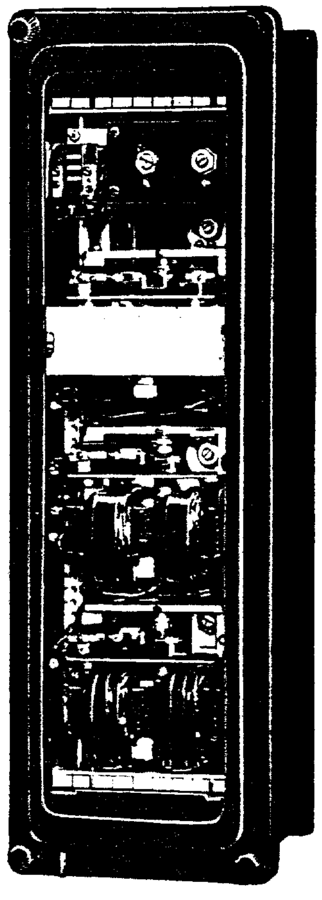
INSTRUCTIONS

GEI-25355B

SUPERSEDES GEI-25355A

MHO DISTANCE RELAYS



Type GCY12

POWER SYSTEMS MANAGEMENT DEPARTMENT

GENERAL ELECTRIC

PHILADELPHIA, PA.

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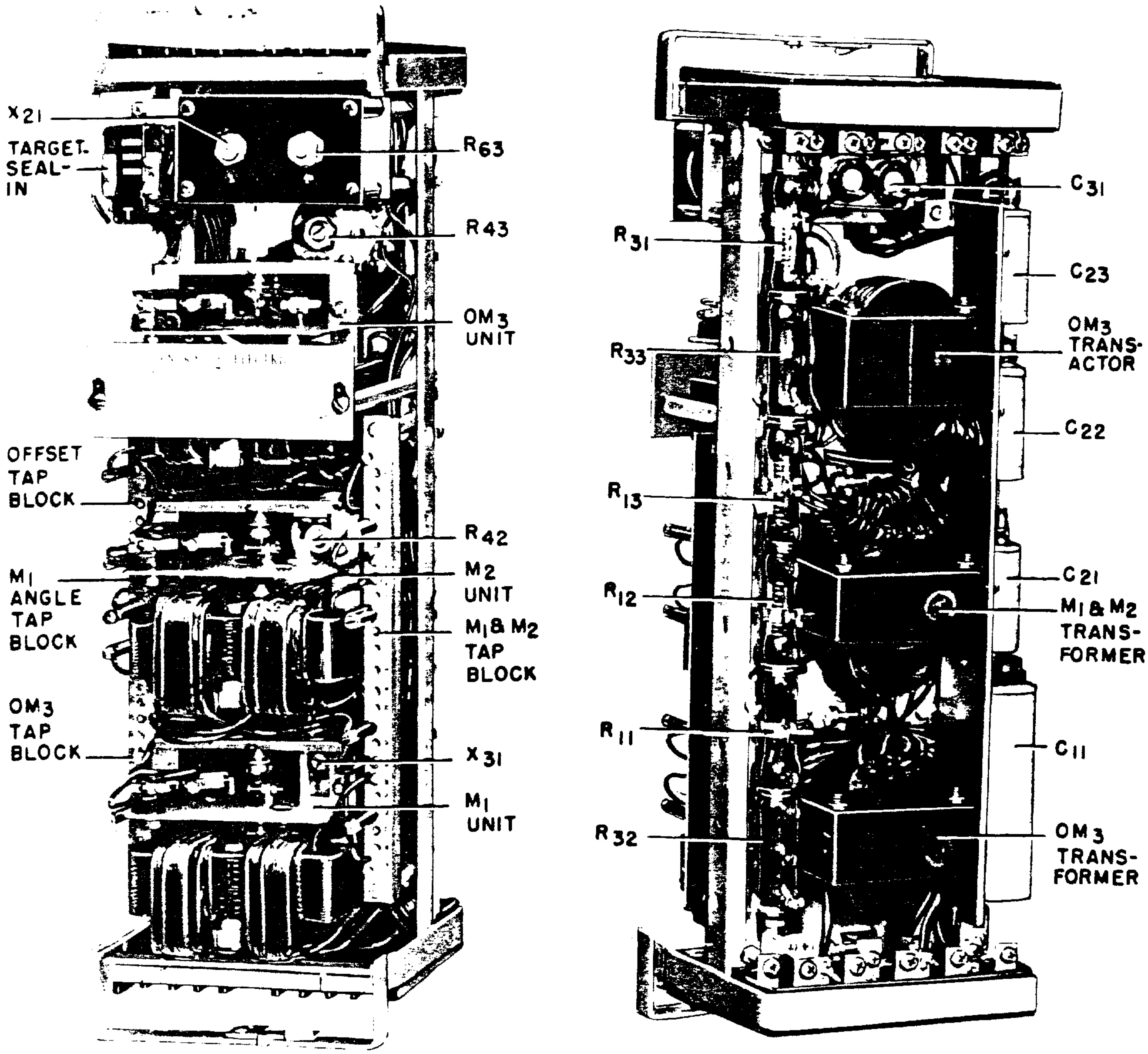

Fig. 1 Type GCY12A Relay in Cradle with Case Removed Front View on Left and Rear View on Right

MHO DISTANCE RELAY
TYPE GCY12A

INTRODUCTION

APPLICATION

The Type GCY12A relay is a high-speed directional distance relay containing three mho units which operate in conjunction with a separate RPM timing relay to provide three-step time-distance protection for transmission lines. These units operate on the induction cylinder principle, which provides a high steady torque acting on low inertia parts.

The bottom unit, M1, used for the first or instantaneous step, has been designed to control tripping independently of any other relays and has minimum error due to transient conditions at the inception of a fault.

The middle unit, M2, used for the second setting is designed to operate in conjunction with a timing relay or as the directional unit in a carrier-pilot relaying scheme. The mho characteristic, being inherently small, makes the relay insensitive to power swings which may occur on long or heavily loaded lines.

The top unit OM3 is an offset mho unit; i.e., it has a circular impedance characteristic similar to that of the M_1 and M_2 units except that it is offset so as to encircle the origin of the impedance diagram instead of passing through it. This offset characteristic is provided by the voltage drop across a transactor in the current circuits in conjunction with an element which is otherwise similar to the M_2 unit. Transactor is the name given to a reactor which has a secondary winding with a step-up ratio so as to provide more reactance with less burden on the current circuits. The unit is designed as a second-back-up setting in conjunction with a timing relay and in conjunction with the M_2 unit and an auxiliary relay, for out-of-step blocking when used in a straight distance relaying scheme; or for fast action to start carrier and as a second back-up setting in conjunction with a timing relay when used in a carrier-current relaying scheme.

All three units are supplied with line-to-line voltage and the vector difference of the currents in these same two lines (delta current). Consequently, the ohmic reach of any unit is the same for three phase, phase-to-phase, or two phase-to-ground faults.

The relays have M_1 and M_2 units that are available with adjustment ranges of 1-10, 2-20 or 3-30 ohms with the normal factory adjustment angle of maximum torque. The OM3 unit is available with the 3-30* ohm range only. Within these ranges, the ohmic reaches of the M1 and M2 units are adjusted by means of a tapped transformer which supplies a percentage of the terminal voltage to the restraint circuits, adjustable in one percent steps.

For convenience the text describes only one range, the 3-30 ohm rating. Where necessary means are described for adopting the information to the 1-10 and 2-20 ohm ranges.

The OM3 unit is adjusted within its range of ohmic setting by means of a second autotransformer which has five percent steps because accurate adjustment is not necessary.

The Type GCY12A relay can also be used in conjunction with an RPM timer and other auxiliary relays to provide carrier-current transmission line protection with three-step distance relay backup protection. This application is explained in detail in GEI-25363.

When applying the Type GCY12A relay with a line-side potential source, the relay may be required to operate when the breaker is closed in on a fault. Under such conditions the secondary phase-to-phase voltage, resulting from a fault will be low, reducing the current flowing through the relay, thereby, reducing the ohmic reach. For an error of minus 10 percent in reach, for any nominal setting of Z ohms phase-to-neutral, the minimum operating current for a fault at 90 percent of this setting will be approximately $\sqrt{\frac{30T}{Z^2 \text{ min}}}$

Where T is the voltage restraint tap setting in percent divided by 100 and Z_{min} is the minimum phase-to-neutral ohmic reach which is given on the relay nameplate. This underreach should be considered when making the second zone setting, particularly in a carrier current application, to be certain that the line breaker will be retripped for a persisting line fault. The first zone unit under the same conditions will also underreach and will protect only 81 percent of the line section instead of the original 90 percent for which it is usually set.

* The ohmic values in these instructions refer to phase-to-neutral ohms when the relay is connected as shown in Fig. 19 unless specifically stated otherwise.

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

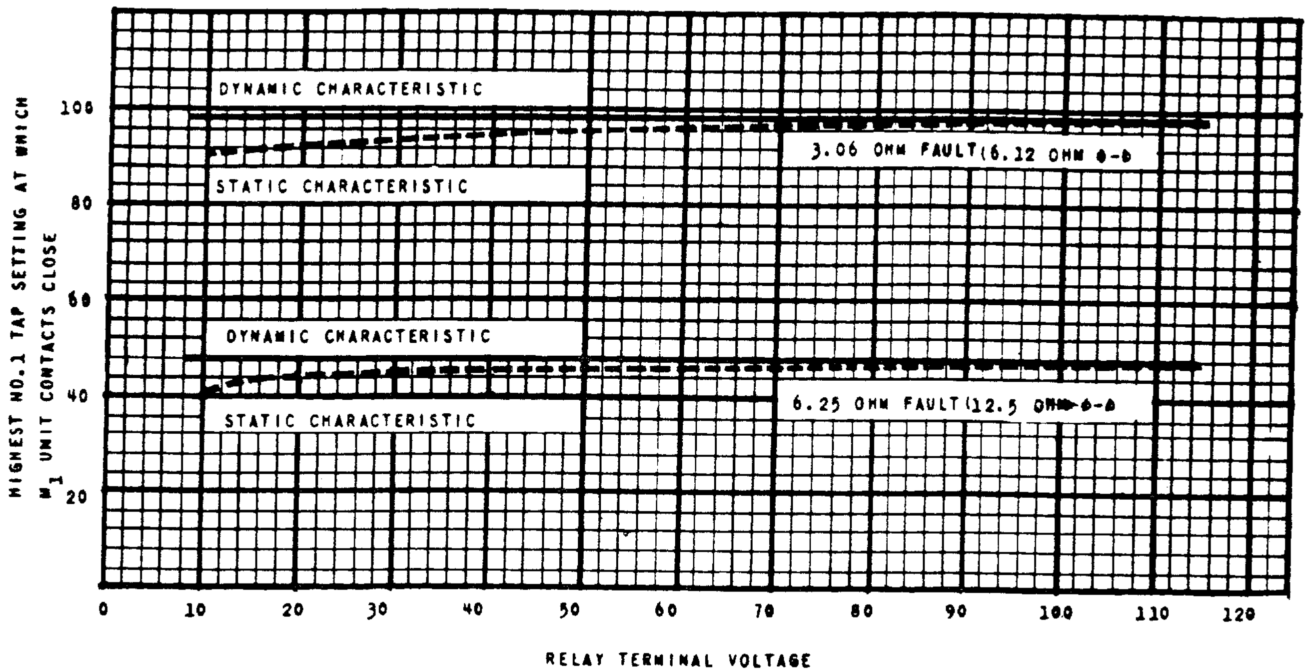

Fig. 2 Accuracy of M_1 Unit Under Static and Dynamic Conditions. Data Taken for Phase-to-phase Fault With 60 Degree Phase Angle.

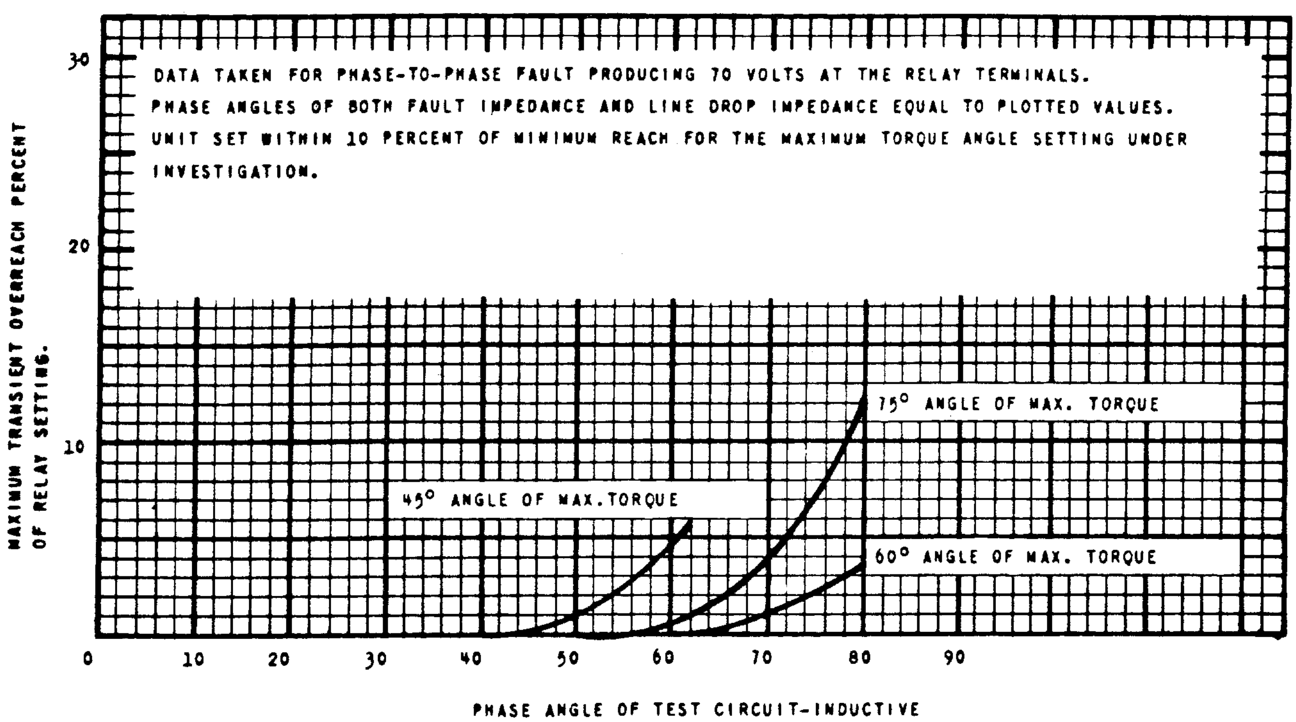

Fig. 3 Maximum Transient Overreach of M_1 Unit Versus Phase Angle of Test Circuit

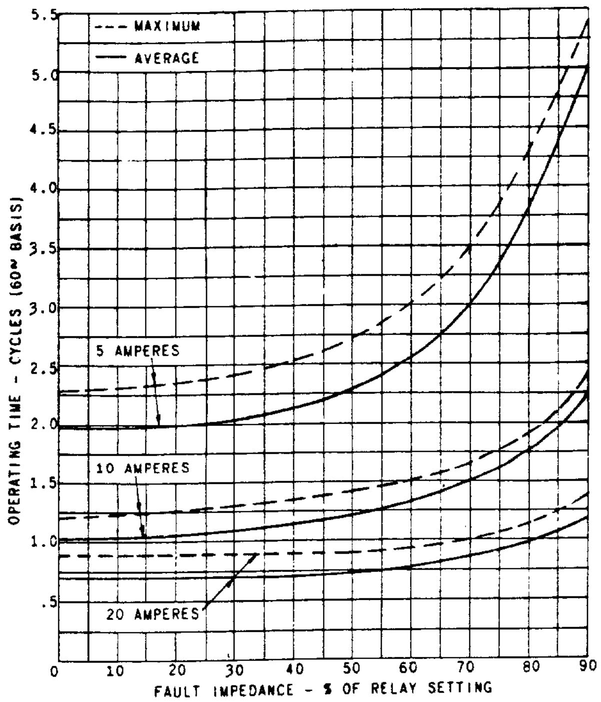

Fig. 4 Operating Times of M_1 Unit Set for 3 Ohms At 60 Degrees.

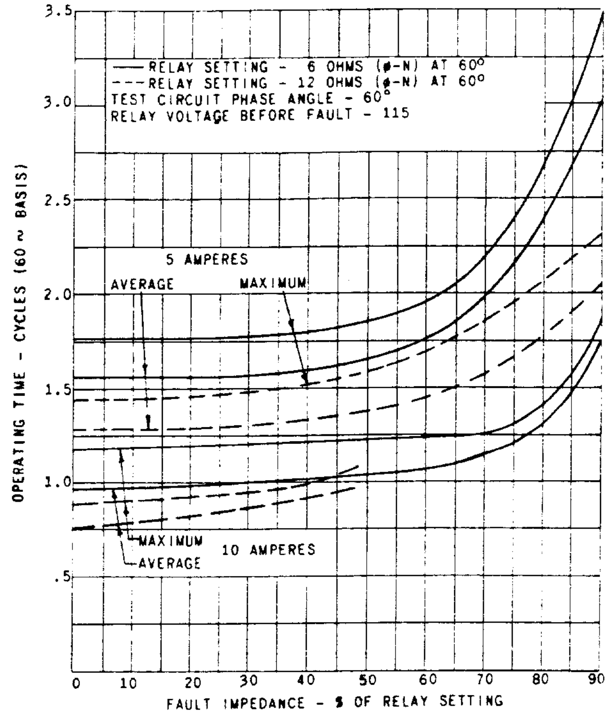

Fig. 5 Operating Times of M_1 Unit Set for 6 and 12 Ohms At 60 Degrees.

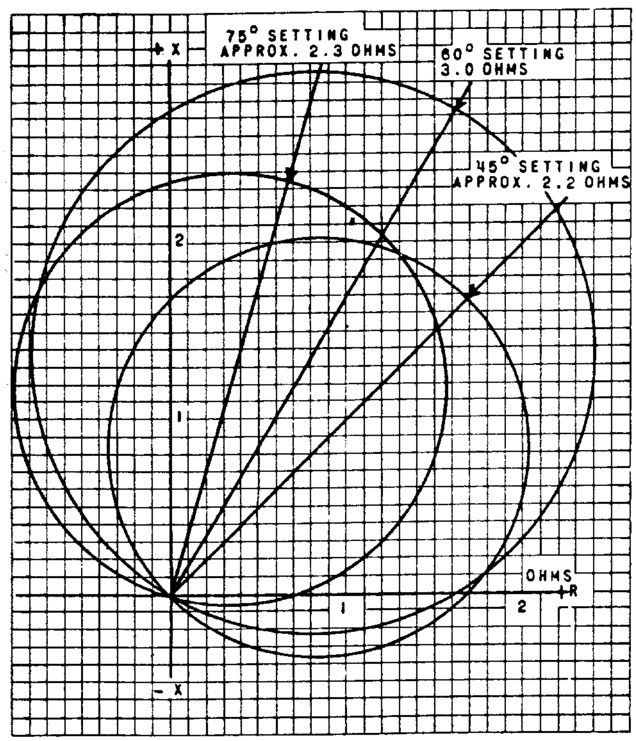

Fig. 6 Minimum Static Operating Characteristic of M_1 Unit.

Fig. 4 (389A787)

Fig. 5 (389A787)

Fig. 6 (K-6556578)

OPERATING CHARACTERISTICS

M_1 UNIT

The minimum operating characteristics of the M_1 Unit are shown in Fig. 6. The relay is adjusted at the factory so that the 60 degree setting has a three ohm diameter, as shown by the heavy circle when the terminal voltage of the relay is supplied directly to the restraint circuit of the M_1 unit. This circle can be enlarged by reducing the percentage of the terminal voltage which is supplied to the restraint circuit by means of the No. 1 taps on the autotransformer. The circle will always pass through the origin and have a diameter along the 60 degree impedance line equal to the ohmic reach as expressed in equation (1) below:

$$\text{Ohmic Reach} = \frac{\text{(Input tap) Z min}}{\text{No. 1 tap setting (\%)}} \qquad (1)$$

Where:

Input Tap = Input tap setting in percent (Normally is 100 except as explained under "Adjustment and Tests")

No. 1 tap setting (%) = E^2 or voltage restraint tap setting in percent. Z_{min} = minimum phase-to-neutral ohmic reach of the relay value of which is given on the relay nameplate.

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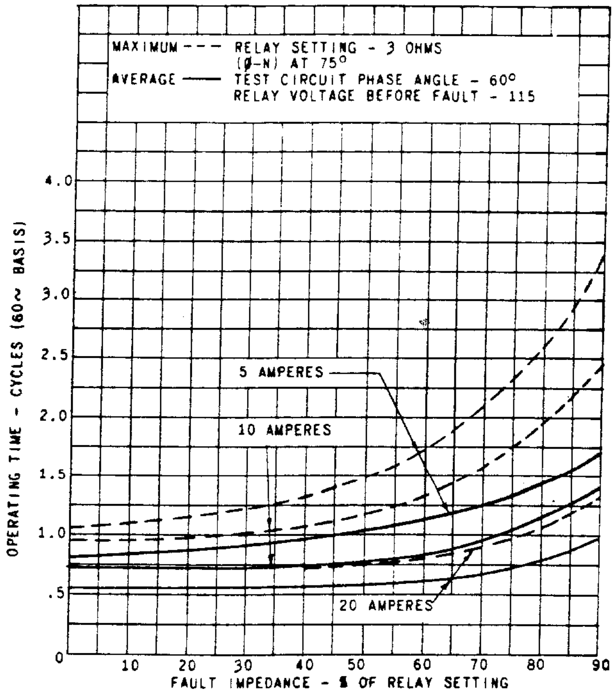

Fig. 7 Operating Times of M_2 Unit Set for 3 Ohms At 75 Degrees.

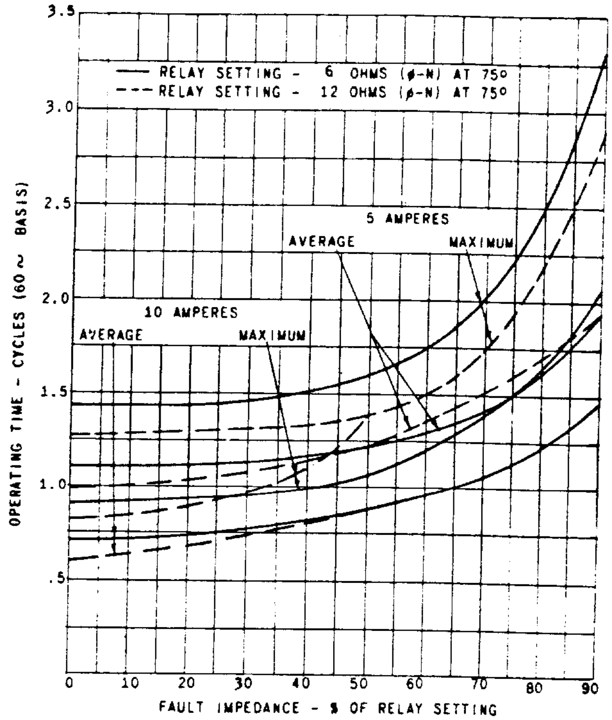

Fig. 8 Operating Times of M_2 Unit Set for 6 and 12 Ohms At 75 Degrees.

For a 3-30 ohm relay set at 100 percent input, ohmic reach and No. 1 tap setting at 100 percent the ohmic reach is 3 ohms.

Two other settings of the angle of maximum torque are provided, 75 degrees (70 for 50 cycle rating) and 45 degrees. These settings are adjusted at the factory for the correct angle, but there is a slight variation from relay to relay in the ohmic reach at each of these angles. For the magnitude of this variation, refer to Table I.

For a given setting of the relay, the ohmic value at which the M_1 unit will operate may be somewhat lower than the calculated value as is indicated by the static curve of Fig. 2. This curve shows the change in the restraint autotransformer tap setting at which the relay will just operate for a constant fault impedance as a function of voltage. This data is most easily checked by test, and is indicative of the change in ohmic value at which the relay will just operate for a constant restraint setting as a function of voltage, which is the actual operating condition. It will be noted that the percentage change for a given voltage is practically independent of whether a high or low value of restraint tap setting is being used. The dynamic curve of Fig. 2 illustrates the effect of the memory action in the mho unit which maintains the polarizing voltage on the unit for a few cycles after the inception of the fault insuring a high torque for even a zero voltage or very close-in fault.

The operation of the M_1 unit under transient conditions at the inception of a fault is important because the relay is normally connected so that the M_1 contacts will trip a breaker independently of any other contacts. The curves shown in Fig. 6 and the static curves of Fig. 2 represent steady-state conditions. Fig. 3 indicates the extent to which the M_1 unit may overreach, i.e., close its contacts momentarily when the impedance being measured is greater than that for which the contacts close under steady-state conditions. Maximum transient overreach, occurs when a fault occurs at the one instant, in either half of a cycle, which produces the maximum amount of d-c offset to the current wave. If the fault occurs midway between these two instants, there is no transient overreach.

The M_1 unit is carefully adjusted to have correct directional action under steady-state low voltage and current conditions. For faults in the tripping direction the unit will close its contacts at 1.5 volts and between 2 and 60 amperes. The minimum closing current for the 1 and 2 ohm units are 6 and 3 amps respectively. For faults in the non-tripping direction the contacts will remain open at zero volts and between 0 and 60 amperes. The unit will also have the correct directional action.

Under transient low voltage conditions where memory action is present, the unit (3 ohm) will close its contacts at zero-fault voltage and 3 to 150 amperes in the tripping direction, provided the voltage is normal at 115 volts before the fault occurs. The minimum current value will be 9 amperes and 6 amperes for the 1 and 2 ohm units respectively.

Fig. 9 (K-6556578)

The speed of operation of the M_1 unit is also dependent upon the phase angle of the current circuit and the instant at which a fault occurs. The curves of operating times shown in Figs. 4 and 5 indicate the average operating times and the maximum times.

The time curves in Figs. 4 and 5 apply to the 3-30 ohm rel::ys. They can be adapted to the 1-10 and 2-20 ohm relays at corresponding percentage tap settings by multiplying the operating currents shown on the curves by 3 and 1.5 respectively. For example the time-current curve for a one ohm relay at 50 percent tap (2 ohms) setting and 15 amperes will be the same as the 3 ohm relay set for 6 ohms (50 percent tap setting) and at 5 amperes.

M_2 UNIT

The minimum operating characteristics of the M_2 unit are shown in Fig. 9. The relay is adjusted for the 75 degree setting of 3.0 ohms as shown. As in the case of M_1 unit, this circle can be expanded, always passing through the origin and with a diameter along the 75 degree line equal to the ohmic reach as expressed below. In the case of M_2 unit, the restraint adjustment is made by means of the No. 2 taps.

$$\text{Ohmic Reach} = \frac{(\text{Input Tap})(\text{Z min})}{\text{No. 2 Tap Setting (\%)}} \qquad (2)$$

The angle of maximum torque can be adjusted continuously from 75 deg::es to 60 degrees. This involves a decrease in the ohmic reach as indicated by the circle of the 60 degree setting in Fig. 9. There are slight variations from relay to relay in the minimum ohmic reach of the M_2 unit when not set on 75 degrees, as indicated also in Table I.

The accuracy of the M_2 unit under static and dynamic conditions as a function of voltage is the same as that of the M_1 unit, Fig. 2.

Change in minimum ohmic reach at 115 volts with change in angle of maximum torque.

This data can be applied to the 1-10 and 2-20 ohm relays by multiplying the values by 1/3 and 2/3 respectively.

TABLE I

Angle of Maximum Torque	Freq.	Minimum Ohmic Reach Z_M	
		M_1	M_2 & OM_3
75 deg.	60	2.23 to 2.44	2.94 to 3.06
70 deg.	60	-	2.82 to 2.97
65 deg.	60	-	2.64 to 2.87
60 deg.	60	2.94 to 3.06	2.37 to 2.78
45 deg.	60	2.10 to 2.20	-
75 deg.	50	-	2.94 to 3.06
70 deg.	50	2.35 to 2.50	2.82 to 2.97
65 deg.	50	-	2.64 to 2.87
60 deg.	50	2.94 to 3.06	2.37 to 2.78
45 deg.	50	2.35 to 2.50	-

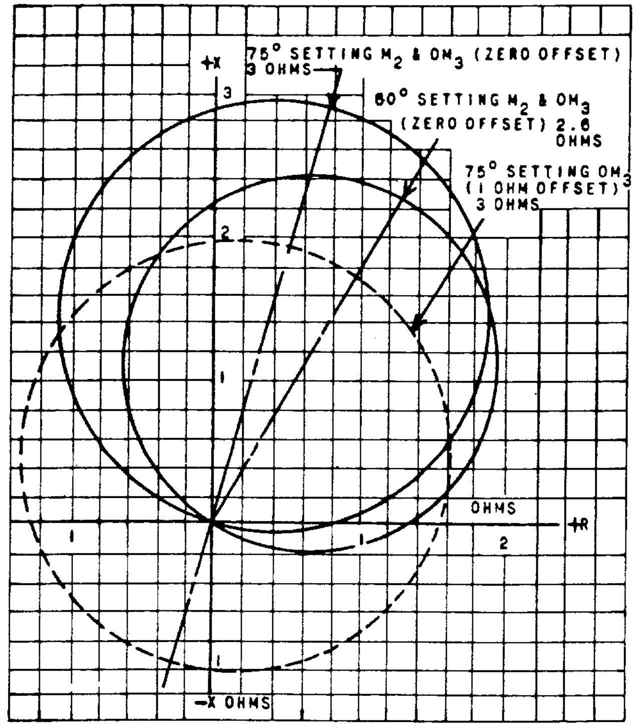

Fig. 9 Minimum Static Operating Characteristics of M_2 and OM_3 Units.

It is not necessary to reduce the transient overreach in the M_2 unit because it operates to trip through time delay contacts or as the directional unit in a carrier-current relaying scheme, and it has correct directional action for nearby faults under transient conditions. The average operating times are consequently faster than those of the M_1 unit as is shown by Figs. 7 and 8.

These time curves can be adopted to the 1-10 and 2-20 ohm relays at corresponding percentage tap settings by multiplying the operating currents shown on the curve by 3 and 1.5 ohms respectively as previously described in the section on the M_1 unit.

The M_2 unit is carefully adjusted to have the correct directional action under steady-state low voltage and current conditions. For faults in the tripping direction, the unit will close its contacts at 1.5 volts and between 2 and 60 amperes. The minimum closing current for the 1-10 and 2-20 ohm relays is 6 and 3 amps respectively. For faults in the non-tripping direction the contacts will remain open at 0 volts and between 0 and 60 amperes. The unit will also have the correct directional action under transient low voltage conditions where memory action is present. The unit will close its contacts for faults in the tripping direction at zero fault voltage and 5 to 150 amperes, provided the voltage is normal at 115 volts before the fault occurs.

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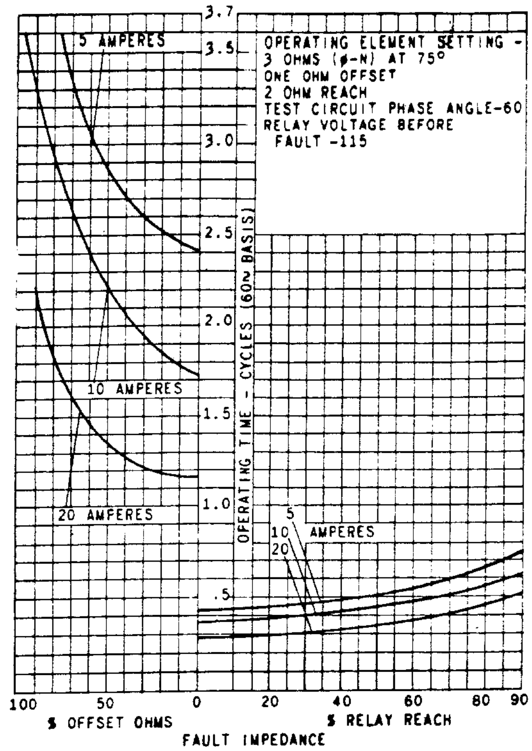

Fig. 10 Average Operating Times of Normally Closed Contacts on M_3 Unit.

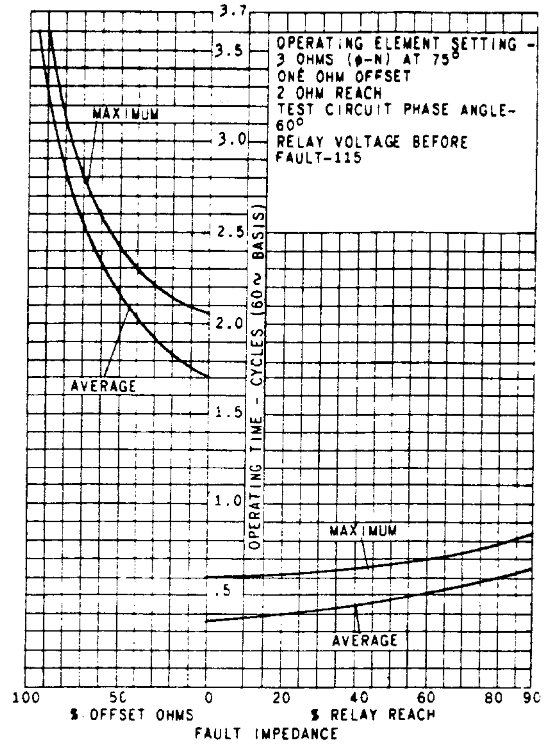

Fig. 11 Operating Times of Normally Closed Contact of OM_3 Unit at 10 Amperes Fault Current.

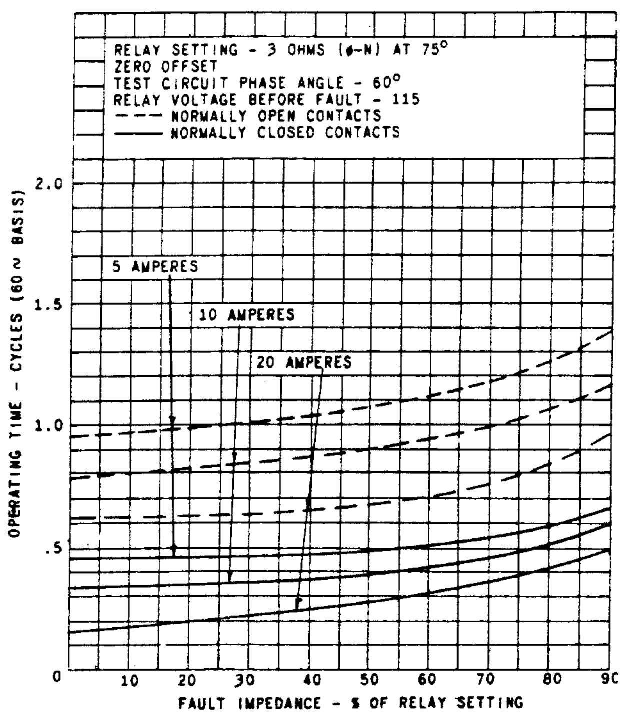

Fig. 12 Operation Times of OM_3 Unit Set for 3 Ohms At 75 - Degrees Offset

OM3 UNIT

The OM3 unit is similar to the M2 unit with the addition of a transactor. The transactor is an air gap reactor with a secondary winding for obtaining the desired voltage at a given primary current without the attendant high current burden, and also for obtaining electrical insulation. By adding the transactor secondary voltage in series with the terminal voltage and applying the vector sum to the operating unit, the effect is to offset the ohmic characteristic without changing its diameter.

The connections shown in Fig. 19 cause the offset to be in the direction to include the origin instead of pass through it. This enables the OM3 unit characteristic to be adjusted to be approximately concentric with the M2 unit characteristic for use in recognizing out-of-step conditions when used as a three-step distance relay. When used as part of a carrier-current scheme in which the OM3 unit turns on the carrier signal, the offset provides continuous operating torque during a low voltage fault.

Taps are provided on the transactor secondary winding in order to obtain 0, 1, 2, 3, or 4 ohms offset. For an ordinary third step distance setting with no out-of-step blocking, zero offset may be used.

Fig. 13 (K-6556577)

Fig. 14 (K-6556575)

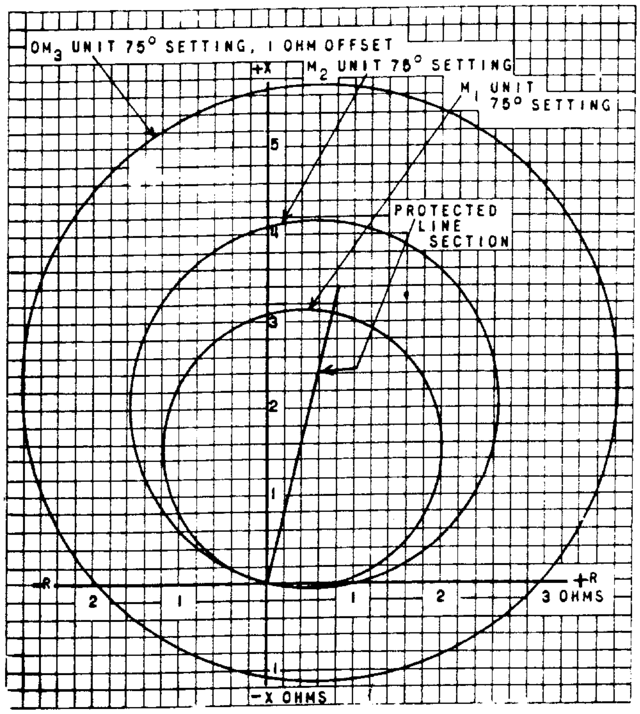

Fig. 13 Typical Static Operating Characteristics of the Type GCY12A Relay with Forward OM3 Unit

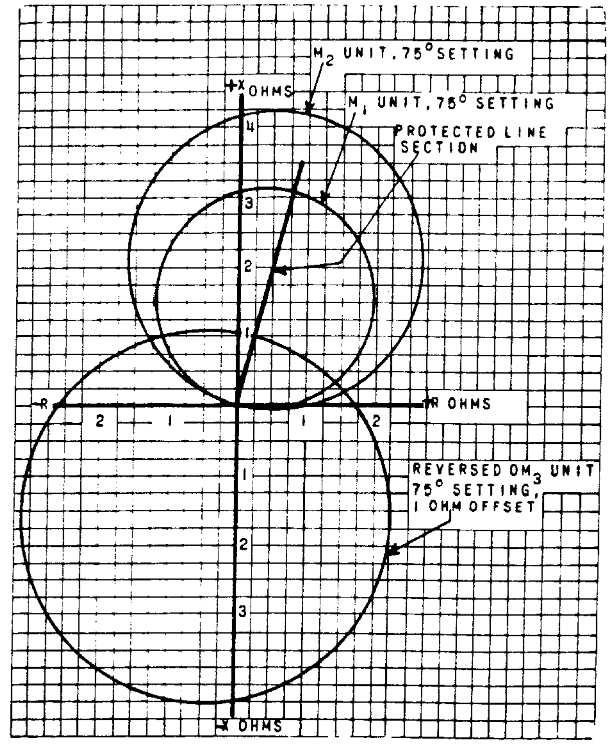

Fig. 14 Typical Static Operating Characteristics of the Type GCY12A Relay with Reversed OM3 Unit

Referring to Fig. 9, the OM3 unit characteristic at 75 degrees with zero offset is the same as the M_2 unit characteristic. By using the one ohm offset tap, the circle is moved one ohm along its 75 degree characteristic line as shown by the dashed circle.

In the same manner as for the M_1 and M_2 units, this circle can be expanded by reducing the voltage supplied to the restraint circuit. To accomplish this, use is made of the No. 3 taps, by means of which five per cent steps of the voltage are available. In the case of the OM3 unit the diameter of the circle will be called the "ohmic setting" instead of the "ohmic reach", consequently the ohmic reach may be defined as the ohmic setting reduced by the ohmic offset. Thus for circles with the 75 degree line as a diameter.

$$\text{Ohmic Setting} = \frac{\text{(Input Tap) Z min}}{\text{No. 3 Tap Setting (\%)}} \qquad (3)$$

When zero offset is used, these circles all pass through the origin as in the M_1 and M_2 units. When one ohm offset is used, these circles continue to pass through a common point which has moved to a point one ohm away from the origin as shown in Fig. 9 by the dashed circle.

The direction of the zero offset characteristic can be adjusted from the 75 degrees setting to any angle down to the 60 degrees setting shown in Fig. 9. This is exactly the same as the M_2 unit, and will have the same variation, in minimum ohmic setting as is indicated in Table I. This adjustment is made by decreasing the resistance in R_{33} plus R_{43}. If no change is made in the setting of R_{63}, and if no offset is used, the new circle initially, at 60 degrees for example, will be shifted along a 75 degrees line. In order to have the offset along a 60 degrees line, the resistance of R_{63} must be reduced.

As in the case of the M_2 unit, no attempt has been made to limit the transient overreach of the OM3 unit. The unit is adjusted to have the correct directional action under steady-state low voltage and current conditions. For faults in the tripping direction the unit will close its contacts at 6 volts and between 3 and 60 amperes. For faults in the non-tripping direction, the contacts will remain open at 0 volts and between 0 and 60 amperes.

Operating times for the OM3 unit are shown in Figs. 10, 11, and 12.

Fig. 12 shows average operating times for the unit with zero offset and minimum reach (maximum restraint). Fig. 10 shows the average times for opening the normally closed contacts, also on the minimum setting, but with one ohm offset, the correspondingly less reach. It will be noted that plotting fault impedance in percent of the unit's reach causes the curves of the operating time for faults in the direction of the unit's setting (i.e., the direction in which the unit operates with zero offset) to

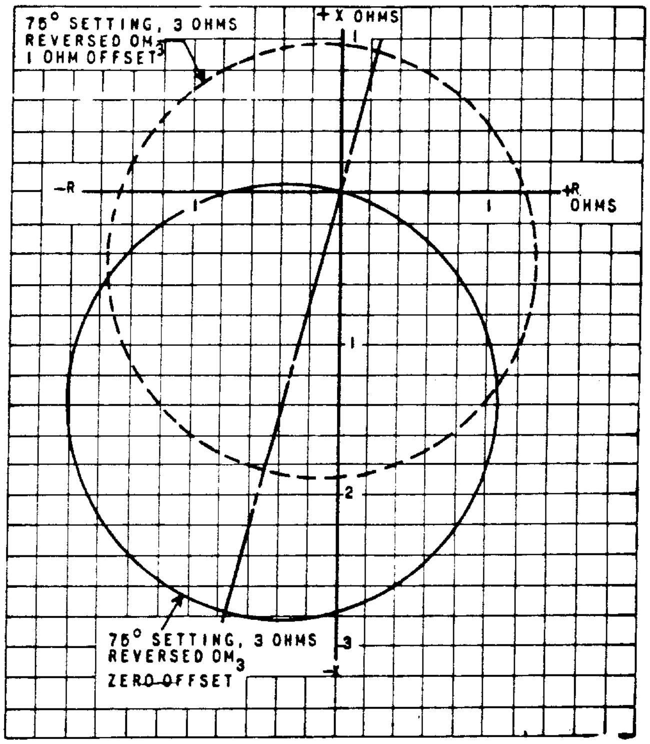

Fig. 15 Minimum Static Operating Characteristics of Reversed OM_3 Unit.

be very nearly the same with or without offset. The one ohm offset causes the reach to be reduced, so that in order to obtain the same reach, the ohmic setting must be increased by reducing the restraint voltage. Any reduction in restraint causes a slight reduction in operating time, so that the curves of Fig. 12 are suitable for general use with zero offset and the curves of Fig. 10 are suitable for general use with one ohm offset.

The use of more than one ohm offset will not appreciably change the operating times for faults in the direction of the unit's setting when plotted in percent of the unit's reach, and will somewhat reduce the operating times for faults in the offset direction when plotted as percent of the ohmic offset. Therefore it is impossible to make general use of the curves of Fig. 10 for any setting using offset.

Fig. 11 shows a typical spread between the average operating times, and maximum operating times of the normally closed contacts.

It will be noted that the speed of the OM_3 unit is considerably greater for faults in the direction of the OM_3 unit setting (i.e., the direction of the OM_3 unit's ohmic characteristic with zero offset) than for faults in the offset direction. This is caused by the strong initial "memory action" which is present in all three units to insure positive directional action when the voltage is suddenly reduced to zero. In order to obtain high speed for turning on carrier current, when used, the polarity of the OM_3 unit should be reversed and offset any amount desired up to one-half the ohmic setting of the unit. It is recommended that some offset always be used for carrier-current relaying applications otherwise, there may be poor contact action after the memory action has disappeared.

This connection, with the direction of the OM_3 unit opposite to that of the other two units, is known as the "reversed OM_3 connections". The characteristics for this connections are illustrated by the two curves of Fig. 15. All the preceding description of the OM_3 unit for the forward connections applies to the reversed connection except that everything is rotated 180 electrical degrees. Figs. 13 and 14 illustrate the characteristics of the three units, with OM_3 connected for forward and reverse connections, respectively, as they would appear on a typical application for transmission line protection.

RATINGS

The Types GCY12 relay is available for 115 volts, 5 amperes, 50 or 60 cycle ratings. The basic range of ohmic adjustment is 3 to 30 ohms, phase-to-neutral, when set with the factory angular adjustments, M_1 on 60 degrees, M_2 and OM_3 on 75 degrees.

Other ranges of 1-10 and 2-20 ohms are available for the M_1 and M_2 units. The ohmic setting of M_1 and M_2 units can be made in one percent steps, and the setting for the OM_3 unit in 5 percent steps.

The current closing contacts of the relays will close and carry momentarily 30 amps d-c. The breaker trip circuit, however, should always be opened by an auxiliary switch or suitable means; it cannot be opened by the tripping relay contacts or by the contacts of the units. The combination target and seal-in unit has a dual rating of 0.6/2.0 amperes.

The tap setting used on the target and seal-in unit is determined by the current drawn by the trip coil. The 0.6 ampere tap is used with trip coils which operate on currents ranging from 0.6 amperes to 2.0 amperes at the minimum control voltage while the 2.0 amperes tap should be used when trip currents are greater than 2.0 amperes. It is not good practice to use the 0.6 ampere tap when the trip current is greater than 2.0 amperes since the 0.6 ohm resistance of the 0.6 ampere tap will cause an unnecessarily high voltage drop which will reduce the voltage of the circuit breaker trip coil. If the tripping current should exceed 30 amperes it is recommended that an auxiliary tripping relay be used.

TARGET SEAL-IN UNIT

TABLE II

Function	Amperes AC or DC	
	2-Amp Tap (0.3 ohms)	0.6 Amp Tap (0.6 ohms)
Carry for Tripping Duty	30	6
Carry Continuously	4	0.8
Min. Target Operating Current	2	0.6

The normally closed contacts of the OM3 unit will close, carry continuously, and open 0.3 amperes in non-inductive circuits up to 250 volts.

BURDENS

Because of the presence of the transactor in the relay the ohmic burdens imposed upon the current and potential transformers by the OM_3 unit are not constant, but vary somewhat with the ohmic reach, amount of offset, and current. This variation is of little importance to the current transformer, so that a formula for calculating only the potential burden will be given.

CURRENT CIRCUITS

The maximum current burden imposed on each C.T. by a practical setting on a three-phase terminal of three GCY relays, 3-30 ohm range, at 5 amperes, and rated frequency:

Freq.	Watts	Vars	Volt-Amperes
60	10.7	13.5	17.2
50	11.1	11.9	16.3

This corresponds to:

Freq.	R	X	Z
60	0.43	0.54	0.69
50	0.44	0.48	0.65

The above burden was measured under phase-to-phase fault conditions which yields higher burden readings than balanced three-phase conditions. Also any other change caused by different conditions in the OM_3 unit will cause the burden to be slightly less than indicated.

The current burden of the 1-10 ohm relay is approximately 50 percent and the 2-20 ohm relay is 70 percent of the above figures.

POTENTIAL COILS

The maximum potential burden imposed on each P.T. by a practical setting on a three-phase terminal of three GCY relays at 115 volts, 5 amperes and rated frequency is as follows for the 1-10, 2-20, and 3-30 ohm relays

Freq.	Watts	Vars	Volt Amperes
60	41.0	13.5	43
50	36.7	16.0	40

The potential burden of all three units is altered by changing the restraint setting in order to choose the proper reach. In order to present equations for calculating the burden, the following symbols will be used:

$W_1 + jV_1$ = Volt-amperes in M_1

$W_2 + jV_2$ = Volt-amperes in M_2

$W_3 + jV_3$ = Volt-amperes in OM_3

E = Relay terminal voltage

Z_O = Ohmic offset (secondary)

Z_L = Ohms thru the fault or load (secondary)

Z_3P = Self impedance of OM_3 potential circuits

No. 1 = Setting of No. 1 (M_1) restraint taps in per cent.

No. 2 = Setting of No. 2 (M_2) restraint taps in per cent.

No. 3 = Setting of No. 3 (OM_3) restraint taps in per cent.

The burden for any set of conditions can be computed by using the equations below.

In equation (7) the difference in the angles of Z_O and Z_L may be neglected, so that the volt-ampere burden of the OM_3 unit is the conjugate of E^2/Z_{3P}, where Z_{3P} is a complex value computed from the circuit impedance and the mutual coupling with the current circuits of $1 \pm Z_O/Z_L$, where the scalar value of Z_O/Z_L may be used.

The choice of the positive or negative sign in the correction factor ($1 \pm Z_O/Z_L$) is listed in Table III below.

TABLE III

Direction of Fault Referred to M_1 & M_2	* OM_3 Direction	Sign
Trip	Forward	+
Trip	Reverse	-
Non-trip	Forward	-
Non-trip	Reverse	+

* Neglecting Offset

POTENTIAL BURDEN EQUATIONS

60 CYCLE RATING

$$\text{Total Burden} = W_1 + W_2 + W_3 + j(V_1 + V_2 + V_3) \quad (4)$$

$$W_1 + W_2 = 15.7 + \left(\frac{\text{No. 1}}{100}\right)^2 (5.4) + \left(\frac{\text{No. 2}}{100}\right)^2 (6.3) \quad (5)$$

$$V_1 + V_2 = 0.8 + \left(\frac{\text{No. 2}}{100}\right)^2 (7.0) \quad (6)$$

$$W_3 - jV_3 = \frac{(115)^2}{Z_{3P}}\left(1 \pm \frac{Z_O}{Z_L}\right) \quad (7)$$

(see Table III for sign)

$$Z_{3P} = \frac{1900\ (952 + j\ 1050)}{(\text{No. 3})^2\ (0.19 + jo) + 952 + j1050} + Z_O^2\ (4.5 + j14.5) \quad (8)$$

50 CYCLE RATING

$$W_1 + W_2 = 14.6 + \left(\frac{\text{No. 1}}{100}\right)^2 (4.5) + \left(\frac{\text{No. 2}}{100}\right)^2 (5) \quad (5A)$$

$$V_1 + V_2 = 1.0 + \left(\frac{\text{No. 2}}{100}\right)^2 (6.5) \quad (6A)$$

$$Z_{3P} = \frac{1000\ (1435 + j2550)}{(\text{No. 3})^2\ (0.192 + j.0278) + 890 + j1160} + Z_O^2\ (5.4 + j17.4) \quad (8A)$$

RECEIVING, HANDLING AND STORAGE

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

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

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

DESCRIPTION

GENERAL CONSTRUCTION

The mho units of the GCY12A relay are of the four pole induction cylinder construction. The schematic connections for this unit are shown in Fig. 16. The two side poles, energized with phase-to-phase voltage, produce the polarizing flux which interacts with the flux produced in the back poles energized with a percentage of the same voltage to produce the restraint torque in the relay. The flux produced in the front pole, energized with the two line currents associated with the phase-to-phase voltage used, interacts with the polarizing flux to produce the operating torque. The torque equation at pickup is therefore:

$$T = O = EI \cos(\phi - \theta) - KE^2$$

where E is the phase-to-phase voltage

I is the delta current $(I_1 - I_2)$

θ is the angle of maximum torque of the relay.

ϕ is the power factor angle

K is a design constant

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

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

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

The mho unit contacts are of fine silver for low contact resistance and are of the ideal design of two cylinders at right angles, which provides a point contact without using an actually pointed contact. To protect the contacts from damage caused by high operating torques under short circuit conditions, a felt clutch is provided between the shaft and the contact arm.

A combination target and seal-in element is mounted at the top of the relay and is connected in series with the tripping circuits.

Fig. 1, shows the locations of the component parts of the relay visible when the relay is removed from its case.

CASE

The case is suitable for surface or semiflush panel mounting and an assortment of hardware is provided for either method. The cover attaches to the case and carries the reset mechanism when one is required. Each cover screw has provision for a sealing wire.

The case has studs or screw connections at both ends for external connections. The electrical connections between the relay units and the case studs are made through spring backed contact fingers mounted in stationary molded inner and outer blocks between which nests a removable connection plug which completes the circuits. The outer blocks, attached to the case, have the studs for the external connections, and the inner blocks have the terminals for the internal connections.

The relay mechanism is mounted in a steel framework called the cradle and is a complete unit with all leads terminating at the inner block. This cradle is held firmly in the case with a latch at the top and the bottom and by a guide pin at the back of the case. The case and cradle are so constructed that the relay cannot be inserted in the case upside down. The connecting plug, besides making the electrical connections between the blocks of the cradle and case, also locks the latch in place. The cover, which is fastened to the case by thumbscrews, holds the connecting plug in place.

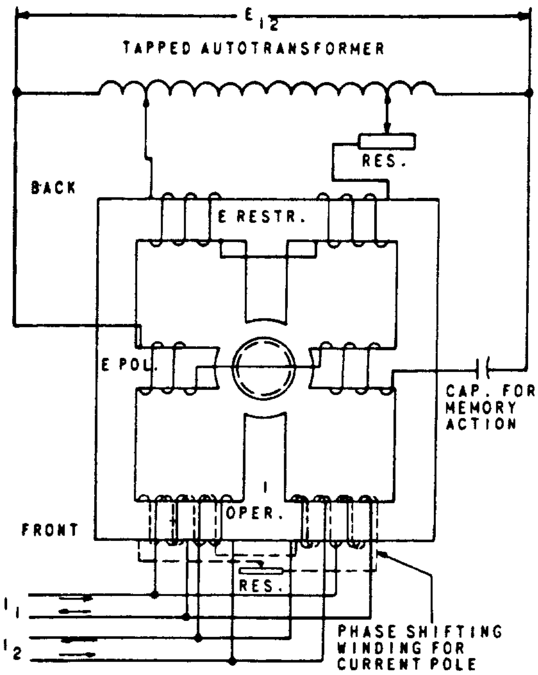

Fig. 16 Schematic Connections of the MHO Units Assciated with Phase 1-2 (Top View)

Fig. 16 (K-6556581)

To draw out the relay unit, the cover is removed and the plug is drawn out. Shorting bars are provided in the case to short the current transformer circuits. The latches are then released, and the relay unit can be easily drawn out.

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

INSTALLATION

LOCATION

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

MOUNTiNG

The relay should be mounted on a vertical surface. The outline and panel drilling is shown in Fig. 17.

The rotating structure of the mho units is not balanced, so that any slight torque caused by a tilt of the shaft when the relay is installed ready for operation should be compensated using the control spring adjusting arm at the top rear of the unit. First loosen the set screw on the front of the top pivot support, and rotate the control spring adjusting arm so as to return the contact arm to the right-hand contact (front view), or the backstop as the case may be, but without supplying enough torque so that the contact would move beyond this position if

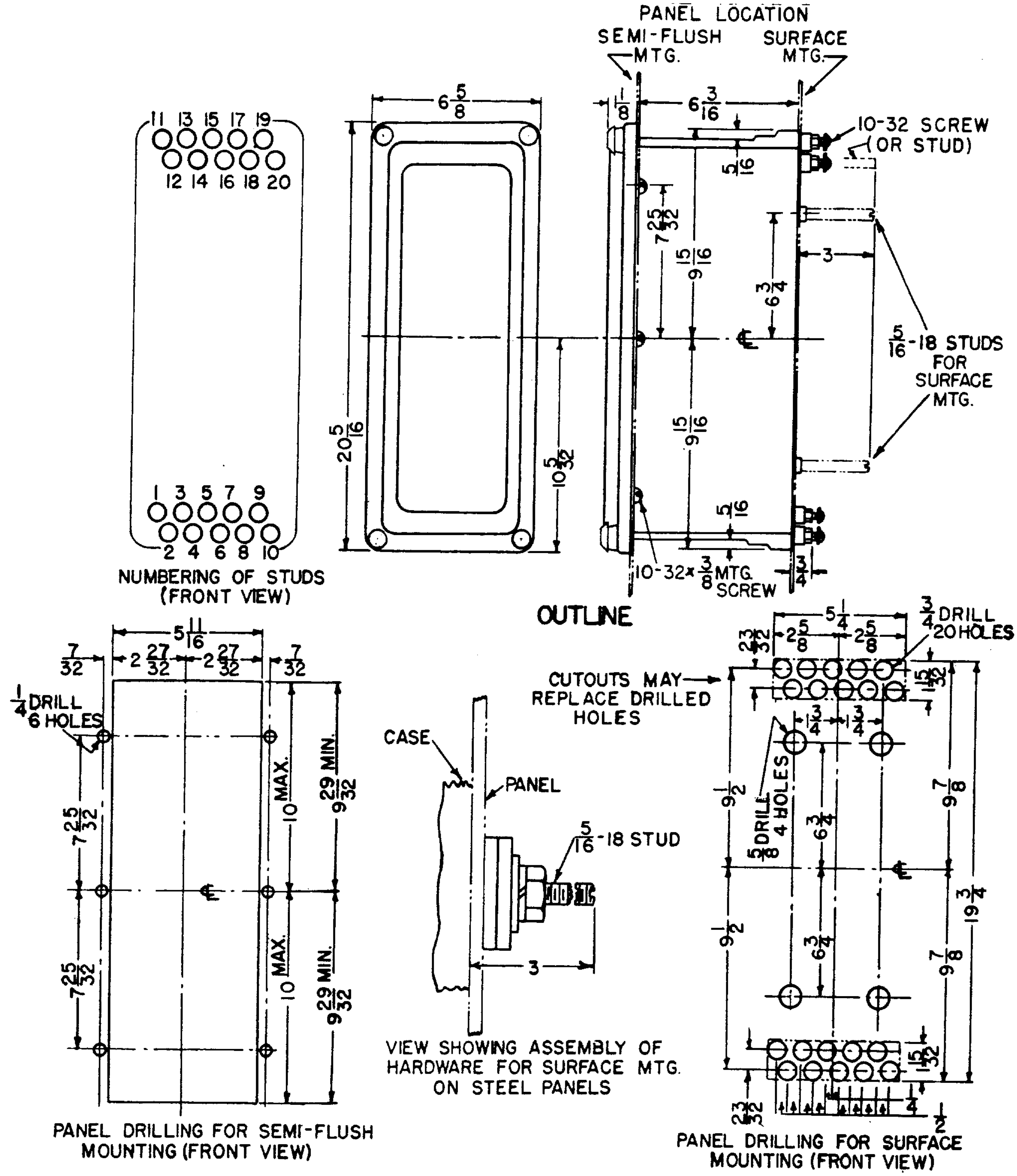

Fig. 17 Outline & Panel Drilling Dimensions for Type GCY12A Relay

the stationary contact or backstop were removed. Tighten the set screw permitting approximately 1/64 inch end play to the shaft.

CONNECTIONS

The internal connection diagram for the relay is shown in Fig. 18. A typical wiring diagram is given in Fig. 19.

One of the mounting studs or screws of each relay case should be permanently grounded by a conductor not less than No. 12 B & S gage copper wire or its equivalent.

ADJUSTMENTS AND TESTS

The relay is properly calibrated at the factory and it is not advisable to disturb the adjustments. If it is necessary to check the factory calibration of the units or to change the calibration, refer to the MAINTENANCE section of this book where detailed instructions are given under the SERVICING subsection.

The relay connection plugs should be inserted slowly to allow any transients to subside before the trip circuits are completed. When removing the plugs, the top plug should be removed first to preclude any possibility of inadvertently tripping the breaker.

To make the proper tap settings of the units, the following procedure may be used. To set the units by test, refer to the SERVICING subsection.

CAUTION: When making the relay tap setting make certain that the tap leads do not touch any other tap holes or tap leads. Otherwise, a portion of the autotransformer may be short-circuited.

M_1 UNIT

The connections for the jumpers to the A, B, C and D taps on the left-hand tap block determine the angular setting of the M_1 unit. The proper connections are shown in Fig. 18 for each angle.

The No. 1 tap setting is given by equation (9) where the following symbols are used:

Z_R = Ohmic reach at angular setting of unit

Z_M = Minimum ohmic reach at angular setting of unit (from Table I)

θ = Angular setting of Unit

Z_L = Desired ohmic reach at angle ϕ, if the angle ϕ and θ are different.

$$\text{No. 1 Tap Setting (\%)} = 100\, Z_M/Z_R \qquad (9)$$

$$Z_R = Z_L/\cos(\theta-\phi) \qquad (10)$$

These quantities are all in secondary ohms phase-to-neutral. Secondary ohms are determined from primary ohms by the relation:

$$Z_{SEC} = Z_{PRI} \times \frac{\text{CT ratio}}{\text{PT ratio}}$$

The setting calculated with equation (9) is made on the right-hand tap block. The lower jumper labeled No. 1 is connected to one of the ten per cent step taps on the lower half of the block, and the upper No. 1 jumper is connected to one of the eleven one percent step taps (either jumper may be connected to the zero tap) so that the sum of the two taps used is the desired setting. There are times when this setting may not be considered fine enough. It is often helpful to supply the in-put voltage to other than 90 plus 10 or 100 percent of the winding. Terminal voltage may be applied to a fractional part of the winding down to 90 per cent without damage to the autotransformer. This is accomplished by moving the lead, which is under the hexagonal stud in the top (10 per cent) tap, to one of the other taps on the upper half of the tap block. For example, with No. 1 taps on 75, and the in-put leads on 98, the No. 1 target setting per cent is 76.5.

CAUTION: Do not reduce the in-put setting below the out-put setting. This change in in-put for obtaining a finer adjustment of the No. 1 tap setting also effects the No. 2 tap setting.

M_2 UNIT

The ohmic reach can be set by calculation as in the case of the M_1 unit using equations (11) and (10) in which the symbols which are used have the same meaning as defined under the M_1 unit above (use correct value of Z_M from Table I.)

$$\text{No. 2 Tap Setting (\%)} = 100\, Z_M/Z_R \qquad (11)$$

$$Z_R = Z_L/\cos(\theta-\phi) \qquad (10)$$

OM_3 UNIT

The operating element of the OM_3 element has exactly the same circuit elements as the M_2 unit so that, with slight modifications, the procedure for adjustment will be the same.

If no offset is to be used, the restraint adjustment is the same as for the M_2 unit also, and the No. 3 tap setting can be made according to equations (12) and (10), where the correct value of Z_M should again be taken from Table I.

$$\text{No. 3 Tap Setting (\%)} = 100\, Z_M/Z_R \qquad (12)$$

$$Z_R = Z_L/\cos(\theta-\phi) \qquad (10)$$

When offset is to be used, the error of calculated settings may increase another 5 per cent, but this is acceptable in many cases. The setting of the OM_3 unit, defined as the diameter of its ohmic characteristic, becomes equal to the sum of the ohmic reach plus the offset. There is an appreciable increase in the ohmic setting for a given No. 3 tap

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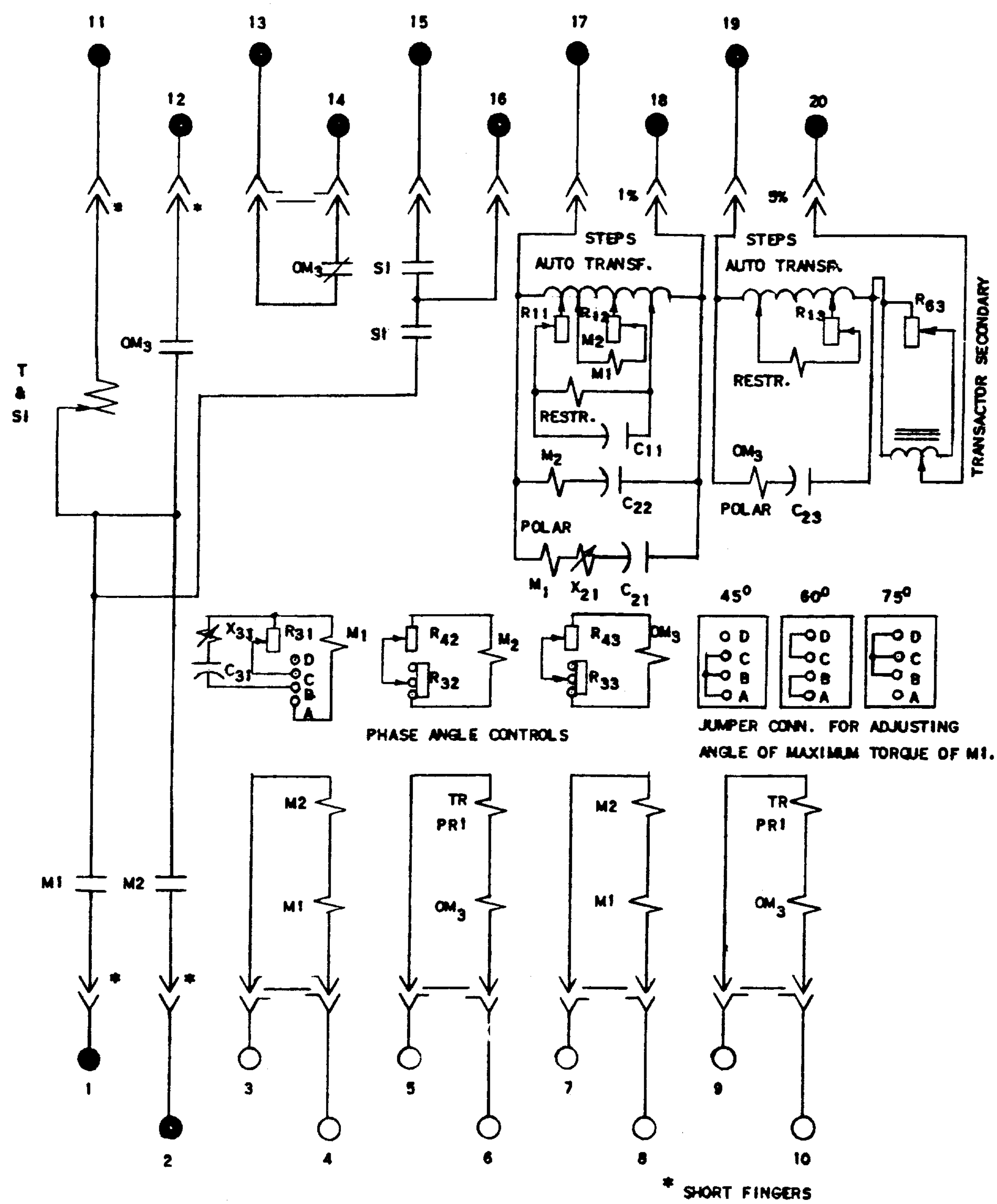
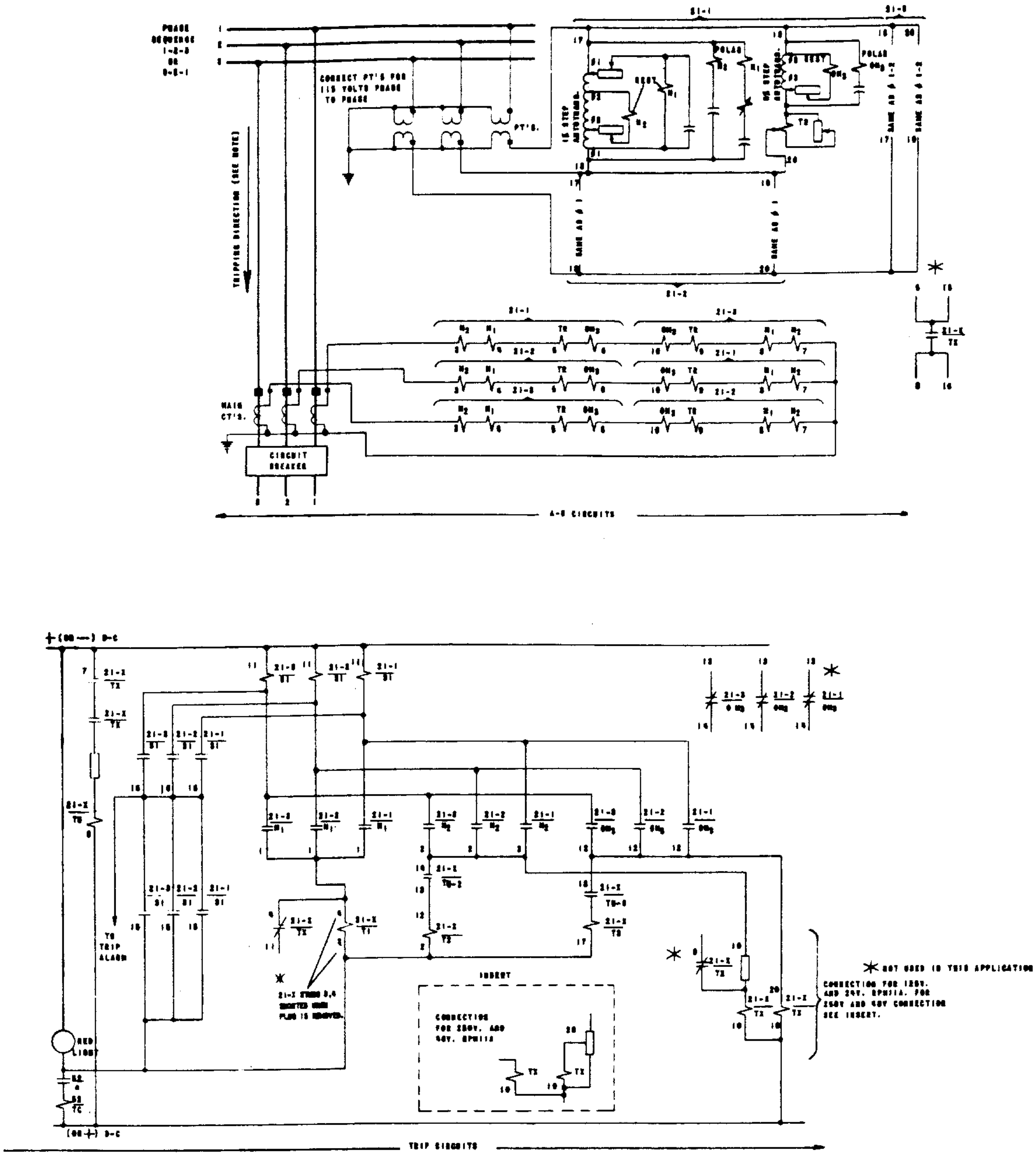


Fig. 18 Internal Connections for Type GCY12A Relay



DEVICE FUNCTION NUMBERS AND SYMBOLS		
SYMBOL	ON DEVICE	DESCRIPTION
A		AUXILIARY SWITCH ON CIRCUIT BREAKER
M_1	GCY	MHO UNIT ZONE 1
M_2	GCY	MHO UNIT ZONE 2
OM_3	GCY	MHO UNIT ZONE 3
SI	GCY	SEAL-IN
T		TARGET
TC		CIRCUIT BREAKER TRIP COIL
TR	GCY	TRANSACTOR
TU	RPM	TIMING UNIT
TX	RPM	TIMING UNIT AUXILIARY
21-1	GCY	PHASE 1 DISTANCE RELAY
21-X	RPM	TIMING RELAY
52		CIRCUIT BREAKER

NOTE: TO REVERSE TRIPPING DIRECTION OF OM_3 REVERSE PT CONNECTIONS TO STUDS 19 AND 20 ON ALL THREE PHASES.

DRAWING REFERENCES		
DEVICE	INT. CONNS.	OUTLINE
GCY	K-[illegible]	K-[illegible]
RPM 250V 48V	K-[illegible]	K-[illegible]
RPM 125V 24V	K-[illegible]	

Fig. 19 Typical Wiring Diagram for Type GCY12A Relay

Fig. 19 (7021B56)

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setting as offset is used. This varies with the No. 3 tap setting and the offset, but can be approximated as a 7 per cent increase in the diameter of the ohmic characteristic for practical settings. Using this approximation, the setting of the No. 3 taps, when offset is used, can be calculated from equations (13) and (14) when the angular settings of the operating element and the transactor are the same.

$$\text{No. 3 Tap Setting } (\%) = 107\, Z_M/(Z_O + Z_R) \qquad (13)$$

Z_O = ohmic offset

$$Z_R = \frac{Z_L^2 + Z_O Z_L \cos(\theta - \phi)}{Z_O + Z_L \cos(\theta - \phi)} \qquad (14)$$

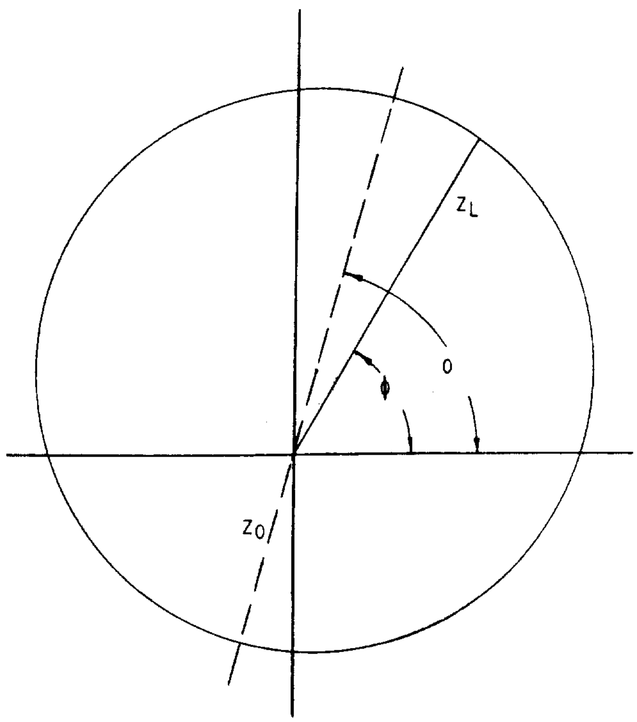

Fig. 20 Static Characteristic Of OM_3 Unit Showing Angular Relationship Of Impedance Quantities In Equation 14

TARGET AND SEAL-IN UNIT

The choice of tap on the target and seal-in unit is described above under RATINGS. To change this tap, the spare screw above the left contacts should be inserted into the vacant tap on the right-hand contact, and the other screw removed and placed in the spare position. Do not leave screws in both taps on the right-side of the unit.

OVERALL TESTS

Overall tests on current transformer polarities relay connections, and wiring can be made on the complete installation. Referring to Fig. 21, a check of the indicated phase angle meter readings will indicate that the relay is receiving the proper voltages and currents from the connections to the current and potential transformers for the conventional connections of Fig. 19.

A calibration check can be made on the units if power is flowing into the protected line section of the relay. By reading load and power factor, the impedance Z_L and its phase angle ϕ as seen by the relay can be calculated. The No. 1, No. 2 and No. 3 tap settings for operation at this point can be calculated from the equations given under the unit adjustments above. The various tap settings can be reduced until the associated unit operates, and this observed value compared with the calculated value. So long as the impedance Z_L intersects the ohmic characteristic at an angle close to 90 degrees, the observed and calculated tap settings should check within 10 per cent for the No. 1 and No. 2 tap settings and 15 per cent for the No. 3 taps.

A shorter test which will check for most of the possible open circuits in the a-c portion of the relay is as follows: Remove the lower connection plug disconnecting the current circuits. All units should have strong torque to the right when full voltage is applied. Replace the lower plug and open up the No. 1, No. 2 and No. 3 taps.

All units should operate if power and reactive flow are away from the station bus and into the protected line section (OM3 set with zero offset). If the direction of reactive power flow is into the station bus, the resultant phase angle may be such that the units will not operate.

ELECTRICAL CHECK TESTS ON THE MHO UNITS

The manner in which reach settings are made for the ohm and mho unit is briefly discussed in the introduction of these instructions. It is the purpose of the electrical tests in this section to check the ohmic pickup at the settings which have been made for a particular line section.

To eliminate the errors which may result from possible instrument inaccuracies a test circuit has been selected which requires no instruments. Such a circuit is shown in Fig. 25. In Fig. 25 $R_S + jX_S$ is the source impedance, S_F is the fault switch and $R_L + jX_L$ is the impedance of the line section for which the relay is being tested. The autotransformer, TA, which is across the fault switch and line impedance is tapped in 10 per cent and 1 per cent steps so that the line impedance $R_L + jX_L$ may be made to appear to the relay very nearly as the actual line on which the relay is to be used. This is necessary since it is not feasible to provide the portable test reactor, X_L, and the test resistor with enough taps so that the combination may be made to match any line.

Fig. 20 (402A939)

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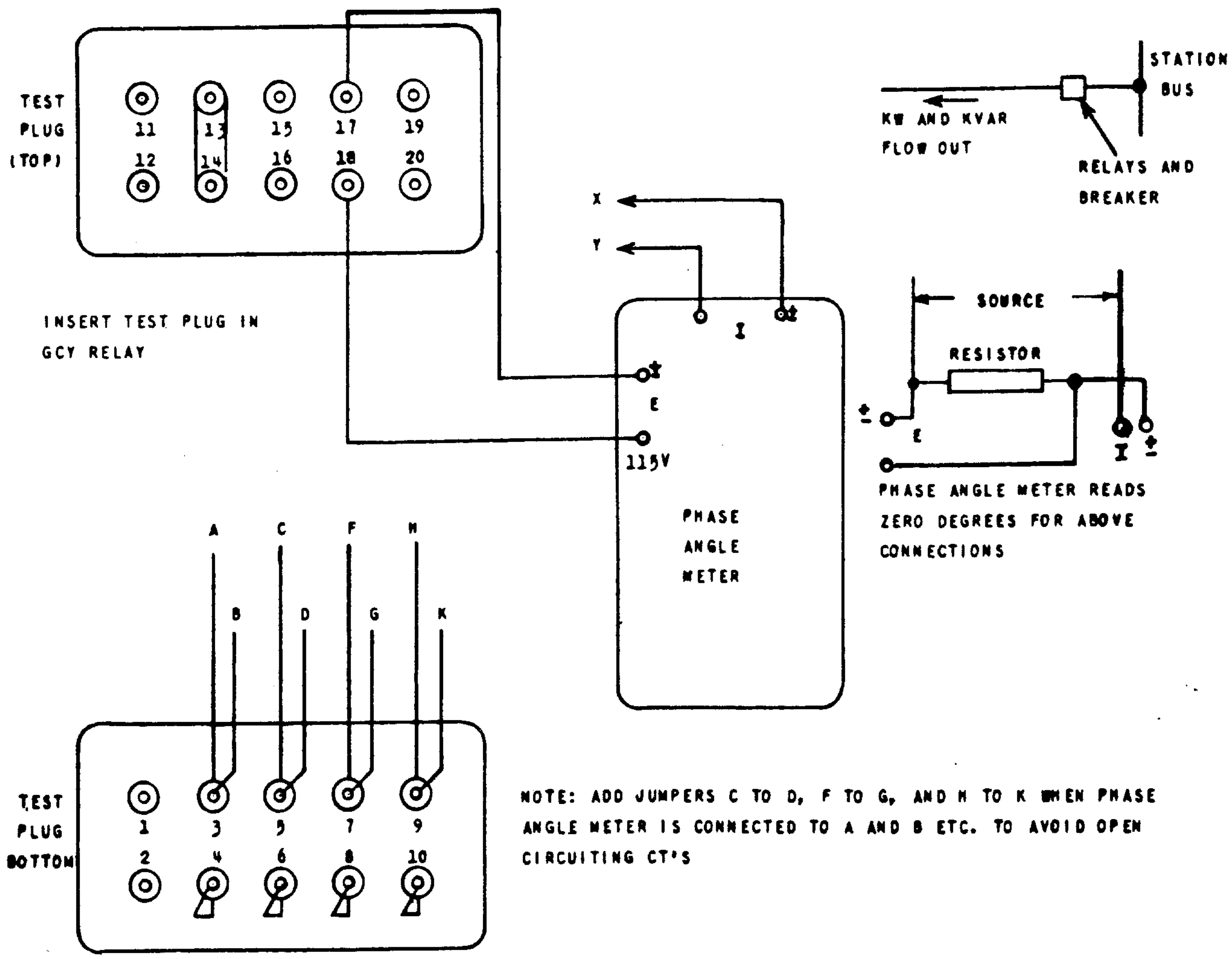


			(PROPER READING FOR PHASE SEQUENCE 1-2-3)							
POWER FACTOR ANGLE (DEG.LEAD) →			0-45	45-90	90-135	135-180	180-225	225-270	270-315	315-360
KW AND KVAR DIRECTIONS WITH RESPECT TO THE BUS			KW OUT> KVAR IN	KVAR IN> KW OUT	KVAR IN> KW IN	KW IN> KVAR IN	KW IN > KVAR OUT	KVAR OUT> KW IN	KVAR OUT> KW OUT	KW OUT> KVAR OUT
RELAY CONNECTIONS	(E) (I)	X TO A OR C / Y TO B OR D	330-15	15-60	60-105	105-150	150-195	195-240	240-285	285-330
	(E) (I)	X TO F OR H / Y TO G OR K	30-75	75-120	120-165	165-210	210-255	255-300	300-345	345-30
			(PROPER READING FOR PHASE SEQUENCE 1-3-2)							
	(E) (I)	X TO A OR C / Y TO B OR D	30-75	75-120	120-165	165-210	210-255	255-300	300-345	345-75
	(E) (I)	X TO F OR H / Y TO G OR K	330-15	15-60	60-105	105-150	150-195	195-240	240-285	285-330

THE VOLTAGE CONNECTIONS TO THE OM3 UNIT ON RELAY STUDS 17 AND 18 TO STUDS 19 AND 20 SHOULD BE VISUALLY CHECKED.

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

CAUTION: MAKE CORRECTIONS FOR METER ERRORS ON LOW CURRENTS, INHERENT IN SOME PHASE-ANGLE METERS.

Fig. 21 Test Connections For Overall Test of Type GCY12A Relaying Terminal

Fig. 21 (K-6556595)

For convenience in field testing the fault switch and tapped autotransformer of Fig. 25 have been arranged in a portable test box, Cat. No. 102L201, which is particularly adapted for testing directional and distance relays. The box is provided with terminals to which the relay current and potential circuits as well as the line and source impedances may be readily connected. For a complete description of the test box the user is referred to GEI-38977.

Other equipment required includes:

Load Box
Tapped Test Reactor
Tapped Test Resistor
Voltmeter
Ammeter
Test Plugs

To check the calibration of the mho units it is suggested that the test box Cat. 102L201; test reactor (Cat. 6054975); and test resistor (Cat. 615B546) be arranged with the type XLA test plugs as shown in Fig. 22. This circuit is similar to that shown in Fig. 25 except that the source impedance $R_S + jX_S$ is replaced by the load box which controls the level of the fault current and produces the source voltage drop.

Use of a source impedance $R_S + jX_S$ is only necessary when the relay is being tested for overreach and contact coordination. Such tests are not considered necessary at the time of installation or during periodic testing. Tests of this nature are described later in the section on SERVICING.

Since the reactance of the test reactor may be very accurately determined from its calibration curve, it is desirable to check relay pickup with the fault reactor alone, due account being taken of the angular difference between the line reactance, X_L, and the relay angle of maximum reach. The line reactance, X_L, selected should be the test reactor tap nearest above twice the mho unit reach with account being taken of the difference in angle of the test reactor tap impedance and the relay angle of maximum reach. From Fig. 24 it is seen that twice the relay reach at the angle of the test reactor impedance is:

$$2Z \text{ Relay} = 2 \frac{Z \text{ min. ohms}}{E^2 \text{ tap}} \cos(\phi - \theta)$$ where ϕ is the angle of the test reactor impedance, θ is the relay angle of maximum reach, and E^2 tap set is the voltage restraint tap setting expressed as a decimal. The test-box autotransformer percent tap for the mho-unit pickup is given by:

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

To illustrate by an example let us consider the percent tap required on the test box autotransformer for a M1 unit that has been factory adjusted to pick up at 3 ohms minimum at a maximum torque angle of 60 degrees. In determining the reactor tap setting to use it may be assumed that the angle (ϕ) of the test reactor impedance is 80 degrees. From the above, twice the relay reach at the angle of the test-reactor impedance is:

$$2 Z \text{ relay} = 2 \frac{3}{1.0} \cos(80-60) = 5.64 \text{ ohms}$$

Therefore, use the reactor 6 ohm tap. Twice the relay reach at the angle of test reactor impedance should be recalculated using the actual angle of the reactor tap impedance rather than the assumed 80 degrees. Table IV shows the angles for each of the reactor taps.

TABLE IV

Tap	Angle	cos ϕ-60
24	88	0.883
12	87	0.891
6	86	0.899
3	85	0.906
2	83	0.921
1	81	0.934
0.5	78	0.951

From the table it is seen that the angle of the impedance of the 6 ohms tap is 8 degrees. Therefore:

$$2 Z \text{ relay} = 2 \frac{3}{1.0} \cos(86-60) = 5.4 \text{ ohms}$$

The calibration curve for the portable test reactor should again be referred to in order to determine the exact reactance of the 6 ohm tap at the current level being used. For the purpose of this illustration assume that the reactance is 6.1 ohms. Since the angle of the impedance of the 6 ohm tap is 86 degrees, the impedance of this tap may be calculated as follows:

$$Z_L = \frac{X_L}{\cos 4} = \frac{6.1}{.9976} = 6.115$$

From this calculation it is seen that the reactance and the impedance may be assumed the same for this particular reactor tap. Actually the difference need only be taken into account on the reactor 3, 2, 1 and 0.5 ohm taps.

The test box autotransformer tap setting required to close the mho-unit contacts with the fault switch closed is:

$$\% = \frac{5.4}{6.1} (100) = 89\%$$

If the ohmic pickup of the mho unit checks correctly according to the above, the chances are that the angle of the characteristic is correct. The angle may, however, be very easily checked by using the calibrated test resistor in combination with various reactor taps. The calibrated test resistor taps are pre-set in such a manner that when used with 12 and 6 ohm taps of the specified test reactor, impedances at 60 degrees and 30 degrees respectively will be available for checking the mho-unit reach at the 60 degree and 30 degree positions.

The mho-unit ohmic reach at the zero-degree position may be checked by using the calibrated test resistor alone as the line impedance. The calibrated test resistor is supplied with a data sheet which gives the exact impedance and angle for each of the combinations available. The test-box autotransformer per cent tap for pickup at a particular angle is given by:

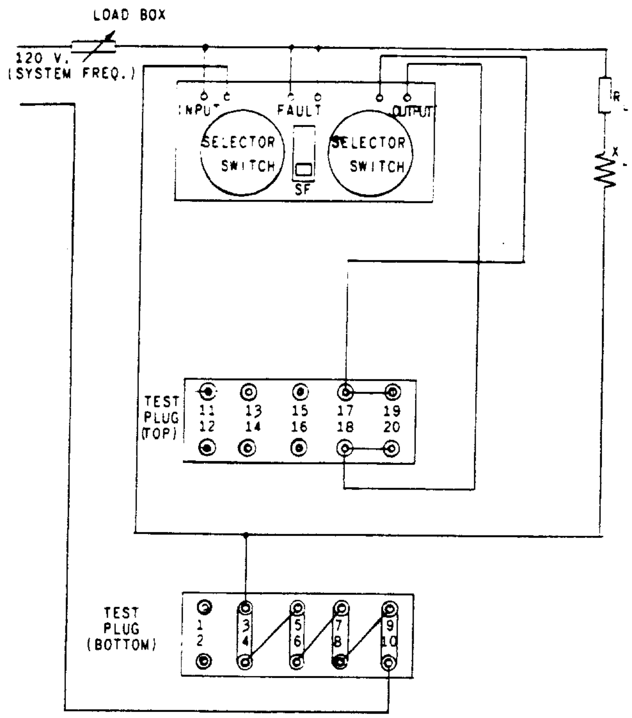
$$\% \text{ Tap} = \frac{2(3.0) \cos (60-a)}{(E^2 tap)\ Z_L}\ 100$$

where "a" is the angle of the test impedance (Z_L), Z_L is the 60 degree, 30 degree or zero degree impedance value taken from the calibrated resistor data sheet and E^2 is mho unit restraint tap setting expressed as a decimal. As in the case of the previous tests, the load box which serves as source impedance should be adjusted to allow approximately 10 amperes to flow in the fault circuit when the fault switch is closed.

When checking the angle of maximum reach of the mho unit as indicated above, there are two factors to keep in mind which affect the accuracy of the results. First, when checking the mho unit at angles of more than 30 degrees off the maximum reach position, the error becomes relatively large with phase angle error. This is apparent from Fig. 26 where it is seen, for example, at the zero-degree position that a two or three degree error in phase angle will cause a considerable apparent error in reach.

Second the effect of the control spring should be considered when testing the OM3 unit since the mho unit can only have a perfectly circular characteristic when the control-spring torque is negligible. The spring torque on the M1 and M2 units can be considered negligible. For any normal level of polarizing voltage, the control spring may be neglected but in testing the OM3 unit as indicated above it may be necessary to reduce the test box autotransformer tap setting to a point where the voltage supplied to the unit may be relatively low. This reduces the torque level since the polarizing as well as the restraint torque will be low, making the control spring torque no longer negligible. The result of the control spring at low polarizing voltage is to cause the reach of the mho unit to be reduced. However, for the third zone back-up protection for which OM3 unit is used, the voltage at the relay for remote faults, is not apt to be low. Furthermore, the accuracy of a third zone back-up unit is not as important as that of a first zone unit.

In addition to the above tests on the mho units, they may also be checked for directional action with the test box circuits as shown in Fig. 22. The fault resistor R_L may be zero and the test reactor should be set on the 0.5 ohm tap. With connections made as shown, the M1 and M2 unit contacts should close over the current range as specified with 1.5 volts applied.



NOTE: TO REVERSE DIRECTION OF OM3, INTERCHANGE CONNECTIONS TO STUDS 19 AND 20.

Fig. 22 Test Connections For Type GCY12A Relay Using Portable Test Box 102L201

Fig. 22 (402A934)

Minimum Ohmic Reach	1	2	3
Minimum Amperes Maximum Amperes	6 60	3 60	2 60

The M3 unit will close its contacts from 3 to 60 amperes with 6 volts applied.

When the current connections at the relay terminals 3 and 10 are reversed the M_1, M_2 and M_3 unit contacts should remain open from 0 to 60 amperes.

INSPECTION

Before placing a relay into service, the following mechanical adjustments should be checked, and faulty conditions corrected according to instructions for the preceding adjustments or under MAINTENANCE.

The armature and contacts of the target and seal-in unit should operate freely by hand.

There should be a screw in only one of the taps on the right-hand contact of the target and seal-in unit.

The target should reset promptly when the reset button at the bottom of the cover is operated, with the cover on the relay.

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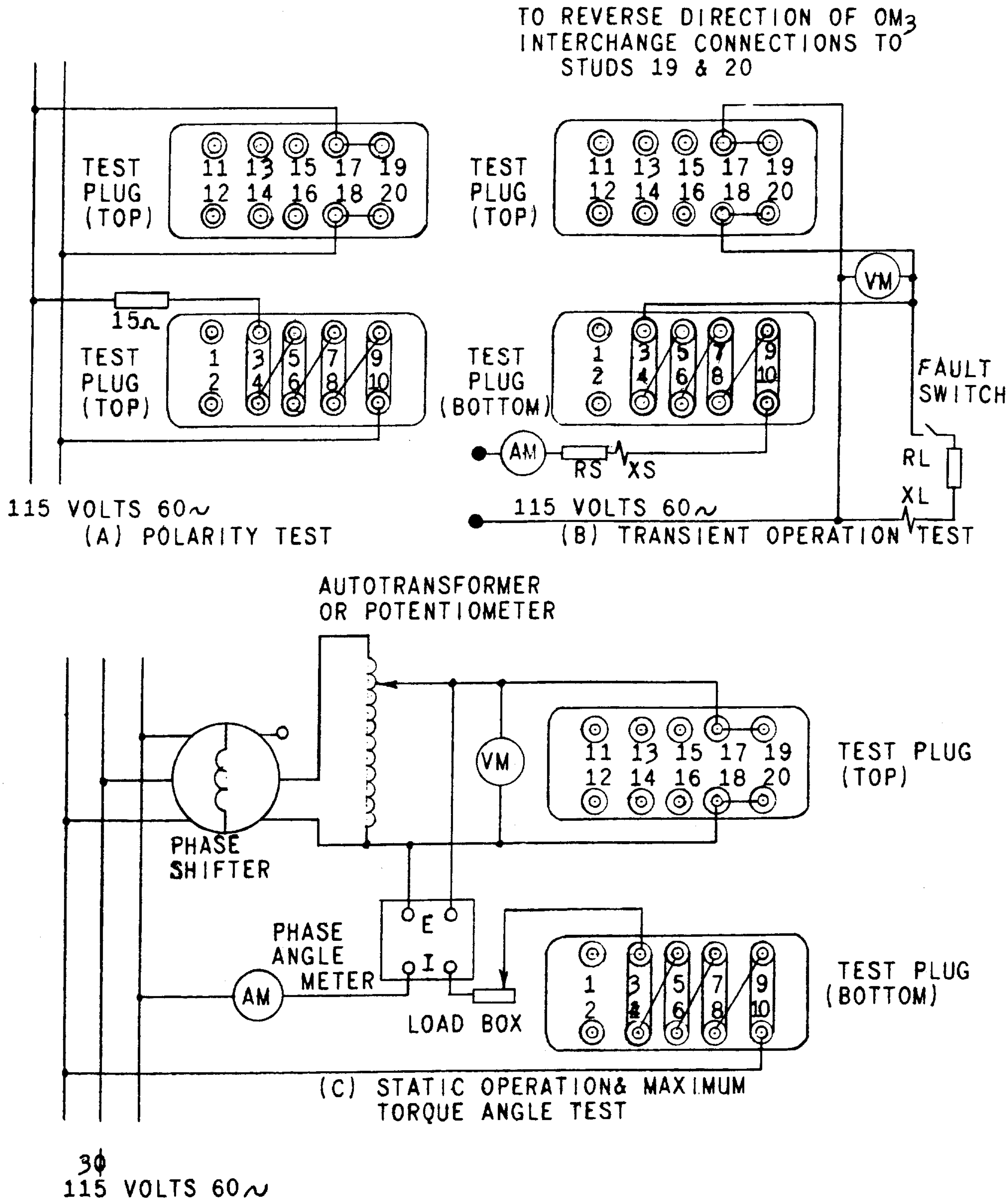

Fig. 23 (K-6305876)

Fig. 23 Test Connections For Type GCY12 Relay Using Test Plugs Model XLA12A

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There should be no noticeable friction in the rotating structure of the mho units. The M_1 and M_2 units should barely return to the right when the relay is de-energized. The OM_3 unit has a stronger restraining spring torque and will move to the right more readily.

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

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

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

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

The contact surfaces should be clean.

The moving contact backstops should be clean. The backstops should be wiped clean at regular intervals with a cloth moistened with carbontetrachloride solution.

If possible, the relay contact circuits should be given an electrical test in place by closing each of the mho unit contacts successively by hand and allowing tripping current to pass through the contacts and the target and seal-in element. The target should promptly appear.

Caution: Examine the tap block with great care to make sure the tap lead terminals do not come in contact with adjacent terminals, tap hole shoulders, mounting screw heads or other grounded parts. Even on those relays provided with tap lead-sleeve insulation, it is possible to mechanically puncture the sleeve insulation by forcing the tap lead terminal against some nearby part. The punctured insulation may cause a portion of the tapped autotransformer to be shorted or grounded, the result from this being eventual failure of the transformer. As a good general practice, it is recommended that the tap leads be placed horizontally on the tap block with the leads coming out rather than in toward the relay.

MAINTENANCE

INSPECTION AND TESTS

The relay should receive an inspection such as described under INSPECTION at least once every six months, with enough of an electrical test to determine that all three units and the seal-in will operate.

For a complete laboratory test, the procedures using the connections of Fig. 22 (c) and described under the adjustments for the three mho units should be followed.

CONTACT CLEANING

For cleaning the fine silver 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 corroded material will be removed rapidly and thoroughly. The flexibility of the tool insures the cleaning of the actual points of contact.

Fine silver contacts should not be cleaned with knives, files, or abrasive paper or cloth. Knives or files may leave scratches which increase arcing and deterioration of the contacts. Abrasive paper or cloth may leave minute particles of insulating abrasive material in the contacts and thus prevent closing.

The burnishing tool described is included in the standard relay tool kit obtainable from the factory.

SERVICING

The three units are adjusted at the factory to have the following phase angle settings with the minimum relay setting of 1, 2 or 3 ohms, when the No. 1, No. 2, and No. 3 taps are on 100 percent. If these angular settings are retained, the relay settings can be made (with approximately 5 per cent accuracy for the M_1 and M_2 unit settings) by using the formulas given under ADJUSTMENTS AND TESTS. If it is desired to set the M_1 unit on 45 degrees or 75 degrees, the increase in possible error in calculated settings can be deducted from Table I. If more accurate settings are desired, or if a change in the angular setting of the M_2 or OM_3 units is desired, a test circuit should be set up to measure the impedances at which the relay operates.

UNIT	OHMIC SETTING	MAX. TORQUE ANGLE
M_1	1, 2, 3	60°
M_2	1, 2, 3	75°
M_3	3	75°

The clutch on each mho unit is adjusted by means of the steel collar at the upper end of the rotating shaft. Adjustments should be made in the following manner. The test connections of Fig. 23 (c) can be used except the current leads to terminals 3 and 10 should be reversed from positions as shown. This in effect will make the restraint and operating torques additive. The units will develope a strong torque to the right. To adjust the clutch, loosen the set screw in the collar, rotate the collar on the

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shaft through the number of half turns necessary to obtain the correct pressure. Moving the collar down increases the clutch pressure. The collar is locked by means of a set screw which seats itself in a groove provided on the shaft. Since starting friction is variable, it is recommended that the current be raised above the slipping point and then be decreased to the point where the clutch ceases to slip. This value should be from 10 to 15 amperes for all units.

POLARITY

To check the polarity of the relay, the connections of Fig. 23 (a) may be used. With these connections and the relay taps on 100 per cent, the mho unit contacts should remain open. The correct polarity is indicated by the closing of the left-hand contacts of all the mho units when one of the No. 1, No. 2, and No. 3 tap leads are removed from the tap block.

CONTACT ADJUSTMENT

Figure 24 illustrates and specifies the contact gaps and other adjustments required to obtain proper operations. The gaps should be set by suitable thickness gages.

CONTROL SPRING ADJUSTMENT

After the relay has been mounted in the test stand, the M_1 and M_2 units should have their control springs adjusted so that the moving contacts will just return to the right when the relay is de-energized. If the backstop were removed, the contact would not move further to the right. The clutch is then slipped mechanically and it is observed if the reset position is away from the backstop. The clutch position is found at which there is the greatest torque away from the backstop and the spring is readjusted so that the moving contact will just return to the backstop with this clutch setting.

The M_3 contacts should be adjusted to have a 5.6 volt-ampere pickup under zero restraint conditions. Refer to Fig. 23 for test connections. Remove the restraint taps (#3) and apply 4 volts and 1.4 amperes to the relay. Using the control spring adjuster make the adjustment so that the left contacts just close with the above voltage and current applied at the angle of maximum torque of the unit (75° lag.)

M_1 UNIT

The contacts should have an 0.032 inch gap when open (set by gage) and no wipe except the compressibility of the felt backstop.

If the pickup of the M_1 unit is to be set by test, use the connections of Fig. 23 (c). Correct phase angle meter polarity is when the conventional current entering stud 5 and the potential applied to studs 15 and 17 are at their positive maximum simultaneously and the phase-angle meter reading is zero. Adjust current, voltage and phase-angle according to the desired ohmic setting and adjust the No. 1 taps so that the M_1 contacts will just close, but will remain open with a one per cent increase in voltage.

IMPORTANT: The impedance calculated from voltage and current readings with these connections corresponds to phase-to-phase impedance and is double the phase-to-neutral Z_R or Z_L, described previously. When setting for low values of impedance, it is advisable to use approximately 55 volts to avoid excessive currents.

When a phase shifter and phase-angle meter are not available, the circuit of Fig. 23 (b) can be used. The impedance and phase angle of $R_L + jX_L$ must be considered in making an accurate setting.

If it is desired to check the factory setting of the relay use Fig. 23 (c) and current representing 6 ohms, phase-to-phase, lagging the voltage by 60 degrees. If the contacts do not just close at the correct current when the No. 1 taps are on 100 per cent, the setting of R_{11} should be changed to obtain the correct pick-up current. Raising the slide band decreases the pick-up current.

If angular settings are to be checked, use the connections of Fig. 23 (c) with about 55 volts on the relay, and current sufficiently high to cause the contacts to close over a span of 90 degrees or more. Turn the phase shifter and find the two values of phase angle at which the contacts will just close (always taking the reading as contacts move from open to closed position), maintaining the same voltage and current when both angles are read. The angle midway between these two values is the angular setting of the unit, or its angle of maximum operating torque. Check the 75 degree setting first and correct any error by means of X_{21}. Turning the adjusting screw of X_{21} to the right increases the angular setting of the unit. Check the 60 degree setting next and correct any errors by means of X_{31}. Turning the adjusting screw of X_{31} to the right decreases the angular setting of the unit. Check the 45 degree setting last and correct any error by adjusting R_{31}. Moving the slide band up will increase the angular setting.

When cold the relay tends to underreach by 3 or 4 per cent; i.e., the No. 1 tap setting at which the M_1 unit contacts just close is lower than the normal value. If the relay is permitted to warm up under normal operating conditions with the cover on for 10 minutes, the error due to temperature will be less than one per cent.

M_2 UNIT

The contacts should have 0.020 inch gap when open and no wipe except the compressibility of the felt backstop.

The angular setting of the M_2 unit as adjusted at the factory is 75 degrees. If any other angular setting desired within its range, 60 to 75 degrees, the same test circuit as described above for measuring the angular setting of M_1 must be used. The angle is adjusted by means of R_{32} plus R_{42}.

Fig. 24 (402A935)

Fig. 25 (402A933)

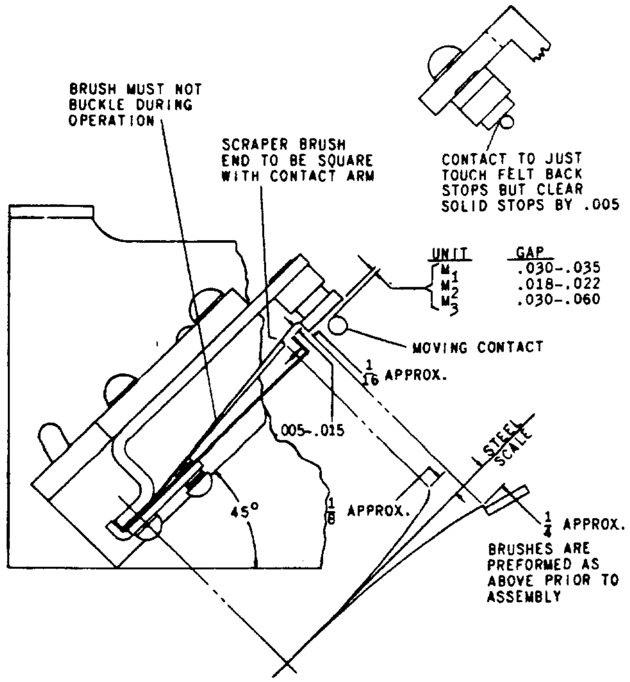

Fig. 24 Contact Adjustment

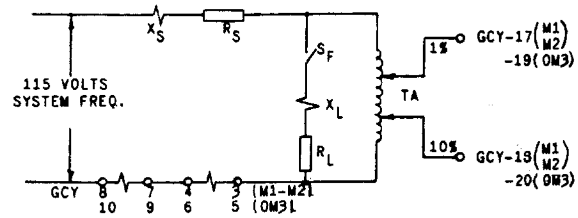

Fig. 25 Test Connections

Fig. 26 (362A625)

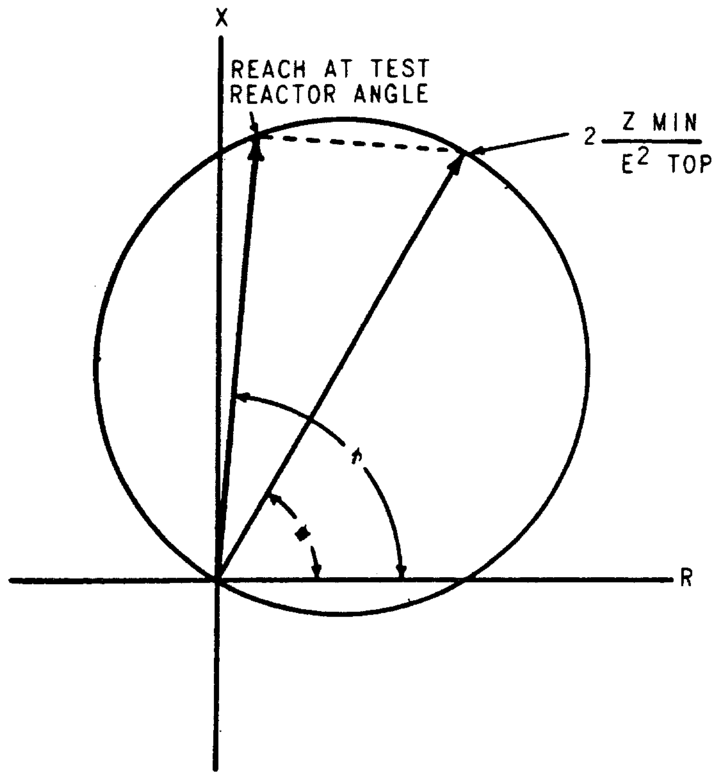

Fig. 26 Reach Of MHO Unit At The Angle Of The Test Reactor

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To reduce the angle from 75 degrees, turn R_{42} to the left. If there is not sufficient adjustment in R_{42}, change the jumpered connection from R_{32} to the next lower tap and continue from the extreme clockwise position of R_{42}.

The ohmic reach can be adjusted accurately by test using the same connections and similar procedure as that described for M_1 unit.

Where the factory adjustment is to be checked, adjust R_{32} plus R_{42} for a 75 degree setting, and apply current and potential corresponding to a 6 ohm (phase-to-phase) fault at 75 degrees. With the No. 2 taps on 100 per cent, any error in operating current should be corrected by adjusting R_{12}. Raising the slide band decreases the pick-up current.

OM_3 UNIT

The normally open (left) contacts should have .045 of an inch gap when open and 0.005 of an inch wipe. The normally closed contacts should have 0.005 of an inch wipe. If the left-hand stationary contact is replaced, the following precautions should be observed. The brush should be carefully formed so that the silver contact meets its backstop simultaneously along their entire line of contact. The contact brush along with the 0.003 of an inch scraper brush in front of it should be formed so that the contact brush has the minimum initial tension which will produce the required amount of wipe. The adjusting screw for the brushes should not be used for more than one quarter of a turn of effective adjustment.

The operating element of the OM_3 unit has exactly the same circuit elements as the M_2 unit, sc that, with slight modifications, the procedure for adjustment will be the same.

The method of angular adjustment is the same as for the M_2 unit. The resistance involved for the OM_3 unit is R_{33} plus R_{43}. To reduce the angle from 75 degrees, reduce this sum using a lower tap on R_{33} if there is not sufficient adjustment in R_{43}.

The ohmic reach can also be adjusted accurately by test using the same procedures as for the M_1 and M_2 units. If the factory adjustment is to be checked, set R_{33} plus R_{43} for the 75 degree setting and correct any error in pick-up current by adjusting R_{13}. Raising the slide band decreases the pick-up current.

Accurate settings can be made using the test circuit of Fig. 23 (c). These connections are for the OM_3 unit to be in the forward direction, i.e., for current in the first lagging quadrant. The connections to studs 19 and 20 may be reversed if it is desired to test the relay with its exact polarities for the reversed OM_3 connection when the reversed connection is to be used. In this case, the offset ohms will be measured with current in the first lagging quadrant.

The angular setting of the transactor can be changed to match any change in the angular setting of the operating element by means of the resistance R_{63}. The test circuit of Fig. 23 (c) should be used and two ohmic characteristic curves similar to Fig. 9 plotted, one with offset, and one without offset. Draw the best circle approximating each of the curves and mark the position of their centers. A line joining the centers gives the angle of the offset. To decrease the angle, turn R_{63} to the left.

TRANSIENT TESTS

If a test is desired showing the operation of the relay under transient conditions, the circuit shown in Fig. 23 (b) should be used. As mentioned previously, the impedance measured by the relay is the combination of $R_L + jX_L$ in parallel with the potential circuit of the relay. This should be approximately equal in magnitude and phase angle to the secondary impedance from the relay bus to and including the fault to be investigated. Ideally, the impedance of the test bus plus R_S, X_S, the ammeter and the relay current coils in series, should be equal to the secondary impedance from the internal voltages at the sources of generation behind the relay bus to the relay bus. Ordinarily a test bus can be found of capacity large enough to permit neglecting its impedance. The fault impedance of this test circuit represents phase-to-phase fault impedance and is double the value calculated as the relay setting. A neon lamp in the contact circuit of the M_1 unit is satisfactory for detecting closure of the contacts.

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 part wanted, and give complete nameplate data, including serial number. If possible, give the General Electric Company requisition number on which the relay was furnished.