MHO AND AUXILIARY RELAY

for

OUT-OF-STEP PROTECTION

TYPE GSY51A

GENERAL ✺ ELECTRIC

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DESCRIPTION

The Type GSY51A relay is designed specifically for use in conjunction with the Type CEX57E angle-impedance relay to detect an out-of-step condition on a power system. The relay includes a mho-type distance unit with provision for offsetting its characteristics, six telephone-type auxiliary units with the necessary series resistors, and a target seal-in unit, all mounted in an L2 size case. The outline and panel drilling dimensions are shown in Figure 9, and the internal connections in Figure 3.

APPLICATION

The usual application of the Type GSY51A relay and its associated Type CEX57E angle-impedance relay is at the terminals of a generator to provide out-of-step protection of the machine. When a generator loses synchronism, the resulting high current peaks and off-frequency operation may cause winding stresses, pulsation torques and mechanical resonances that have the potential of damaging the turbine-generator. Therefore, to minimize the possibility of damage, it is generally accepted that the machine should be tripped without delay, preferably during the first half-slip cycle of the loss of synchronism condition.

Formerly the generator, transformer and system impedance characteristics were such that the electrical center during loss-of-synchronism conditions generally occurred out in the transmission system. Hence the resulting swing impedance locus intersected transmission lines and would be detected by line relaying or by out-of-step detection schemes located at line terminals, and in most instances the system could be separated without the need for tripping generators.

With the advent of EHV systems, larger generators and the general expansion of transmission systems, the impedances involved have changed significantly. Generator and step-up transformer impedances have increased in magnitude, while system impedances have decreased. As a result, on many systems today the electrical center during loss-of-synchronism conditions can, and frequently does, occur in the generator or in the step-up transformer.

In general, the protection normally applied in the generator zone, such as differential relaying, time-delay system back-up, etc., will not protect a generator during a loss of synchronism. The loss of excitation relay may

provide some degree of protection, but cannot be relied on to detect generator loss of synchronism under all system conditions. Therefore, if during a loss of synchronism the electrical center is located in the region from the high voltage terminals of the generator step-up transformer down into the generator, separate out-of-step relaying should be considered to protect the machine.

The combination of the GSY51A and CEX57E relays, located at the generator terminals, is intended to detect an out-of-step condition when the swing locus passes through the machine or step-up transformer impedance. This scheme utilizes three impedance measuring units and the logic circuitry provided by the auxiliary units in the GSY to evaluate the progressive change in impedance during a loss of synchronism condition, and to initiate tripping when the angle between generator and system voltages is 900 or less. This typical application of the GS51A and CEX57E relays at the terminals of a generator is covered by the external connection diagram in Figure 10A. The contact circuit logic is shown in Figure 10B.

Although the CEX-GSY scheme is normally applied at the terminals of the generator, there are some applications where it will be more advantageous to apply these relays at the high voltage terminals of the step-up transformer. This is discussed further in the section on **CALCULATION OF SETTINGS.**

The occurrence of a single-phase-to-ground fault that evolves into a double-phase-to-ground fault may, under certain conditions, appear as an impedance swing to the CEX-GSY scheme. To avoid this remote possibility of a misoperation during the clearing of such a fault on the system, it is suggested that an instantaneous ground overcurrent relay be connected to supervise the CEX-GSY contact circuit, as shown in Figure 10B.

OPERATION OF THE SCHEME

The operating principles of the scheme can be explained with the aid of the R-X diagram and contact circuit in Figure 10B. This diagram shows the angle-impedance, or blinder, unit contacts (21ST/A1, 21ST/A2, 21ST/B1 and 21ST/B2), the offset mho unit contacts (21M/a and 21M/b), and the contacts of the six auxiliary units(X, X1, X2, X3, X4, and X5). The angle impedance units and their associated auxiliary units (X1, X2, X4, and X5) operate independently to determine a loss of synchronism, but their trip output unit, X3, is supervised by the 21M/a contact via 21M/X. This assures that tripping is initiated only for an impedance swing that traverses the mho unit characteristic (21M of the R-X diagram in Figure 10B). Final tripping is permitted by 21M/b when the impedance swing leaves the mho characteristic, causing the mho unit to reset.

The R-X diagram in Figure 10B shows the are of closure of the 21ST/A and 21ST/B blinder unit contacts A1, A2, B1, and B2. For example, when an impedance phasor terminates to the right of blinder B, 21ST/A2 and 21ST/B2 will be closed. When the impedance is between the blinders, 21ST/A2 and 21ST/B1 will be closed, and when the impedance is to the left of blinder A, 21STA1 and 21ST/B1 will be closed. It should be noted that for normal steady-state conditions, load impedance will fall somewhere near the R axis,

to the right of 21ST/B and outside the 21M mho characteristic. For this condition 21ST/A2 and 21ST/B2 will be closed, 21M/X1 will be picked up, 21M/b will be closed, and 21M/a will be open.

Referring to the contact circuitry and the R-X diagram in Figure 10B, the step-by-step operation of the scheme during an impedance swing will be as follows:

Step 1 - Assume that a swing impedance locus traverses the relay characteristics from C to K. Before the swing reaches point D the mho unit (21M) will be dropped out, the 21ST/A2 and 21ST/B2 contacts are closed, and the two 21M/X1 contacts are closed. The 21ST/A1 and 21ST/B1 contacts are both open.

Step 2 - When the swing locus enters the mho unit characteristic at point D, the 21M/b contact in the trip circuit opens and 21M/a closes, picking up unit 21M/X, which closes its contact in the X3 coil circuit.

Step 3 - The impedance swing next enters the area, G, between the two blinder characteristics, closing 21ST/B1 and opening 21ST/B2, which in turn de-energizes the X1 unit. Closure of the B1 contact picks up X2 through the A2 contact, which is still closed, and the X1 contact, which has a 12-cycle time-delay dropout. Unit X2 seals in around the X1 contact.

Step 4 - When the impedance locus enters region H, to the left of blinder A, 21ST/A2 opens, 21ST/A1 closes, and 21ST/B1 remains closed. The opening of A2 de-energizes the X2 unit and the closure of A1 picks up unit X4. The 12-cycle dropout time of the X2 unit provides time for X3 to pick up through the X2 and X4 contacts, and the X unit contact which has previously closed. The X3 unit seals in around these contacts, and the X3 contact in the trip circuit closes.

Step 5 - When the impedance locus enters region K, the mho unit resets, opening 21M/a and closing 21M/b. The closure of 21M/b completes the trip coil circuit through the 21M/X3 contact which closed in Step 4.

The previous description assumes an impedance swing from right to left (C to K), which will be the case for generator loss of synchronism. However, the scheme will perform correctly for swings in either direction, and hence is applicable for out-of-step protection out on the transmission system as well as at the generator terminals.

APPLICATION CONSIDERATIONS

The application of out-of-step relaying schemes at a generator, or out in the system, is not a simple procedure. In general, the proper application of such schemes requires extensive stability studies to determine the following:

1.   Loss-of-synchronism characteristics (i.e., impedance loci).

2.   Maximum expected generator slip.

3.   Characteristics of expected stable swings.

4.   Expected current levels.

The relationship between this information and the application of the CEX-GSY scheme is covered in a technical paper.   If the user desires further information on this subject, he should request it from the nearest General Electric Company Sales Office.

RATINGS

Refer to Figures 1 and 2. The GSY51A relay is rated for 120 volts, 5 amperes, and is available for 50 or 60 hertz frequencies.

The basic minimum reach is 2, 4, 6 ohms phase-to-neutral at $90°$ lead, with the restraint leads connected at 100% on the restraint transformer.

Each basic minimum reach can be selected with a link arrangement located behind the relay.   There are two sections of reach on one tap block; each section is marked A-B and 2, 0, 4.   By connecting both sections as shown in Table I, the basic minimum ohmic reach of the relay can be selected.

TABLE I

Minimum Reach	Links	
Phase-to-Neutral	"A"	"B"
2.0 ohms	2	0
4.0 ohms	0	4
6.0 ohms	2	4

The basic minimum reach can be extended up to ten times the basic reach by reducing the restraint circuit setting on the restraint transformer.

The following equation can be used for increasing the basic minimum reach of the relay.

$$(90° \text{ lead}) \quad Z \text{ Relay} = \frac{100 \text{ (\%)}}{\text{Transformer setting (\%)}} \times \text{basic minimum reach}$$

Ohmic reach settings greater than the basic minimum reach can be set within 1% increments by selecting the proper taps on the restraint transformer, which is tapped in 10% and 1% steps.

The relay also has a reverse offset transactor with a phase-to-neutral offset reach of 0 to 4 ohms in 0.5 ohm steps.   The taps are selected with the "H" and "L" leads on the offset tap block, which is located on the left front side, approximately in the center of the relay.

The transactor angle can be adjusted with the R63 rheostat, located just to the right of the offset tap block.

CURRENT CIRCUIT

The current circuit is continuously rated at 5 amperes, with a one-second rating of 250 amperes. Higher magnitudes of current above 5 amperes can be applied for shorter periods of time, according to the following equation.

$$K = I^2T$$

where: I = the applied current in amperes
         T = time in seconds
         K = Constant = (250^2) = 62500

Therefore: t seconds = $\dfrac{K}{I^2}$

POTENTIAL CIRCUIT

The potential circuit is continuously rated at 120 volts at rated frequency.

AMBIENT TEMPERATURES

The relays are designed to operate continuously at rated voltage, current and frequency in an ambient temperature not to exceed 40°C.

DC RATINGS

The DC voltage circuits are available at 48/110-125/220-250 volts DC. The circuits consist of telephone relays whose contacts, when closed, can carry 30 amperes for one second, with a continuous rating of 3 amperes.

The interrupting rating of these contacts is listed in Table II.

TABLE II

Volts	Interrupting Rating in Amperes	
DC	Inductive	Non-Inductive
125	0.50	1.5

TARGET/SEAL-IN

The combination target and seal-in unit has a dual rating of 0.6 or 2.0 amperes.

The tap setting selected on the target/seal-in unit is determined by the current drawn by the breaker trip coil. The 0.6 ampere tap is used with trip coils which operate on currents ranging from 0.6 ampere to 2.0 amperes at the maximum control voltage. The 0.6 ampere tap can be used also with trip coils drawing as much as 30 amperes, provided that the voltage drop across the coil with trip current flowing is not excessive. The 2.0 ampere tap can be used with all trip coils that draw more than 2.0 amperes at the maximum control voltage.

The ratings of the target/seal-in unit are shown in TABLE III.

TABLE III
HI-G TARGET/SEAL-IN UNIT

	0.6 Amp Tap	2.0 Amp Tap
Minimum operating	0.6 amp	2.0 amps
Carry continuously	1.8 amps	2.6 amps
Carry 30 amps for	0.5 sec.	3.5 secs.
Carry 10 amps for	5 secs	30 secs.
DC Resistance	0.78 ohm	0.18 ohm
60 cycle impedance	6.2 ohms	0.65 ohm
50 cycle impedance	5.1 ohms	0.54 ohm

MHO UNIT CONTACTS

The mho unit contacts, when closed, will carry 30 amperes momentarily up to a 250 volt DC control voltage. However, the contacts do not have an interrupting rating; therefore some other suitable method must be used to open the trip circuit after a trip condition.

OPERATING PRINCIPLES

The mho unit of the GSY51A relay is of the four-pole induction cylinder construction, where the torque is produced by the interaction between the polarizing flux and the fluxes which are proportional to the restraining and/or operating quantities.

The torque at the balance point of the mho unit can be expressed by the following equation.

$$\text{Torque} = 0 = Ei \, \text{Cos} \, (\emptyset - \theta) - KE^2 - K_S$$

Where:
E = Phase-to-phase voltage
I = Delta currents $(I_1 - I_2)$
θ = Angle of maximum torque
$\emptyset$ = Power factor angle of the fault impedance
K = Design constant
K_S = Control spring constant

To prove that the equation defines an mho characteristic, divide both sides by E^2 and transpose. The equation reduces to:

$$\frac{1}{Z} \text{Cos} \, (\emptyset - \theta) = K$$

or $Y \, \text{Cos} \, (\emptyset - \theta) = K$

Thus, the unit will pick up at a constant component of admittance at a fixed angle, depending on the angle of maximum torque. Hence the name mho unit.

When the offset is used, the transactor is energized with line current which produces a voltage proportional to the current and added to the line-to-line voltage in the unit's potential circuit. This voltage will offset the

circular characteristic of the mho unit as shown in the R-X diagram, Figure 4. Although not shown in Figure 4, the offset can be set between 0 and 4 ohms in 0.5 ohm steps.

CHARACTERISTICS

The mho unit produces a circular impedance characteristic as shown in Figure 4.

The diameter of the characteristic can be increased as shown in Figure 5, by reducing the restraint tap leads on the restraint transformer. It is not recommended that the restraint leads be set below 10% on the restraint transformer.

BURDENS

CURRENT CIRCUITS

The burden imposed on each current transformer at 5 amperes by the current circuits of the GSY51A relay is listed in Table IV for each basic minimum reach tap at 60 hertz.

TABLE IV

Basic Reach Tap, Ø-N	R	X	W	V.A.	P.F.
2.0	0.142	0.054	3.55	3.30	0.930
4.0	0.110	0.065	2.75	2.365	0.860
6.0	0.081	0.170	2.025	0.870	0.430

The burden at 50 hertz will be slightly lower.

POTENTIAL CIRCUITS

The maximum burden imposed on each potential transformer, with 120 volts 60 hertz applied, is shown in Table V.

TABLE V

Offset Tap, Ø-N	R	X	W	V.A.	P.F.
0	705	451	12.53	14.87	0.840
0.5	725	417	12.84	14.82	0.866
1.0	752	377	13.10	14.66	0.893
2.5	785	348	13.06	14.28	0.914
4.0	855	297	12.93	13.67	0.945

The 50 hertz burden will be slightly lower.

CALCULATION OF SETTINGS

The determination of relay settings for the CEX-GSY scheme need not be a complicated procedure. Preliminary settings of the blinder and mho units can be obtained by means of a simplified graphical approach on an R-X diagram, and then the validity of these settings can be checked with the results of the stability study.

GRAPHICAL PROCEDURE

In the simplified graphical procedure, the generator is represented by its transient reactance (X'_d). This reactance, along with the transformer reactance (X_T) and the system impedance (Z_S) is plotted to scale on an R-X diagram, the origin of which is at the terminals of the generator, as shown in Figure 18. If the system impedance is variable, the smallest system impedance should be used, since this will ensure that the subsequent blinder settings will be able to detect the smaller swing impedance locus associated with low system impedances.

The total impedance line is then drawn between points C and D. The angle of this line with respect to the horizontal axis represents the system angle. With the system characteristic thus established, settings for the blinders can now be determined.

BLINDER SETTINGS

Referring to Figure 18, the distance, N, from the origin to the blinder, and angle B between the blinder and the horizontal axis, can be adjusted separately for each blinder. The angle, B, is normally selected so that both blinders are approximately parallel to the total impedance line, CD. The spacing between blinders is generally selected so that at the point in an impedance swing where the blinders operate, the angular separation, S, between generator and system is 120°. This angular separation can be determined by drawing construction lines at points C and D that are 30° from the total impedance line, CD. The blinders are then plotted to pass through the 120° points E and F at an angle, B, with respect to the R axis, as shown in Figure 18. It should be noted that the dashed line, which is the bisector of the 120° angles, passes through the impedance center of the system and would represent the locus of the impedance swing for the case where the ratio of the generator internal voltage to the system voltage equals one (1).

MHO UNIT SETTING

The mho unit is set so that it will permit tripping for all impedance loci that will appear in the region from the high voltage terminals of the step-up transformer down into the generator. To accomplish this, the mho unit is generally connected with its forward reach looking into the generator and with its offset adjusted to encompass the transformer reactance with some margin.

The forward reach of the unit should be set so that it will detect all impedance loci that can go through the generator but not operate for stable transient swings. A forward reach setting which is equal to 2 to 3 times generator transient reactance (X'_d) would meet this criterion.

The offset must be adjusted so that it will detect an impedance locus that will go through the high voltage terminals of the step-up transformer. A setting which is equal to 1.5 to 2 times transformer reactance will usually accomplish this purpose. With the proper setting, the offset circle should be outside the blinders for swings going through the high voltage terminals of the transformer, as shown in Figure 18. This spacing assures that there will be proper coordination between the mho unit and the blinders for this extreme swing. It may be difficult to achieve this adjustment where the system impedance is large. This will be illustrated shortly.

It should be noted that, in order to detect swings at the transformer high voltage terminals, the offset setting reaches out into the system, and therefore the scheme may detect a swing which is outside the generator zone. While this is a possibility, the probability of this happening is small, since the impedance locus will be near the balance point of the relay, where relay operation is slow. The chances are that system relaying will operate before the out-of-step relaying scheme. If the scheme does operate for such swings, this is generally accepted as a desired option.

VERIFICATION OF SETTINGS

Once the settings have been determined, they should be checked with the actual impedance loci as determined from the stability studies. Figures 19, 20, 21 and 22 compare the calculated settings with expected impedance loci for system impedances of 0.05, 0.09, 0.2 and 0.4 per unit on the generator base. To facilitate comparison with the relay characteristics, the examples in these figures are presented in terms of secondary ohms.

Figure 19 is intended to represent the impedance locus that would occur with a system impedance of 0.05 per unit and the voltage regulator out of service. For this situation, the impedance locus tends to be small in diameter and thus more difficult to detect. With the blinders set for 120° angle separation between generator and system (solid lines in Figure 19), the impedance locus just barely crosses the left blinder. To provide additional operating margin for this situation, both blinders can be shifted to the right as indicated by the dashed lines. In addition, the forward reach of the mho unit should be held to twice the generator transient reactance (X'_d), as shown, to assure that the impedance locus will leave the area of the mho characteristic, thereby permitting tripping.

Figure 20 typifies an application of the CEX-GSY scheme where the system impedance equals 0.09 per unit. In this case, the blinder and mho settings as previously described would be satisfactory and would not require modification. This figure also shows that there is ample margin between the assumed stable impedance locus and the forward reach of the mho unit, which in this case is set for 3 times the transient reactance (X'_d).

Figure 21 typifies the application of the scheme where the system impedance equals 0.2 per unit. In this example, the settings based on the previous calculations would be satisfactory and would require no modification.

Figure 22 shows the application of the CEX-GSY scheme where the system impedance equals 0.4 per unit. In this instance, the calculated settings would be adequate, but the spacing between the mho unit and the blinder for swings near the high voltage terminals of the transformer might be considered marginal. The mho unit is at its maximum offset reach of 4 ohms and therefore cannot be increased further.

If additional margin is desired, the relays can be shifted to the high voltage terminals of the transformer, as shown in Figure 23. Now, with a 3-ohm offset, there is more margin available betwen the CEX and mho unit settings. This problem of spacing between the blinders and the mho unit at the extreme limits of possible swings will only arise for high system impedances.

It was noted earlier that when system impedance is variable, the smallest impedance should be used to determine the settings. In general, if the resulting settings are adequate with the small system impedance, they will also be adequate with the higher system impedance. For example, if the system impedance can be 0.05 and 0.2 per unit, it should be readily apparent that the settings for the 0.05 system would be able to detect the larger impedance locus of the 0.2 system. On the other hand, if the relays had been set for the 0.2 system impedance (Figure 21), these settings would not have detected the smaller impedance locus shown in Figure 19.

As a final point of interest, it should be noted that while the simple graphical approach is an approximate procedure, it does give a fairly good indication as to where the actual impedance locus will go. As noted earlier, the bisector of the 120° angle between generator and system will go through the impedance locus for $E_G/E_{sys} = 1$. As can be seen in Figures 19, 20, 21 and 22, the actual impedance loci are only slightly below this impedance center.

It should be emphasized that the guidelines and data presented here are the results of generalized studies that do not consider the effects of all types and designs of generators and system parameters, or the interaction effect of other generators. These effects can only be completely determined by the study of a generator connected to a specific system. Therefore, it is recommended that the user determine the actual loss-of-synchronism characteristic for each generator, considering the overall effects of the system.

CONSTRUCTION

The type GSY51A relay is assembled in a large size, double ended (L2) drawout case. There are stud connections at both ends at the rear of the case for external connections.

The electrical connections between the relay units and the case studs are made with a removable connection plug.

Every circuit in the drawout case has an auxiliary brush, as shown in Figure 6, to provide adequate overlap between the auxiliary brush, relay fingers and shorting bar.

GENERAL

DRAWOUT RELAYS

Since all drawout relays in service operate in their cases, it is recommended that they be tested in their cases or an equivalent steel case. In this way, any magnetic effects of the enclosure will be accurately duplicated during testing. A relay may be tested without removing it from the panel, by using a 12XLA13A test plug. This plug makes connections only with the relay, and does not disturb any shorting bars in the case. Of course, the 12XLA12A test plug may aos be used. Although this test plug allows greater testing flexibility, it also requires CT shorting jumpers and the exercise of greater care, since connections are made to both the relay and the external circuitry. Refer to GEI-25372 for further information on the XLA test plugs.

POWER REQUIREMENTS

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

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

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

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 calibration was not disturbed.

VISUAL INSPECTION

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

Remove the cover, connection plugs and the relay from its case and check that there are no broken or cracked molded parts or other indications of physical damage.

MECHANICAL INSPECTION

1.   Check the mechanical adjustments as listed in Table VI.

TABLE VI

MHO unit	Mechanical Parameters
Rotating Shaft End Play	0.005 inch to 0.008 inch
Contact Gap	0.055 inch to 0.065 inch
Contact Wipe	0.003 inch to 0.005 inch

2.   Move the mho unit contact manually to determine if the rotating member has any friction.

3.   Check that the control spring is not deformed and that the other turn is not hooked behind the spring soldering post.

4.   Check the telephone relays manually to determine if they are free and have not been damaged.

5.   Check that the target/seal-in unit is not damaged, and that it is free of mechanical binds.

6.   Check the contact fingers and shorting bars in the case and relay against the internal connection diagram for the relay (Figure 3).

ELECTRICAL TESTS

Note: All electrical tests must be performed with the relay in its own case or an equivalent steel test case.

Connect the relay per the test circuit diagram of Figure 7 and Table VII.

TABLE VII

Connect lead A to stud 17.
Connect lead B to stud 18.
Connect lead C to stud 7.
Connect lead D to stud 10.
Jumper stud 8 to stud 9.

Connect a contact light to the normally-open contact of the mho unit. This is the contact on the left side of the unit, front view.

There are two conditions that exist which must be taken into consideration before any attempt is made to check the calibration of the mho unit. Either:

1.   The relay was calibrated for a standard factory test; or

2.   The relay was calibrated per the customer's recommended settings. Do not disturb the settings if this was the case.

MHO UNIT - ACCEPTANCE TESTS (STANDARD FACTORY CALIBRATION)

The relay should be leveled in its own case or a test case, in the upright position. Set the following conditions.

1. Restraint circuit taps set at 100% on the restraint transformer.

2. Set both reach taps at 4 ohms $\emptyset$-N.

>   2A links to 0
>   2B links to 4

3. Set the offset transactor tap leads (H and L) to 0 on the offset block.

Before applying power to the circuit, check that the moving contact of the mho unit is closed to the right side, front view.

Directional Tests

Apply 120 volts, rated frequency and 5 amperes to the relay.

Adjust the phase shifter to set the phase angle meter for 90° lead. Reduce the voltage to 3 volts and the current to 0 amperes. Gradually increase the current; the left contact should close between 1.5 and 2.0 amperes.

Increase the current from the pickup to 60 amperes very quickly and note that the left contact remains closed. **Do not apply this current for too long a period of time, because it will overheat and possibly damage the unit.**

Reduce the current to 0 and remove the voltage from studs 17 and 18. Place a jumper across 17 and 18. Note that left contact opens. Again, increase the current from 0 to 60 amperes and note that the left contact remains open.

Remove the short from studs 17-18 and connect the potential to these studs according to the test connections diagram (Figure 7).

Reach

Apply 120 volts and increase the current until the left contact closes. This should occur at 14.80 to 15.15 amperes. Make sure that the phase angle meter is set for 90° lead during this test.

Angle of Maximum Torque

In order to check the angle of maximum torque of the mho unit, the reach should be checked at two angles which are 30° on either side of the angle of maximum torque.

Check the reach at 60° and at 120° by setting the phase angle meter for these angles.

Apply 120 volts; left contact will open. Increase the current until the left contact of the unit closes. This should occur between 17.0 to 17.7 amperes at 60° and at 120° lead.

Additional Reach Taps

For a check on the additional two reach taps, set the reach taps, phase angle, and voltage as listed in Table VIII and check the current necessary to operate the mho unit.

TABLE VIII

Reach Links A	B	Reach Ø - Ø	Phase Angle (Lead)	Voltage Applied	Current Pickup
2	0	4.0	90°	60 V	14.55-15.45
2	4	12.0	90°	120V	9.7 -10.3

Offset Test

The offset is in the reverse direction from the unit, therefore its angle is at 270° lead.

Table IX is a listing of the ohmic reach for each offset tap.

Apply the voltage, 5 amperes of current, set the phase angle listed, then increase the current. The unit should operate between the values listed under Current Pickup.

TABLE IX

Offset Tap Ø - N	Ohmic Reach Ø - Ø	Phase Angle (Lead)	Applied Voltage	Current Pickup
0.5 Ω	1.0 Ω	270°	20 V	18 -22
1.0 Ω	2.0 Ω	270°	40 V	18 -22
2.5 Ω	5.0 Ω	270°	100 V	18 -22
4.0 Ω	8.0 Ω	270°	120 V	14.5-16.5

Refer to the section on **SERVICING** if any of these tests do not function properly within specifications.

Target/Seal-in

Connect the following studs to a DC current circuit consisting of a 125 volt DC source with a rheostat, ammeter and target coil studs connected in series across the DC source. The circuit should be capable of varying the current ove a range of 0.03 to 2.0 amperes.

Connect one test circuit coil lead to stud 11. Connect the other test circuit coil lead to stud 19. Put an external jumper between studs 19 and 1.

The external jumper is used to determine if the target/seal-in circuit is functioning properly. Failure to put the jumper on the proper studs will result in a damaged control spring on the normally-closed M/b mho unit contact.

Reduce the current to approximately 0.

Close the M_b (normally-closed contact) on the mho unit; gradually increase the current until the target/seal-in unit picks up. Open the M_b contact and note that the target remains sealed in. With the M_b contact held open, reduce the DC current and check the dropout current of the unit. The values for pickup and dropout are listed in Table X.

TABLE X

Target Tap	DC Pickup Current	DC Dropout Current
0.60 A	0.36-0.60 A	0.15 or higher
2.00 A	1.20-2.00 A	0.50 or higher

In order to change taps without disturbing the mechanical adjustments of the contacts, proceed as follows:

1. Remove one of the screws on the left-hand plate, front view.

2. Place this screw into the desired tap on the right-hand plate (tap plate), front view.

3. Remove the screw from the undesired tap and put it in the left-hand plate.

Restraint Transformer

The offset transactor lead (H-L) should be connected to 0 on the offset block.

Apply 100 volts, rated frequency, to studs 17 and 18 at 0 current.

Read the voltage on each tap on the restraint transformer with an accurate high-input impedance voltmeter. Connect one lead of the voltmeter to 0 on the restraint transformer block and the other lead to each tap. The reading should be equal to tap value ($\pm$ 1%).

Telephone Relays

There are six telephone relays that must be checked for pickup voltage, pickup time and dropout time.

Connect the relays per the test circuit of Figure 8 and refer to the test parameters listed in Table XI. Always connect (-)DC to terminal 2 for testing of telephone relays.

TABLE XI

Tests	Telephone Relays					
Ref. Fig. 8	X	X1	X2	X3	X4	X5
Connections A - B	Studs 2-20	Studs 2-12	Studs 2-15	Studs 2-6	Studs 2-3	Studs 2-15
Connections C - D	Studs 13-14	Studs 4-5	Studs 4-5	Studs 1-16	Studs 4-5	Studs 4-5
Operate Manually	Mho N.O. Contact	X-5	X1 X4	-- --	X2	X1 X4
Pickup Voltage	80% or less of rated voltage	80% or less of rated voltage	80% or less of rated voltage	80% or less of rated voltage	80% or less of rated voltage	80% or less of rated voltage
Pickup Time	0.008 Sec. or less	p.008 Sec. or less	0.008 Sec. or less	0.009 Sec. or less	0.008 Sec. or less	0.008 Sec. or less
Dropout Time (Sec.)	0.200 0.220	0.200 0.220	0.200 0.220	0.100 0.110	0.200 0.220	0.200 0.220

Because of the fast pickup times involved with these telephone relays, it is recommended that the pickup times be checked on an electronic timer and an initiating switch with a minimum of timing error between the two poles.

Pickup voltage is defined as the DC voltage, gradually applied, that causes the telephone relay armature to pick up and seal in against the pole piece.

Pickup time is defined as the time interval between the energization of the telephone relay and the closing of an "a" (normally open) contact, as rated DC voltage is suddenly applied.

Dropout time is defined as the time interval between the de-energization of the telephone relay and the opening of an "a" contact, as the DC voltage is suddenly reduced from rated DC to 0 volts.

MHO UNIT - ACCEPTANCE TESTS (FACTORY ADJUSTED PER THE CUSTOMER'S SETTINGS)

If the relay was calibrated at the factory per the customer's settings that were listed on the requisition, then the following test procedure is recommended:

1. Visual inspection - Same as before.

2. Mechanical inspection - Same as before.

3. Electrical tests (mho unit) - New procedure; see below, beginning with Directional Test.

4. Target/Seal-in - Same as before.

5. Restraint Transformer - Same as before.

6. Telephone relays - Same as before.

Relays that have been set per the requisition will be set by the factory and shipped with those settings. Therefore, do not disturb any of the adjustments.

Directional Test

With the relay set for a particular application, the directional test can be omitted because the unit will be set for both a forward and a reverse reach. After the relay is leveled in its upright position in its own case or in a similar test case, note that the normally-closed contact is closed.

Reach

Check the requisition for the reach settings, both in the forward direction (90º lead) and in the reverse direction (270º lead). These values are ordinarily stated in ohms-phase-to-neutral, but the test circuit will test for a phase-to-phase ohmic reach. This will be equal to two times the phase-to-neutral ohmic reach.

Connect the relay per the test circuit of Figure 7 and Table VII.

The following equation will determine the current operating pickup.

$$I_{pickup \atop (90º\ lead)} = \frac{Applied\ Voltage}{ohmic\ reach\ setting\ (\emptyset-\emptyset)}$$

Apply enough voltage, up to the relay's rated voltage, to provide as much operating current as possible, up to a maximum of 20 amperes.

Angle of Maximum Torque

Set the phase angle at 60º lead. The current operating pickup should be as determined in the following equation.

$$I_{pickup \atop (60º\ lead)} = \frac{Applied\ Voltage}{ohmic\ reach\ setting\ (\emptyset-\emptyset)\ x\ cos\ 30º}$$

Set the phase angle at 120º lead. The current operating pickup should be the same as determined at 60º lead ($\pm$ 3% of each other).

Other Reach Taps

The other reach taps should not be checked, because in order to set the mho unit characteristic per the customer's request the adjustments were changed so that the basic minimum reach taps are not at the nominal values as shown on the reach tap block.

Offset Tests

The offset should be checked at the offset tap setting that was made per the customer's requisition settings.

Set the phase ange for 270⁰ lead.

Calculate the current pickup with the following equation.

$$I_{pickup} = \frac{Applied\ Voltage}{offset\ ohmic\ reach\ (\emptyset-\emptyset)}$$
(270⁰ lead)

Apply enough voltage, up to the rated voltage of the unit, to provide as much operating current as possible, to a maximum of 20 amperes.

INSTALLATION PROCEDURE

INSPECTION

Inspect all parts and components of the relay as described under **ACCEPTANCE TESTS**.

Check the nameplate information against the purchase order.

Check the fingers and shorting bars in relay and relay case against the internal connection diagram, Figure 3.

LOCATION

The relay should be installed in a clean and dry location, free from dust and excessive vibration, and in a well lighted area in order to facilitate inspection and testing.

MOUNTING

The relay should be mounted on a vertical surface in the upright position, and as level as possible.

The outline and panel drilling is shown in Figure 9.

CONNECTIONS

The internal connections of the relay are shown in Figure 3.

The external connections are shown in Figures 10A and 10B.

Unless the relay is mounted on a steel panel which adequately grounds the relay case, it is recommended that the case be grounded through a mounting screw with a conductor not less than #12B and S gage copper wire or its equivalent.

MECHANICAL INSPECTION

Check the mechanical adjustments according to those listed in TABLE VI in the **ACCEPTANCE TEST** section.

PERIODIC CHECKS AND ROUTINE MAINTENANCE

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

CONTACT CLEANING

For cleaning fine silver relay contacts, a flexible burnishing tool should be used. This consists of an etched-roughened strip of flexible metal, resembling a superfine file. The polishing action is so delicate that no scratches are left, yet it will clean off any corrosion thoroughly and rapidly. The flexibility of the tool insures the cleaning of the actual points of contact. Never use knives, files, or abrasive paper or cloth of any kind to clean fine silver contacts. A burnishing tool as described above can be obtained from the factory.

SERVICING (STANDARD FACTORY CALIBRATION)

Check the relay, (see **ACCEPTANCE TESTS** section) for the auxiliary circuits.

Connect the relay per Figure 7 and Table VII for the mho unit calibration.

In the event that the mho unit must be recalibrated, the following procedure can be followed, along with reference to the information under **ACCEPTANCE TESTS**, (STANDARD FACTORY CALIBRATION).

Directional Tests

Refer to Figure 12 for a picture of the induction cup unit used in the GSY51A relay. See Figures 1 and 2 for component location.

The control spring is adjusted to obtain the pickup mentioned under **ACCEPTANCE TESTS** where the voltage is reduced to 3 volts and the current pickup is between 1.5 and 2.0 amperes at 90° lead. If the relay does not operate between these currents, adjust the spring adjusting ring, shown in Figure 12,

with a screw driver inserted in the slot. Turning the ring to the right will increase the pickup and to the left will decrease the pickup.

The correct directional action as explained in the **ACCEPTANCE TESTS** is controlled by the adjustment of the core (inner stator) of the unit.

The adjustment is accomplished by rotating the core with a special wrench (Cat. No. 0178A9455 PT 1). The wrench is inserted underneath the unit to engage the D washer on the core locking assembly. The core assembly is shown in Figure 11. Because of the type of locking device, the assembly does not have to be loosened to rotate the core. The adjustment is continuous through a 360° revolution in either direction without disturbing the locking mechanism.

Reach

The adjustment of the reach is accomplished with the R11 rheostat, which is the upper rheostat on the mounting plate, just to the left of the mho unit. See Figures 1 and 2.

Angle of Maximum Torque

The angle of maximum torque is adjusted with the R21 rheostat and/or the X21 reactor. It is preferred to adjust the angle with the R21 rheostat, but it is not objectionable to use the X21 reactor if necessary. The R21 rheostat is the lower rheostat located on the mounting plate, just to the left of the mho unit. The X21 reactor is located above the unit on the right side of the mounting plate.

Additional Reach Taps

There are no adjustments for the two additional reach taps. Their accuracy is dependent on the accuracy of the previously-mentioned reach adjustment and the turns ratio of these two taps. Accuracy of $\pm$ 3% of the tap value is acceptable.

Offset Taps

The offset reach taps are not adjustable. The R-63A resistor is used to set the angle of the offset transactor and the accuracy is dependent on the turns ratio of the coil. Accuracy of $\pm$ 10% of the tap value is acceptable. The R-63 rheostat is located above the mho unit, to the left of the X-21 reactor.

SERVICING (RELAY FACTORY-ADJUSTED PER CUSTOMER'S SETTINGS)

It was recommended that the GSY51A relay be calibrated at the factory for the customer's specific application because of some characteristic changes that occur from the basic unit settings as the restraint transformer and/or offset tap is varied.

The customer should specify the reach in ohms, phase-to-neutral at 90° lead and the reach in ohms, phase-to-neutral at 270° lead. The relay will be set at

the factory and shipped with the relay calibrated for these settings.

In the event that servicing is necessary, the following procedure must be followed.

Connect the relay per Figure 7 and Table VII.

Directional Tests

With the relay set to reach both in the forward and the reverse direction, the directional test need not be checked. A visual check should be made to determine that the normally-closed contact (right side, front view) is closed when the relay is leveled in its upright position and in a de-energized condition.

The effect of calibrating the relay for a specific application, then changing the offset tap to another value, is shown in Figures 13, 14, 15 and 16.

Figure 13 shows the mho unit characteristic when the uni was calibrated for 8 Ω $\emptyset$-N at 90⁰ lead, and for 4 Ω $\emptyset$-N at 270⁰ lead, as explained under **ACCEPTANCE TESTS**, FACTORY ADJUSTED PER CUSTOMER'S SETTINGS.

Figures 14, 15 and 16 show the effect on the unit's characteristic of moving the offset tap from 4 Ω to 2.5 Ω, 1.0 Ω and 0.5 Ω.

The angle of maximum torque varied from 90⁰ lead to 98⁰ lead as the offset tap moved from 4 Ω down to 0.5 Ω. The effect of ballooning of the characteristic is shown in the reverse direction as the offset taps are moved from the highest tap to the lowest tap. The diameter of the characteristic (Figure 13) is 11.84 Ω phase-to-neutral with the offset in the 4 Ω phase-to-neutral tap. As the offset tap was reduced, the diameter of the characteristic became smaller, as shown in Table XII.

TABLE XII

Unit Tap $\emptyset$-N	Offset Tap $\emptyset$-N	Restraint Transformer Setting	Diameter of Circle
6 Ω	4.0 Ω	50%	11.85 Ω
6 Ω	2.5 Ω	50%	10.99 Ω
6 Ω	1.0 Ω	50%	10.62 Ω
6 Ω	0.5 Ω	50%	10.80 Ω

Although this condition exists, the relay can be adjusted for any given combination of offset tap, reach tap and restraint transformer setting. Table XIII lists the adjustments necessary to calibrate the relay to a given parameter.

TABLE XIII

Reach and Angle Check	Reach Angle	Adjust
Forward	90° Lead	R11
Reverse	270° Lead	R63
max. tor.	0° Lead	R21/X21
max. tor.	180° Lead	R21/X21

There is no adjustment for the offset reach. This is determined by the turns ratio of the offset transactor.

Cross-adjust all components until no further adjustments are necessary to meet the calibration limits.

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 complete model number of the relay for which the part is required. If possible, give the General Electric requisition number on which the relay was furnished.

HI-G TARGET SEAL-IN

OFFSET TAP BLOCK

R63

R11

R21

X

X1

X2

X3

X4

X5

X 21

RESTRAINT TRANSFORMER
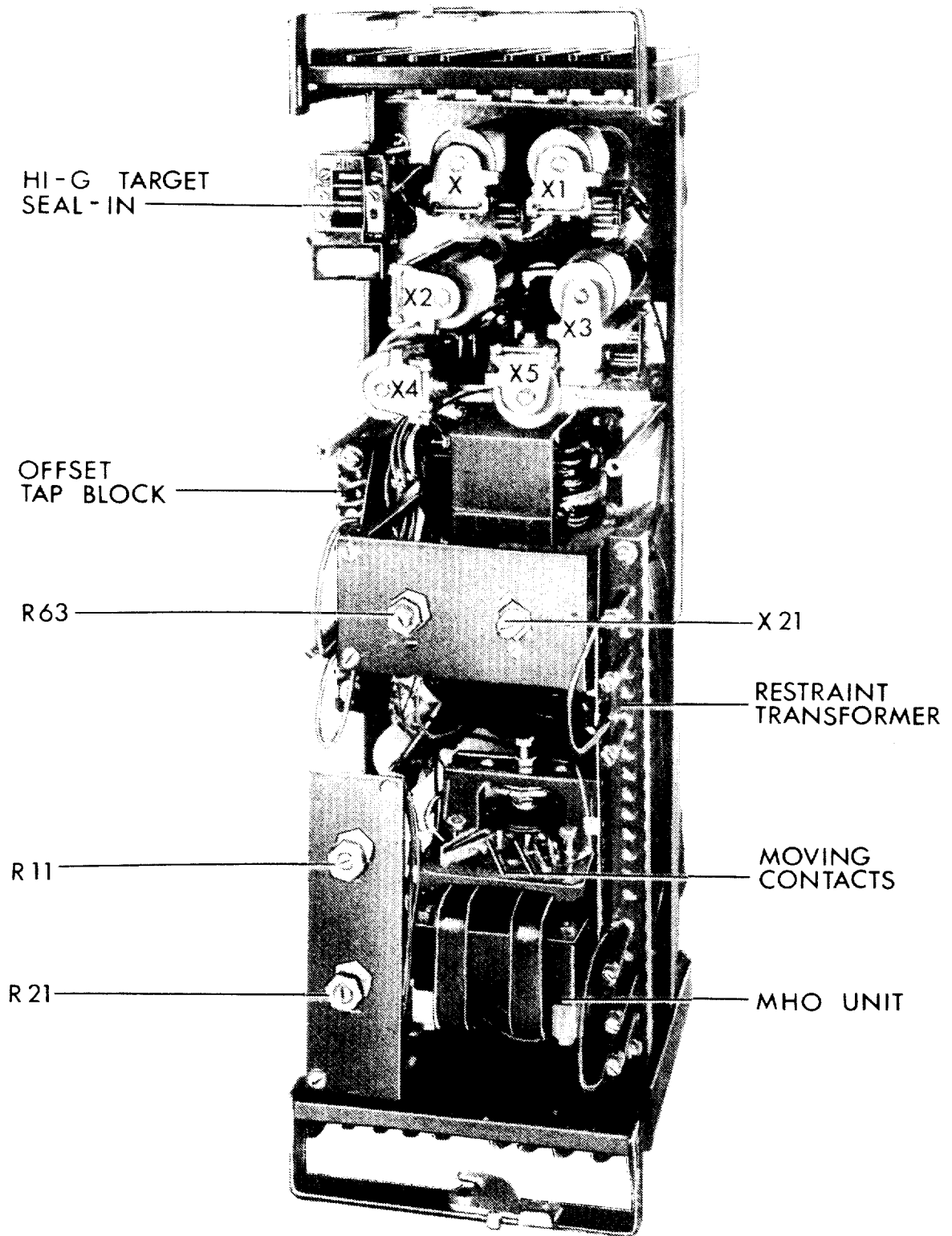
MOVING CONTACTS

MHO UNIT

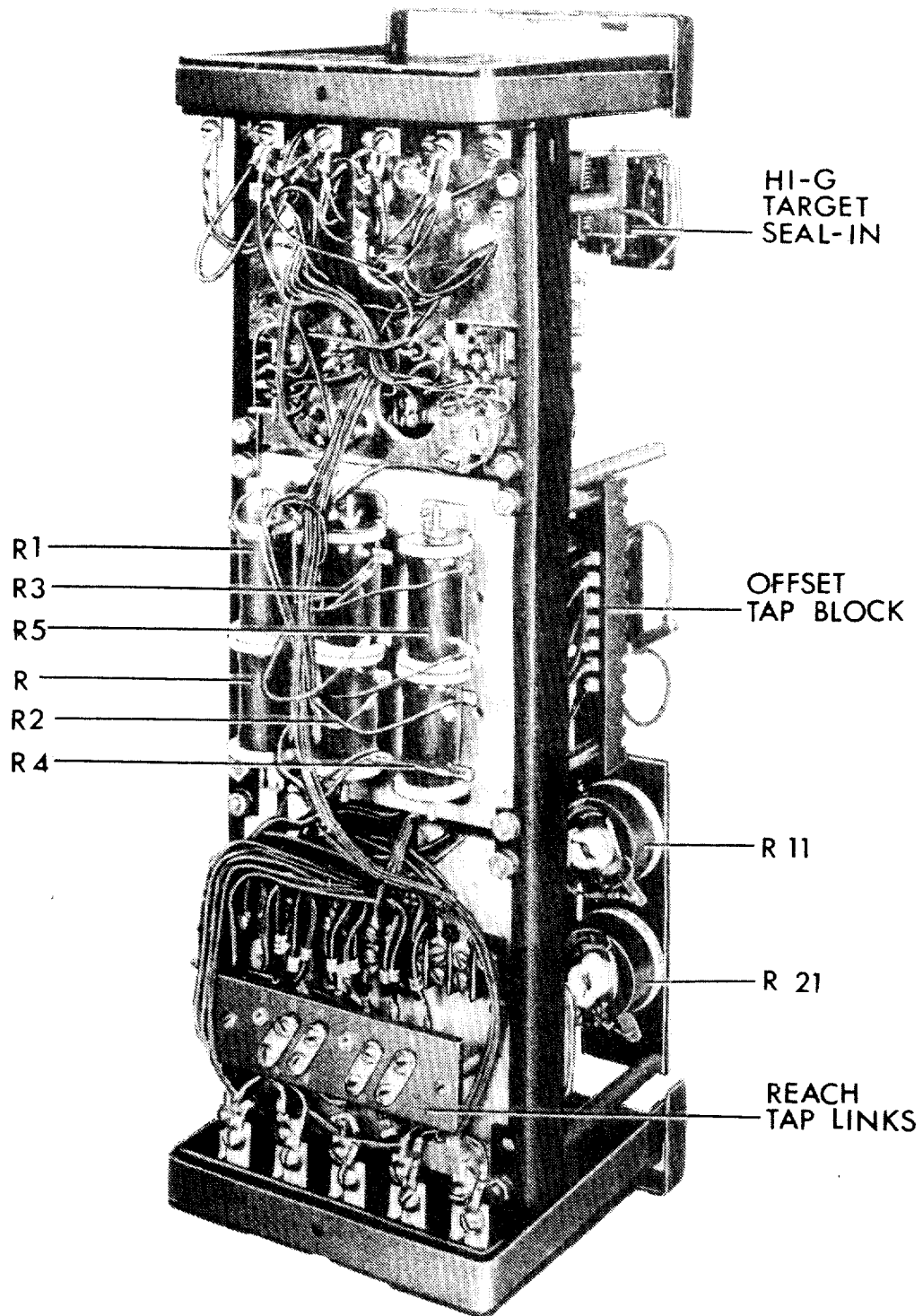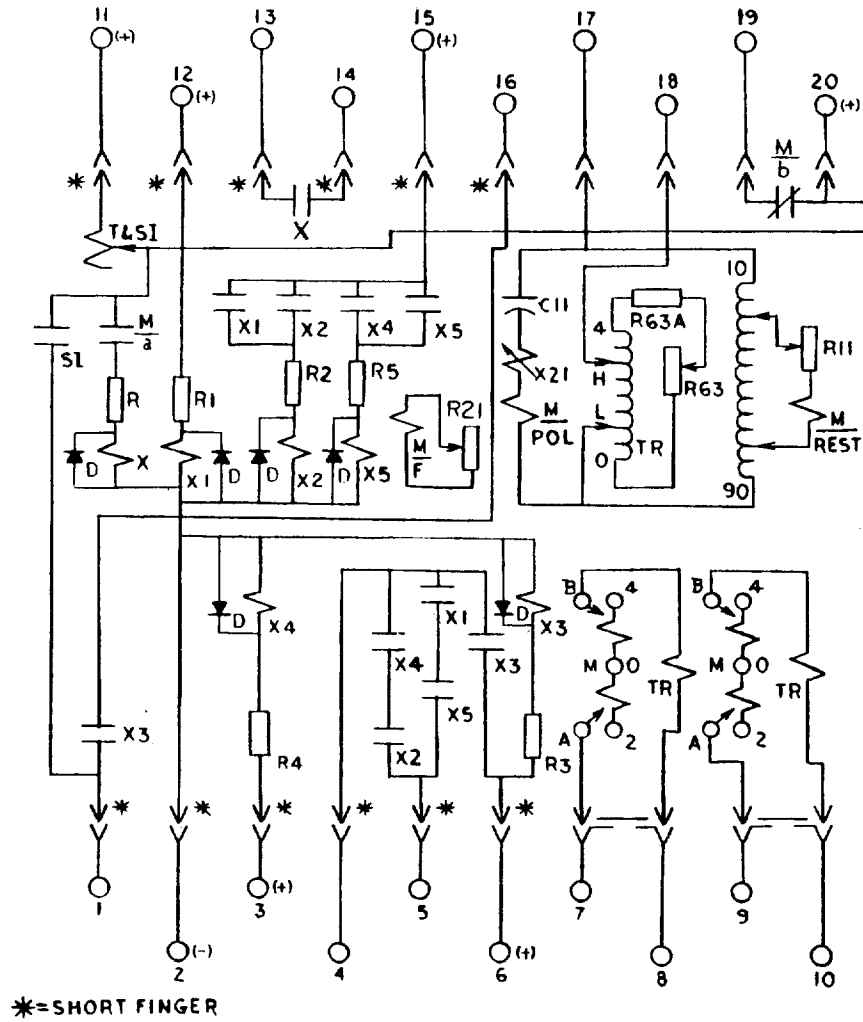Figure 1 (8043152) Type GSY51A Relay Out of the Case, Front View, Nameplate Removed

Figure 2 (8043153) Type GSY51A Relay Out of the Case, Rear View, Nameplate Removed

*=SHORT FINGER

MODEL	FORM NUMBER							
12GSY51A(-)A	1	2	3					
VOLTS	120	120	120					
HERTZ	60	50	50					
RESISTANCE IN OHMS								
X,X1,X2,X4,X5 COIL	1200	1200	1200					
X3 COIL	800	800	800					
R3	2000	2000	4000					
R,R1,R2,R4,R5	2500	2500	5000					
R63A	2500	2500	2500					
R63	5000	5000	5000					
R11	1000	1000	1000					
R21	2500	2500	2500					
D DIODES	IN5061							
CAPACITANCE VALUE								
C11	.75uf	1.0uf	1.0uf					

Figure 3 (0257A9608-2, Sh. 1 and 2) Internal Connections Diagram for the GSY51A Relay
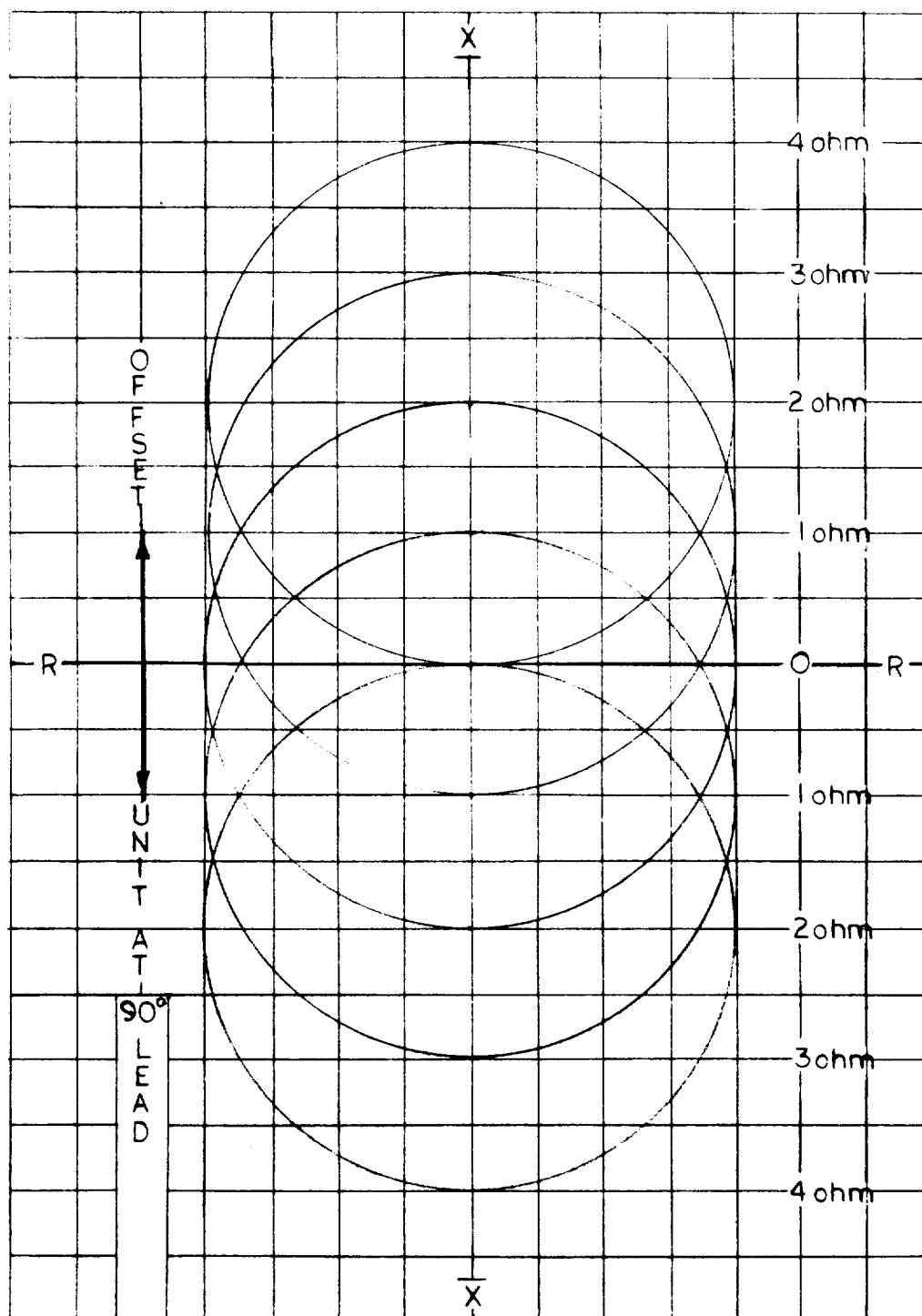
Figure 4 (0269A3045-0) Type GSY51A Relay Characteristic with Offset

TYPE CEH11A RELAY
CHARACTERISTICS OF RELAY WITH VARIOUS TAP SETTING WHEN SET
FOR 1 OHM OFFSET.
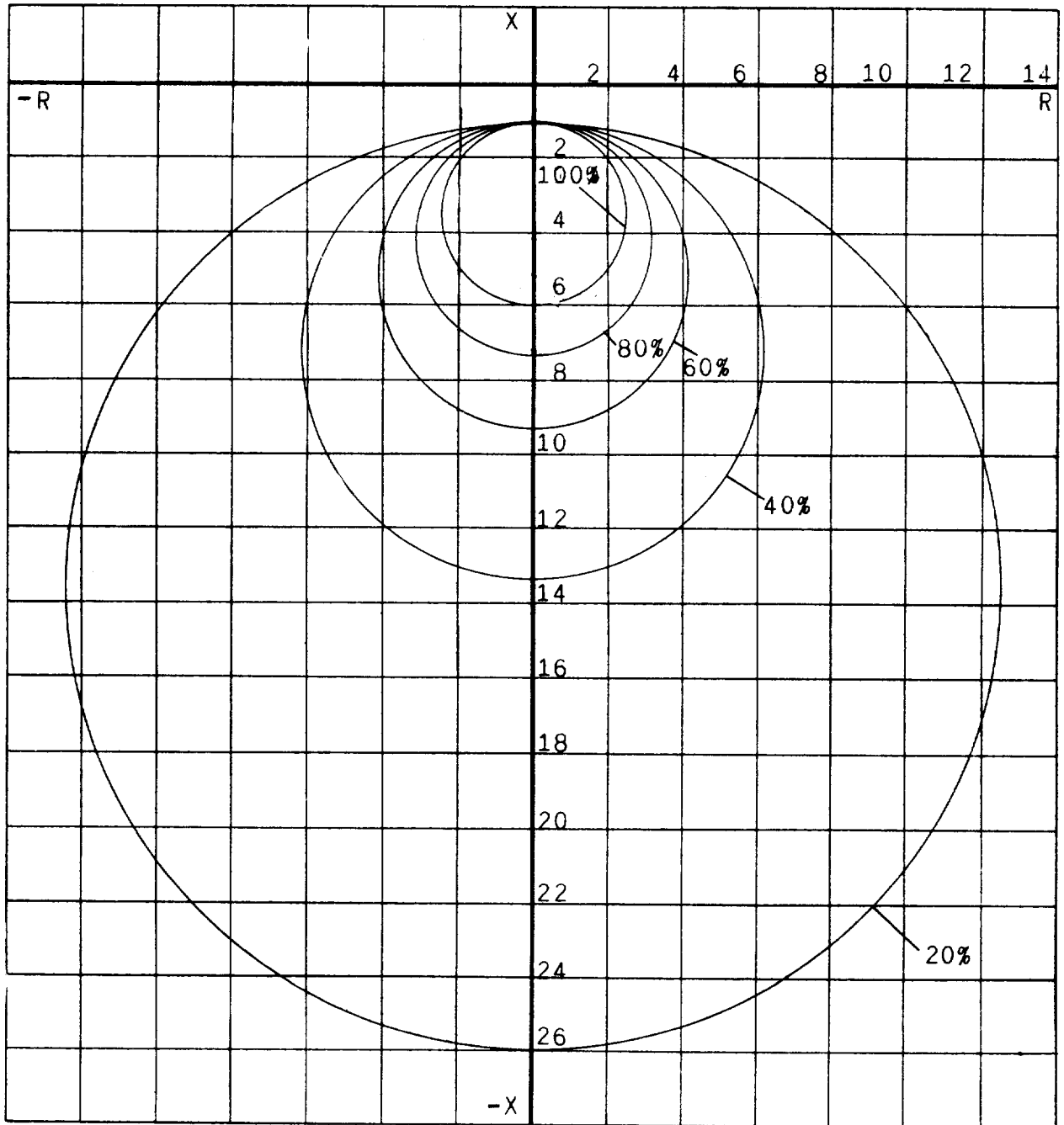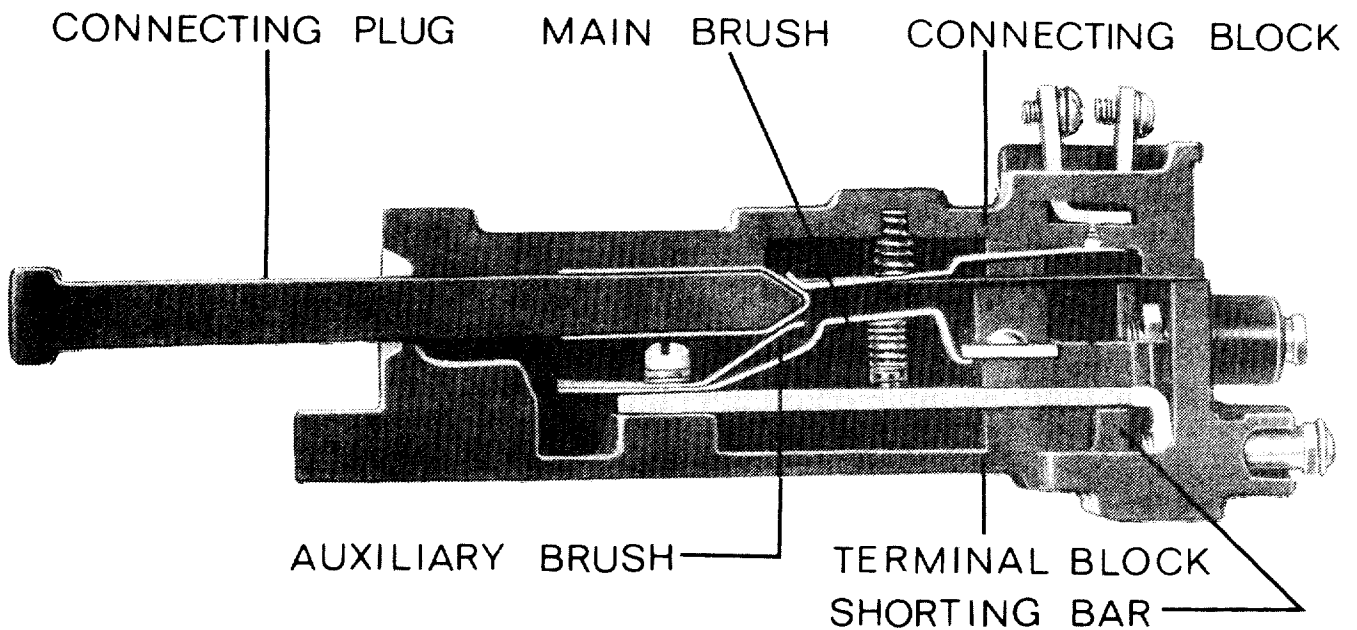ALL VALUES ARE PHASE – TO – NEUTRAL OHMS

Figure 5 (0402A0978-0) Characteristic of the GSY51A Relay
as the Restraint Transformer is Reduced

CONNECTING PLUG   MAIN BRUSH   CONNECTING BLOCK

AUXILIARY BRUSH   TERMINAL BLOCK
                       SHORTING BAR

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

Figure 6 (8025039) Cross Section of Drawout Case and Cradle Blocks
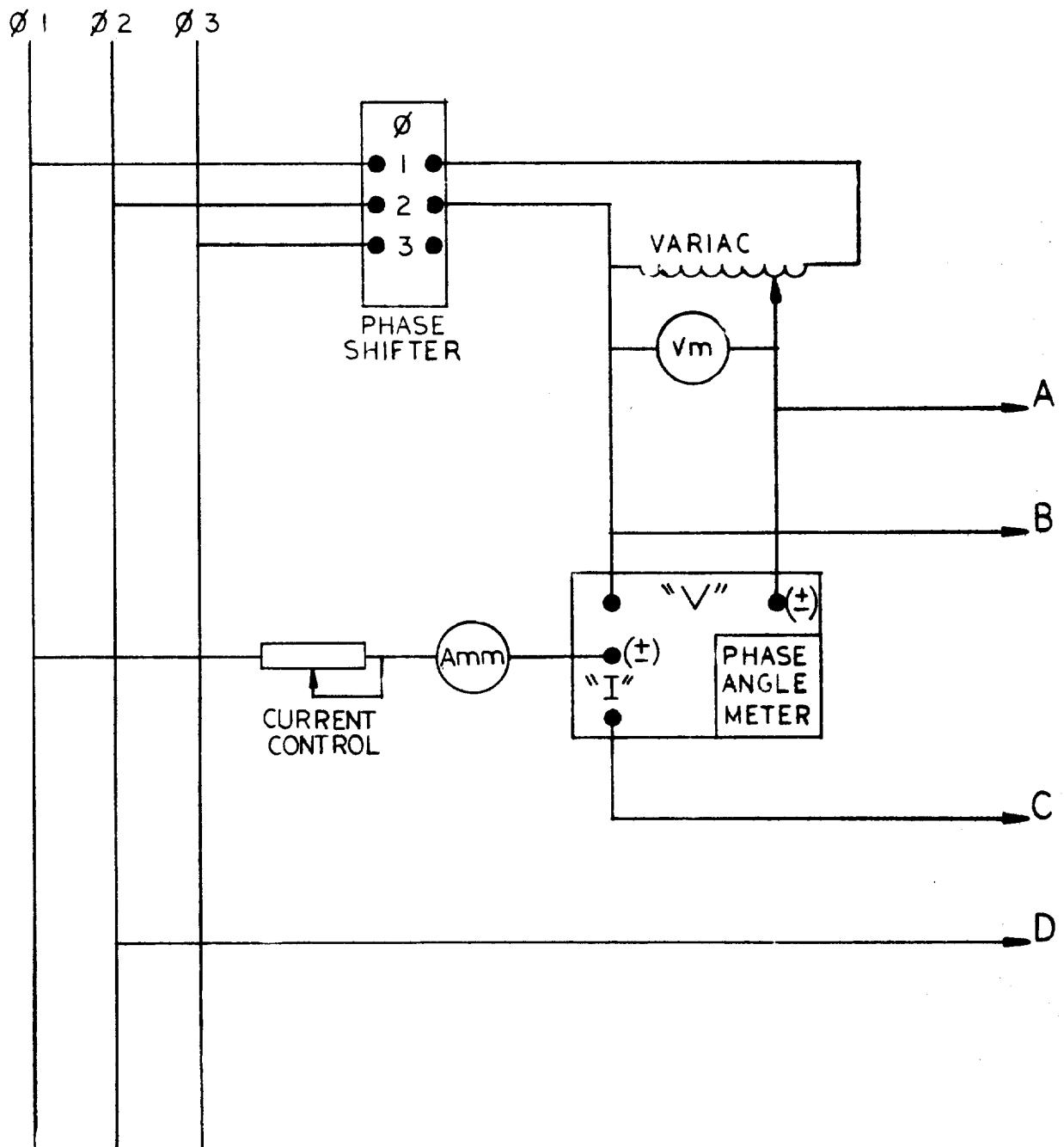Showing the Auxiliary Brush and Shorting Bar

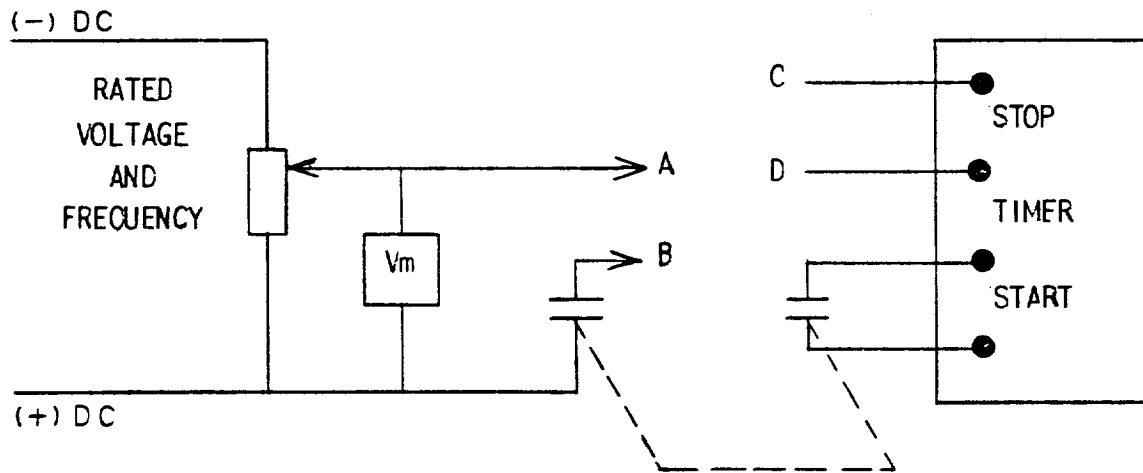Figure 7 (0269A3000-0) Type GSY51A Mho Unit Test Circuit

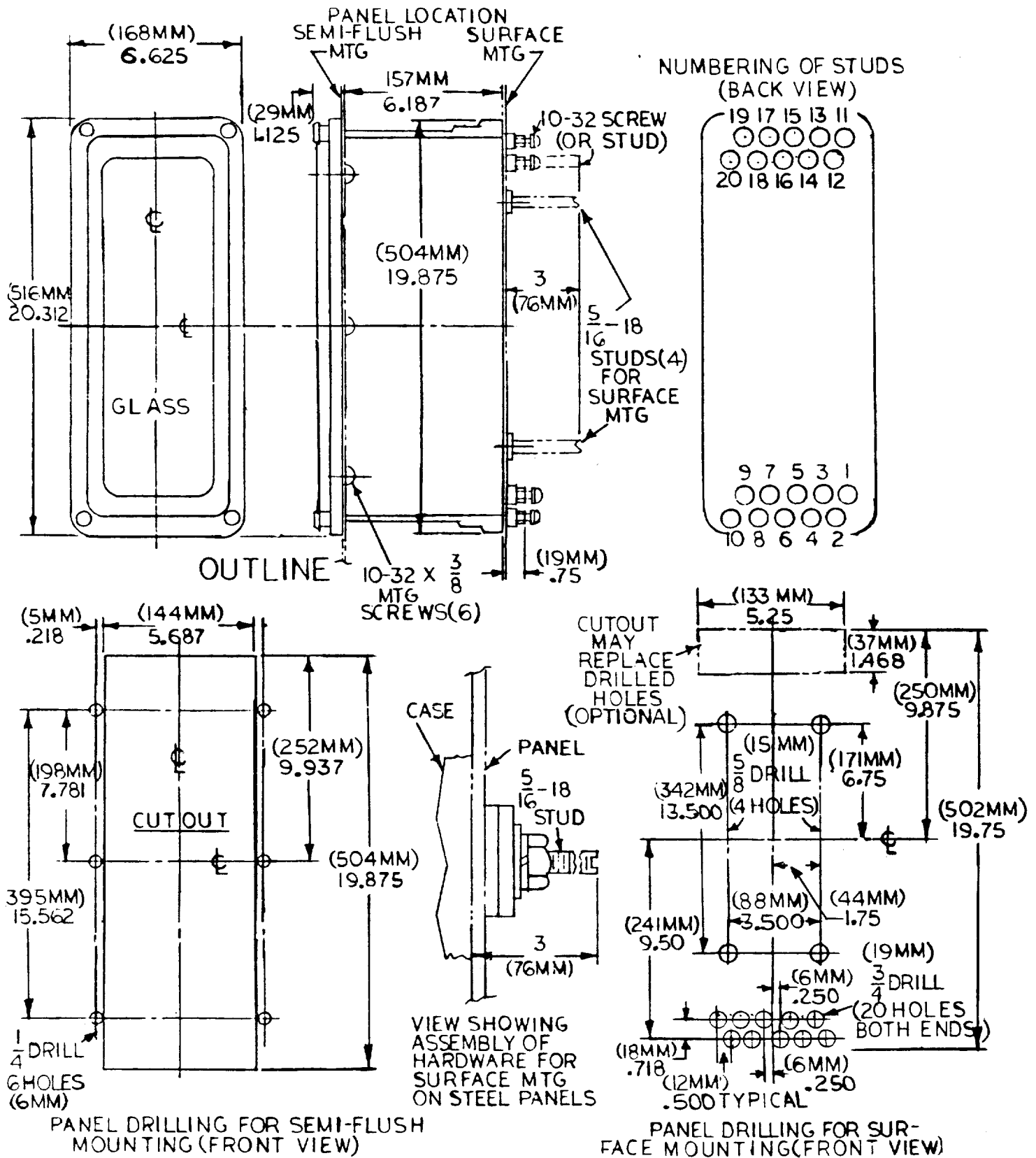Figure 8 (0246A3787-1) Telephone Relay Test Circuit

Figure 9 (K-6209276-3) Outline and Panel Drilling for the GSY51A Relay Case

NO	DEVICE	UNIT	DESCRIPTION
21M	GSY51A		OFFSET MHO SUPERVISING AND AUX UNITS
		a	NORMALLY OPEN CONTACT
		b	NORMALLY CLOSED CONTACT
		POL	POLARIZING CIRCUIT
		RESTR	RESTRAINT CIRCUIT
		OP	OPERATING CIRCUIT
		TR	OFFSET TRANSACTOR
		X,X1,ETC.	AUXILIARY TELEPHONE RELAYS
		TSI	TARGET SEAL-IN
50N	PJC11A (CODE 02)		INSTANTANEOUS GROUND CURRENT RELAY
21ST	CEX57E		OUT-OF-STEP BLINDER UNITS
		A	LOWER BLINDER UNIT
		B	UPPER BLINDER UNIT
52			CIRCUIT BREAKER
		a	AUXILIARY CONTACT
		TC	TRIP COIL

DEVICE	DRAWINGS INTERNAL	OUTLINE
CEX57E	0269A3037	006209274
GSY51A	0257A9608	00620927G
PJC11A	006174680	006174680

NOTE: 1 – TO REVERSE 21M DIRECTION OF FORWARD REACH REVERSE CT CONNECTIONS TO STUDS 7–8 AND 9–10.

NOTE: 2 – OMIT EXTERNAL JUMPERS FOR ANGLE OF MAXIMUM TORQUE GREATER THAN 25 DEGREES. (REFER TO TABLE IN CEX57E INSTRUCTION BOOK)

PHASE SEQUENCE 1–2–3 OR 3–2–1

CONNECT PTS FOR 120 VOLTS PHASE TO PHASE

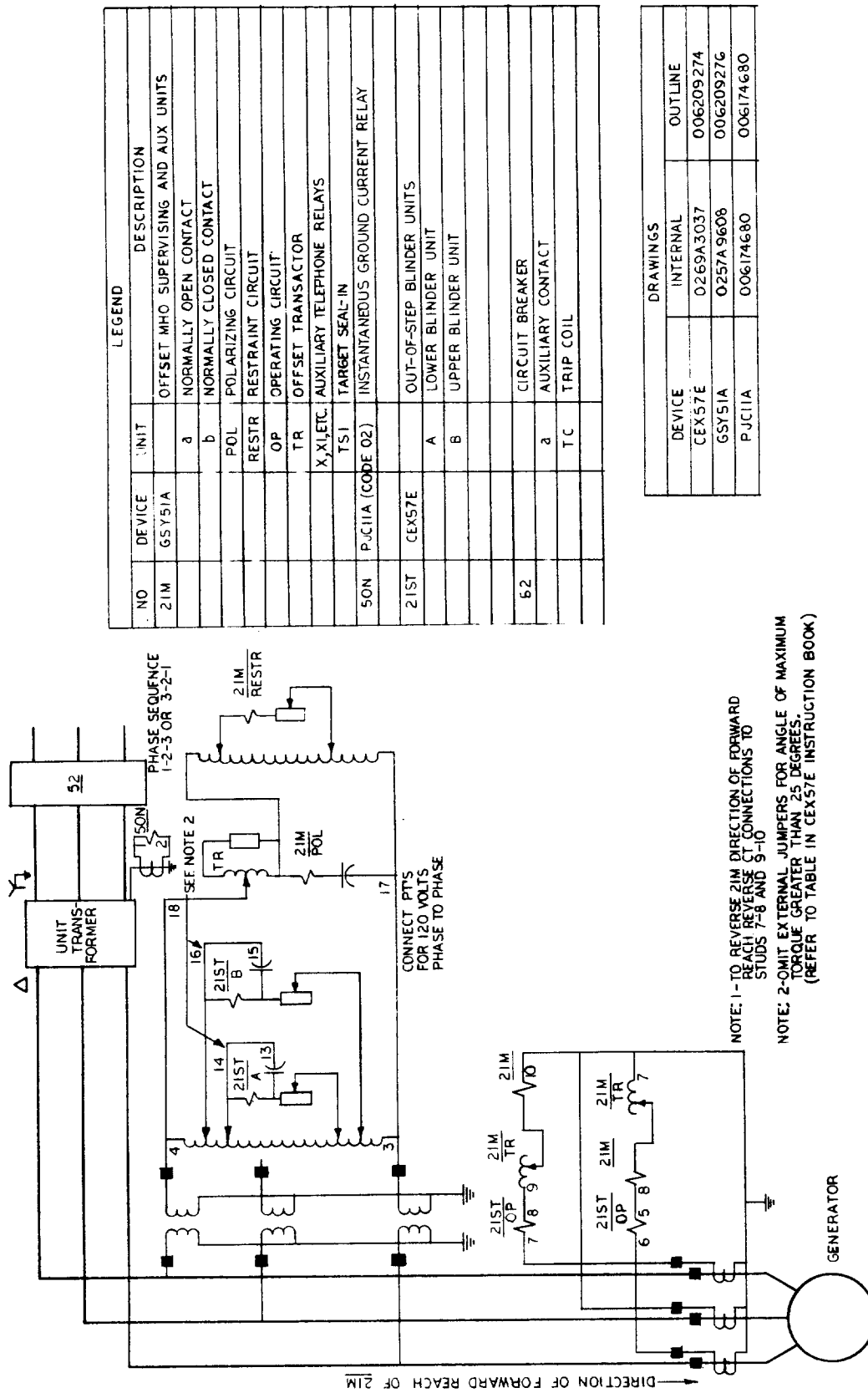DIRECTION OF FORWARD REACH OF 21M

GENERATOR

Figure 10A (0108B9010-1 Sh.1) Typical External Connections Diagram for the GSY51A Relay
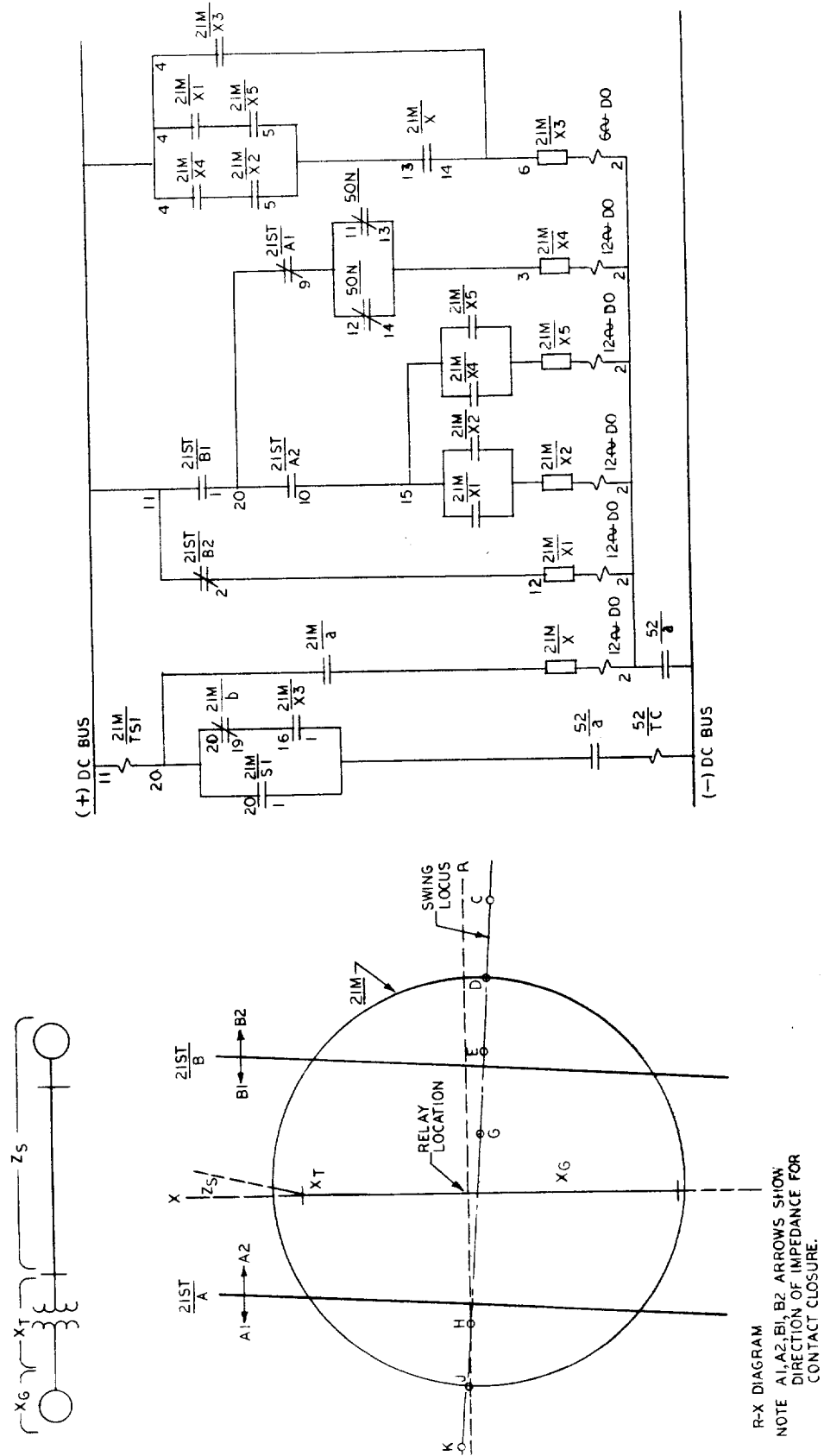
Figure 10B (0108B9010-0 Sh.2) Typical External Connections Diagram for the GSY51A Relay

A. INNER STATOR OR CORE
B. MAGNET & COILS
C. WAVE WASHERS
D. OCTAGON NUT FOR CORE ADJUSTMENT
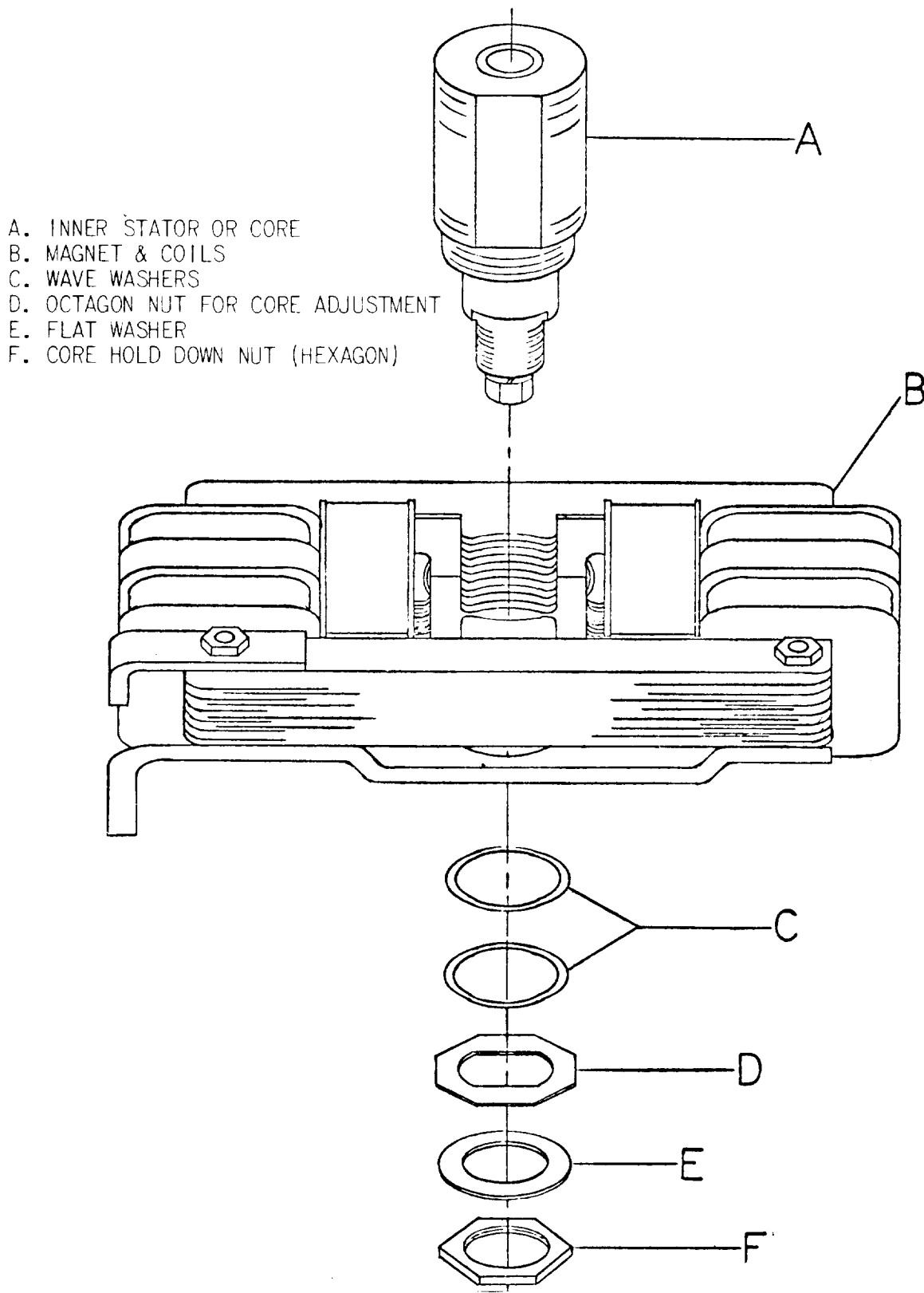E. FLAT WASHER
F. CORE HOLD DOWN NUT (HEXAGON)

Figure 11 (0208A3583-0) Core Adjustment of the Mho Unit in the GSY51A Relay
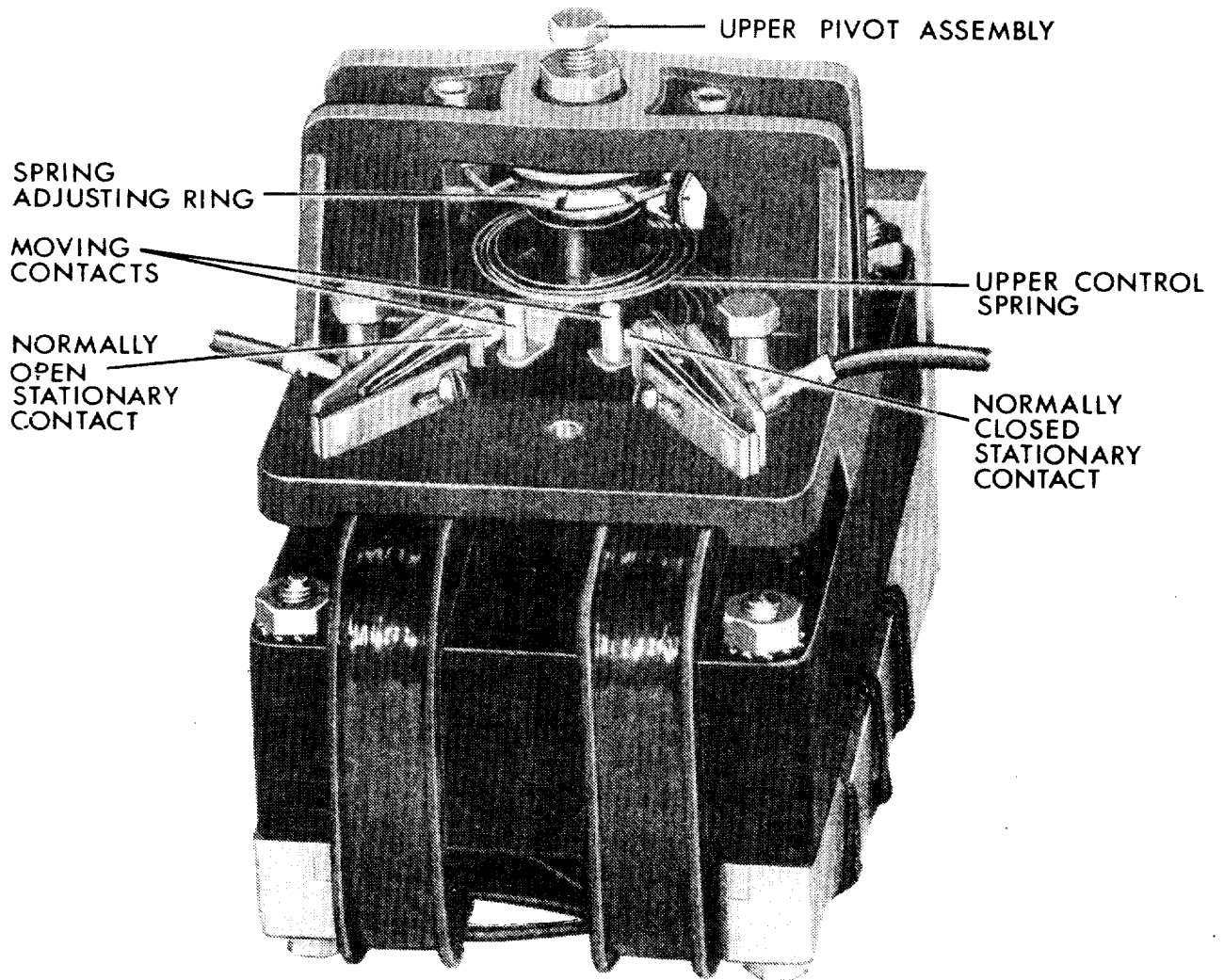
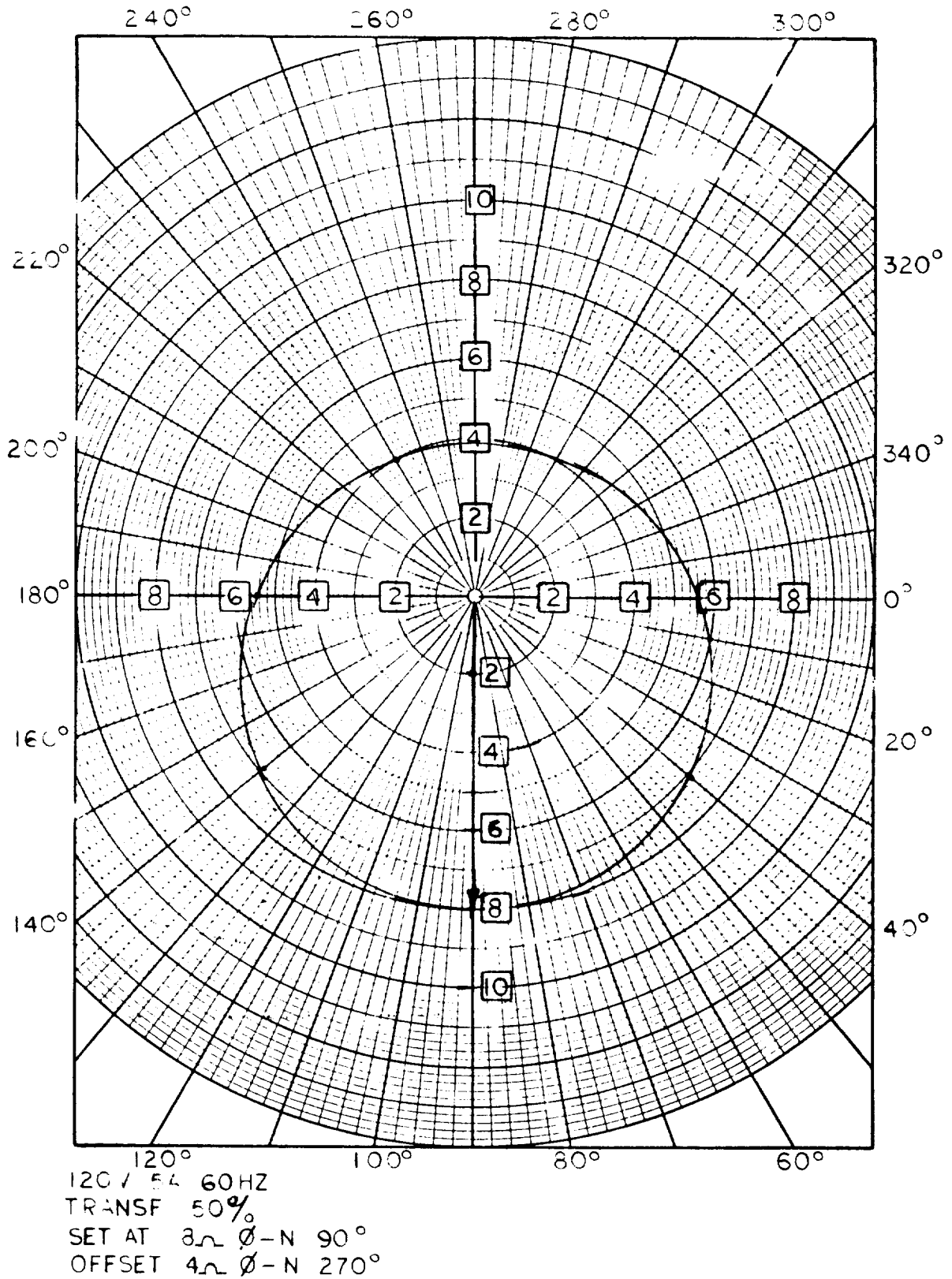Figure 12 (8041447) Four Pole, Induction Cup Unit Used in the GSY51A Relay

120 / 5A 60HZ
TRANSF 50%
SET AT 8Ω Ø-N 90°
OFFSET 4Ω Ø-N 270°

Figure 13 (0269A3046-0) GSY51A Relay Calibration
for 8Ω Ø-N Forward and 4Ω Ø-N Reverse Direction

240°   260°   280°   300°

120V 5A 60 HZ
TRANSF 50%
UNIT 9.5Ω ∅-N @ 90° LEAD
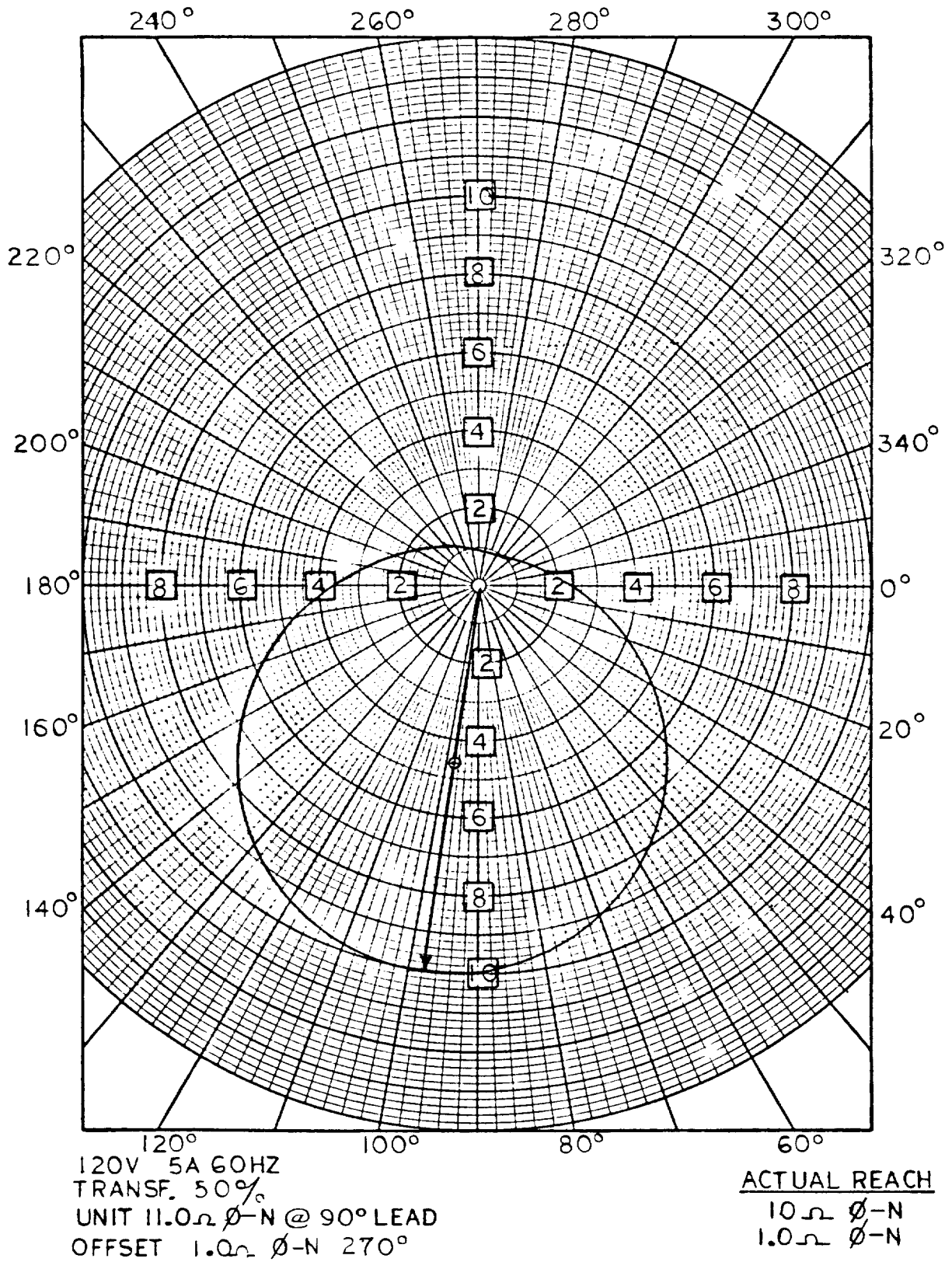OFFSET 2.5Ω ∅-N 270°

ACTUAL REACH
8.6Ω ∅-N
2.45Ω ∅-N
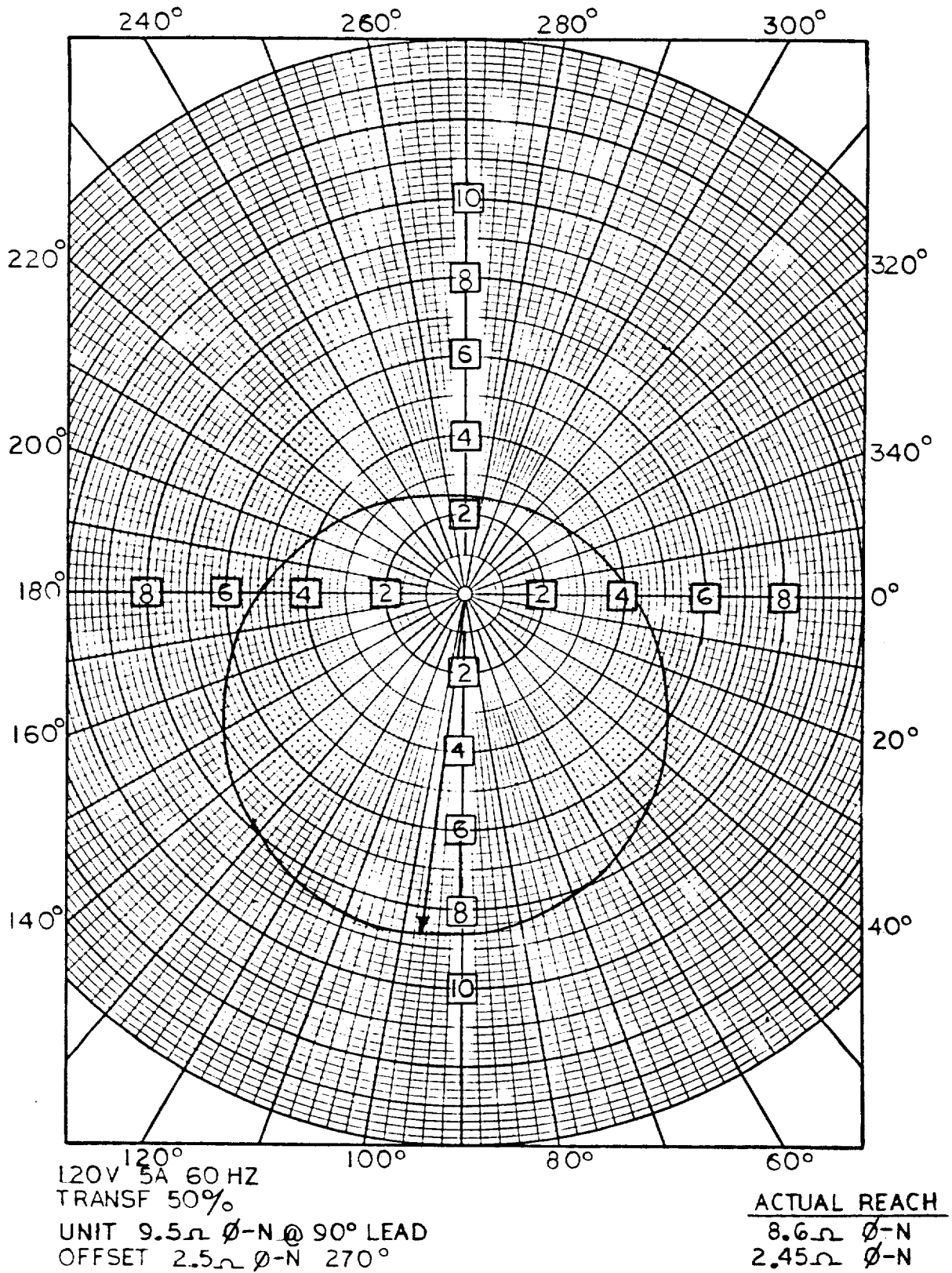
Figure 14 (0269A3047-1) GSY51A Relay Characteristic Check
with 2.5Ω ∅-N Offset Tap

Figure 15 (0269A3048-1) GSY51A Relay Characteristic Check
with 1.0Ω Ø-N Offset Tap

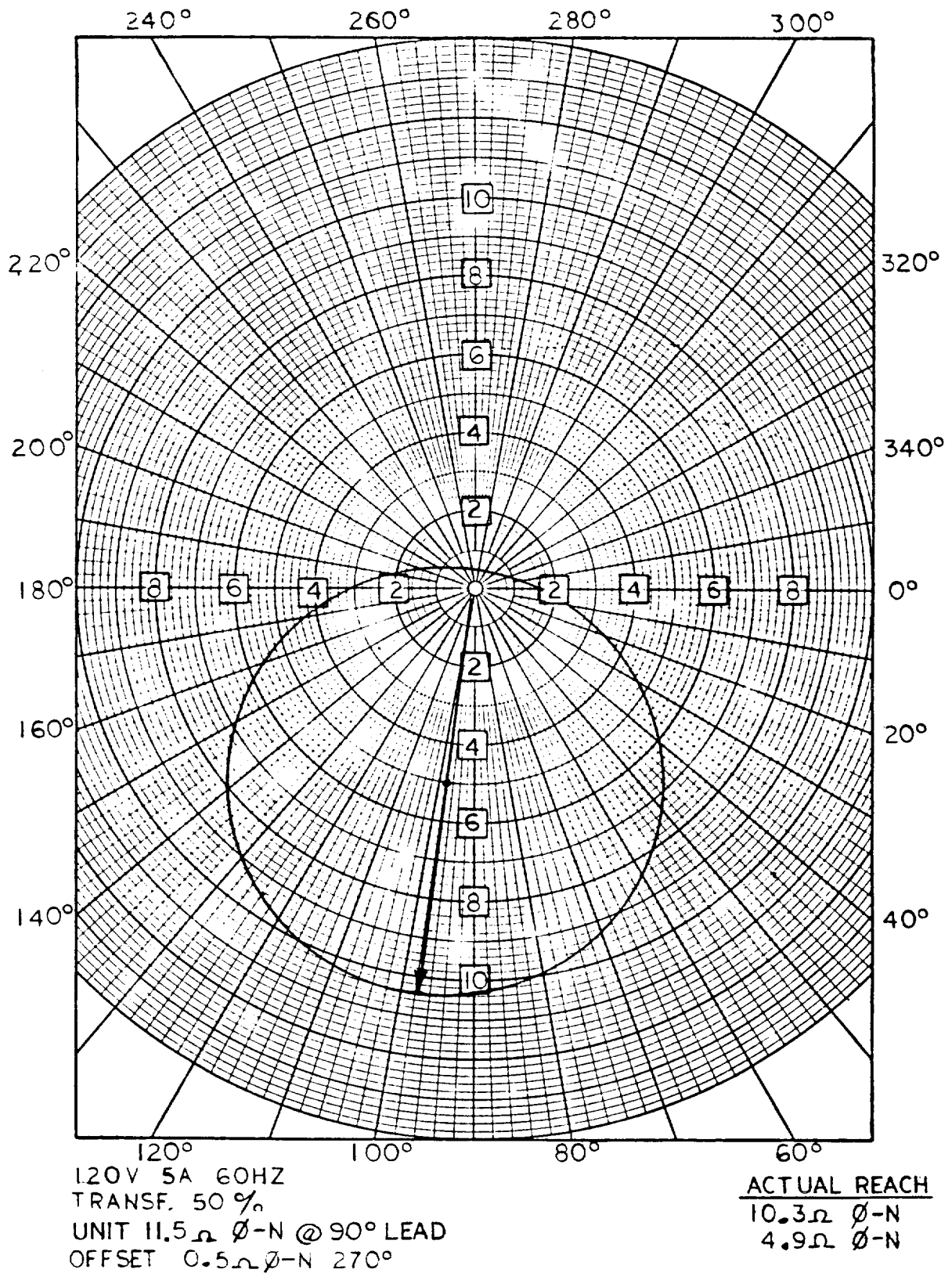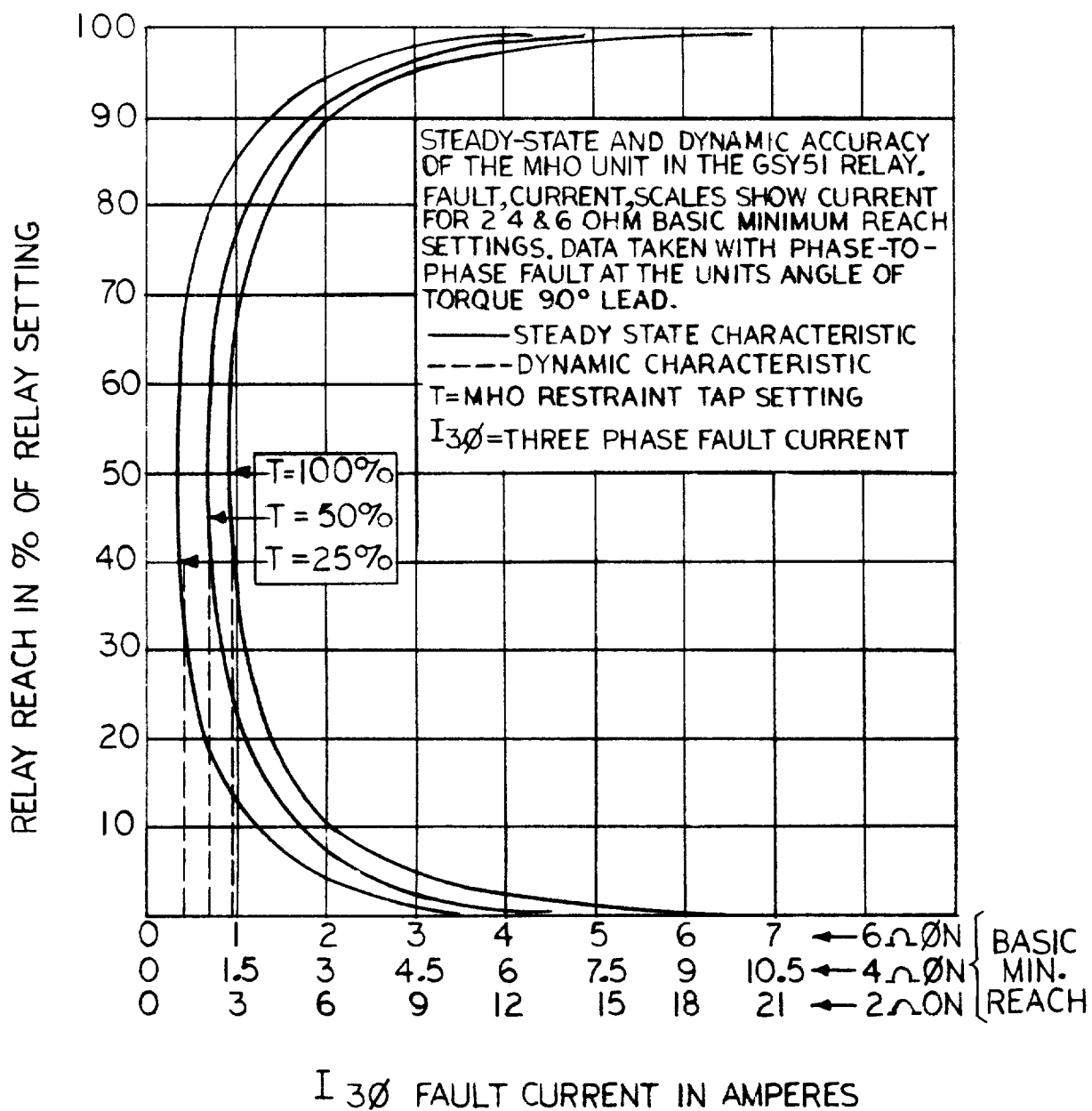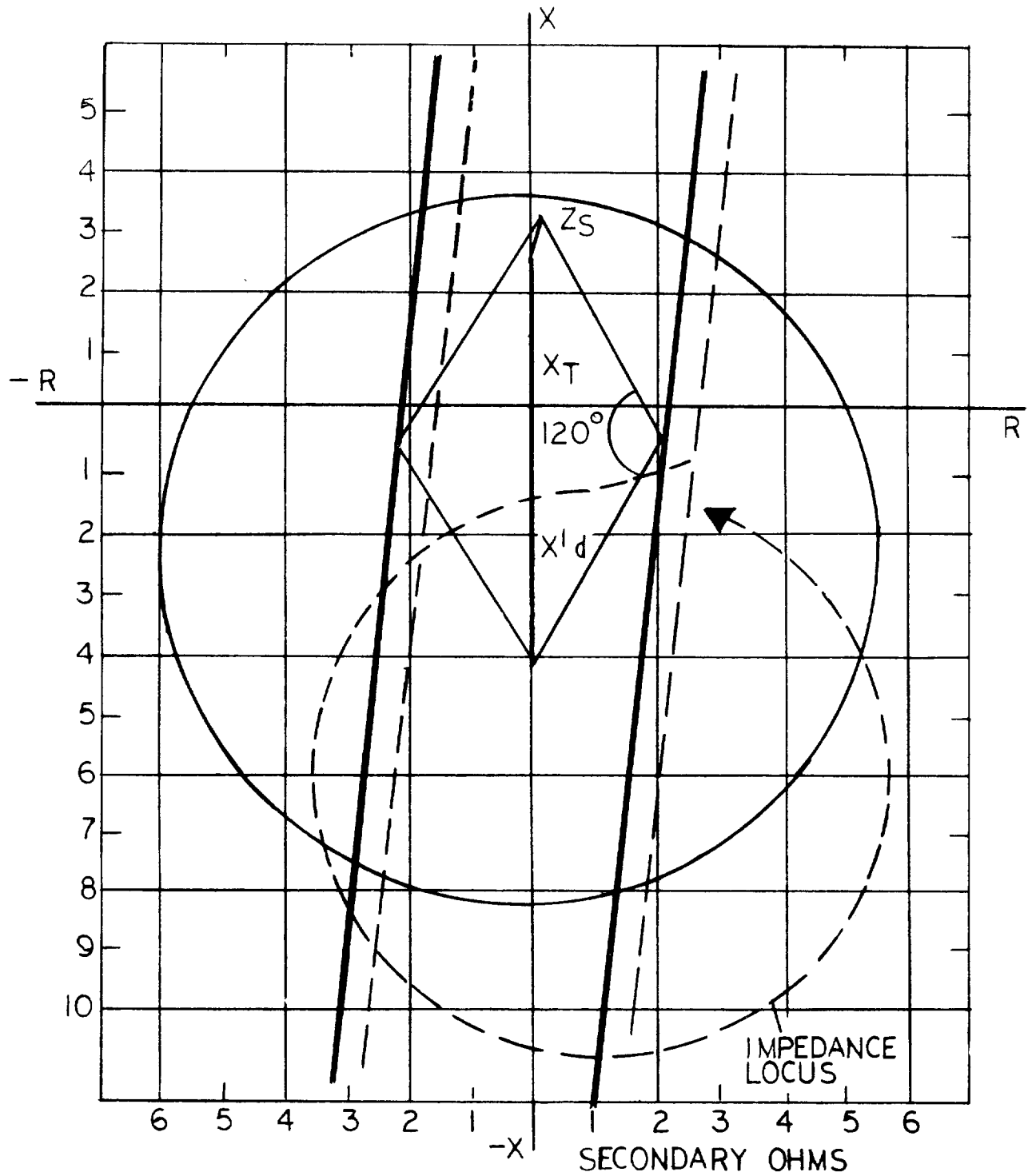240° 260° 280° 300°
220° 320°
200° 340°
180° 0°
160° 20°
140° 40°
120° 100° 80° 60°

1.20V 5A 60HZ
TRANSF. 50 %
UNIT 11.5 Ω Ø-N @ 90° LEAD
OFFSET 0.5 Ω Ø-N 270°

ACTUAL REACH
10.3 Ω Ø-N
4.9 Ω Ø-N

Figure 16 (0269A3049-1) GSY51A Relay Characteristic Check
with 0.5Ω Ø-N Offset Tap

STEADY-STATE AND DYNAMIC ACCURACY
OF THE MHO UNIT IN THE GSY51 RELAY.
FAULT, CURRENT, SCALES SHOW CURRENT
FOR 2 4 & 6 OHM BASIC MINIMUM REACH
SETTINGS. DATA TAKEN WITH PHASE-TO-
PHASE FAULT AT THE UNITS ANGLE OF
TORQUE 90° LEAD.

———— STEADY STATE CHARACTERISTIC
———— DYNAMIC CHARACTERISTIC
T=MHO RESTRAINT TAP SETTING
$I_{3\emptyset}$=THREE PHASE FAULT CURRENT

Figure 17 (0257A6173-0) Steady State and Dynamic Curves for the GSY51A Relay

Z_S = SYSTEM IMPEDANCE

X_T = TRANSF REACTANCE

X'_d = GEN TRANSIENT REACTANCE

Figure 18 (0208A8542-0) Typical Settings for the CEX and GSY Relays

Figure 19 (0208A8543-0) Application of CEX-GSY for Z System = 0.05 P.U.

Z_S = SYSTEM IMPEDANCE
X_T = TRANSF REACTANCE
X'_d = GEN TRANSIENT REACTANCE

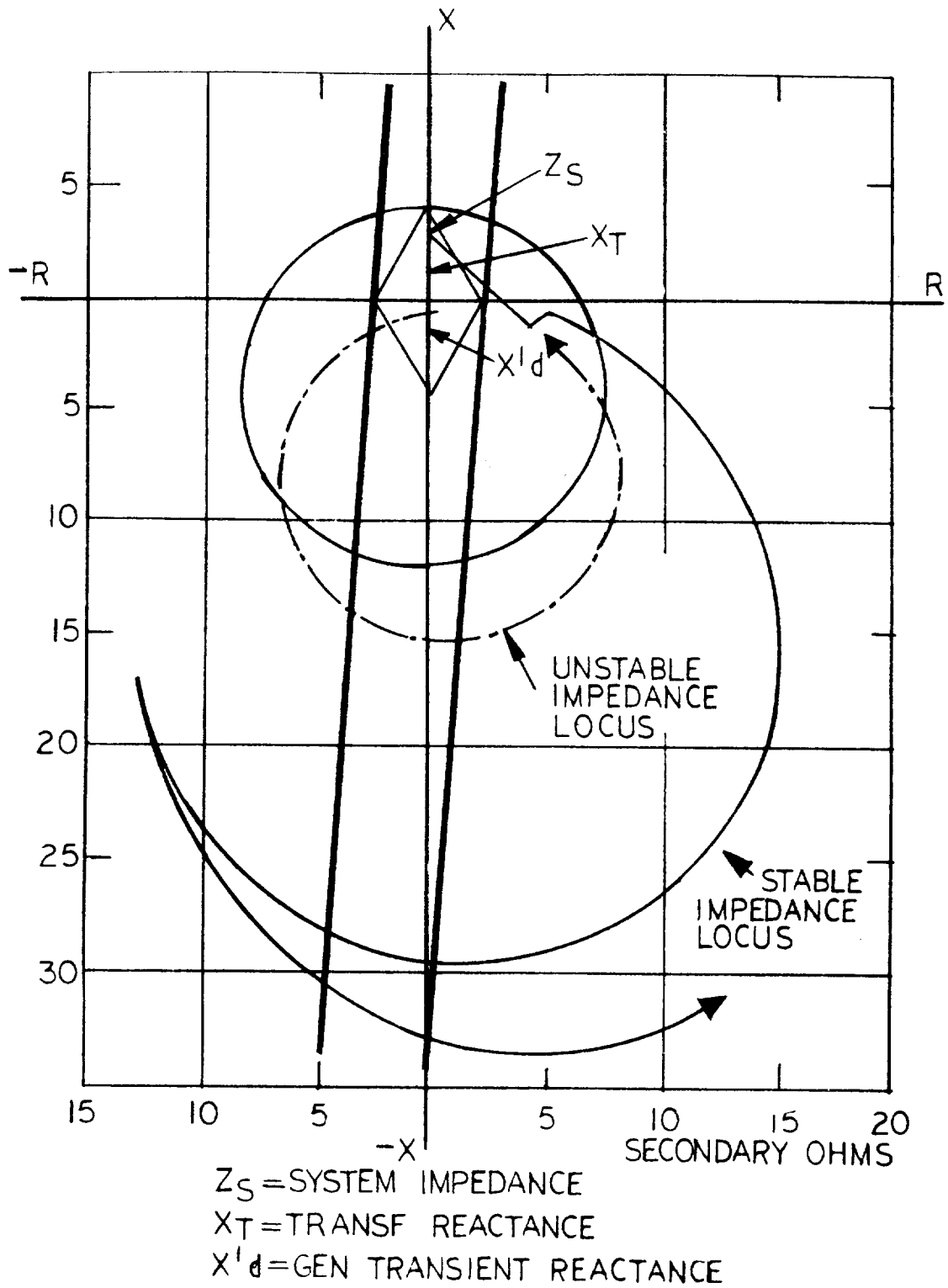Figure 20 (0208A8544-0) Application of CEX-GSY for Z System = 0.09 P.U.

X_S = SYSTEM IMPEDANCE
X_T = TRANS. REACTANCE
X^I_d = GEN. TRANSIENT REACTANCE

Figure 21 (0208A8545-0) Application of CEX-GSY for Z System = 0.2 P.U.

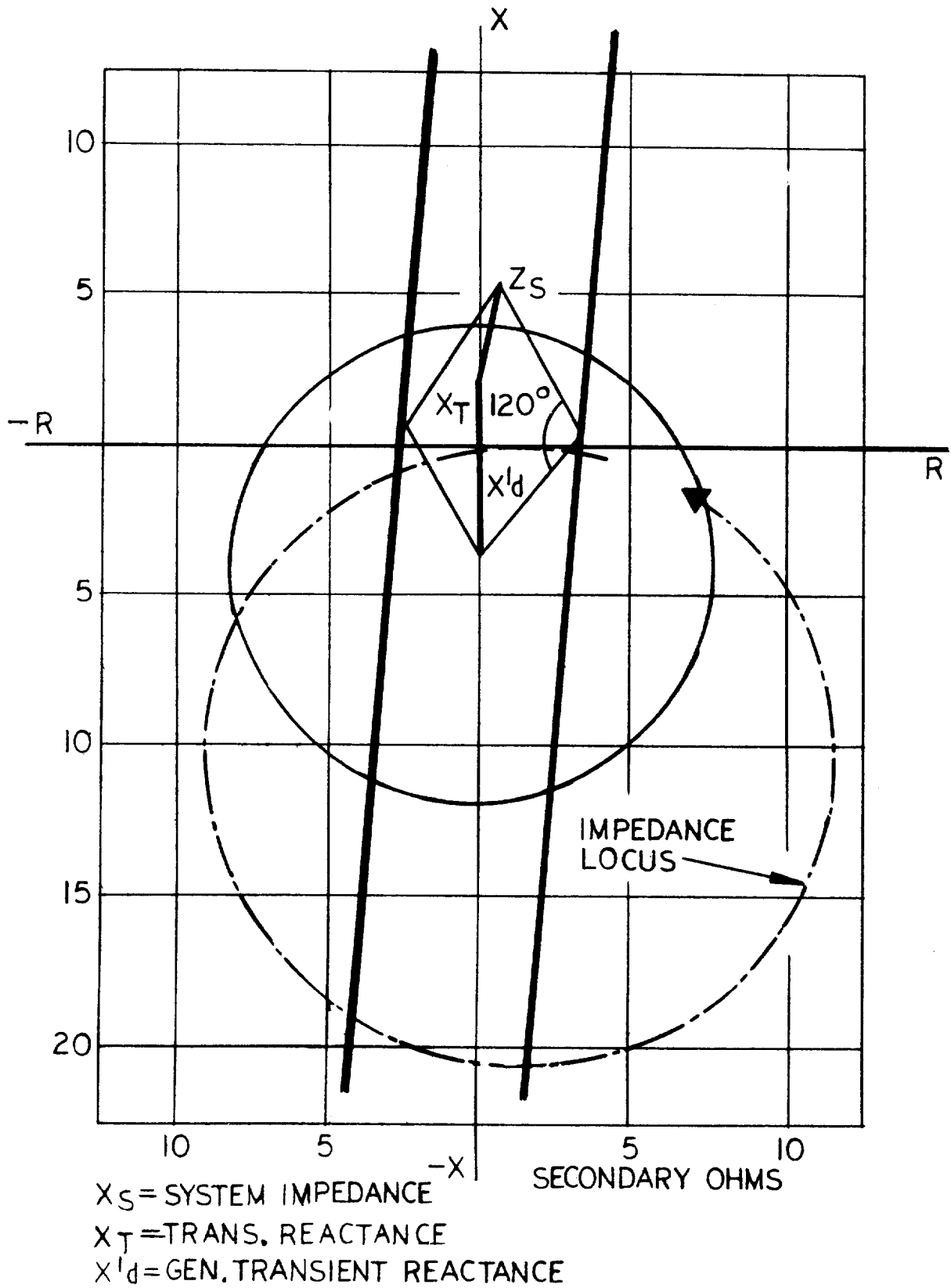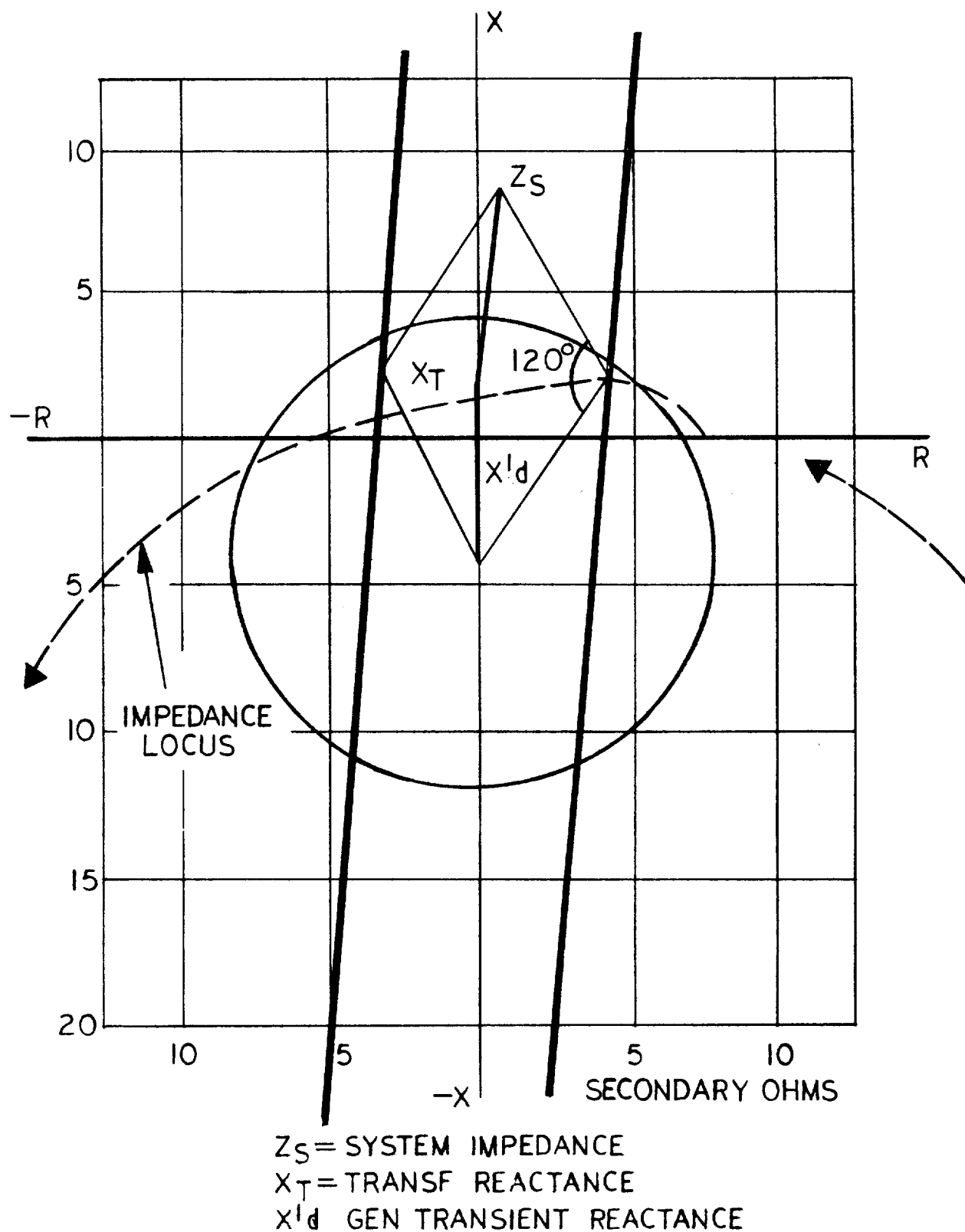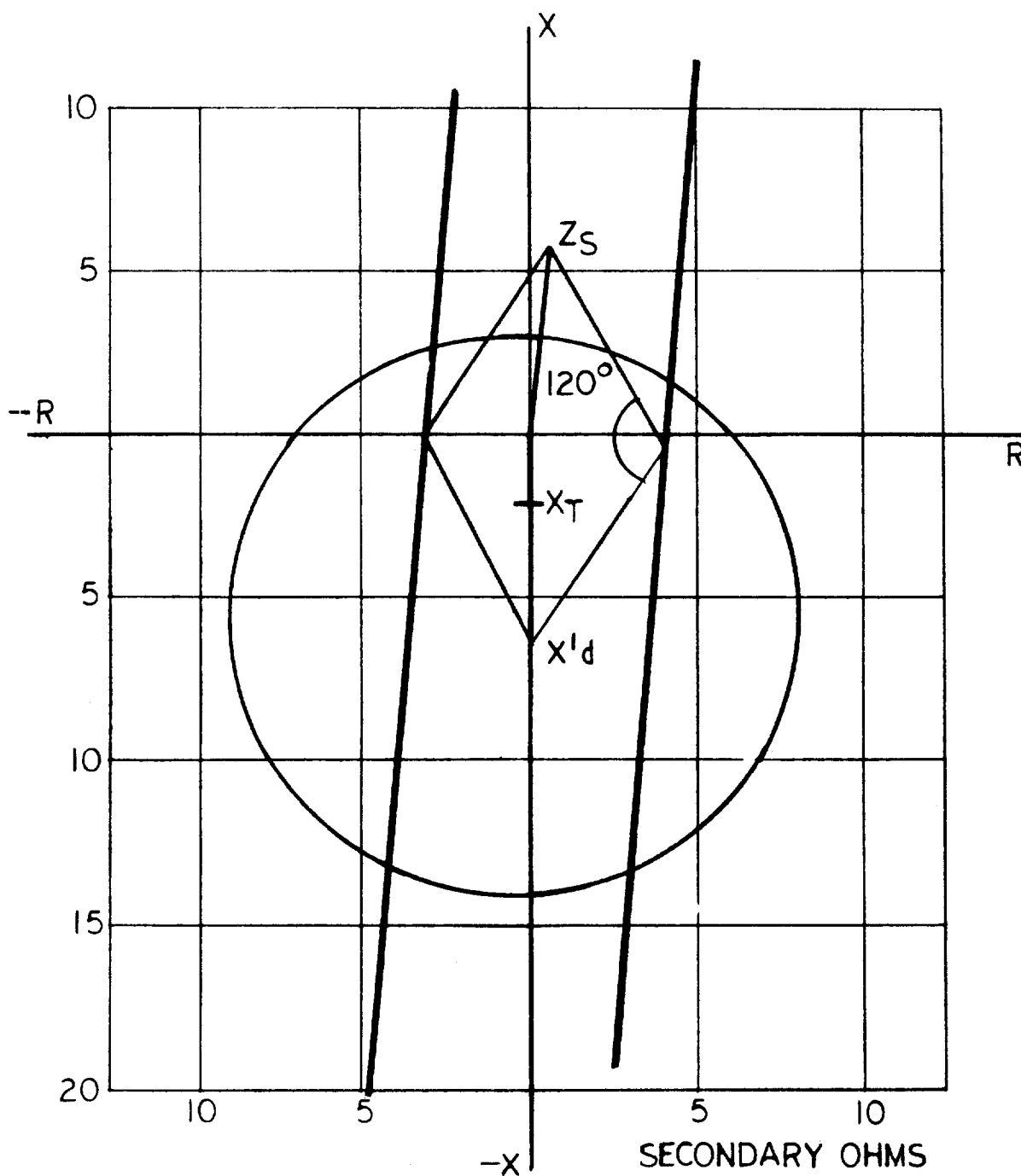Figure 22 (0208A8546-0) Application of CEX-GSY for Z System = 0.4 P.U.

Z_S = SYSTEM IMPEDANCE
X_T = TRANSFORMER REACTANCE
X'_d = GEN TRANSIENT REACTANCE

Figure 23 (0208A8547-0) Application of CEX-GSY at High Voltage Terminals,
Z System = 0.4 P.U.