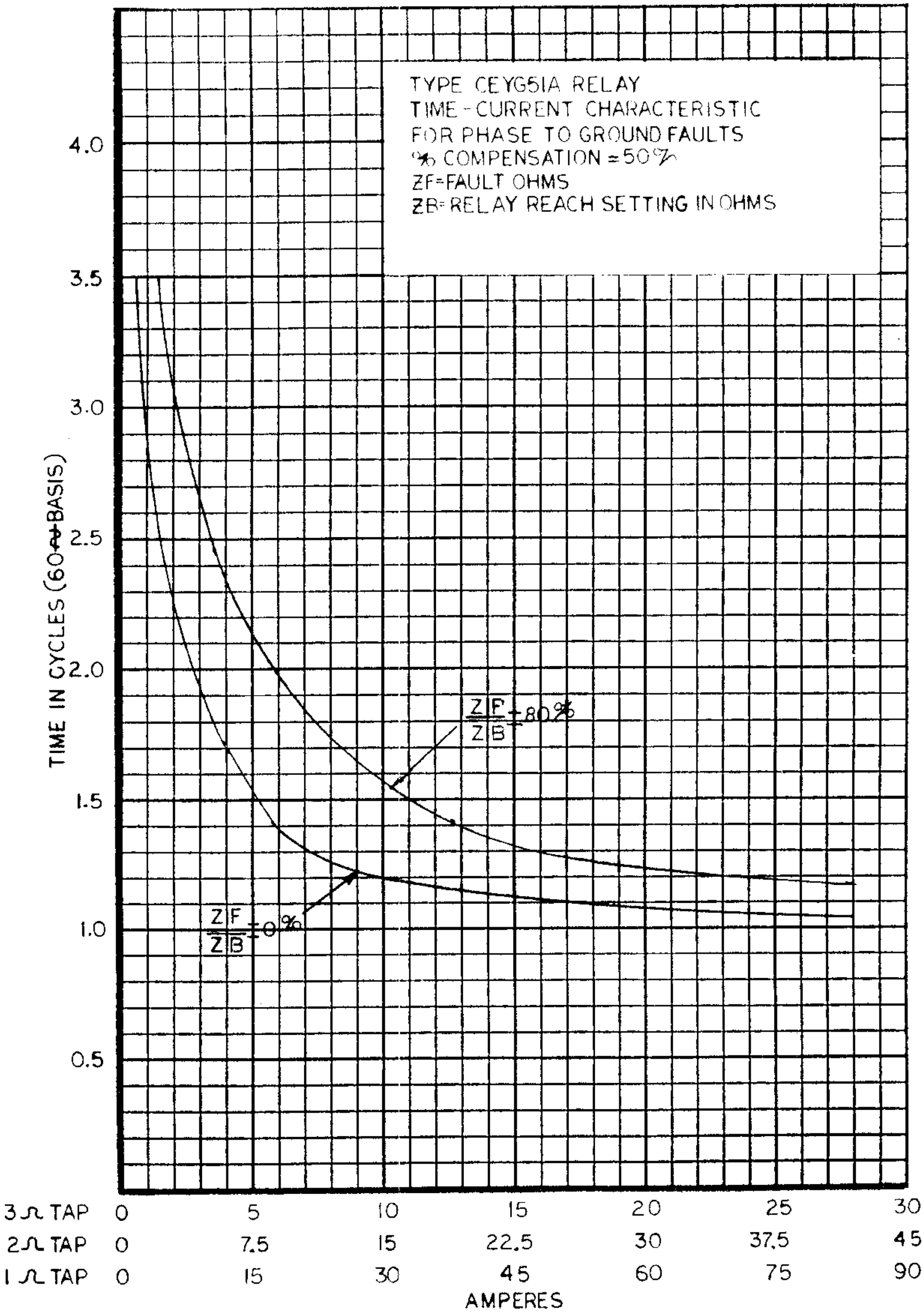


FIG. 13B (0273A9030-0) TYPICAL TIME-CURRENT CHARACTERISTIC WHEN TYPE CEYG51A IS USED WITH 50 PERCENT COMPENSATION

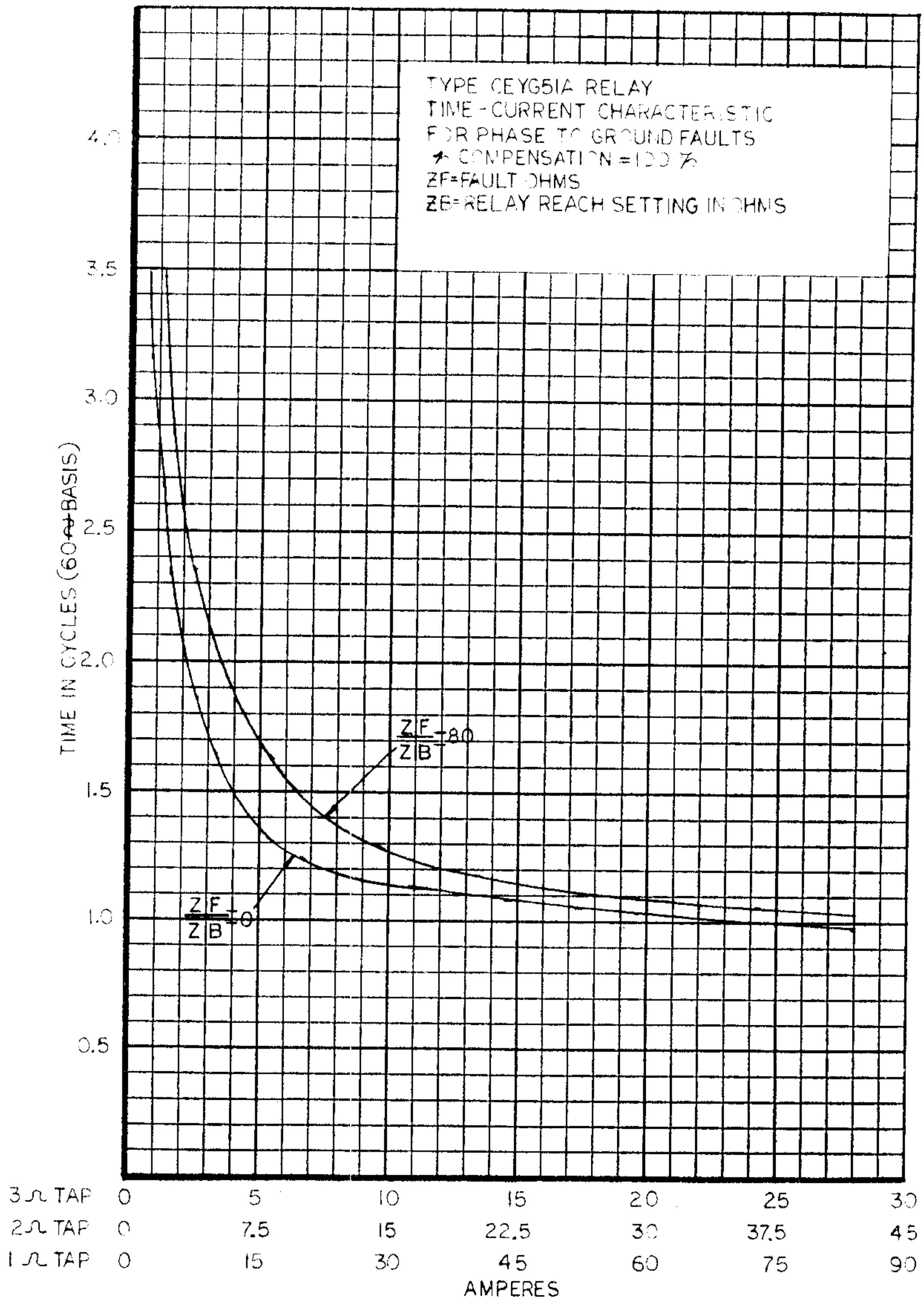


FIG. 13C (0273A9029-0) TYPICAL TIME-CURRENT CHARACTERISTIC WHEN TYPE CEYG51A IS USED WITH 100 PERCENT COMPENSATION

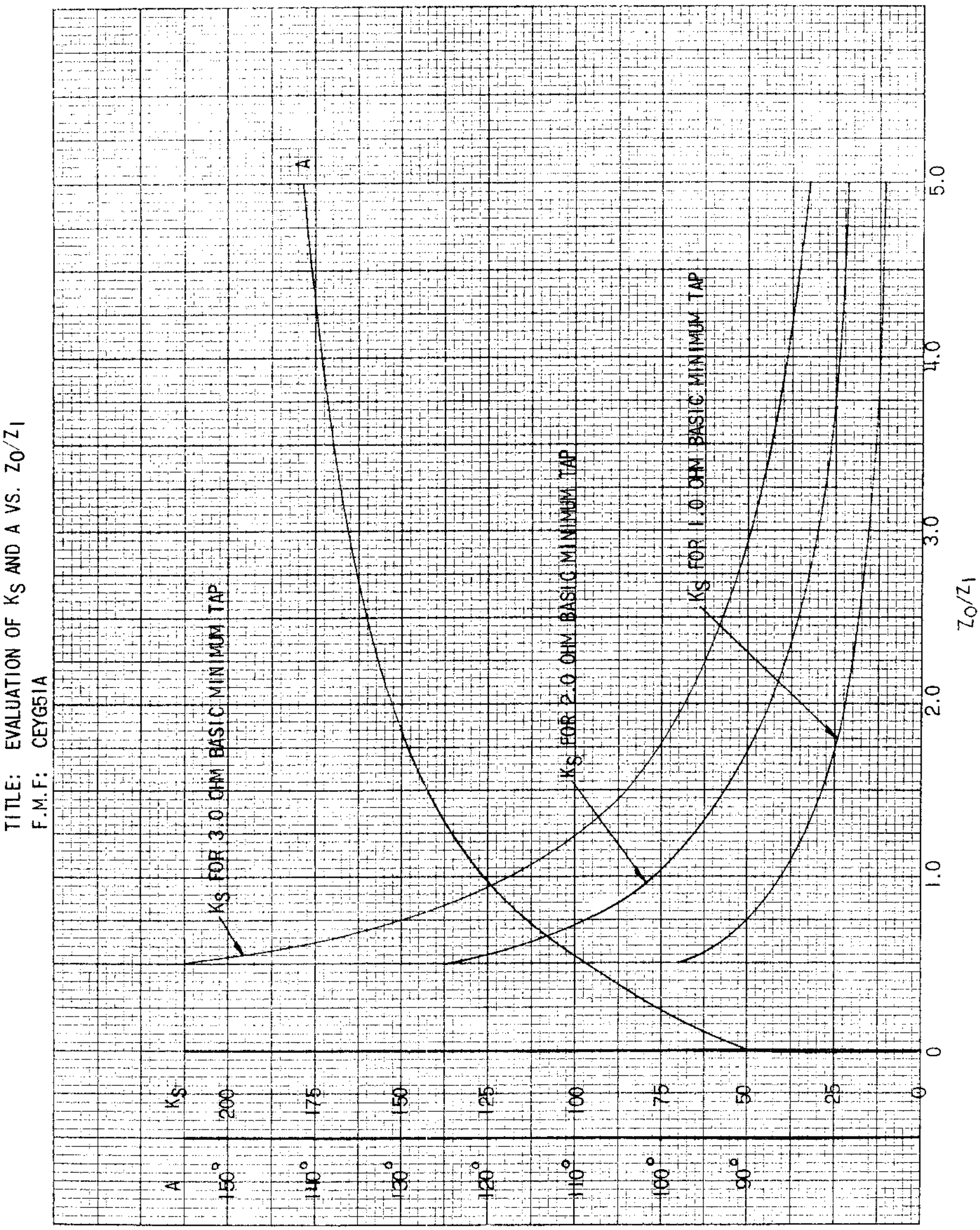


FIG. 14 (0208A5542-0) EVALUATION OF K_S AND A VS. Z_0/Z_1

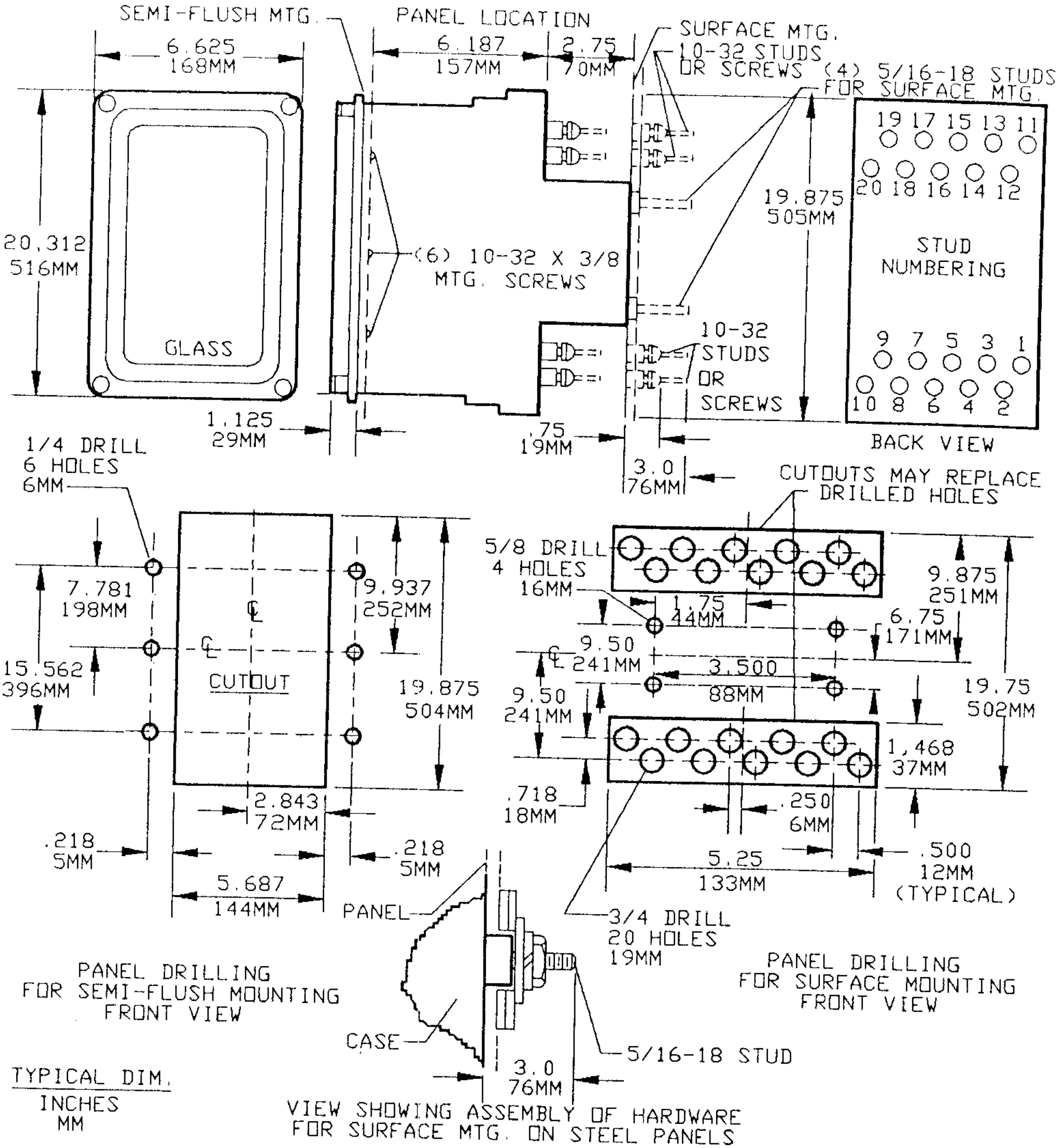
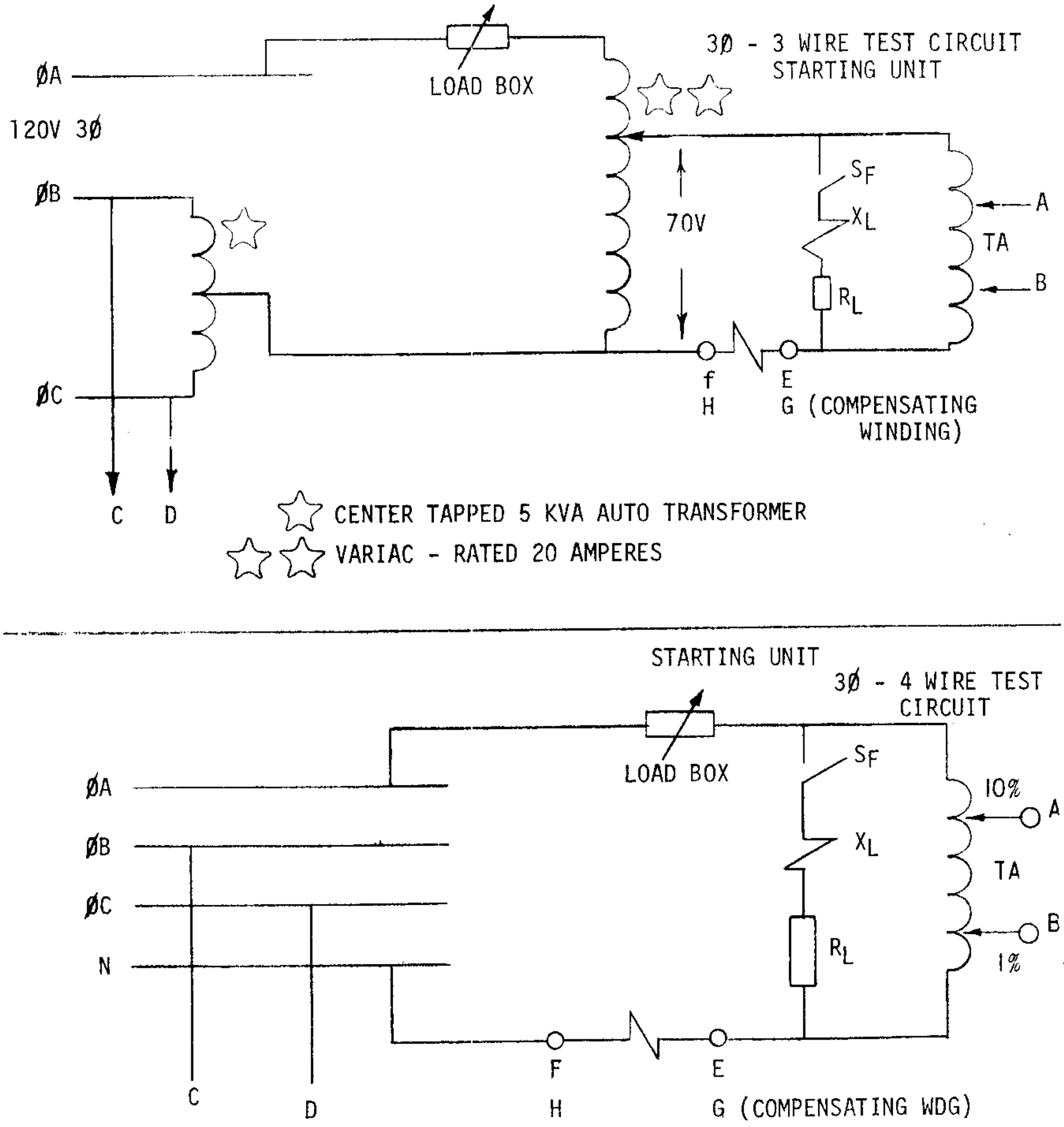
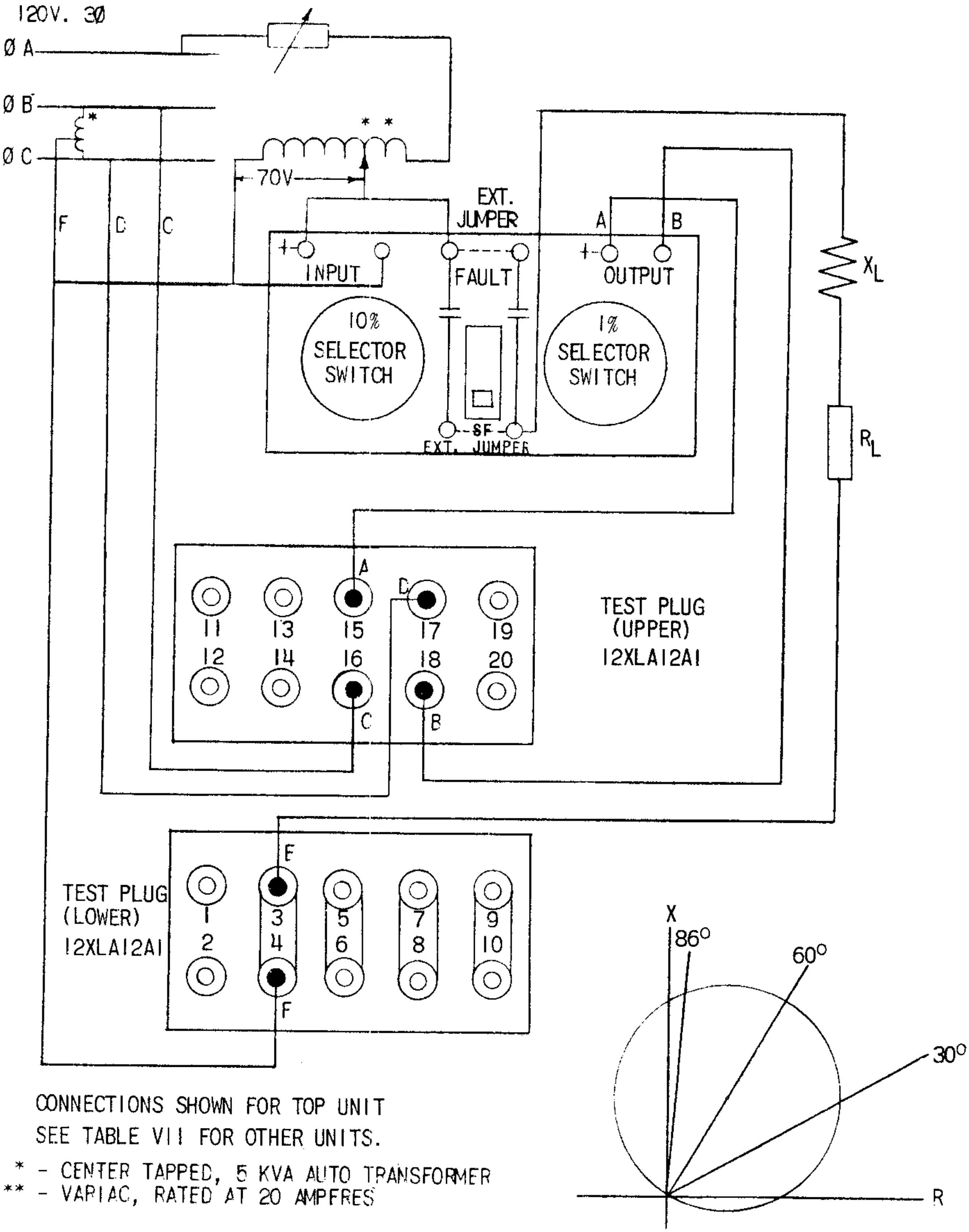


FIG. 15 (0178A7336 [5]) OUTLINE AND PANEL DRILLING DIMENSIONS FOR THE CEYG51A RELAY



SEE TABLE VII FOR STUD CONNECTIONS

FIG. 16 (0227A7005-0) SCHEMATIC DIAGRAM OF TEST CIRCUITS FOR CEYG51A RELAYS



CONNECTIONS SHOWN FOR TOP UNIT
SEE TABLE VII FOR OTHER UNITS.
* - CENTER TAPPED, 5 KVA AUTO TRANSFORMER
** - VARIAC, RATED AT 20 AMPERES

FIG. 17 (0227A7004-2) TEST CIRCUIT FOR FIELD TESTING THE STARTING UNITS OF THE CEYG51A RELAY USING A 3 PHASE, 3 WIRE TEST SOURCE

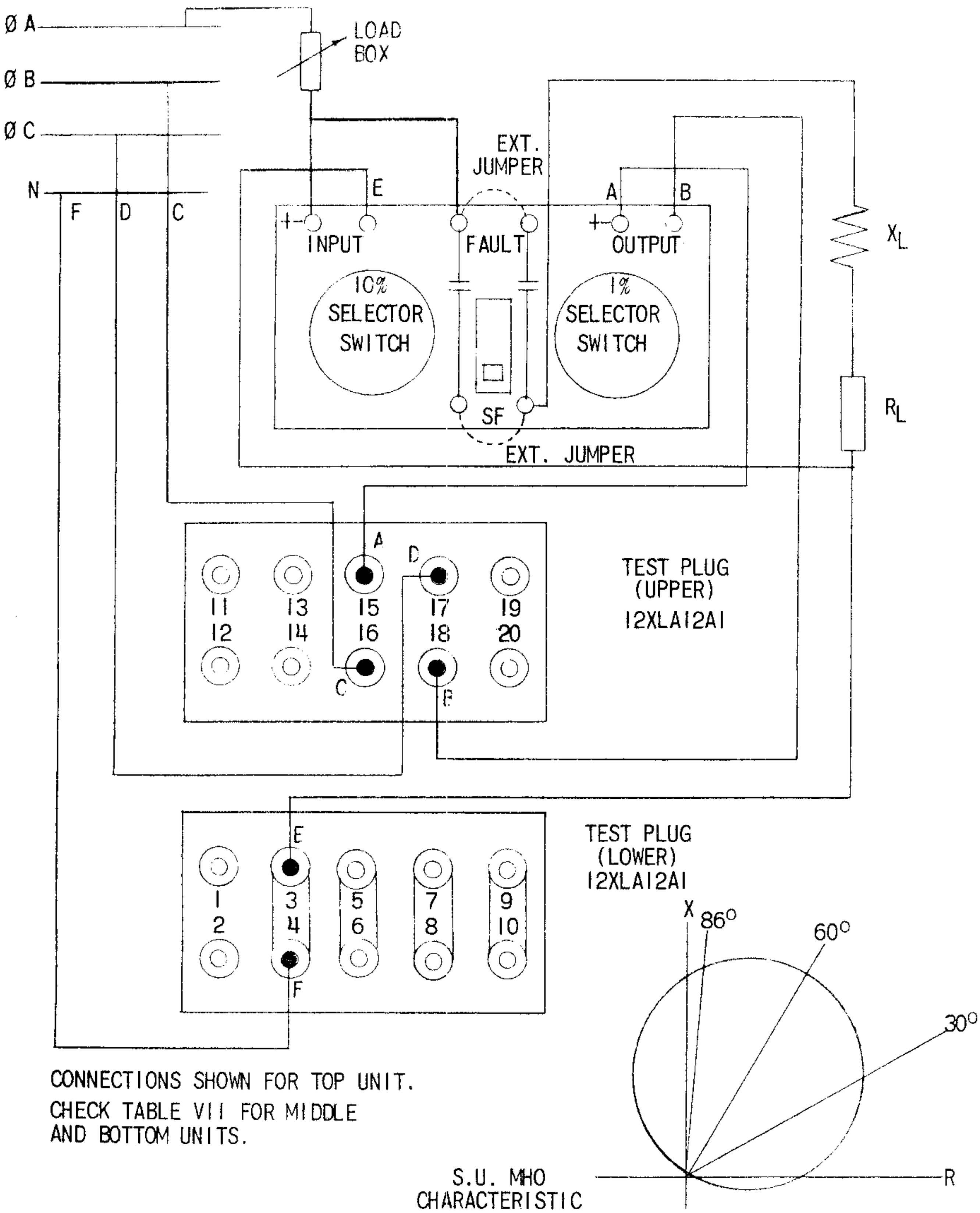


FIG. 18 (0227A7006-2) TEST CIRCUIT FOR FIELD TESTING THE STARTING UNITS OF THE CEYG51A RELAY USING A 3 PHASE, 4 WIRE TEST SOURCE