INSTRUCTIONS

GEK-33922D

GROUND DISTANCE RELAY

TYPE CEYG53A

GENERAL ELECTRIC

CONTENTS

GROUND DISTANCE RELAY

TYPE CEYG53A

INTRODUCTION

The CEYG53A 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 CEYG53A 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 type CEYG53A ground mho relay is typically applied as the primary ground relay in directional comparison blocking schemes or in permissive overreaching transferred tripping schemes, employing separate primary and backup protection.

The ground mho units of the CEYG53A relay employ median voltage polarization. Therefore, the polarizing voltage will be at least 33 percent of normal even on close-in zero voltage line-to-ground faults. Since this is ample polarizing voltage for proper operation of the unit, no memory action is required. As long as the phase-to-neutral voltage remains in phase with the median voltage, the unit will remain a true mho unit. However, a nearby fault with arc resistance will result in the characteristic increasing in size and tipping its maximum torque angle towards the R axis. Thus the mho unit can tolerate more arc resistance in the fault which on most ground distance relay applications is beneficial.

The ground mho units will also respond to three phase faults. If this is objectionable, the relay can be made unresponsive to any fault 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 II for the minimum permissible reach settings under both conditions.

In directional comparison schemes, two CEYG53A 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 CEYG53A 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 zero 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

FIG. 1 (Not Available) Front View Relay Out Of Case

FIG. 2 (Not Available) Rear View Relay Out Of Case 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 IIIA gives the limitations of the mho unit reach setting when zero sequence current compensation is NOT used. Appendix IIIB 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 IIIA and IIIB, 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 CEYG53 operation. This will permit tripping only when the fault is in the forward direction. The external connections are shown in Figure 4.

Since the CEYG53A 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 CEYG53 relays covered by these instructions are available with a rating of 120 volt, 60 Hz. polarizing circuit, and 70 volts, 60 Hz. restraint circuit. The current circuit is rated 5 amperes continuous, with a one second rating of 115 amperes.

The basic minimum reach settings and adjustments ranges of the mho units are shown in Table 1.

TABLE 1

	MHO UNIT	
BASIC MIN. REACH** (Ø-N OHMS)	RANGE (Ø-N OHMS)	ANGLE OF MAX. TORQUE
2/6 Ω	2/60 Ω	*60°/75°
1/3 Ω	1/30 Ω	*60°/75°

* Angle by which the operating current lags the phase-to-neutral restraint voltage. The mho unit may also be set for 75° lag. The reach at this angle will be 3 to 10% greater than that at 60°.

** In selecting the basic minimum reach tap or link setting always use the highest basic minimum reach compatible with the required reach setting of the unit.

The reach settings of the mho units can be adjusted in five percent steps by means of auto-transformer tap leads on the tap blocks at the right side of the relay.

The contacts of the CEYG53 relays will close and momentarily carry 30 amperes DC. However, the circuit breaker trip circuit must be opened by an auxiliary switch contact or other suitable means since the relay contact have no interrupting rating.

The 0.6/2 ampere target seal-in unit used in the CEYG53 relays has ratings as shown in Table II.

TABLE 11

TARGET SEAL-IN UNIT		
	0.6 Amp Tap	2.0 Amp Tap
Minimum Operating	0.6 amps	2.0 amps
Carry Continuously	1.5 amps	3.5 amps
Carry 30 Amps For	0.5 sec.	4 secs.
Carry 10 Amps For	4 secs.	30 secs.
DC Resistance	0.6 ohms	0.13 ohms
60 Cycle Impedance	6 ohms	0.53 ohms

OPERATING PRINCIPLES

MHO UNIT

The mho units of the Type CEYG53 relays are of the four-pole induction-cylinder construction (see Fig. 6) with schematic connections as shown in Fig. 7. The two side poles, which are energized by the phase-to-median voltage in phase 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 mho unit can therefore be expressed by the following equation.

$$\text{Torque} = 0 = KI'_a\, E'_{am} \cos\,(\alpha - \Delta) - TE'_a\, E'_{am}$$

where:
- K = design constant (basic ohmic reach tap)
- E'_a = Phase-A-to-neutral voltage at the relay location.
- E'_{am} = Phase B to median voltage at the relay.
- I'_a = Phase A current at the relay location
- α = Angle by which I'_a, E'_{am} lags
- T = Restraint tap setting
- Δ = Angle of maximum torque (60 or 75°)

A separate testing plug can be inserted in place of the connecting plug to test the relay on the panel either from its own source of current and voltage, or from other sources. Or the relay can be drawn out and replaced by another which has been tested in the laboratory.

Figs. 1 and 2 show the relay removed from its drawout case with all major components identified. Symbols used to identify circuit components are the same as those which appear on the internal connection diagram in Fig. 3.

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 damaged 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.

CONSTRUCTION

The type CEYG52 relays are assembled in the large-size, double-end L2D drawout case having studs at both ends in the rear for external connections. The electrical connections between the relay units and the case studs are made through stationary molded inner and outer blocks between which nests a removable connecting plug which completes the circuits. The outer blocks attached to the case have the studs for the external connections and the inner blocks have the terminals for the internal connections.

The relay mechanism is mounted in the steel framework called the cradle and is a complete unit with all leads being terminated at the inner block. This cradle is held firmly in the case with a latch at both top and bottom and by a guide pin at the back of the case. The connecting plug, besides making the electrical connections between the respective blocks of the cradle and case, also locks the latch in place. The cover, which is drawn to the case by thumbscrews, holds the connecting plugs in place.

CHARACTERISTICS

The operating characteristics of the mho units in the CEYG53 relay may be represented on an R-X impedance diagram as shown in Fig. 8. It should be noted that these are steady-state characteristics and are for rather specific fault conditions as described below.

MHO UNIT

The mho unit has a circular characteristic which passes through the origin and defines the angle of maximum torque of the unit, which occurs when linecurrent (I_a for example) lags the polarizing voltage (E'_{am} for example) by 60° or 75°. 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°, which is the condition represented in Fig. 8.

OPERATING TIME

The operating time characteristics of the mho units in the CEYG53 relay are determined by a number of factors such as the basic minimum reach setting of the unit, fault current magnitude, and the ratio of fault impedance to the reach of the unit.

Typical time curves for the mho unit are shown in Fig. 9 for several ratios of fault impedance to unit reach. These curves are for a single-phase-to-ground fault where the fault impedance (Z_{FAULT}) seen by the unit can be calculated as described in Appendix II. Note in the figure that the fault current scale changes with the basic minimum reach setting.

CHOICE AND CALCULATION OF SETTINGS

The required settings of the mho distance units in the CEYG53A relay must be determined prior to the installation of the relays. Three settings are required.

1. Angle of maximum reach.
2. Reach setting including the basic minimum reach tap and the percent voltage tap.
3. The zero zequence current compensation setting on the auxiliary CT if this is used.

ANGLE OF MAXIMUM REACH

Angles of maximum reach settings between 60 and 75 degrees lag are available. The factory setting is 60 degrees and it is recommended that this degree setting be used wherever possible because it will accommodate more fault resistance than the 75 degree setting. This is of particular importance with ground faults since they tend to include higher fault resistance then do phase faults. Changing the maximum torque angle from 60 to 75 degrees changes the basic minimum taps as described in the section on ratings.

REACH SETTINGS

The ground mho units must be set with a reach great enough to insure tripping for faults at the far end of the line. The reach settings will be different whether or not zero sequence current compensation is used. With compensation and no mutual coupling with a parallel line, the impedance seen by MT will be equal to the positive sequence line-to-neutral impedance from the relay to the fault. If mutual coupling is present, the apparent impedance seen by MT will usually be greater than the positive sequence line-to-

Since both of these values are less than the normal 10 percent minimum tap setting limit, they impose no further restructions on the relay application.

The same procedure should now be followed with respect to the relay settings at breaker B with system values as viewed from that location.

BURDENS

CURRENT CIRCUITS

The current coil burdens imposed on each current transformer at 5 amperes, 60 Hertz are listed in Table III.

TABLE III

RELAY STUDS	FREQ. HZ	R	X	P.F.	W.	V.A.
3 - 4	60 HZ	.096	.020	.98	4.6	4.7
5 - 6	60 HZ	.096	.020	.98	4.6	4.7
7 - 8	60 HZ	.096	.020	.98	4.6	4.7
9 - 10	60 HZ	.288	.060	.98	13.8	14.1

POTENTIAL CIRCUITS

The maximum potential burden imposed on each potential transformer at rated voltages, 120 volts on the polarizing circuit and 70 volts on the restraint circuit are shown in table IV. Data taken with restraint leads in 100%.

TABLE IV

CIRCUIT	R	X	P.F.	WATTS	V.A.
RESTRAINT	368	+J230	.846	9.8	11.6
POLARIZING	1024	J0	1	10.5	10.5

The potential burden at tap settings less than 100 percent can be calculated from the following formula.

$$VA = (a + Jb) \left[\frac{\text{Relay Tap Setting (\%)}}{\text{Input Tap Setting (\%)}} \right]^2 + (C + JD)$$

The terms (a + Jb) and (C + Jd) represent the burdens of the potential circuits expressed in watts and vars with the taps set at 100%. The values for 60 HZ relays are given in table V.

TABLE V

CIRCUIT	TERM WATTS + J VARS	WATTS + J VARS
RESTRAINT	(a + Jb)	9.8 + J 6.15
POLARIZING	(c + Jd)	10.5 + J o

The total burden can be obtained by adding the watts and vars for each unit as determined by the above formula and converting the total to volt-amperes for the tap setting used.

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 adjustments in Table VI be checked.

2. There should be no noticable friction in the rotating structure of the mho 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 trip contacts must be open.

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. Make sure that the shorting bars are in their proper location on the case block.

TABLE VI

CHECK POINTS	MHO UNIT
ROTATING SHAFT END PLAY	.005 - .008 INCH
CONTACT GAP	.120 - .130 INCH
CONTACT WIPE	.003 - .006 INCH

ELECTRICAL CHECKS

Before any electrical checks are made on the mho units, the relay should be connected as shown in Fig. 11 and allowed to warm up for approximately 15 minutes with the potential circuits alone energized at rated voltage and with the restraint tap leads set at 100%. 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.

MHO UNIT TESTS

A. CONTROL SPRING
With the relay connected per figure 10- Test 1, disconnect the restraint leads from the autotransformers. Set the voltage at 104 volts and the current at 5 amperes. Set the phase shifter so current lags the voltage by 60 degrees, then set the conditions as shown in Table VII.

TABLE VII

RANGE OF UNITS	REACH LINK A (POS.)	B	ANGLE LINK POSITION	VOLTAGE SETTING	CURRENT PICKUP
1/3 Ω	1	2	60°	5V	1.4 - 2.0A
2/6 Ω	2	4	60°	5V	.7 - 1.0A

Spring adjustment is accomplished by turning the notched sprocket directly above the control spring. Turning it to the right increases the current pickup, to the left decreases the current pickup.

Do this test on all units by changing the stud connections shown in figure 10 before proceeding with further tests.

B. ANGLE OF MAXIMUM TORQUE (75° POSITION)
Connect the relay per figure 11. Set the conditions as shown in table VIII.

Impedance, Reactance

Z_0 = System zero sequence phase-to-neutral impedance as viewed from the fault.

Z_1 = System positive sequence phase-to-neutral impedance as viewed from the fault.

Z_2 = System negative sequence phase-to-neutral impedance as viewed from the fault. Assume equal to Z_1.

Z_0' = Zero sequence phase-to-neutral impedance of the protected line from the relay to the remote terminal.

Z_1' = Positive sequence phase-to-neutral impedance of the protected line from the relay to the remote terminal.

Z_2' = Negative sequence phase-to-neutral impedance of the protected line from the relay to the remote terminal, assume equal to Z_1'.

Z_{om} = Total zero sequence mutual impedance between the protected line and a parallel circuit over the entire length of the protected line.

X_1' = Positive sequence phase-to-neutral reactance of the protected line from the relay to the remote terminal.

X_0' = Zero sequence phase-to-neutral reactance of the protected line from the relay to the remote terminal.

X_{om} = Total zero sequence mutual reactance between the protected line and a parallel line over the entire length of the protected line.

Z_a = Phase A impedance for conditions described.

All of the above are secondary ohms, where:

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

and Z_{om} and X_{om} are calculated using the CT ratio for the protected line.

Miscellaneous

T = Relay voltage restaint tap setting in percent.

B, θ, Ø = Angles in degrees as defined where used.

K_Q = Constant depending on the ratio of Z_0/Z_1.

T_B = Relay basic minimum ohmic tap at the set angle of maximum reach.

K' = Zero sequence current compensation tap setting for the protected line; in percent, unless otherwise noted.

K" = Zero sequence current compensation tap setting for the parallel line; in percent, unless otherwise noted.

S = Ratio of distances as defined where used.

M = Reach of Mho function from the origin (relay location) in the direction of the protected line section as forward reach.

M* = Reach of Mho function from the origin (relay location) away from the protected line section as reverse reach or reach in the blocking direction.

APPENDIX II

MINIMUM PERMISSIBLE REACH SETTING FOR THE CEYG53A

The CEYG53A 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 IIc and IIk. The mho units of the CEYG53A relay must not be compensated for the zero sequence mutual impedance due to a parallel line. This is because reversed mutual in the parallel line could cause the mho unit to operate incorrectly on the protected line. (See Appendix I for the definition of symbols used in the following equations).

(A) 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:

$$Z_A = Z_1' + \frac{(Z_0' - Z_1')\, C_0}{2C + C_0} + \frac{Z_{om} I_0''}{I_a'} \qquad \text{II-a}$$

where: Z_A = apparent impedance seen by the ground mho unit on the faulted phase.

The reach setting of the mho unit must be large enough to detect a single-phase-to-ground fault at the remote end of the protected line with margin. The required setting of the restraint tap to provide a reach of Z ohms at the line angle can be expressed as follows:

$$T = \frac{100\, T_B \cos(\phi - \theta)}{Z} \qquad \text{II-b}$$

where:

Z = Desired reach at line angle
θ = Line angle in degrees (i.e. I_a' lags E_a')
ϕ = Angle of maximum torque of mho unit

Referring to equation II-a, for a three-phase fault or for a single-phase-to-ground fault where $Z_0' = Z_1'$ and there is no mutual with a parallel line, the apparent impedance Z_A seen by the mho unit will be Z_1'. However, for the more typical conditions where Z_0' and Z_1' are not equal, and where there may also be zero sequence mutual with a parallel line, the apparent impedance seen by the mho units for a single-phase-to-ground fault will be as shown in equation II-a, and it is apparent that the reach will in effect be pulled back. Written in more general form, and providing for a margin of 1.25, equation II-b becomes:

$$T_{max} = \frac{100\, T_B \cos(\phi - \theta)}{1.25\left[Z_1' + \frac{(Z_0' - Z_1')\, C_0}{2C + C_0} + \frac{Z_{om} I_0''}{I_a'}\right]} \qquad \text{II-c}$$

where:

T_{max} = Maximum permissible restraint tap setting.

If the solution to equation II-c yields a tap setting (Tmax) greater than 100 percent, even the shortest reach setting for the basic tap (T_B) if used will insure that the mho functions reach at least to the remote bus with margin of 1.25. If it is desired to have the unit reach further beyond the remote bus, a lower tap setting of course will be required.

If there is no zero sequence mutual impedance the last term of equation II-a is zero, and the expression for the apparent impedance becomes:

$$Z_A = Z_1' + \frac{(Z_o' - Z_1')\, C_o}{2C + C_o} \qquad \text{II-d}$$

If both the numerator and denominator of the second term of this expression are divided by C_o the equation becomes:

$$Z_A = Z_1' + \frac{(Z_o' - Z_1')}{\left(\frac{2C}{C_o} + 1\right)} \qquad \text{II-e}$$

The influence of the distribution constants C and C_o on the apparent impedance is now more obvious. For example, on an application where $Z_o' = 3Z_1'$ the situation with single-end feed (i.e. $C = C_o = 1$) results in:

$$Z_A = Z_1' + \frac{(3Z_1' - Z_1')}{\frac{2}{1} + 1} = Z_1' + \frac{2Z_1'}{3} = 1.67Z_1'$$

Thus to insure that the mho unit will reach to the far end of the line with the remote breaker open it must be set for $1.67Z_1'$ plus desired margin. Of course, with both breakers closed, and the zero sequence distribution factor (C_o) much greater than the positive sequence factor (C), the required reach setting will be much higher. For example, if $C = 0.3$ and $C_o = 0.8$ for a fault at the remote bus, and $Z_o' = 3Z_1'$, the apparent impedance, Z_A, is $2.1Z_1'$.

The user must determine the apparent impedance seen by the relay for a fault at the remote bus with the most unfavorable combination of distribution factors that he considers possible for the application, and then determine the maximum permissible tap setting for the mho functions from equation II-c which will insure operation for this remote fault. It is apparent that in some instances, especially on long lines, the required settings of the mho functions may be too large to be practical. Use of the zero sequence compensation feature described below should be considered.

If there is zero sequence mutual impedance between the protected line and another circuit, the last term in the demoninator of II-c must be included in the calculations. If this mutual impedance is between the protected line and several other circuits, this last term becomes:

$$\frac{1}{I_a'} \left(\sum Z_{om} I_o''\right) \qquad \text{II-f}$$

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

(B) WITH ZERO SEQUENCE CURRENT COMPENSATION

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

$$Z_A = Z_1' + \frac{Z_{om}\, I_o''}{I_a' + 3K'\, I_o'} \qquad \text{II-g}$$

where K' in per unit is defined as follows:

$$K' = \frac{X_o' - X_1'}{3X_1'} \qquad \text{II-h}$$

As is apparent from equation II-g, the zero sequence current compensation has the effect of reducing the apparent impedance, Z_A, seen by the relay on the faulted phase so that a shorter reach setting can be used with assurance that the mho until will see a fault at the remote end of the protected line. In fact, if complete compensation is achieved, and there is no zero sequence mutual, the apparent impedance, Z_A, will be equal to Z_1'. The expression for the maximum permissible restraint tap setting now becomes:

$$T_{max} = \frac{100\ T_B \cos(\emptyset - \theta)}{1.25\ [Z_1' + \dfrac{Z_{om} I_o''}{I_a' + 3K'\ I_o'}]} \qquad \text{II-k}$$

APPENDIX III

MAXIMUM PERMISSIBLE REACH SETTING

FOR THE CEYG53A

Under some system conditions it is possible, during single-phase or double-phase-to-ground faults in the non-trip direction, for a unit associated with an unfaulted phase to operate. Since this can result in a false trip, it is necessary to limit the reach setting of the ground mho functions to prevent them from picking up on such reverse faults. In the following sections equations are given for determining the minimum permissible restraint tap setting. (i.e. maximum reach) for both types of ground faults. Since zero sequence current compensation is optional in the CEYG53A relays, the following discussion is in two parts; (A) without compensation; (B) with compensation.

(A) WITHOUT COMPENSATION

(1) Single-Phase-To-Ground Faults

Although false tripping on external faults is the chief concern, fault location (F1 or F2 in Figure 17 does not affect relay operation on the unfaulted phase(s) and the following equations are derived using distribution constants for external faults on the bus behind the relay location.

In order to avoid false tripping on external single-phase-to-ground faults it is necessary to limit the reach settings of the ground mho units by keeping the restraint tap setting T higher than the value given in equation IIIA-a. Evaluate this equation for single-phase-to-ground faults on the bus immediately behind the relay location or as faults F2 in Figure 17.

$$T = \frac{T_B K_Q (C_0 - C)}{Z_1} \qquad \text{IIIA-a}$$

where: T = Minimum safe tap setting in percent.

K_Q = System constant depending upon the ratio of system impedance Z_0/Z_1 as seen from the fault. Use curves Figure 15 for 60 degree maximum reach and curves Figure (B) for 75 degree maximum reach and make a direct substitution of the value of K_Q obtained into equation IIIA-a.

C, C_0 and Z_1 are defined in Appendix I.

(2) Double-Phase-To-Ground Faults

In order to avoid false tripping on external double phase-to-ground faults it is necessary to limit the reach settings of the ground mho units by keeping the restraint tap setting T higher than the value given by equation IIIA-b. Evaluate this equation for the same conditions as equation IIIA-a because the system sequence components and distribution constants are independent of the type of fault.

$$T = \frac{100 T_B (C_0 - C) \cos (\theta - \emptyset)}{3Z_0} \qquad \text{IIIA-b}$$

where: Z_0 = System zero sequence phase-to-neutral impedance as seen from the fault.

θ = Impedance angle of Z_0.

$\emptyset$ = Maximum torque angle setting of the relay.

(All other terms are defined previously).

After evaluation of equations IIIA-a and IIIA-b, the higher of the two tap values should be selected. The tap setting used on the relay should be no lower than this value nor should it be any higher than the tap obtained from equation II-c in Appendix II.

For both equations IIIA-a and IIIA-b, if a negative value for T is obtained it signifies that the equation offers no limitation to the setting. Thus, any tap setting of 10 percent or more will be safe. Thus, when evaluating equations IIIA-a and IIIA-b, the first step should be the evaluation of the term $(C_0 - C)$. If this term is negative for all the system operating conditions for a ground fault at F2, this is all that need be determined.

(B) WITH COMPENSATION

When zero sequence current compensation is used with the CEYG53A relay, the same checks as noted in the previous section III-A must be made except that the equations must be modified by the compensation factor as noted below:

(1) Single-phase-to-ground Faults

$$T = \frac{T_B K_Q [(3K' + 1) C_0 - C]}{Z_1}$$

where: K' = Per unit zero sequence current compensation (see equation II-h)
Note that $(3K' + 1) = X_0'/X_1'$

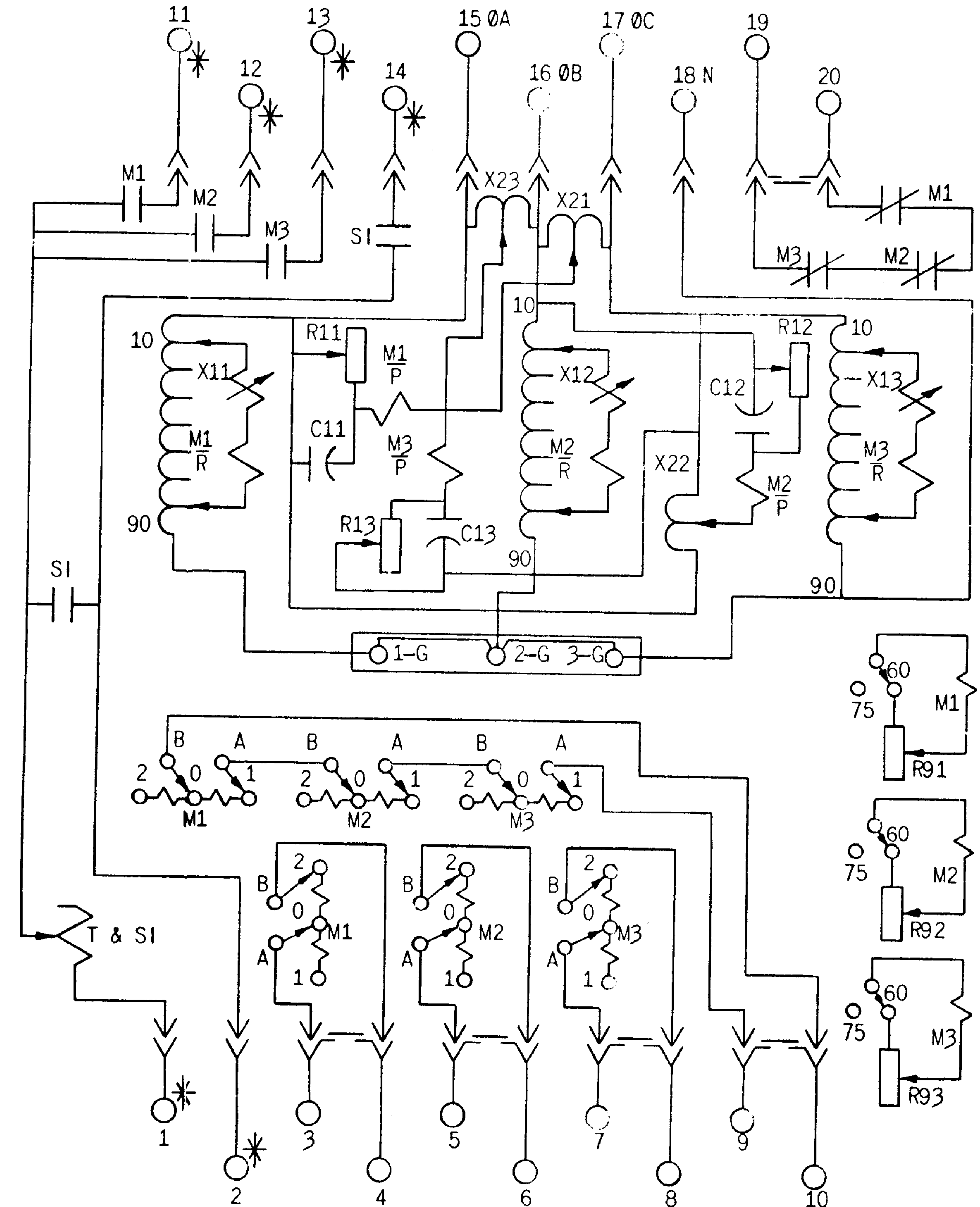
(2) Double-phase-to-ground Faults

$$T = \frac{100T_B [(3K' + 1) C_0 - C] \cos(\theta - \emptyset)}{3Z_0}$$

After evaluation of equations IIIB-a and IIIB-b, the higher of the two tap values should be selected, and then some margin such as 10 percent (not 10 percentage points) should be added to this setting. The tap setting used on the relay should be no lower than this value nor should it be any higher than the tap obtained from equation IIB-d in appendix II.

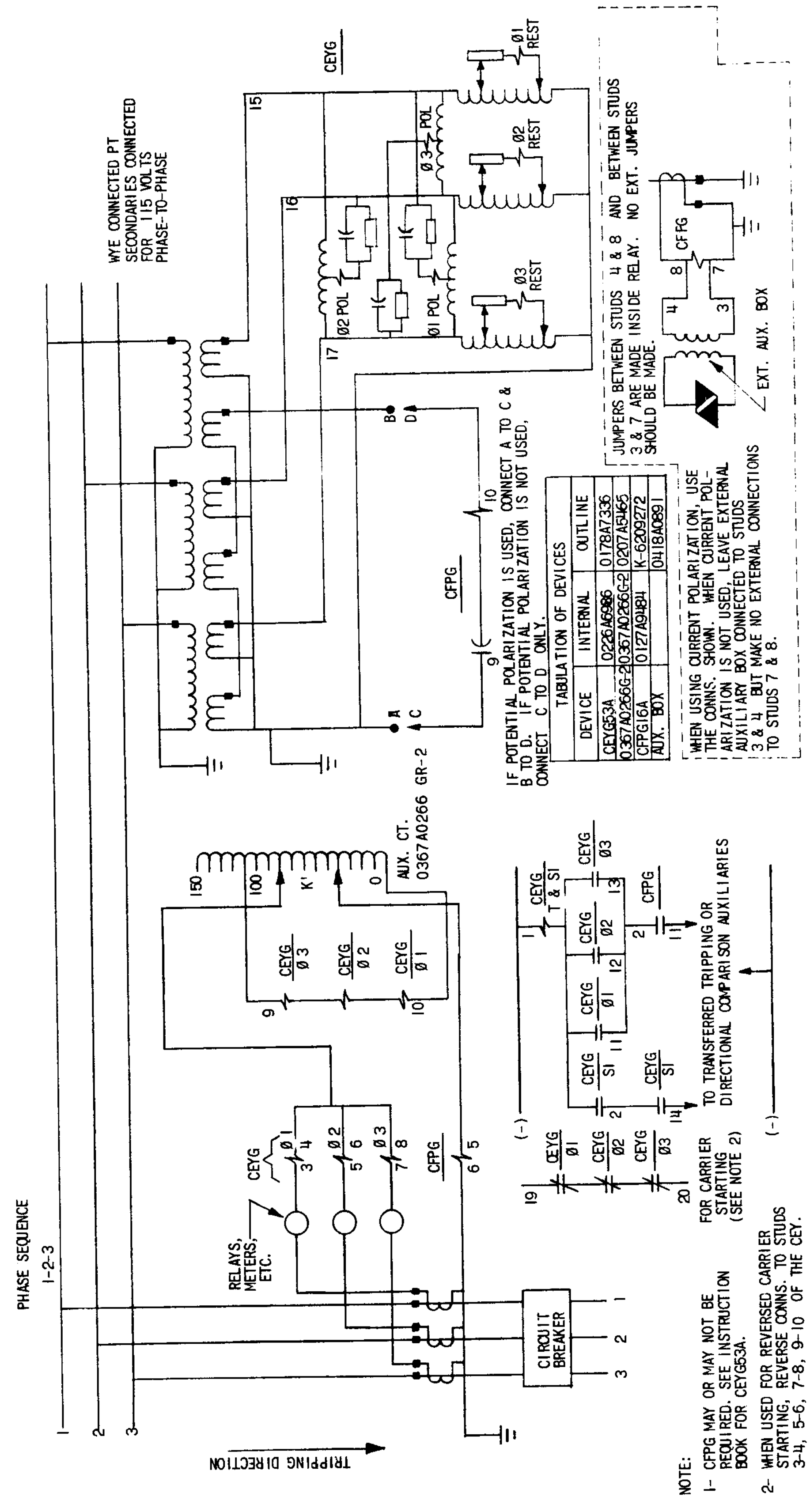
For both equations IIIB-a and IIIB-b, if a negative value for T is obtained, it signifies that the equation offers no limitation to the setting. Thus, any tap setting of 10 percent or more will be safe. Thus, when evaluating equations IIIB-a and IIIB-b, the first step should be the evaluation of the term $[(3K' + 1) C_0 - C]$. If this term is negative for all the system operating conditions for a ground fault at F2, this is all that need be determined.

Since the last edition, Figure 12 has been changed.



✱ = SHORT FINGER M1–TOP UNIT; M2–MIDDLE UNIT; M3–BOTTOM UNIT

FIG. 3 (0226A6986-1) Internal Connections Diagram For CEYG53A(-)D



TABULATION OF DEVICES

DEVICE	INTERNAL	OUTLINE
CEYG53A	0226A6986	0178A7336
0367A0266G-2	0367A0266G-2	0207A5465
CFPG16A	0127A9484	K-6209272
AUX. BOX		0418A0891

FIG. 4 (0165B2550-0) Typical External Connections For CEYG53A(-)D Relay

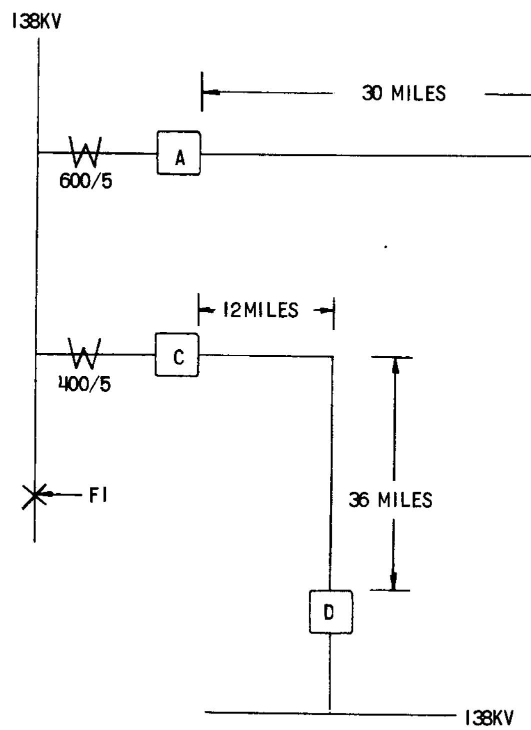


FIG. 5 (0208A5544-0) Typical Transmission Line System

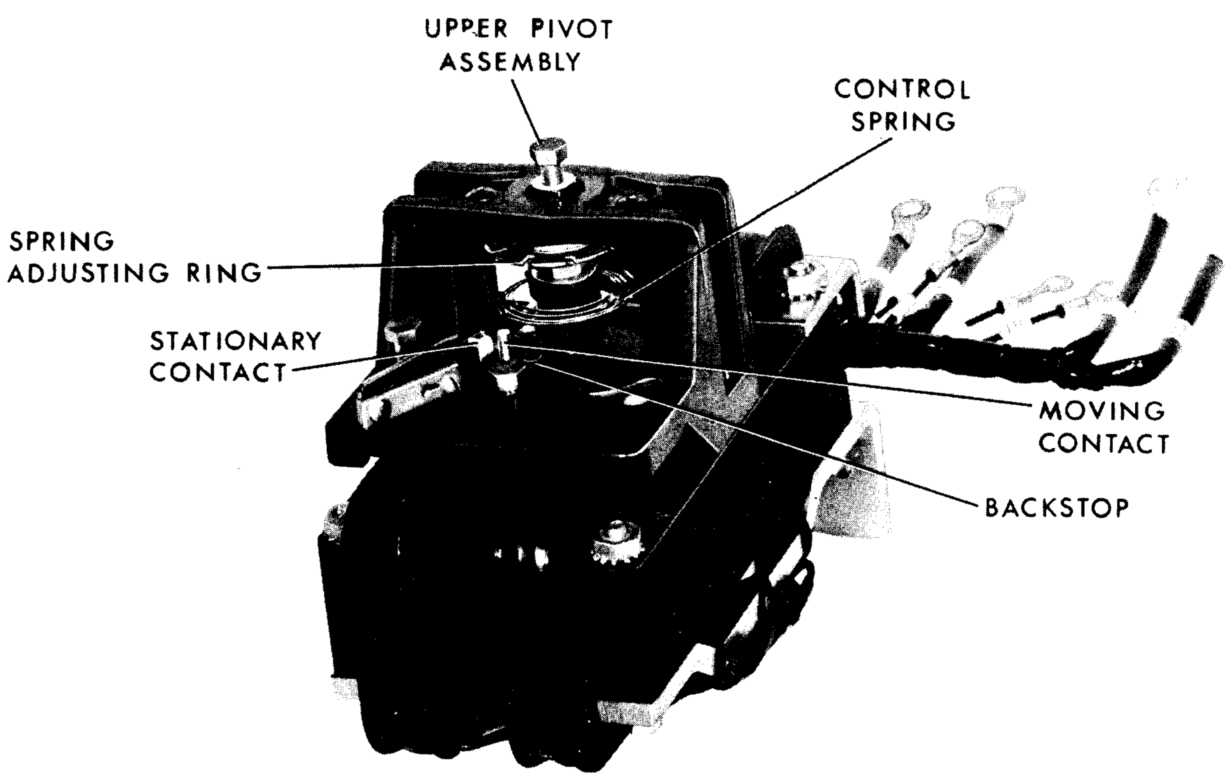


FIG. 6 (8034958) Four Pole Induction Cylinder Unit

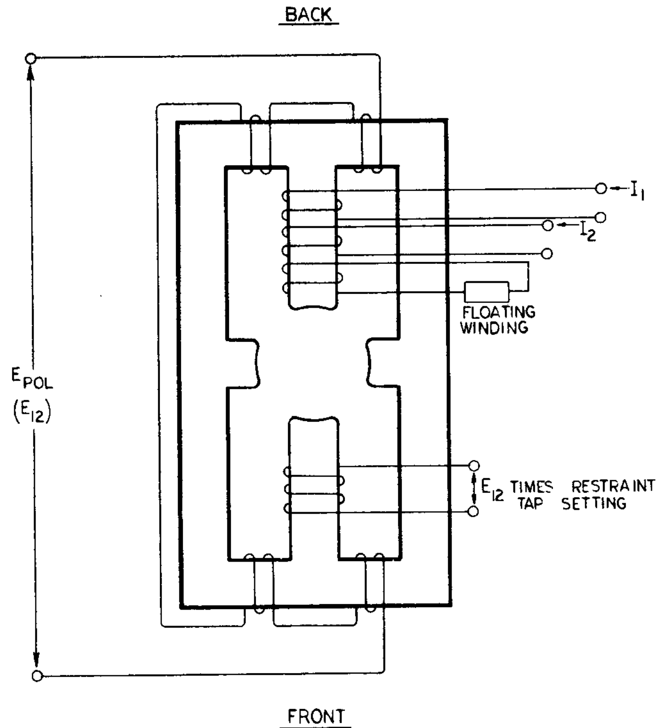


FIG. 7 (0208A5577-0) Schematic Connections Of Typical MHO Unit

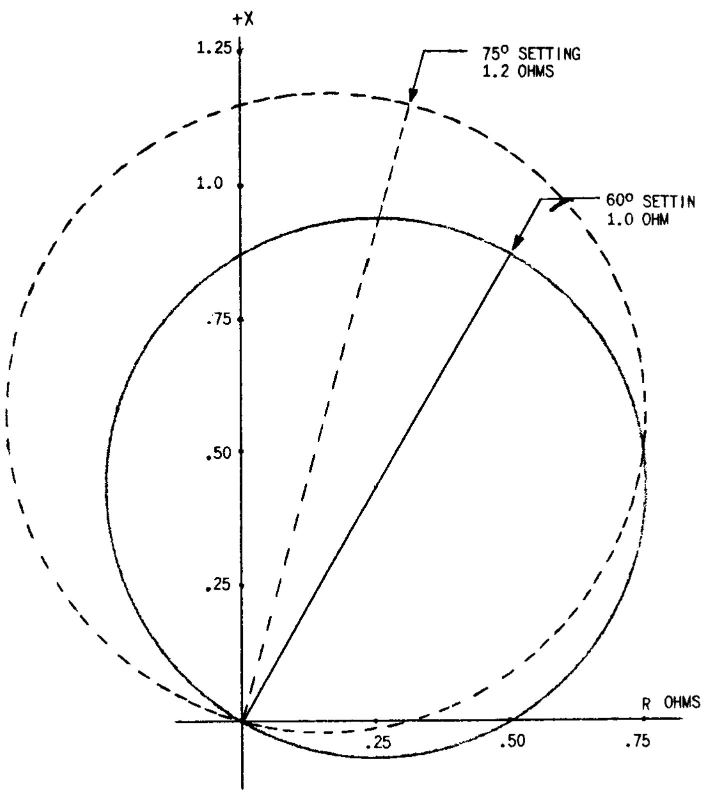


FIG. 8 (0178A8174-0) X-R Impedance Diagram

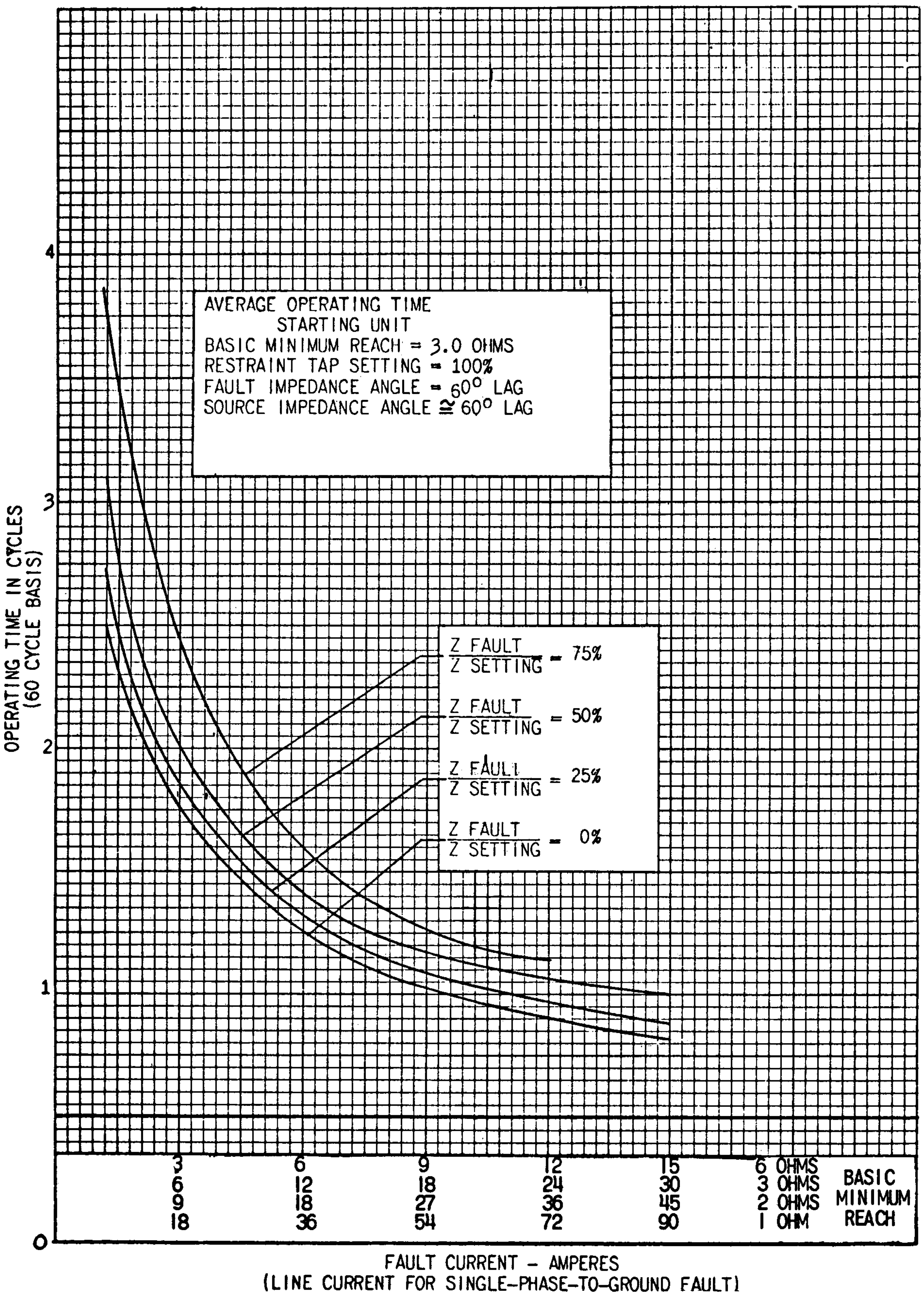


FIG. 9 (0227A2682-0) Operating Time Curves For CEYG53A(-)D Relay

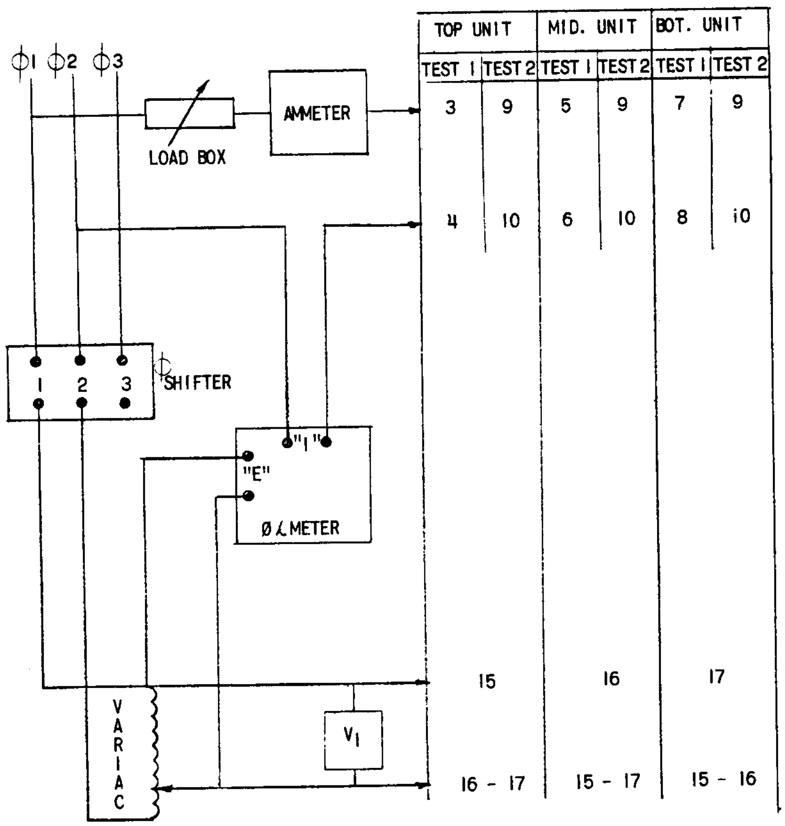


FIG. 10 (0227A7193-0) Test Connections Diagram For Control Spring Adjustment

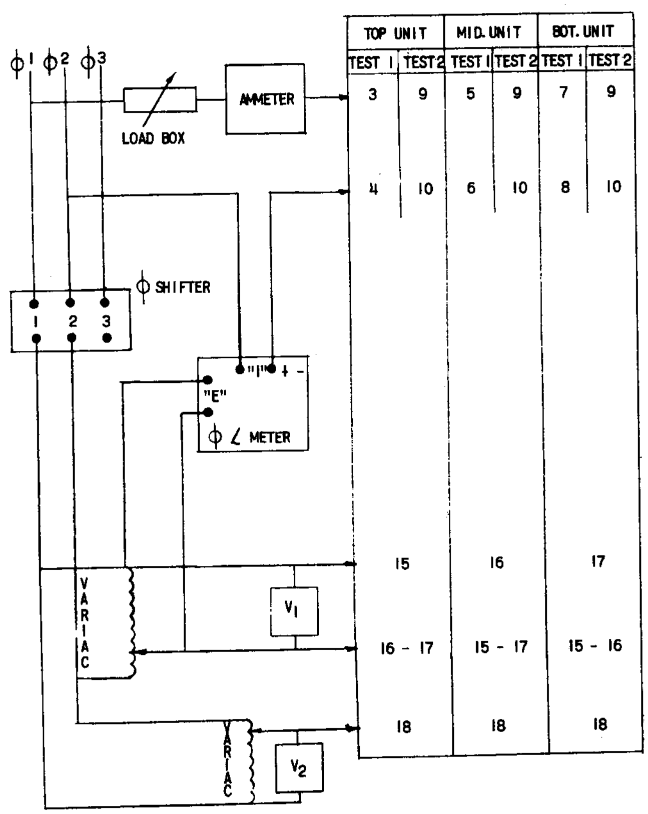


FIG. 11 (0227A7192-0) Test Connections Diagram For Reach And Angle Of Maximum Torque Adjustments

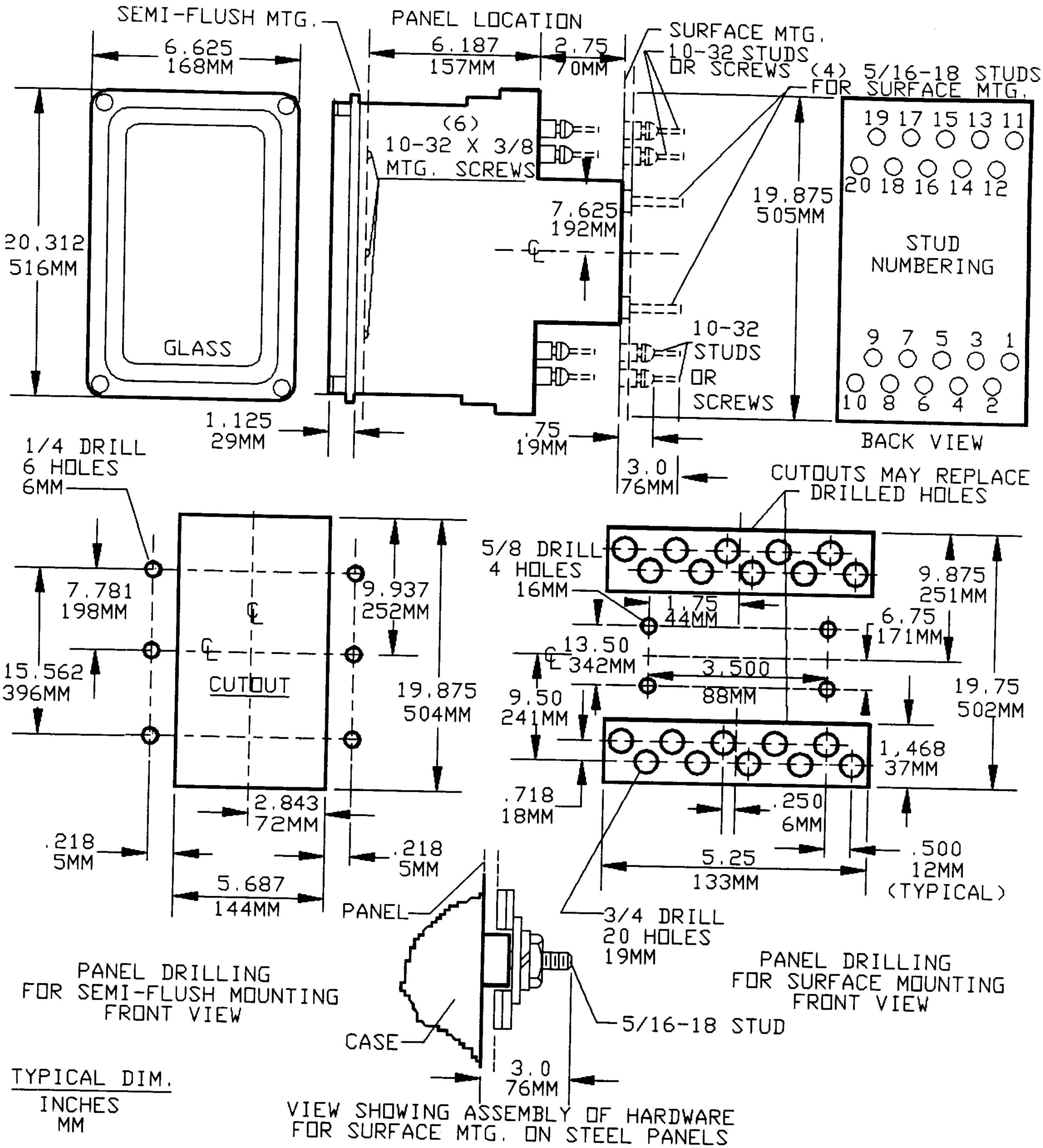


FIG. 12 (0178A7336 [5]) Outline and Panel Drilling Diagram

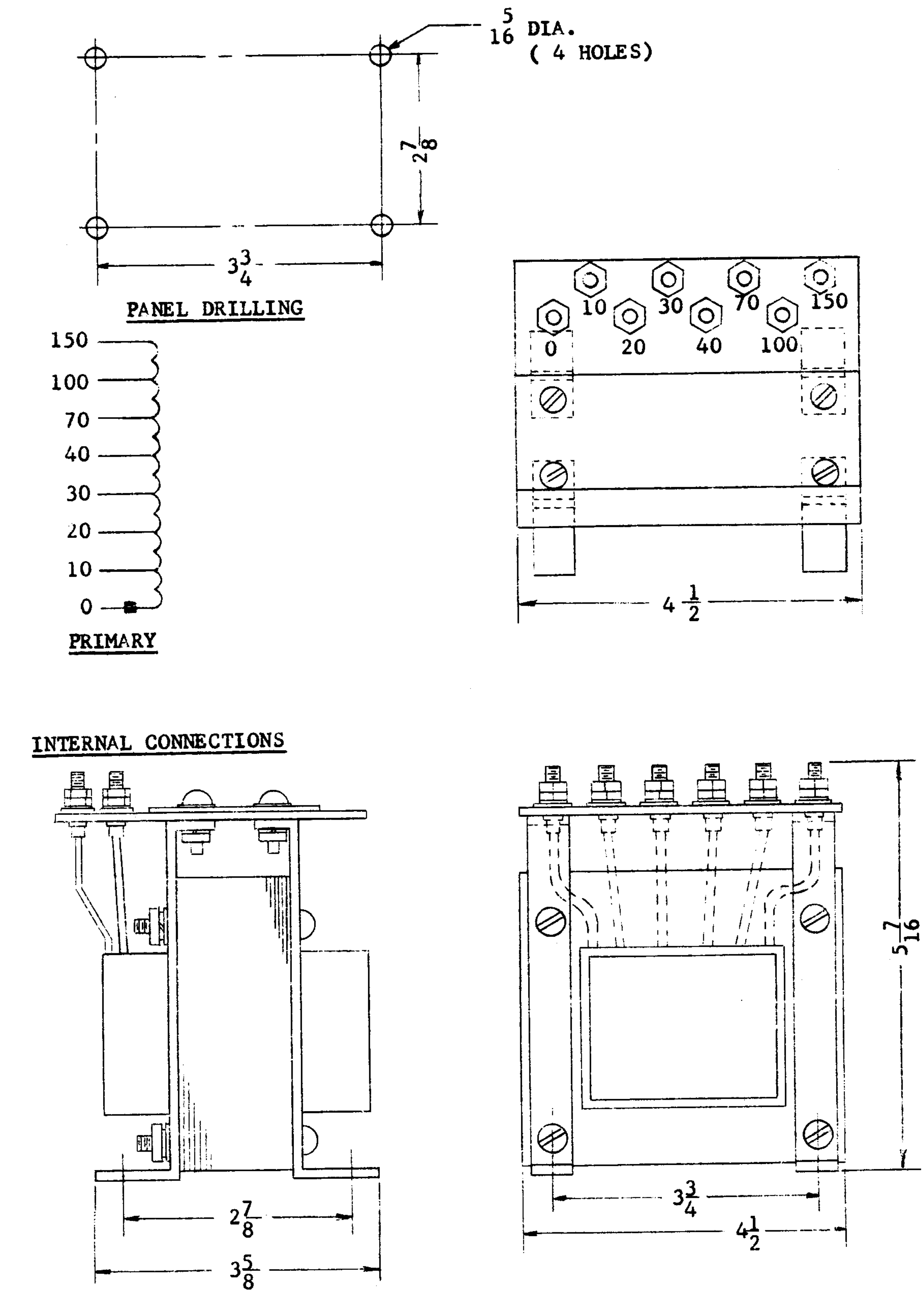


FIG. 13 (0207A5465-0) Internal Connections For The Auxiliary Compensating Transformer

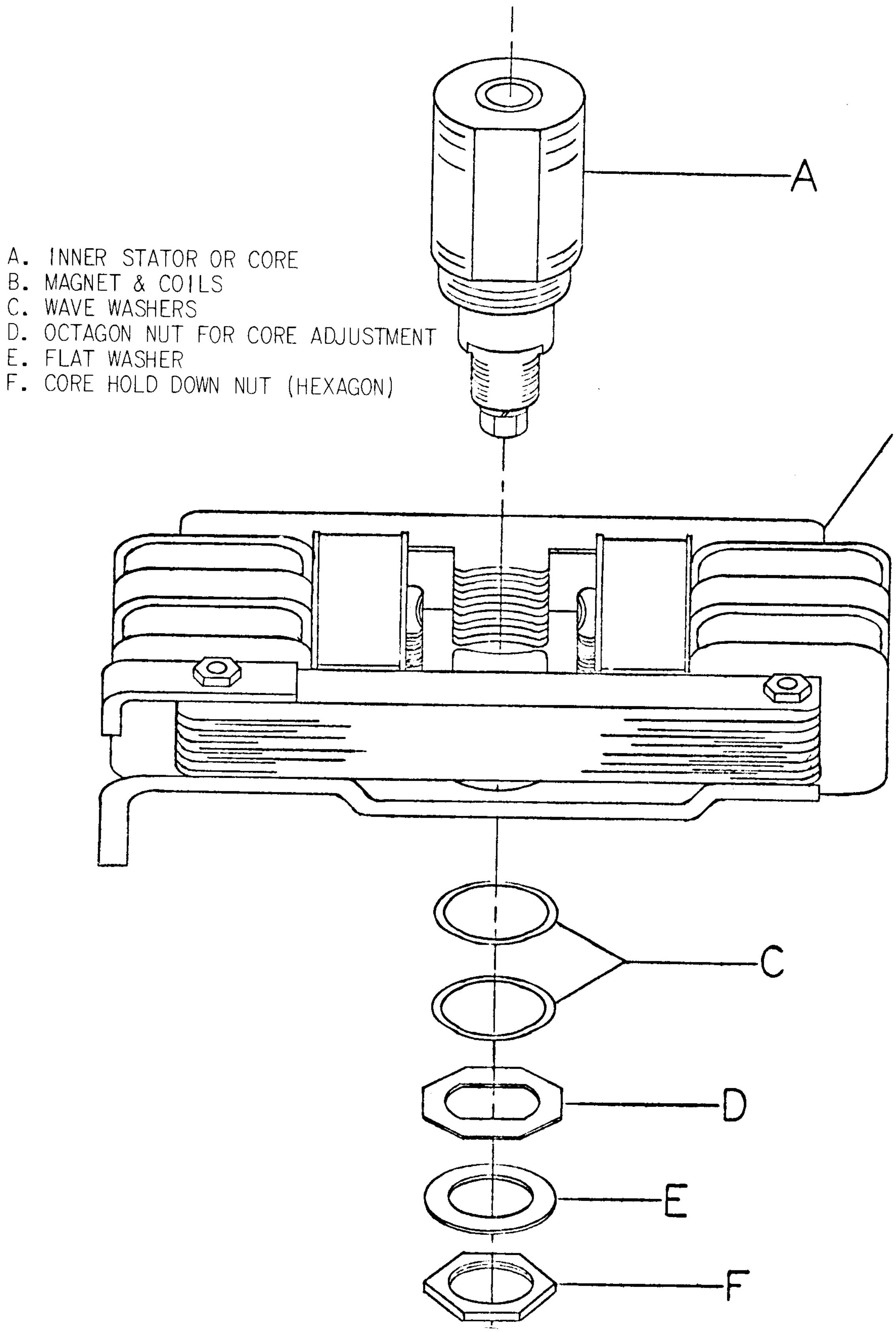


FIG. 14 (0208A3583-0) Assembly Of Core And Associated Parts

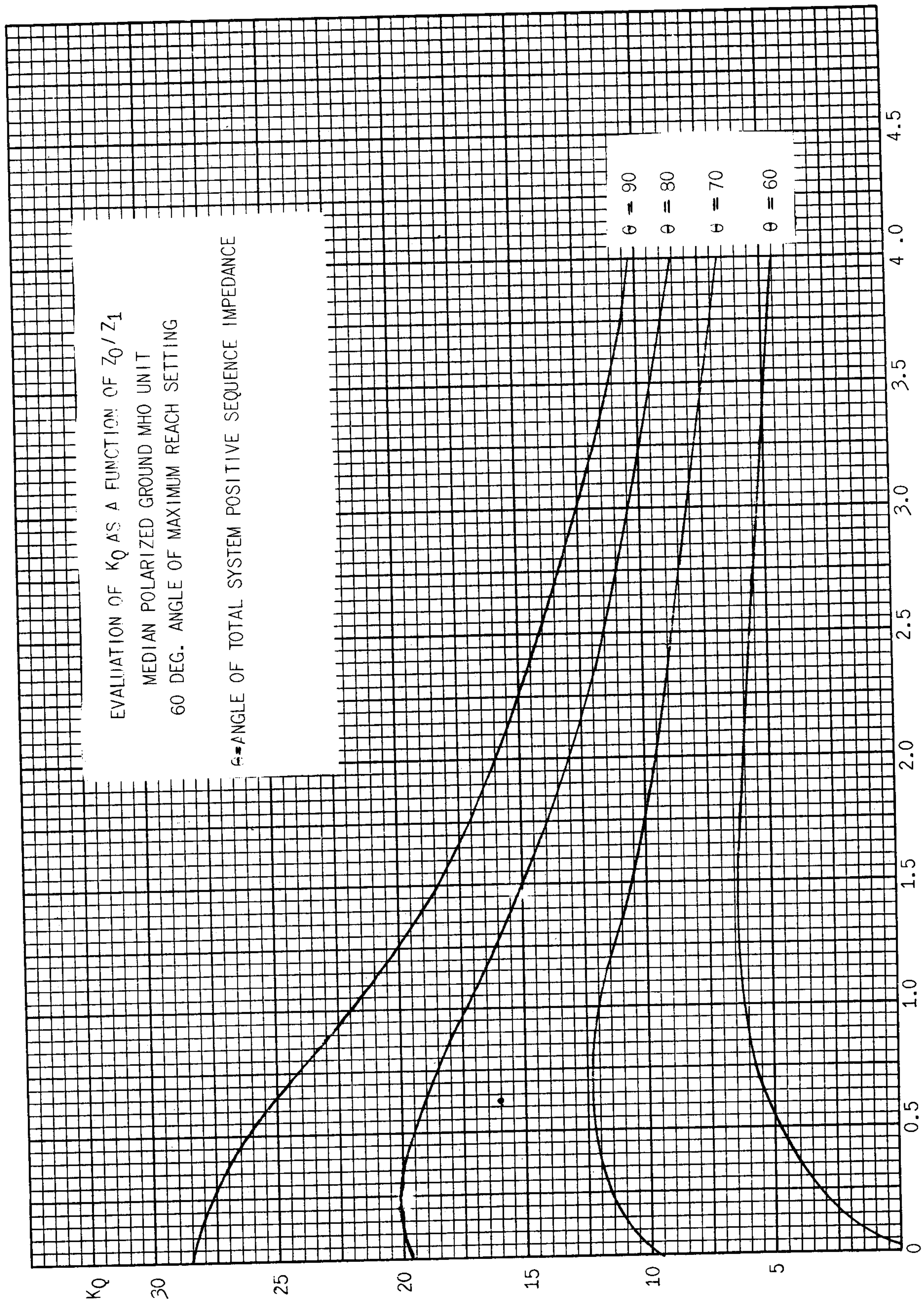


FIG. 15 (0226A6904-2) Evaluation Of K_0 As A Function Of Z_0/Z_1 For MHO Unit With 60° Maximum Torque Angle

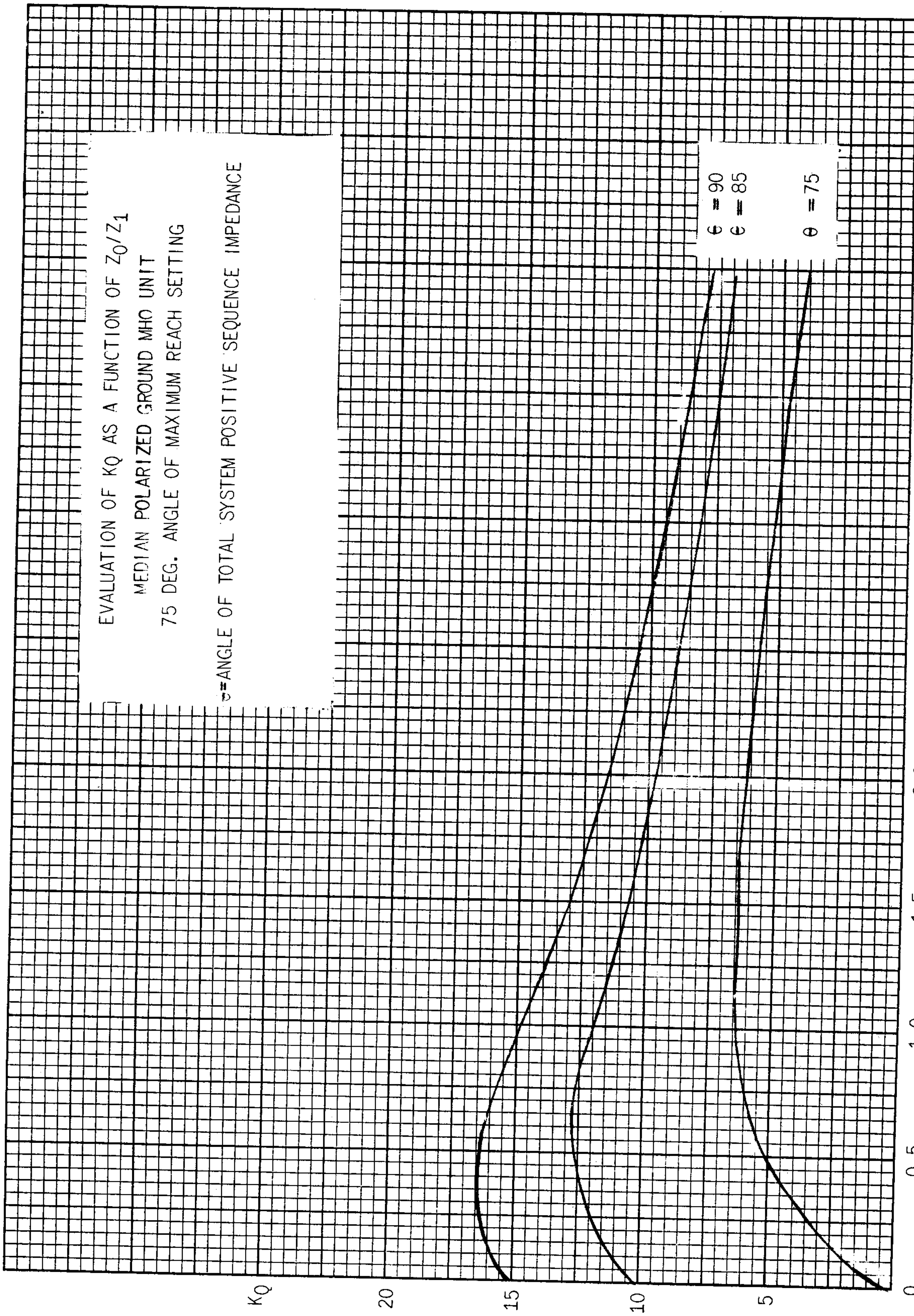


FIG. 16 (0226A6905-2) Evaluation Of K_Q As A Function Of Z_0/Z_1
For MHO Unit With 75° Maximum Torque Angle

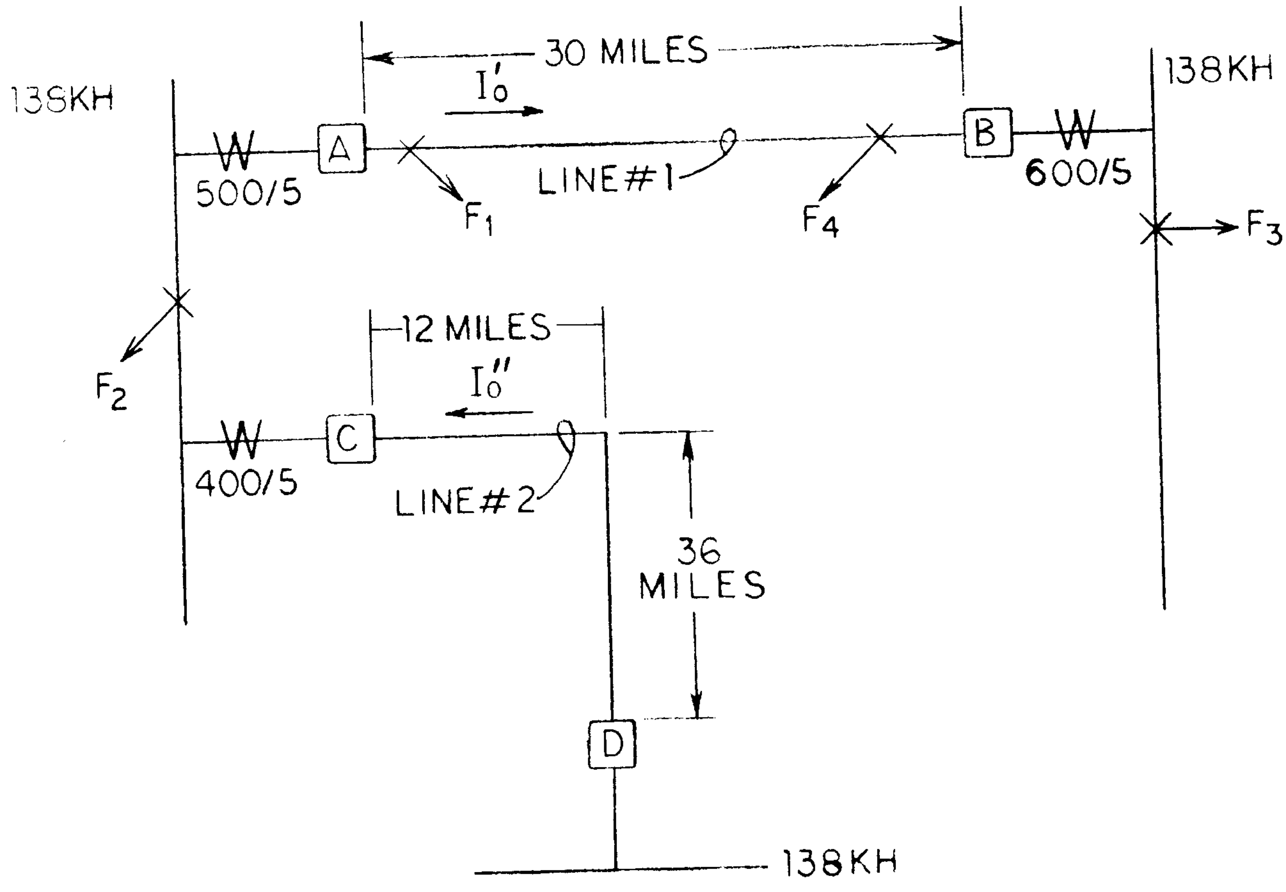


FIG. 17 (0165A7622 [2]) Typical Transmission System

Protection and Control

GE Technology Center
205 Great Valley Parkway
Malvern, Pennsylvania 19355-1337