INSTRUCTIONS

GEK-34091A

SUPERSEDES GEK-34091

REACTANCE GROUND DISTANCE RELAY

TYPE CEXG20A

GENERAL ELECTRIC

CONTENTS

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INTRODUCTION

The Type CEXG20A relay is a single-zone, three-phase reactance type distance relay, with provision for zero sequence current compensation and mutual compensation. It consists of three single-phase units in an L2-B case with facilities for testing one unit at a time. Three target units are included, identifie as PH1, PH2, and PH3. Since the transient overreach is limited the relay is suitable for first-zone applications, but since reactance distance units are not inherently directional, the relay must be used with an associated CEYG51A directional distance relay.

APPLICATION

The Type CEXG20A relay, because of its reactance characteristic and limited overreach, is well suited for application as a first-zone relay on short transmission lines where ground fault resistance may be an appreciable part of the total fault impedance. Since the reactance units are not inherently directional, the relay must always be applied in conjunction with a directional ground distance relay such as the CEYG51 which provides directional supervision of the CEXG contacts.

Typical external connections for the Type CEXG20A relay, with the associated CEYG51A, are shown in Fig. 1 . This diagram covers a two-zone step distance scheme with the CEXG20A providing first zone protection under the supervision of the CEYG51A, which also provides the second zone of protection in conjunction with the timer. Other applications are also possible. For example the CEXG20A could be used in a three-zone step distance scheme with separate CEXG relays for the first and second zones, both supervised by a CEYG51A relay. The CEYG relay would also provide the third zone and start the timer for second and third zone timers. Or the relay could be used as the keying relay in a permissive underreaching transferred trip scheme, again under the supervision of a directional distance relay, which would also provide the permissive function at the receiving ends.

From the d-c connections of Fig. 1 it will be noted that each of the directional distance units in the CEYG51 is associated with an auxiliary unit, A_1, A_2, or A_3, in an NAA15G relay. The contacts of the A_1, A_2, and A3 units are interlocked so that first zone tripping by a CEXG contact is permitted only when a single ground mho unit has operated. If more than one of the CEYG ground mho units picks up, first-zone tripping is blocked. This restricts tripping by the first zone reactance units to single-phase-to-ground faults and prevents an incorrect first zone trip should the reactance units tend to overreach on a double-phase-to-ground fault. The NAA15G relay also includes a zero sequence fault detector I, the contacts of which are connected to prevent tripping by any zone of the ground distance scheme on faults that do not involve ground.

The external connection diagram in Fig.1 shows the auxiliary compensating transformer 0367A0266G1 used with the CEXG relay. This auxiliary transformer serves two purposes: First, it compensates for the zero sequence current flowing in the protected line section. Second, it compensates for the zero sequence mutual impedance between the protected line and other parallel circuits on the same right-of-way. While Fig. 1 illustrates only the connections for zero sequence mutual compensation between two parallel circuits it is possible to provide compensation when the protected line is paralleled by more than one other circuit

Note in Fig. 1 that a separate auxiliary transformer 0367A0266G2 is shown for the zero sequence curren compensation of the mho ground distance units in the CEYG. If it is not necessary to compensate the CEXG reactance units for zero sequence mutual, and it is not contemplated that such compensation will be required in the future, then a single auxiliary transformer 0367A0266G2 can be used to provide zero sequence current compensation of both the CEXG and CEYG relays.

When properly compensated by means of the auxiliary compensating transformer, the reactance units of the CEXG20A measure the positive sequence reactance from the relay location to the fault. However, because it is generally not possible to calculate the zero sequence impedance of a line .

and the zero sequence mutual effects of parallel lines to a high degree of accuracy, and because it is not possible to compensate for these effects completely, it is recommended that these first zone units be set for a maximum of 80 percent of the protected line length.

Before the CEXG relay is applied on the transmission lines of a power system, it is necessary to determine whether or not the system is "homogeneous". In general terms, a homogeneous system is one composed entirely of overhead transmission lines. In such a system the positive and zero sequence impedance of the lines are all at about the same angle.

A "non-homogeneous" system is a system that includes cable transmission circuits as well as overhead lines. While the CEXG can be applied on non-homogeneous systems as well as on homogeneous systems, the information in this book covers only the case of the homogeneous system. Application of the CEXG on non-homogeneous systems and resistance grounded systems requires special consideration and should be referred to the local district office of the General Electric Company.

In the application of the CEXG relay on a homogeneous system there are several points that must be checked in order to assure proper operation. These points are listed below:

1. For a single-phase-to-ground fault, the first-zone ohm unit on the faulted phase must not reach beyond the desired setting. Appendix I illustrates how this may be checked for a variety of system conditions. This includes situations where zero sequence mutual compensation is not employed or where it is lost when a parallel line breaker is tripped.
2. If a second CEXG relay is being used to provide zone-2 protection, for a single-phase-to-ground fault, the relay on the faulted phase must reach at least to the far bus. Appendix I illustrates how this may be checked for a variety of system conditions.
3. The overcurrent unit in the associated NAA15G relay must be set with a pick-up that is low enough to detect all single-phase-to-ground faults for which protection is desired.

RATINGS

The CEXG20A relays covered by these instructions have a rating of 5 amperes and 69 volts. These relays are rated either 50 or 60 Hertz as indicated on the nameplate.

The settings available on the ohm units are 0.15-1.5 ohms, 0.25-2.5 ohms, 0.5-5.0 ohms and 1-10 ohms. The contacts of relay will close and carry 30 amperes mementarily for tripping duty at control voltages of 250 volts DC or less. The trip circuit must be opened by a breaker auxiliary switch or other suitable means as the relay contacts have no interrupting rating. The contacts are used in series with a target seal-in unit and their current carrying ability is limited as indicated in TABLE A.

CHARACTERISTICS

OPERATING PRINCIPLES

The ohm unit is an induction cup unit having four poles. This type of relay has high operating torque and low inertia. Typical time curves are shown in Fig. 3.

A schematic diagram of the ohm unit is shown in Fig. 4. It has two current windings which are supplied respectively with line current and current from the auxiliary compensating transformer. The front and back poles produce a polarizing flux proportional to the sum of the currents and the right hand pole produces a flux which is also proportional to the sum of the currents but which lags the current by about 90 degrees.

The left hand pole has a potential winding which is supplied with phase-to-neutral voltage through a tapped autotransformer.

The interaction of the polarizing flux with the flux from the right hand pole produces an operating torque which is proportional to the square of the current. The interaction of the left hand flux and the polarizing flux produces a restraining torque which is dependent upon the autotransformer ratio and the phase angle between the voltage and current. (This restraining torque is a maximum when the current lags the voltage by 90 degrees).

The relay will just operate when these two torques are equal.

$EIk \sin \phi = I^2$

TABLE "A"

	2.0 Amp Tap	0.6 Amp Tap	0.2 Amp Tap	3.5 Amp Tap
DC Resistance	0.13 Ohms	0.6 Ohms	7.0 Ohms	0.026 Ohms
Min. Oper. Cur.	2.0 Amps	0.6 Amps	0.2 Amps	3.5 Amps
Carry Continuously	3.0 Amps	0.9 Amps	0.3 Amps	6.0 Amps
Carry 30 Amps For	4.0 Sec.	0.5 Sec.	--------	30 Sec.
Carry 10 Amps For	30 Sec.	--------	0.2 Sec.	----------

I is the vector sum of the currents in the current coils and E is the voltage across the potential coil (see Fig. 4) where k depends upon the number of turns in the different windings and the transformer ratio. The angle Ø is the angle between the voltage and the sum of the currents in the current windings.

At the balance point

$$\frac{1}{k} = \frac{EI \sin \emptyset}{I^2} = Z \sin \emptyset = X$$

This shows that this unit measures the reactive component of the impedance represented by the ratio of current and voltage applied at its terminals.

BURDENS

The burdens of the current coils are given in Table "B" and the maximum burdens of the potential coils at rated voltage are given in Table "C" below:

* The maximum burden on each potential transformer can be determined from Table "C" by adding vectoriall the burden of each component used. For tap setting less than 100% make these adjustments:

$$\text{Ohm unit burden} = \text{max. value} \left(\frac{TO}{100}\right)^2$$

Where TO = tap setting of ohm unit in percent.

TABLE "B"

MAXIMUM CURRENT COIL BURDENS AT 60 CYCLES**

Rating In Amperes		Ohm Unit Range Phase		Effective Resistance In Ohms	BURDENS AT 5 AMPERES			Impedance In Ohms At		Volt Amperes At 5 Amps
Cont.	One Sec.	To Neutral	Circuit		Reactance In Ohms	Impedance In Ohms	Power Factor	15 Amp.	50 * Amp.	
5	140	1-10 OR 0.5-5	19-20	0.63	0.78	0.99	0.64	0.99	0.63	24.75
			5-6	0.21	0.26	0.33	0.64	0.33	0.21	8.25
			7-8	0.21	0.26	0.33	0.64	0.33	0.21	8.25
			9-10	0.21	0.26	0.33	0.64	0.33	0.21	8.25
5	220	0.25-2.5 OR 0.15-1.5	19-20	0.165	0.225	0.285	0.58	0.285	0.279	7.14
			5-6	0.055	0.075	0.095	0.58	0.095	0.093	2.38
			7-8	0.055	0.075	0.095	0.58	0.095	0.093	2.38
			9-10	0.055	0.075	0.095	0.58	0.095	0.093	2.38

** Burdens of 50 cycle relays are practically the same as those listed above for 60 cycle relays.

* Indicates revision

TABLE "C"

MAXIMUM POTENTIAL COIL BURDENS
VOLTAGE ON RESTRAINT COILS IS 69 VOLTS

CIRCUIT		TAP	RES. OHMS	REACTANCE OHMS	IMPEDANCE OHMS	WATTS WATTS	VARS	POWER FACTOR	VOLT AMPERES
Ohm Unit	1.0-10,0.5-5.0 & 0.25-2.5	100%	575	0	575	7.80	0	1. 1.00	7.8 7.8
Ohm Unit	0.15 - 1.5	100%	350	0	350	12.6	0	1.0	12.6

CALCULATION OF SETTINGS

There are two and possibly three settings that must be made for each CEXG20A relay application:

1. Percent tap setting of the reactance units.
2. Auxiliary current transformer percent tap setting K'.
3. Auxiliary current transformer secondary percent tap setting K".

If compensation for zero sequence mutual impedance between the protected line and other lines is not required, then setting number 3 above is not involved. In this event the secondary winding of auxiliary CT 0367A0266G1 should be left open circuited, or CT 0367A0266G2 can be used in Common with the CEXG and associated CEYG as noted in APPLICATION.

Typical calculations for setting the CEXG20A relays are illustrated under "SAMPLE CALCULATIONS FOR SETTINGS". The following information indicates how the relay is set after the desired settings have been established. The CEXG measures positive phase sequence secondary ohms so the first step is to convert primary ohms to secondary ohms.

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

REACTANCE UNIT TAP SETTING

$$\text{Percent Tap} = \frac{X_{min}}{X} \times 100 \quad *$$

where: X_{min} = minimum oums of the relay as stamped on the nameplate

X = desired reach in secondary reactive ohms

*

COMPENSATING CT SETTING

If the two winding CT 0367A0266G1 is to be used, two settings are required. The setting on the primary side is identified as K' and provides the zero sequence current compensation. The other setting on the secondary side is identified as K" and provides compensation for zero sequence mutual. If zero sequence mutual compensation is not to be used only the K' setting is required. The single winding transformer 0367A0266G2 may be used as noted in APPLICATION.

(a) K' Setting - The zero sequence current compensation setting K' is determined by the following equation:

$$K' = \frac{X_0' - X_1'}{3X_1'} \times 100$$

where: K' = the primary tap setting in percent

X_0' = zero sequence reactance of the protected line in secondary ohms.

* Indicates revision

X_1' = positive sequence reactance of the protected line in secondary ohms.

(b) K" Setting - The zero sequence mutual compensation setting K" is determined by the following equation:

$$K'' = \frac{2X_{om}S_2}{3X_1'S_1} \times \frac{(CTRP)}{(CTR)} \times 100$$

where:

K" = the secondary tap setting in percent

X_{om} = total zero sequence mutual reactance between the protected line and the parallel line in secondary ohms

S_1 = first zone reach setting in per unit of protected line length. Thus, if first zone is set for 75 percent of the line, S_1 would be 0.75.

S_2 = the per unit of total X_{om} which is effective between the relay and the first zone balance point

(CTRP) = CT ratio on the parallel line

(CTR) = CT ratio on the protected line

Note that the compensating auxiliary CT has only 10 percent steps. It should be set to the nearest tap available.

SAMPLE CALCULATIONS FOR SETTINGS

In order to illustrate the calculations required, assume the portion of a transmission system shown on Figure 2.

Consider the protected line to be line #1 having the following characteristics:

$Z_1' = 6.0 \angle 79^\circ$ primary ohms

$Z_0' = 18.0 \angle 75^\circ$ primary ohms

$Z_{om} = 3.6 \angle 75^\circ$ primary ohms

CT Ratio = 600/5

PT Ratio = 1200/1

$Z_1' = 0.6 \angle 79^\circ = 0.12 + j\ 0.59$ secondary ohms

$Z_0' = 1.8 \angle 75^\circ = 0.48 + j\ 1.74$ secondary ohms

$Z_{om} = 0.36 \angle 75^\circ = 0.09 + j\ 0.34$ secondary ohms

Consider the relays at breaker A. The zone 1 unit should be set for a maximum of 80 percent of the reactive component (X_1') of Z_1'.

0.8 (0.59) = 0.47 ohms

The 0.25 ohm relay would be used in this instance, and the tap setting would be:

$$T = \frac{0.25}{0.47} \times 100 = 53 \text{ percent}$$

$$K' = \frac{1.74 - 0.59}{3\ (0.59)} \times 100 = 65 \text{ percent}$$

Since K' can be set in 10 percent steps, set K' for 60 or 70 percent. The higher setting will cause the relay to reach slightly farther than desired. The lower setting will shorten the reach slightly. For 70 percent setting set on taps 0 and 70. For 60 percent setting set on taps 40 and 100.

$$K'' = \frac{2\ (0.34)}{3\ (0.59)(0.8)} \times \frac{400}{600} \times 100 = 32 \text{ percent}$$

Set K" for 30 percent (taps 10 and 40).

The factor 400/600 appears because the CT's on the protected line are 600/5 while those on the parallel line are 400/5. The factor 0.8 appears in the denominator because only 80 percent of X_1 exists between the relay and the balance point while 100 percent of X_{om} is effective. If the two lines were parallel all the way, then the factor 0.8 would appear in both the numerator and the denominator and would cancel.

If a second CEXG relay is being used for zone 2 protection, it should be set to reach beyond the remote terminal of the protected line, say for 150 percent of X_1. Thus the tap setting of the second zone CEXG would be:

$$T = \frac{0.25}{1.5\ (0.47)} \times 100 = 35 \text{ percent}$$

This zone-2 CEXG can be compensated from the same auxiliary CT used for the zone-1 CEXG.

Now consider the relays at Terminal "B". Since there is mutual impedance between Line #1 and Line #2 that cannot be compensated for at Terminal "B", the secondary of the 0367A0266G1 auxiliary current transformer will be left open circuited. For this condition the reach of the CEXG at Terminal "B" will be somewhat in error. In order to evaluate this, equation I-c of Appendix I will give the reactance seen by the ohm unit at Terminal "B" for single phase to ground fault at F_2 in Figure 2. Since there is no mutual compensation at Terminal "B", the last term in the denominator of equation I-c is zero.

The primary setting of the compensating auxiliary CT (K') at Terminal "B" will be the same as that setting for Terminal "A".

K' - 70 percent

From the system configuration and the location of the fault we have:

$X_1' = 0.59$ secondary ohms

$X_{om}' = 0.34$ secondary ohms

$S_1 = 1.0$

$S_3 = 1.0$

From a board study of the system:

$I_a' = 15.4$ sec. amps. based on 600/5 CT's

$I_0' = 2.7$ sec. amps. based on 600/5 CT's

$I_0''' = 1.6$ sec. amps. based on 600/5 CT's

Substituting these values into equation I-c of Appendix I, the reactance seen by the relay is 0.63 secondary ohms. Since the actual positive sequence reactance from the relay to the fault is 0.59 secondary ohms, the ohm unit underreaches by about 6.7 percent as a result of the lack of mutual compensation. Because the uncompensated mutual causes underreaching in this case, the first zone may be set at 80 percent of the line length. The second zone must be set for at least 107 percent of the line length. Actually the second zone should be set for 125-150 percent of the protected line length.

CONSTRUCTION

The relay components are mounted in a cradle assembly which is latched into a drawout case when the relay is in operation but it can be easily removed when desired. To do this, the relay is first disconnected by removing the connection plug which completes the electrical connections between the case block and the cradle block. To test the relay in its case this connection block can be replaced by a test plug. The cover, which is attached to front of the relay case, contains the target reset mechanism and an interlock arm which prevents the cover from being replaced until the connection plugs have been inserted.

* Indicates revision

Every circuit in the drawout case has an auxiliary brush, as shown in Fig. 6 , to provide adequate overlap when the connecting plug is withdrawn or inserted. Some circuits are equipped with shorting bars (see Fig. 5) and on these circuits it is especially important that the auxiliary brush makes contact as indicated in Fig. 6 with adequate pressure to prevent the opening of C.T. secondary circuits or important interlock circuits.

The relay case is suitable for either semiflush or surface mounting on all panels up to 2 inches thick and appropriate hardware is available. However panel thickness must be indicated on the relay order to insure that proper hardware will be included. For outline and drilling dimensions, see Fig. 7

The target unit is a small hinged armature type relay consisting of a "U" shaped magnet frame, fixed pole piece, armature, and a tapped coil.

RECEIVING, HANDLING AND STORAGE

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

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

ACCEPTANCE TESTS

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

VISUAL INSPECTION

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

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

Check that the shorting bars are in the correct locations as indicated in Fig. 5 and that the auxiliary brushes are properly adjusted.

MECHANICAL INSPECTION

It is recommended that the following mechanical adjustments checks:

1. CHECK POINTS

Rotating Shaft End Play	5 - 8 mils
Contact Gap	55 - 65 mils
Contact Wipe	5 - 10 mils

2. There should be no noticable friction in the rotating structure of the ohm 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 ohm unit contacts must be open. The moving contact of the ohm units should rest against their backstops lightly.
5. *The armature of the target unit should move freely when operated by hand.

* Indicates revision

ELECTRICAL TESTS

DRAWOUT RELAYS GENERAL

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

POWER REQUIREMENTS GENERAL

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

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

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

* Before electrical checks are made on the ohm unit the relay should be connected as shown in Fig. 8 and should be allowed to warm up for approximately 15 minutes energized with rated voltage on the potential coils.

The tests in this section are for use in the laboratory. See Section on INSTALLATION PROCEDURE for field test instructions.

OHM UNITS

* 1. Potential Bias Test

Apply rated voltage to the relay potential circuit as shown below:

TO TEST UNIT	APPLY TO STUDS	RATED VOLTAGE
TOP	15 - 18	69 VOLTS
MIDDLE	16 - 18	69 VOLTS
BOTTOM	17 - 18	69 VOLTS

With potential applied to the potential circuit the contact should have a very slight torque in the contact opening direction.

If the torque is in the contact closing direction or too strong in the contact opening direction, then the core should be adjusted. The core should be turned slightly to cause the contact to just close. It should then be turned until the contact just moves back until it just touches the backstop. The core should be locked when the potential bias is correct.

2. Set the ohm unit taps for the desired reach.

3. Select the lowest available tap on X_T that is greater than 2 times the ohmic setting selected in 1 above.

4. Close fault switch SF and adjust R_L so that the current in the test reactor and relay current coils is approximately 10 amperes. Adjust selector switches to obtain the balance point where unit contact just closes. This balance should occur at the taps as given by the following equation.

* Indicates revision

$$* \quad \% \; T_T = \frac{(2K \pm 0.04) \quad 100}{(Z_T)\ (\%\ To)\ \sin\theta}$$

Where: K = 100 for 1.0 ohm relay

= 50 for 0.5 ohm relay

= 25 for 0.25 ohm relay

= 15 for 0.15 ohm relay

Z_T = Test reactor impedance ohms

θ = Impedance angle of Z_T

% To = Ohm unit tap setting in %

% T_T = Test box tap setting in %

5. If it is desired to check the effects of arc resistance, insert a resistor R_T which has an ohmic value of about 2.5 X_T and adjust R_L to give essentially the same current as in 4 above and test.

   At the higher ohmic settings it may not be possible to insert resistance and still obtain the same current as in 4 above. If this is the case, the effect of resistance should be checked at the 100% tap.

TARGET UNIT

1. With a source of DC power connected to studs 11 and 1, 12 and 2, or 13 and 3 and thru a variable resistor and an ammeter check that the seal-in unit picks up at rated tap current. During this test, the starting unit contact should be closed manually.

INSTALLATION PROCEDURE

LOCATION

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

MOUNTING

The relay should be mounted on a vertical face. The outline and panel drilling dimensions are shown in Fig. 7.

VISUAL INSPECTION

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

MECHANICAL INSPECTION

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

ELECTRICAL CHECK TEST ON INDUCTION UNITS

The manner in which reach settings are made for the ohm units is briefly discussed on the "CALCULATION OF SETTINGS" section. Examples of calculations for typical settings are given in that section. It is * the purpose of the electrical tests in this section to check the ohm unit ohmic pickup at the settings which have been made for a particular line section.

With relay connected as shown in Fig. 8 , check that the ohm units operate correctly at the settings to be used in its permanent location. Follow the test instruction given under the heading of "Electrical Test" in the ACCEPTANCE TESTS 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 enviroment, 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 relay contacts, a flexible burnishing tool should be used. This consists of a flexible strip of metal with an etched-roughened surface resembling in effect a superfine file. The polishing action is so delicate that no scratches are left, yet it will clean off any corrosion throughly and rapidly. Its flexibility insures the cleaning of the actual points of contact. Do not use knives, files, abrasive paper or cloth of any kind to clean relay contacts.

SERVICING

If any of the mechanical or electrical check points described in the previous sections are found to be out of limits the following points should be observed in restoring them:

MECHANICAL

1. Friction - If a tendency to bind or excessive friction is evident check for obstructions to the induction cylinder travel. Dirt or metallic particles in the stator gap are the most frequent cause of excessive friction.

2. End Play - End play in the shaft is adjusted by means of the upper guide bearing. Loosen the set screw and position the guide bearing so that end play falls within the .005 to .008 inch limit. Note that care must be taken not to disturb the spring windup while the end play is being adjusted.

3. Contact Gap - The contact gaps of the normally open and normally closed contacts are controlled by positioning the stationary contact support on the shelf. The recommended settings are illustrated in Fig. 9.

4. Clutch Slip - The clutch is adjusted by means of the steel collar at the upper end of the rotating shaft. To adjust the clutch loosen the set screw in the collar, and rotate the collar on the shaft through the number of half turns necessary to obtain the correct pressure. Turning the collar down increases the clutch pressure. The pressure required to slip the clutch should be as given in Table "E". The pressure required to slip the clutch should be measured by means of a gram gage applied at the moving contact. The collar should then be locked by means of the set screw which seats in a groove on the shaft. Care should be taken to seat the screw in this groove rather than tightening it against the threaded shaft.

TABLE "E"

Min. Relay Setting	Clutch Pressure Grams
0.15 Ohms	14 - 25
0.25	14 - 25
0.5	25 - 35
1.0	25 - 35

5. Control Spring Adjustment - Make sure the relay is well leveled in its upright position. Loosen the upper shaft bearing lock screw and rotate the control spring adjusting arm so that the moving contact just touches its backstop (when the backstop is removed the moving contact should not move). Now tighten the lock screw.

NOTE: - It is recommended that control spring adjustments be checked with the relay set in its position on the panel.

ELECTRICAL

Reach and Angle of Maximum Torque Adjustment. The minimum reach of the ohm unit is controlled with R31, R32, and R33.

* The ohm unit is a reactance measuring device, and its angle of maximum torque is at 90 degrees current lagging voltage. The angle of maximum torque is controlled with R11, R12, and R13. R31, R32 and R33, however, affect the reach of the relay and R11, R12, and R13 affect the angle of maximum torque.

* With these factors in mind; should it become necessary to recalibrate the ohm unit, use the test circuit shown in Fig. 8 permitting the unit to heat up for 15 minutes before starting the tests. Assuming that the potential bias is correct the adjustment of R_A resistor will rectify an incorrect ohmic reach testing with reactance alone. R_B shifts the angle of maximum torque so that the unit will measure only the reactive component of an impedance. Since each of these adjustments affect one another, check the calibration with and without fault or arc resistance after both resistors are set. The setting of the R_A and R_B is made with currents about 10 amps. Further tests should be made using current ranges in Table F. Of course with the arc resistance in the circuit use the maximum current obtained from the 115 volt supply. During the test to determine the flatness of the curve over the wide range of currents it may become necessary to resort to a minor core adjustment to bring the unit within the tolerable range of measurement. The turning-up of the curve at low currents means the control spring resetting torque is excessive.

*

UNIT TESTED	R_A	R_B
TOP	R_{31}	R_{11}
MIDDLE	R_{32}	R_{12}
BOTTOM	R_{33}	R_{13}

TABLE "F"

MIN. OHMS	TEST CURRENT RANGE AMPS
0.15	5 - 60
0.25	5 - 60
0.5	3 - 50
1.0	2 - 40

RENEWAL PARTS

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

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

* Indicates revision

APPENDIX I

EFFECTS OF UNCOMPENSATED ZERO SEQUENCE MUTUAL REACTANCE ON THE REACH OF THE OHM UNIT

The ohm or reactance unit of the CEXG20A relay, when properly compensated, will measure correctly the positive sequence reactance from the relay to a single-phase-to-ground fault. However, occasions arise where it is not possible or not practical to compensate for zero sequence mutual reactance between transmission lines on the same right-of-way. For example, consider a transmission line from Station A to Station B. Assume a second transmission line originating at Station A and running parallel with the first line, on the same right-of-way, for a considerable distance and then branching off to terminate at Station C. It is not possible to compensate the ohm units of the CEXG20A relays at either Station B or C for the zero sequence mutual coupling between the two lines. For this sort of reason it is of interest to know how uncompensated zero sequence mutual coupling will affect the reach of the ohm unit. There are several different sets of system conditions that should be considered and these are discussed one at a time below.

A. UNCOMPENSATED MUTUAL DUE TO AN OPEN CIRCUIT BREAKER

Consider two similar parallel lines on the same right-of-way as illustrated in Figure I-1

Assume that the auxiliary compensating CT 0367A0266G1 is used at all terminals to provide the proper mutual compensation. If a single-phase-to-ground fault were to occur at F1 and circuit breaker #3 were to trip on first zone, the current in circuit breaker #3 would instantly go to zero. The protective relays at breaker #1 would lose the zero sequence mutual compensation. However, since the fault current flows down line A and back over line B there will be a mutual effect which would tend to cause the ohm unit at breaker #1 to overreach. The ohm unit at breaker #4 will still have its compensation so it will not overreach. For these conditions, it is important that the overreach of the ohm unit at breaker #1 does not result in a lack of co-ordination with the relays at breaker #4.

The reactance as seen by the ohm unit at breaker #1 for a fault at F1 with breaker #3 open and no infeed from Station D is given by the following equation.

$$X_R = X_1' \left[1 + S_3 \frac{2 + K_o - 2K_m K_o}{2 + K_o} \right] \qquad \text{I-a}$$

where:

X_1' = Positive sequence reactance of the protected line, A.

X_o' = Zero sequence reactance of the protected line, A.

$K_o = X_o'/X_1'$

X_{om} = Total zero sequence mutual reactance between line A and line B.

$K_m = X_{om}/X_o'$

S_3 = The ratio of the distance from breaker #4 to the fault - to the total length of Line A or Line B.

There are two points to consider. First, the first-zone ohm unit at breaker #1 should not reach into the first zone of the relays at breaker #4 for a phase-to-neutral fault on Line B with breaker #3 open. Next, the second-zone ohm unit at breaker #1 should not reach into the second zone of the relays at breaker #4 for a phase-to-beutral fault on line B with breaker #3 open.

The most severe condition of overreach will occur for the larger values of K_m and K_o. On actual systems, K_m will have a maximum value of about 0.7 but will generally be about 0.5. K_o will average about 3.5 but may be as high as 5.5. A check of equation I-a will show that the reactance seen by the ohm unit at breaker #1 for a fault anywhere on line B will always be greater than the reactance setting of the first zone which should never exceed 80 percent of the line length. Thus, the first zone unit of the relays at breaker #1 will never reach to the far bus.

The maximum second zone ohm unit reach setting at breaker #1 must be established to insure that it does not reach beyond the first zone unit at breaker #4. Assuming that the first zone units are set for 80 percent of the line length, then the second zone units at breaker #1 should not see faults on line B beyond 50 percent of the distance to breaker #3. For this fault $S_3 = 0.50$.

Referring to equation I-a and assuming K_m=0.5 and $K_o = 3.5$, we get $X_R = 1.18X_1'$. Thus, for the conditions assumed, a single-phase-to-ground fault on line B half-way from breaker #4 to breaker #3 with breaker #3 open and no infeed from Station D, the second zone ohm unit at breaker #1 will see a reactance which is 118 percent of the protected line length. For these conditions, the reach setting of the second zone ohm unit at breaker #1 should not exceed 118 percent of the positive sequence reactance of the protected line section.

Note that system constants (K_o and K_m) which are different from those assumed will lead to a different safe maximum reach setting. Also, any dependable infeed from Station D will permit a longer second zone reach setting at breaker #1. Equation I-b below gives the reactance as seen by the ohm unit at breaker #1 for single-phase-to-ground faults on line B with breaker #3 open and infeed from Station D.

$$X_R = X_1' \left[1 + \frac{S_3}{2C + K_o C_o} \left(K_o + 2 - \left[C_o + 1 \right] K_m K_o \right) \right] \qquad \text{I-b}$$

where:

C = Positive sequence distribution constant I_1'/I_1

C_o = Zero sequence distribution constant I_o'/I_o

Equation I-b applies to the configuration of Figure I-1 except that infeed is present at Station D. Since we do not wish the second zone ohm units at breaker #1 to reach beyond a point half-way from breaker #4 to breaker #3, assume a fault at the midpoint of line B. For this fault $S_3 = 0.5$. As in the previous example, assume $K_m = 0.5$ and $K_o = 3.5$. Assume that the infeed from Station D is rather weak so that $C_o = 0.7$ and $C = 0.8$.

Substituting these values in equation I-b we get:

$$X_R = 1.31\ X_1'$$

Thus, to the relay at breaker #1 this fault will appear to be at a point 31 percent of the distance from breaker #4 to breaker #3. If it is desired to limit the reach of the breaker #1 second zone unit to a point midway on line B, it is necessary to limit the set reach of the unit to 131 percent of the protected line length.

B. UNCOMPENSATED MUTUAL DUE TO PARTIAL PARALLEL CIRCUITS

When it is not possible to compensate for zero sequence mutual reactance between two parallel circuits because they do not terminate at the same stations, it is of interest to know how this lack of compensation affects the reach of the ohm units. Consider the system illustrated in Figure I-2

Line A is the protected line under consideration and the relays associated with breaker #1 are being studied. Line B is a parallel circuit with one end terminating at Station A and the other end terminating at Station B or some other remote station. Since both breakers #1 and #4 terminate at Station A, compensation for the zero sequence mutual reactance between lines A and B is possible for the relays at breakers #1 and #4. In the following analysis this is assumed.

Line C does not terminate at Station A. It may or may not terminate at Station B. Zero sequence mutual exists between lines A and C but the relays at breaker #1 cannot be compensated for this. While zero sequence mutual will exist between lines B and C, the magnitude is not required for these calculations once the fault currents have been obtained.

There are two situations to be investigated. First, the reactance seen by the relays for a fault at the set reach of the relay. It is important that the effects of the uncompensated mutual between lines A and C do not cause the first zone ohm unit to overreach the setting (F_1). Next, it is important to insure that the effect of the uncompensated mutual does not result in a pull back in the reach of the second zone unit so that it fails to see a fault at the far end of the line (F_2).

Note that the effects of the uncompensated mutual will cause both first and second zones to overreach or underreach. It cannot cause one to overreach and the other to underreach. The direction of the current flows (I_0 and I_0''') as assumed in Fig. I-2 will cause both zones to underreach. If I_0 flows in the opposite direction this will cause both zones to overreach.

For a fault at the first zone set balance point (F_1), equation I-c gives the reactance as seen by the relay.

$$X_R = X_1' \left[S_1 + \frac{\frac{1}{X_1'} \sum S_3 X_{om}' I_0'''}{I_a' + 0.03K' I_0' + 0.015 \sum K'' I_0''} \right] \qquad \text{I-c}$$

where:

X_1' = Positive sequence reactance of the protected line.

X_0' = Zero sequence reactance of the protected line.

X_{om}' = Total mutual reactance between line A and line C.

K' = Compensating auxiliary CT primary setting.

K'' = Compensating auxiliary CT secondary setting.

S_1 = Ratio of the distance from breaker #1 to the fault - to the length of line A.

S_3 = Per unit of the total X_{om}' that is involved in the fault.

I_a' = Phase A current in the protected line at the relay location.

I_0' = Zero sequence current in the protected line at the relay location.

I_0'' = Zero sequence current in the parallel line which can be compensated (line B). Taken as positive when flowing in the same direction as I_0.

I_0''' = Zero sequence current in the parallel line which cannot be compensated (line C). Taken as positive when flowing in the same direction as I_0.

The summation in the numerator of equation I-c applies in the event that there is more than one circuit similar to line C for which compensation cannot be or is not applied. The summation in the denominator applies when there is more than one circuit similar to line B for which compensation is applied.

As an example in the use of equation I-c assume the system illustrated in Fig. I-2. Assume that neither line B nor line C terminate at Station B. Check the ohm unit for a fault at the set reach of the first zone ohm unit. Let this be a fault at F_1 in Fig. I-2, 80 percent of the distance to breaker #2. Assume now the following system constants, fault currents, and compensator CT settings.

K' = 80

K'' = 10

I_a' = 50 secondary amperes

I_0' = 15 secondary amperes

I_0'' = 5 secondary amperes

I_0''' = -4.16 secondary amperes

X_{om}' = 0.6 X_1'

S_1 = 0.8

Since the entire mutual of line C will be involved in this fault, S_3 = 1.0.

Substituting these values in equation I-c and noting that the negative sign associated with I_0''' indicates that I_0 is actually flowing in a direction opposite to that assumed in Fig. I-2, we obtain:

$\therefore X_R = 0.771 X_1'$

Thus, the first zone unit will see a reactance which is 96 percent of the actual positive sequence reactance to the fault. Or, stated in other words, the first zone unit will overreach about 4 percent for the condition assumed.

For an end-zone fault at F_2 equation I-c may be used again except that now the currents will be slightly different. Also, the S constants will change. For example, for a fault at F_2:

$S_1 = 1.0$

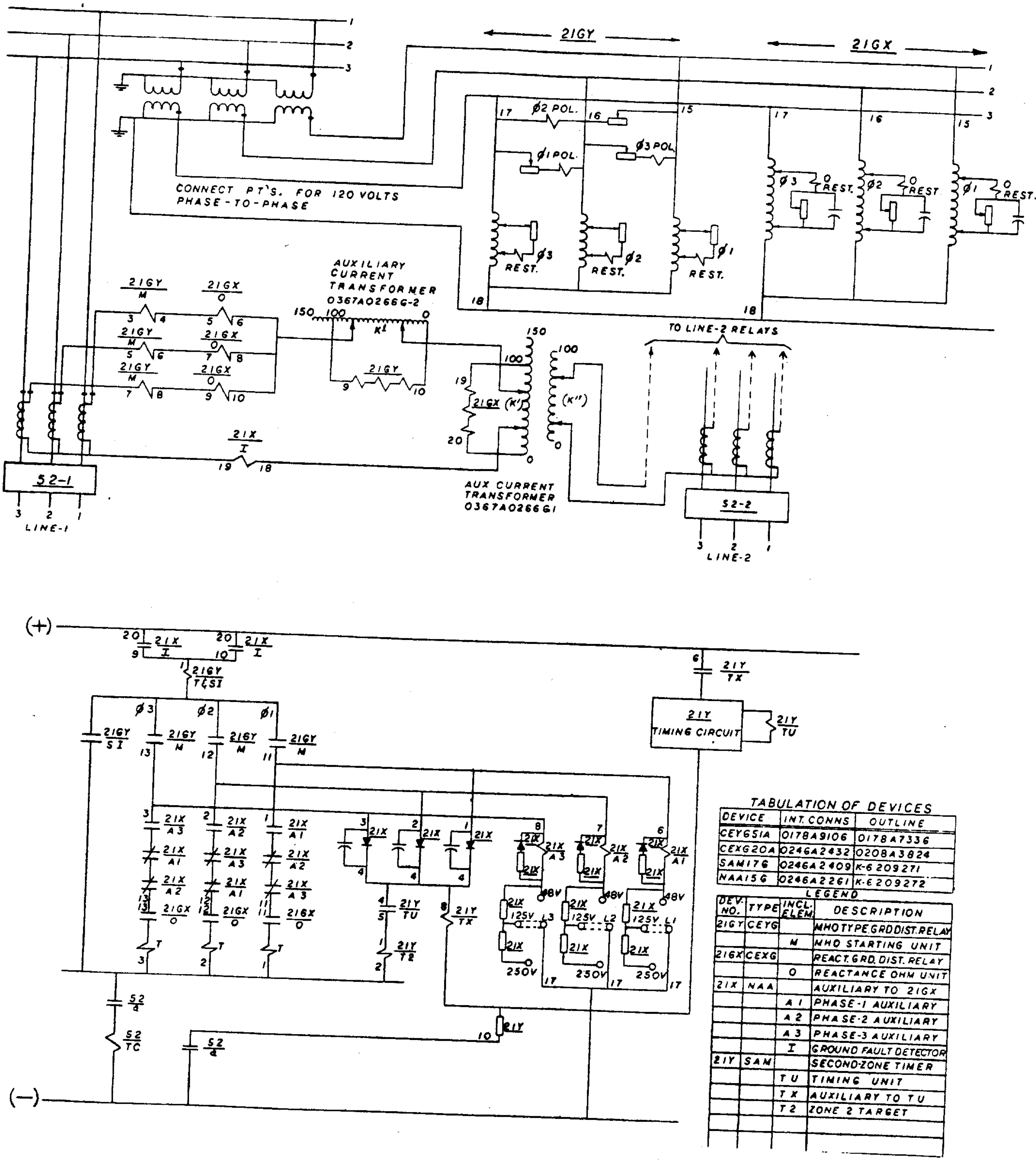
$S_3 = 1.0$

For the conditions assumed, the second zone unit will see a reactance that is slightly smaller than the actual reactance to the fault. However, since the second zone is set to reach beyond the far bus, this slight overreach is of no practical importance. On the other hand, if the current I_0''' had been assumed in the opposite direction, a slight underreach would result. In this case it would be necessary to insure that the setting of the second zone would be sufficiently long so that it sees a fault at the remote bus despite the small underreach.

Note that equation I-c is quite general and may be applied to almost any system configuration for a fault in the protected line section. For example, if there were no zero sequence mutual compensation between the relays at breakers #1 and #4, then the last term in the denominator of equation I-c is zero. Also, the summation in the numerator would then include the effects of line B and I_0''.

If line B did not exist at all, then the last term in the denominator goes to zero and there is no I_0'' term to consider in the numerator.

All voltages, currents and impedances in the above equations are in terms of secondary quantities based on the CT and PT ratios employed on the protected line. This includes I_0''' and I_0'' as well as I_0'.



TABULATION OF DEVICES

DEVICE	INT. CONNS	OUTLINE
CEYG51A	0178A9106	0178A7336
CEXG20A	0246A2432	0208A3824
SAM17G	0246A2409	K-6209271
NAA15G	0246A2261	K-6209272

LEGEND

DEV. NO.	TYPE	INCL. ELEM.	DESCRIPTION
21GY	CEYG		MHO TYPE GRD DIST. RELAY
		M	MHO STARTING UNIT
21GX	CEXG		REACT. GRD. DIST. RELAY
		O	REACTANCE OHM UNIT
21X	NAA		AUXILIARY TO 21GX
		A1	PHASE-1 AUXILIARY
		A2	PHASE-2 AUXILIARY
		A3	PHASE-3 AUXILIARY
		I	GROUND FAULT DETECTOR
21Y	SAM		SECOND-ZONE TIMER
		TU	TIMING UNIT
		TX	AUXILIARY TO TU
		T2	ZONE 2 TARGET

FIG. 1 (0164B9092-0) Typical External Connections For Two Zone Step Distance Protection Of A Transmission Line Using The CEXG20A With CEYG51A, SAM17G And NAA15G

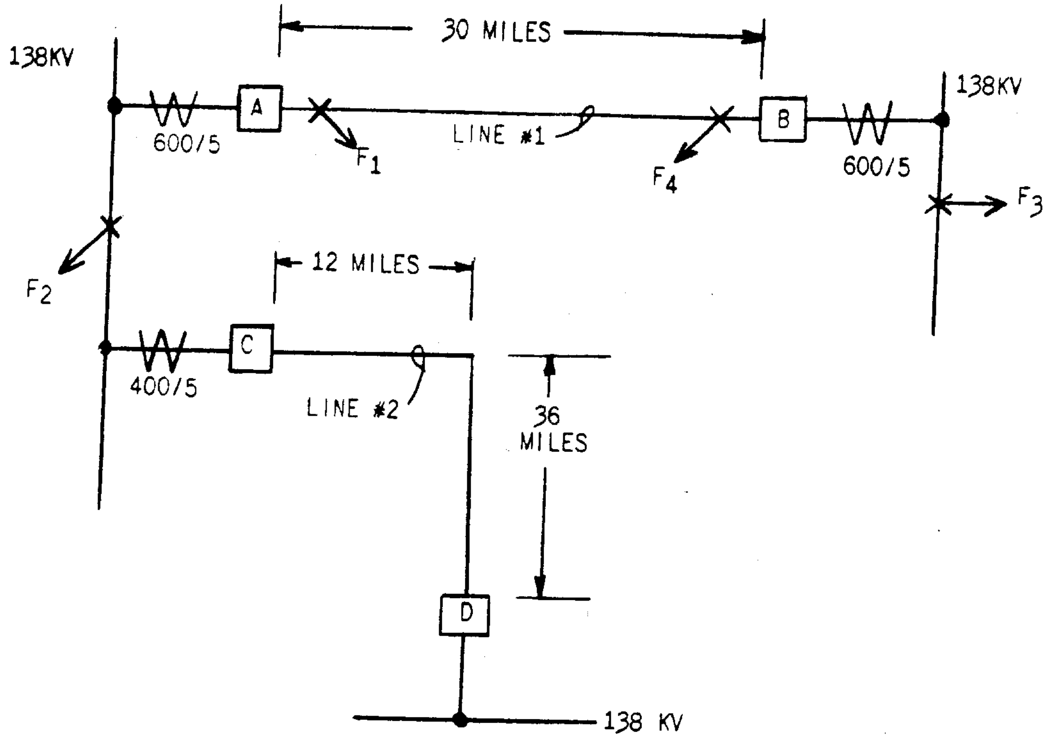


FIG. 2 (0165A7622-0) Portion Of A Transmission System

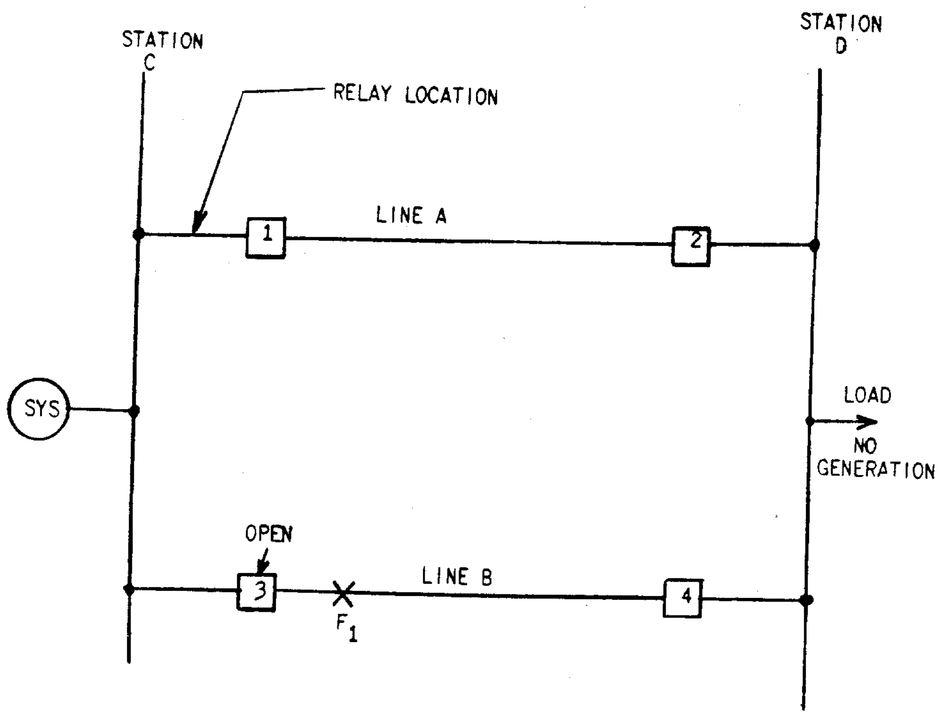


FIG. I-1 (0165A7621-0) Parallel Transmission Lines With Ground Fault

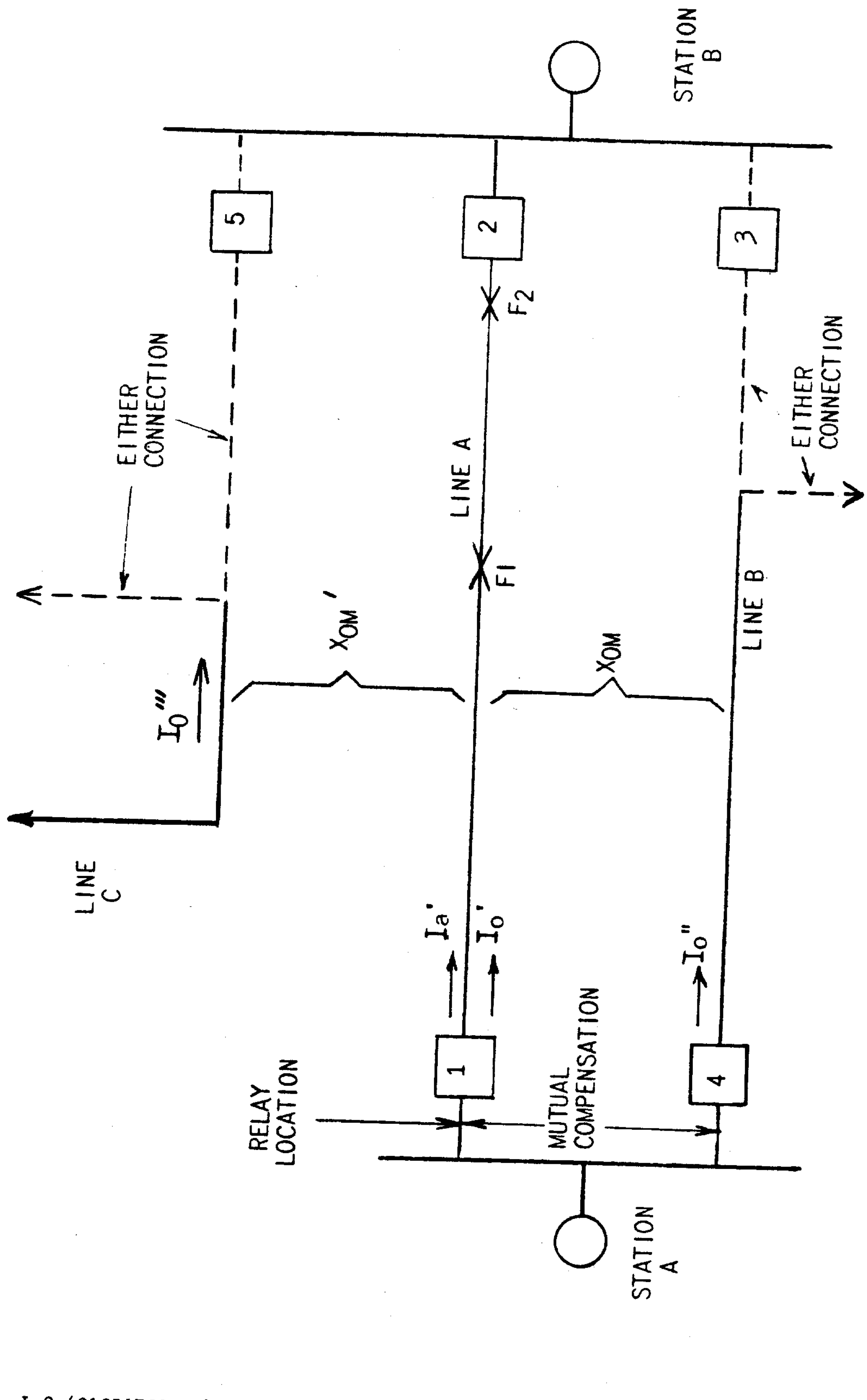


FIG. I-2 (0165A7620-1) Transmission System With Lines Terminating At Remote Stations

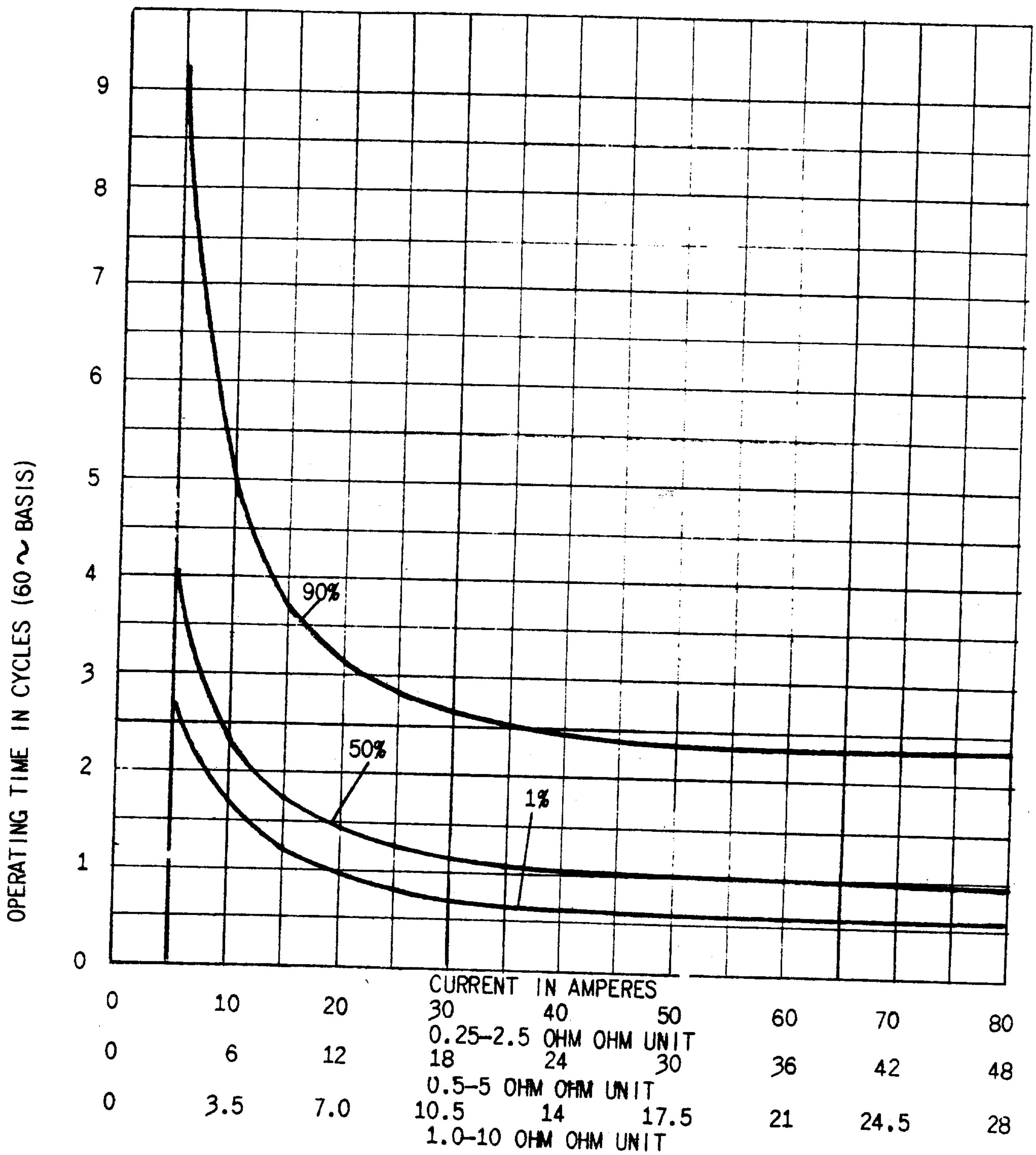
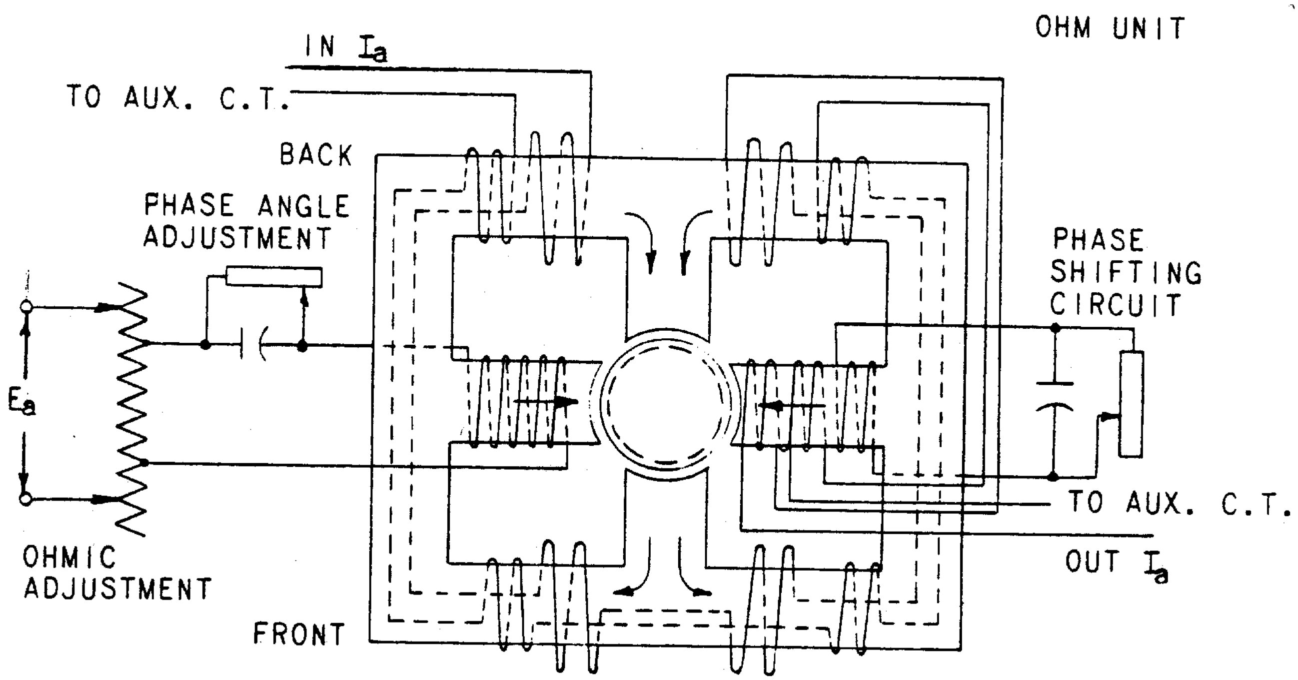


FIG. 3 (K-6209208-6) Operating Time Of Ohm Unit Where Current Is Line Current PLVS $K'I_0$



* FIG. 4 (K-6209285-2) Schematic Diagram For The Ohm Unit

* Indicates revision

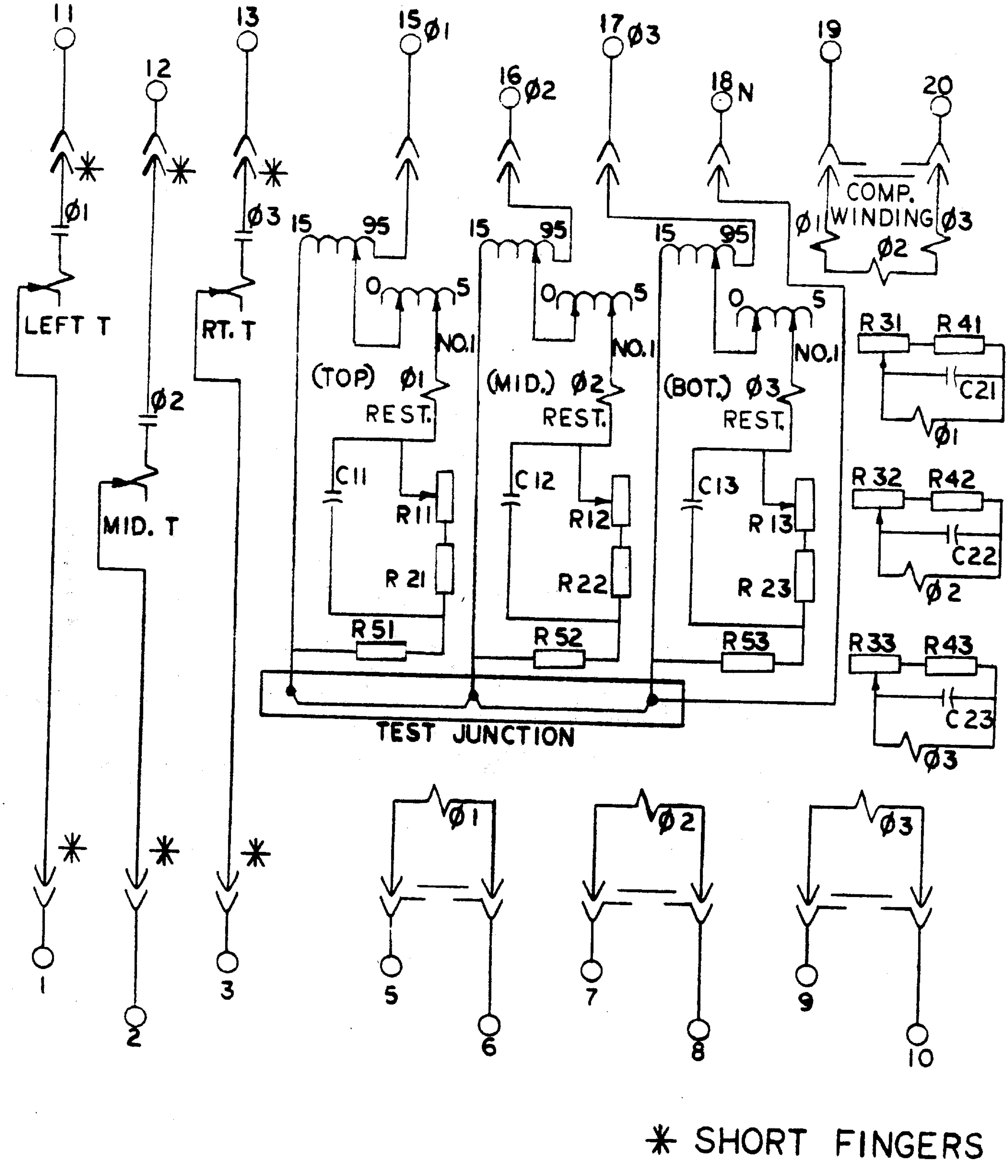


FIG. 5 (0246A2432-0) Internal Connections Of The CEXG20A

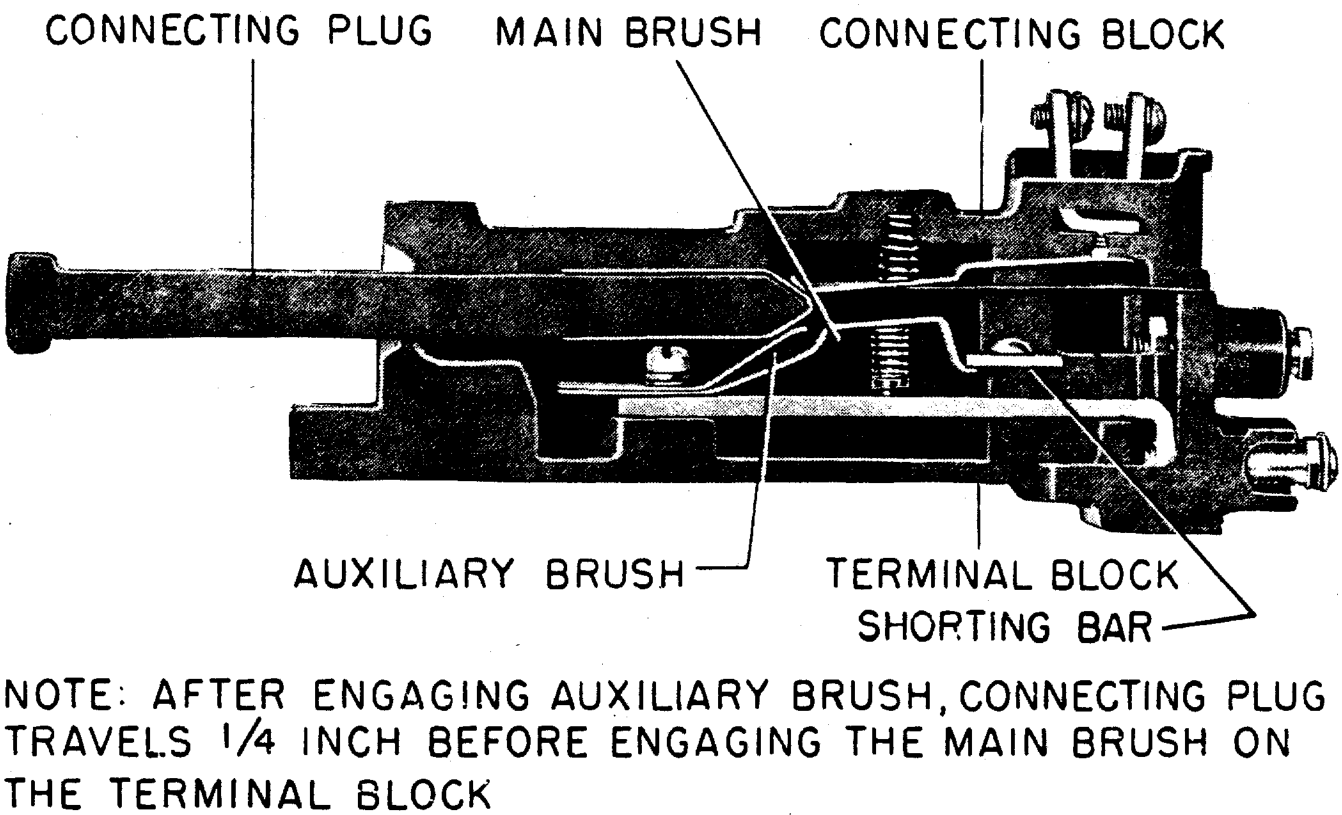
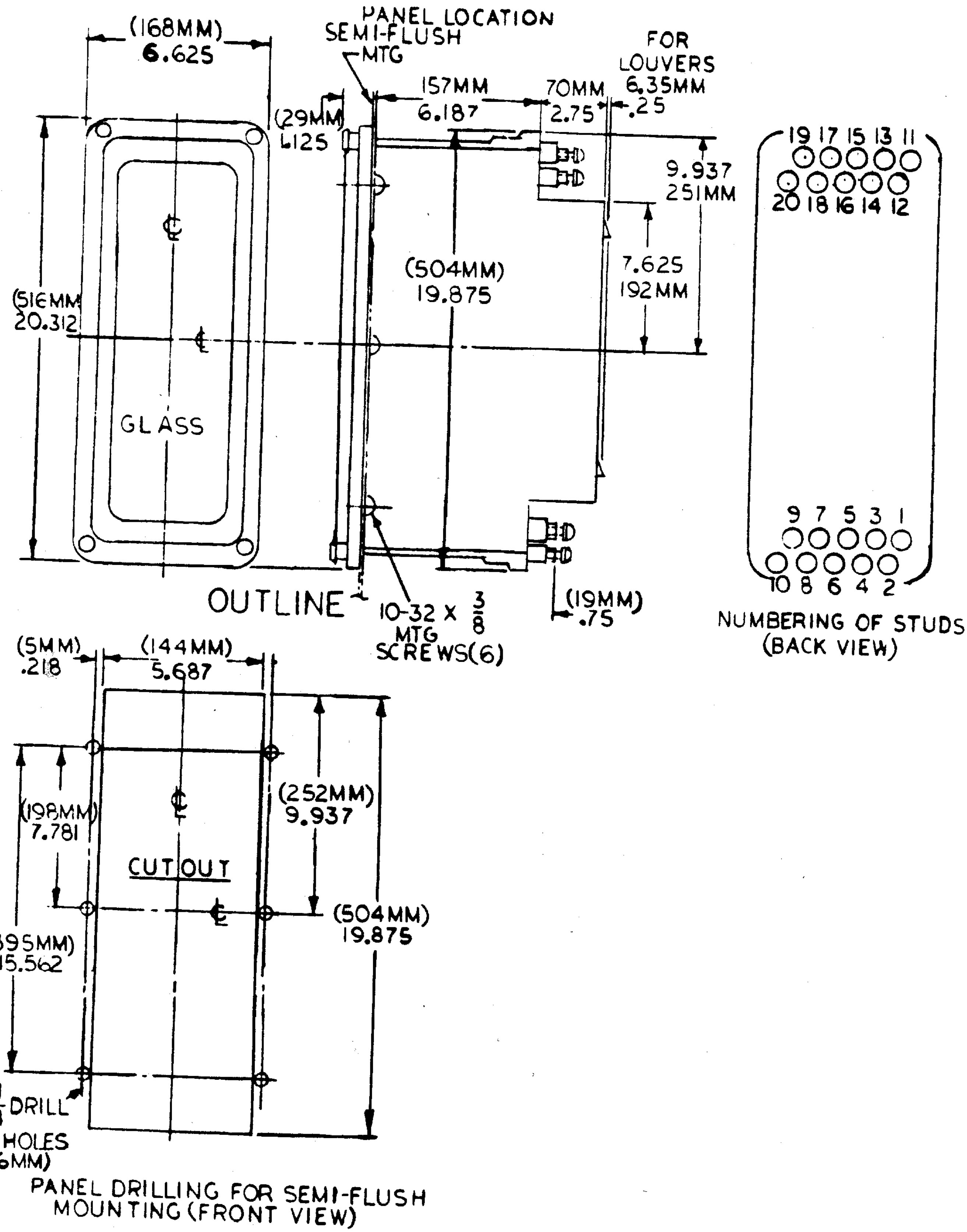


FIG. 6 (8025039) Cross Section Of Drawout Case Showing Position Of Auxiliary Brush And Shorting Bar



* FIG. 7 (0208A3824-3) Outline And Panel Drilling Dimensions For CEXG20A

* Indicates revision

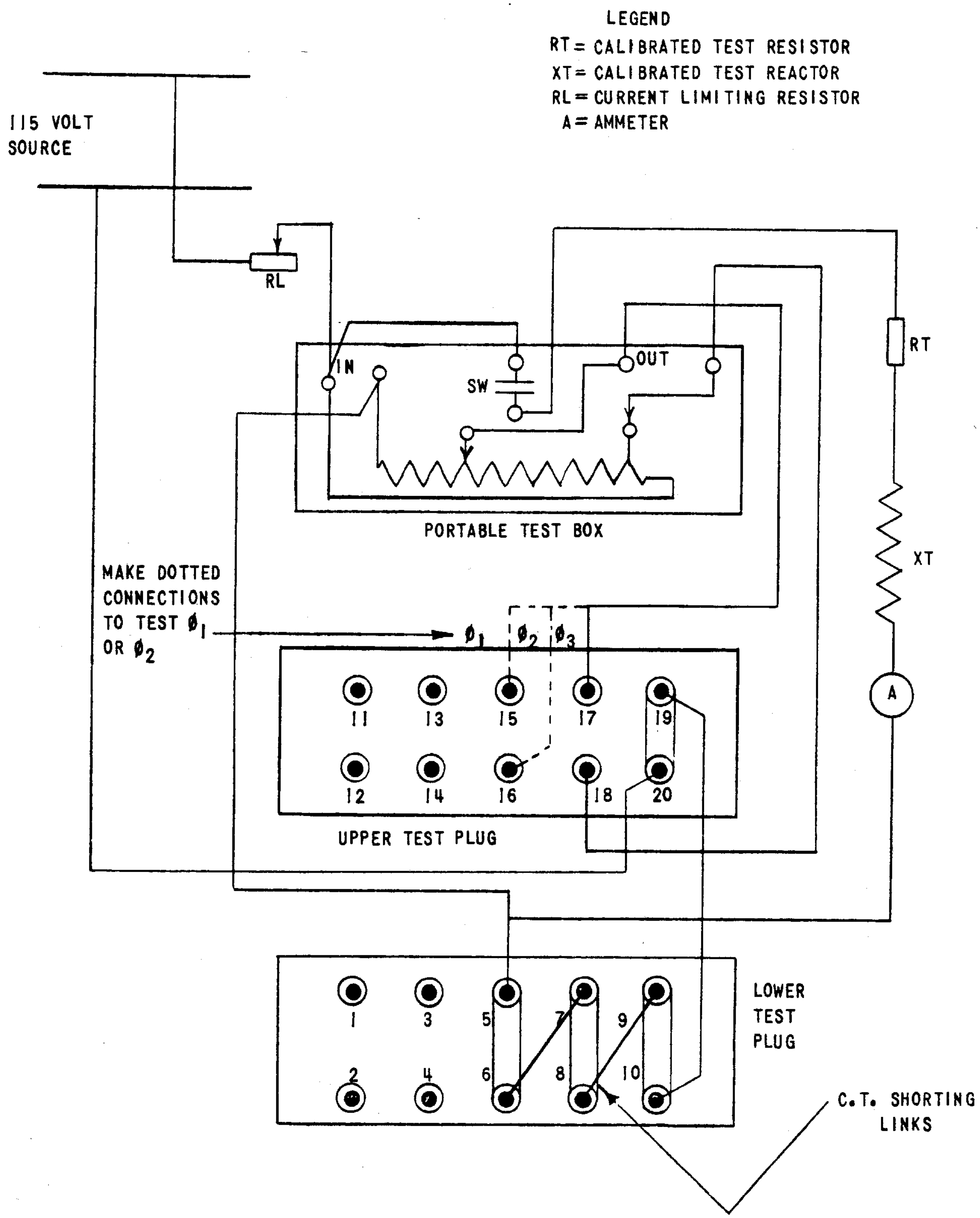


FIG. 8 (0246A2269-1) Test Connections For The CEXG20A

FOR OHM & MHO UNITS AS LISTED

CONTACT GAP	UNIT
.030 - .035	OHM FOR CEX18
.030 - .035	MHO FOR (GCY M1) CEH, CER & CEY
.018 - .022	MHO FOR (GCY M2) & OHM FOR (CEX17E) (GCYMT & UNIT)
.050 - .065	MHO FOR (GCY M3) & CEB13, 14
.090 - .110	MHO FOR GCX17H, GCX17J, GCX17M & GCX17N
.055 - .065	OHM FOR GCX, CEB14
.110 - .135	MHO FOR CEB12

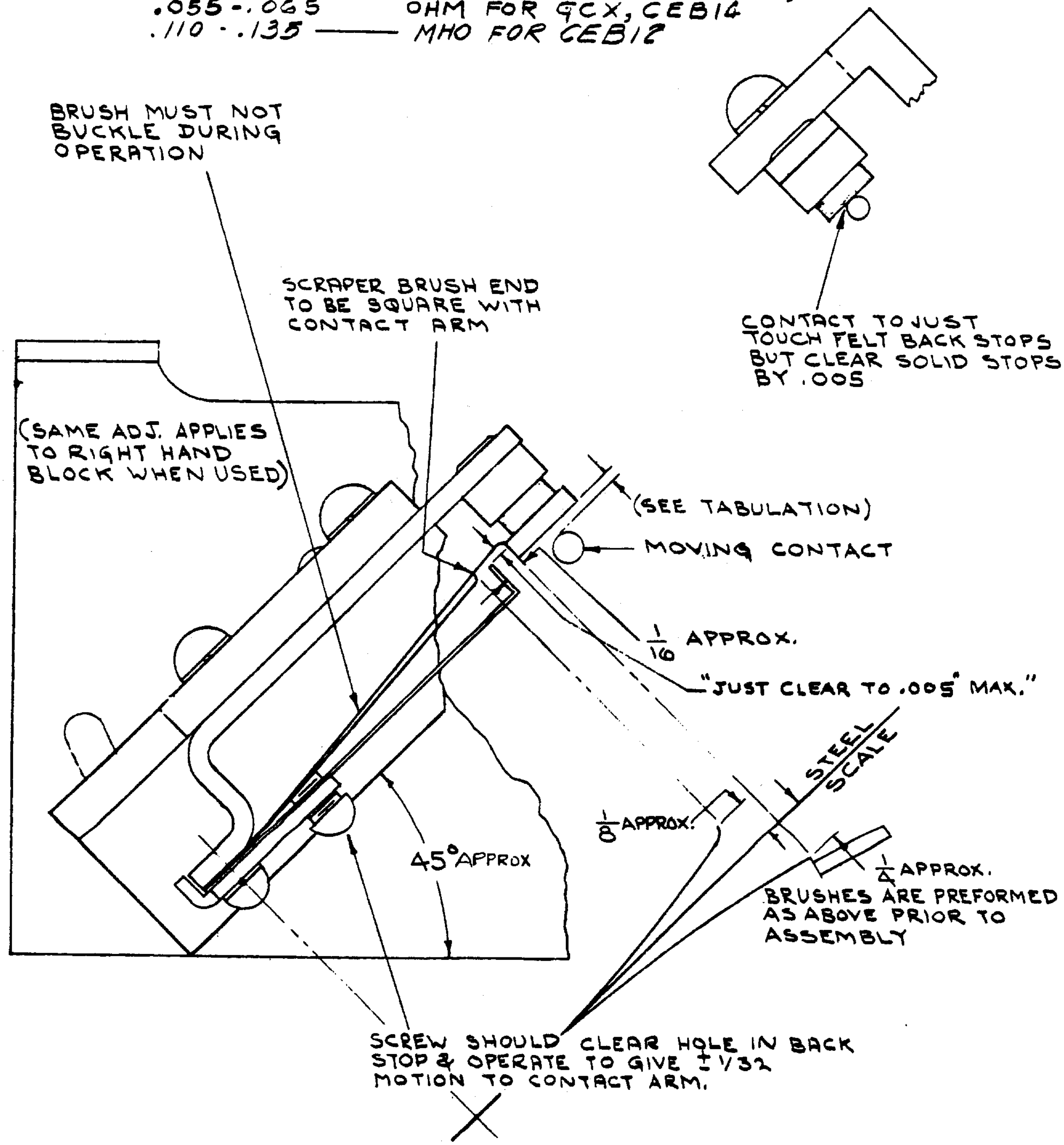


FIG. 9 (365A400-11) Contact Adjustment Of Ohm Units

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