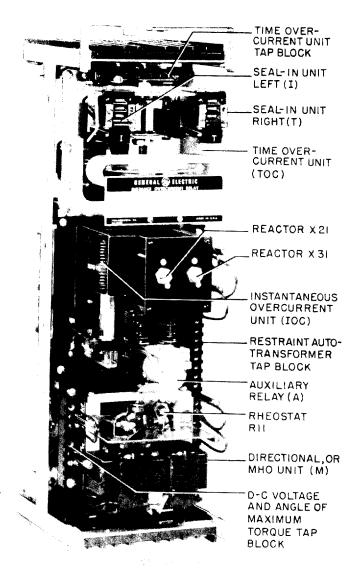
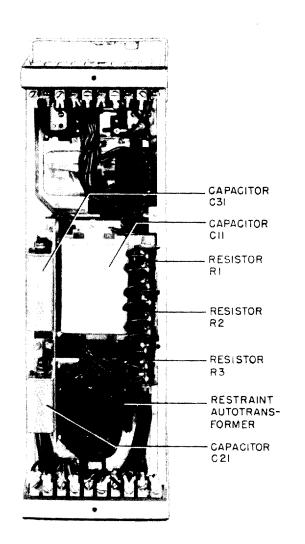




# TWO STEP DISTANCE OVERCURRENT RELAY

Types
GYC51A
GYC53A
GYC77A





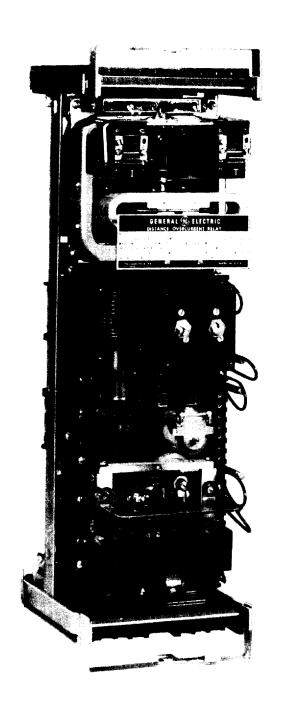
Front View

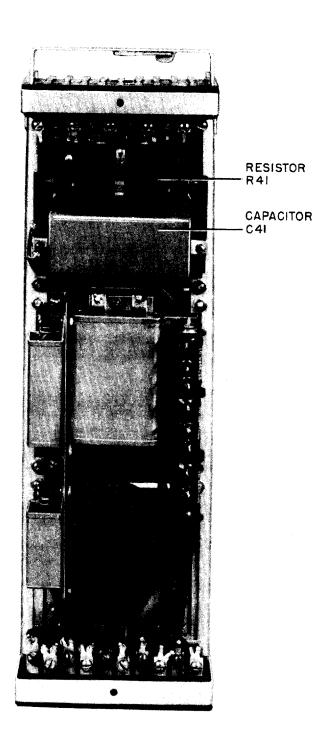
Back View

Fig. 1 Types GYC51A and GYC53A Relays

# **CONTENTS**

	PAGE
INTRODUCTION	5
APPLICATION	
OPERATING CHARACTERISTICS	
Mho Unit	
Time Overcurrent Unit	9
Instantaneous Overcurrent Unit	
Tapped Autotransformers	13
Mho Unit Transfer Auxiliary	
RATINGS	
BURDENS	
Current Circuits	16
Potential Circuit	16
DESCRIPTION	16
GENERAL CONSTRUCTION	
Time Overcurrent Unit	17
Instantaneous Overcurrent Unit	
Seal-In Unit	
CASE	17
RECEIVING, HANDLING AND STORAGE	18
RECEIVING, HANDLING AND STORAGE	10
INSTALLATION	18
INSPECTION	18
ADJUSTMENTS	19
Mho Unit	
Time Overcurrent Unit	19
Instantaneous Overcurrent Unit	19
Target and Seal-In Unit	
Mho Unit Transfer Auxiliary	21
ELECTRICAL CHECK TESTS	21
Mho Unit.	21
Overcurrent Units	23
Overall Test	23
MOUNTING	
LOCATION	24
CONNECTIONS	24
CALCIULATIONS	9.4
CALCULATIONS	24
Arc Resistance	24
Secondary Impedance	
First Zone Reach	25
Second Zone Reach	25
EXAMPLE	26
First Zone Reach Setting	
Second Zone Reach Setting	
Second Zone Time Setting	27
-	
MAINTENANCE	28
PERIODIC TESTS	28
CONTACT CLEANING	28
SERVICING	28
Mho Unit	28
Time Overcurrent Unit	30
RENEWAL DARTS	30





Front View

Back View

Fig. 2 Type GYC77A Relay

# TWO STEP DISTANCE OVERCURRENT RELAY TYPE GYC

# INTRODUCTION

# **APPLICATION**

The GYC is a single phase two zone directional distance relay that is particularly suited for application on sub-transmission lines. Three relays are required at each terminal to provide complete protection for three phase, phase to phase and double phase to ground faults.

The overall relay characteristic is obtained by using a mho distance unit in conjunction with a time delay overcurrent unit to provide instantaneous first zone plus time delay second zone tripping. overcurrent unit is used only to provide the time delay and to initiate switching of the ohmic reach of the mho unit from first zone to the extended second The mho unit acts as the distance zone setting. measuring device for first and second zone tripping thus providing directional distance protection for both first and second zone faults. Fig. 3 indicates how these relays may be applied on a sub-transmission system to obtain selective coordination. The time delay for end zone faults is necessary to assure selectivity with protective relays on adjoining system elements. For the fault indicated on Fig. 3 the second zone time delay at breaker 2 should be longer than the first zone relay plus breaker time at 4. This must be the case for all values of fault current possible.

The high accuracy and low overreach of the mho unit permits instantaneous tripping for up to 90 per cent of the protected circuit while the time-current characteristic of the overcurrent unit provides the necessary coordinating time delay for faults in the second zone reach. No external timer is required.

The GYC relays should be considered whenever fixed reach distance type protection is required on sub-transmission lines. With these relays installed at both ends of a line, high speed tripping (minimum operating time is less than 1 cycle on a 60 cycle basis) of both terminals may be obtained over a maximum portion of the protected circuit. If it is considered that the relays at each end are set to reach 90 percent of the distance to the opposite terminal, then instantaneous tripping at both terminals would result for faults in the middle 80 percent of

the protected zone. Tripping for faults in the end zones - the remaining 10 percent at each end of the line - will be instantaneous by the near breaker and in some short time delay by the far breaker. The high speed protection afforded by these relays will shorten voltage dips and minimize fault damage.

The use of separate stud connections for the instantaneous and time delay trip circuits facilitates the use of the GYC relays with an ACR reclosing relay to remove the instantaneous first zone trip circuit from service after the initial tripout. This provides for coordination with fuses on tapped loads in a manner similar to that employed on distribution circuits.

In addition to the normal stud connections required for two step distance protection, the GYC relays make available a spare contact on the auxiliary transfer relay, "A", which may be used to operate an external RPM timer and HEA lock-out relay. This scheme provides non-directional time delay bus clearing for associated circuit breaker failure.

The mho unit is supplied with line-to-line potential and the corresponding phase currents. The unit, within itself, measures the vector difference between the two currents and in this way provides the same ohmic reach for three phase, phase to phase and double phase to ground faults without the use of any auxiliary current transformers.

An instantaneous overcurrent fault detector is built into all GYC relays. This may be used, if desired, to guard against tripping on loss of potential to the relays.

# OPERATING CHARACTERISTICS

MHO UNIT

The mho unit has a circular impedance characteristic that passes through the origin of an R-X diagram, and whose center lies on the angle of maximum torque line. The minimum operating characteristics of a Type GYC three ohm unit are shown in Fig. 5. The angle of maximum torque of this mho unit can be set at either 60 or 45 degrees,

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.

To the extent required the products described herein meet applicable ANSI, IEEE and NEMA standards; but no such assurance is given with respect to local codes and ordinances because they vary greatly.

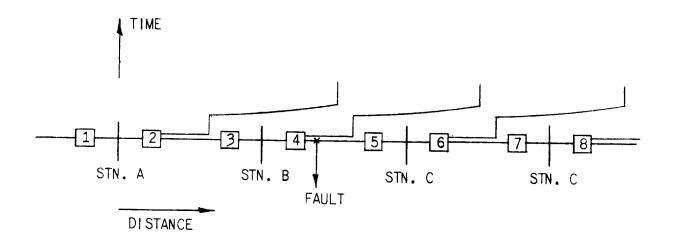


Fig. 3 Zone Setting Diagram for Type GYC Relays

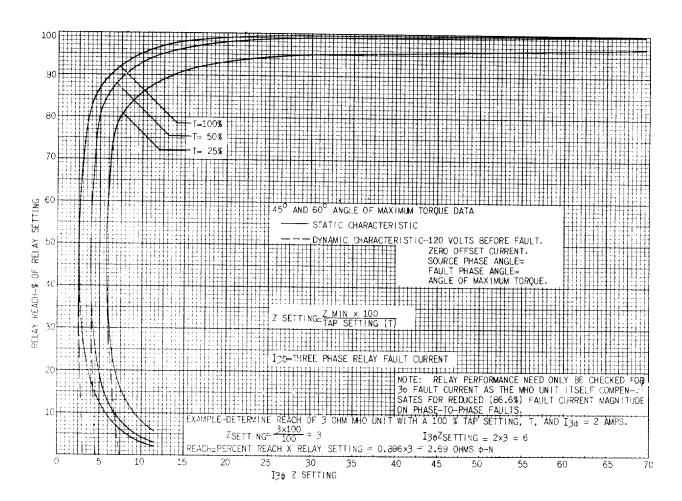


Fig. 4 Static and Dynamic Accuracy of Type GYC Mho Unit. Data taken for Phase-to-Phase Fault at Mho Unit Angle of Maximum Torque.

torque setting has a diameter of three ohms phaseto-neutral when the terminal voltage is supplied directly to the mho unit restraint circuit. This circle can be enlarged by reducing the autotransformer tap setting, thereby reducing the percentage of the terminal voltage supplied to the restraint characteristic is the ohmic reach of the unit, and can be determined from the equation:

## OHMIC REACH=(INPUT TAP) Z min COS (Ø - θ) (OUTPUT TAP)

The diameter of the mho unit circular

voltage leading current. The relay is factory calibrated so that the 60 degree angle of maximum

Where:

 Input tap setting in percent - Normally Input tap 100.

Output tap = No. 1 or No. 2 tap setting (%).

= Mho unit minimum phase-to-neutral  $z_{min}$ ohmic reach - Given on relay nameplate.

= Mho unit angle of maximum torque.

= Phase angle of the line.

For a 3-30 ohm mho unit set with 100 per cent input tap, 100 per cent output tap, and 60 degree angle of maximum torque, the reach of the mho unit would be three ohms if the line phase angle were 60 degrees, voltage leading current.

As shown in Fig. 5, when the angle of maximum torque of the mho unit is set at 45 degrees, its minimum ohmic reach  $Z_{min}$ , increases by approximately 37 per cent. Though the 45 degree angle of maximum torque setting is adjusted at the factory for the correct angle, there is a slight variation from relay to relay in the minimum ohmic reach at this 45 degree angle. For example, a 3 ohm mho unit (angle of maximum torque - 60 degrees) adjusted for a 45 degree angle of maximum torque should have a 4.1 ohm minimum ohmic reach. From relay to relay, however, this minimum ohmic reach at the 45 degree angle of maximum torque may vary from 4.0 ohms to 4.2 ohms. The variation in the other ohmic ranges is proportionate.

At reduced voltage, the ohmic value at which the mho unit will operate may be somewhat lower than its calculated value. This "pullback" or reduction in reach, is shown in Fig. 4 where the percentage change in relay reach for a constant tap setting is expressed as a function of the three phase fault current, 130, and the relay reach setting Zsetting. The mho unit will operate for all points to the right of the curves. The static curves of Fig. 4 were determined by tests performed with no voltage supplied to the relay before the fault was applied. The dynamic curves were obtained with full rated voltage of 120 volts supplied to the relay before the fault was applied. These dynamic curves illustrate the effect of the mho unit memory action which maintains the polarizing voltage on the unit for a few cycles after the inception of the fault.

This memory action is particularly effective at low voltage levels where it enables the mho unit to operate for low fault currents. This can be most forcefully illustrated for a zero voltage fault by re-

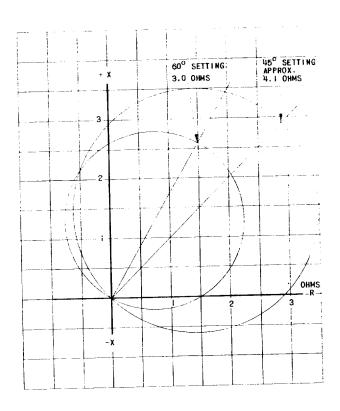


Fig. 5 Minimum Static Operating Characteristics of Type GYC Three Ohm Mho Unit

ferring to Fig. 4. A zero voltage fault must be right at the relay bus and therefore, to protect for this fault, it is imperative that the relay reachzero percent of its setting. Fig. 4 shows the mho unit, under static conditions, will not see a fault at zero percent of the relay setting regardless of the tap setting or the I3ø Zsetting product. However, under dynamic conditions when the memory action is effective, Fig. 4 shows that a mho unit with a 100 percent tap setting will pick up if the I3Ø Zsetting product is greater than three (3). This means, therefore, that a 3 ohm relay with a 100 percent tap setting, or a Zsetting of 3, will pick up if the three phase fault current, 130, is greater than 1 ampere.

The mho unit is carefully adjusted to have correct directional action under steady-state low voltage and current conditions. For faults in the tripping direction at the angle of maximum torque of the mho unit, the 3 ohm unit with a 100 per cent tap setting will close its contacts at 1.5 volts and For faults in the between 1.5 and 60 amperes. non-tripping direction, the contacts will remain open at zero volts and between 0 and 60 ampres. The minimum closing current for the other mho unit ranges is inversely proportional to the ratio of the unit's minimum reach to the 3 ohm unit reach.

Since zone 1 of the Type GYC relay is connected to trip instantaneously, the operation of the mho unit under the transient system conditions NOTE: RELAY PERFORMANCE NEED ONLY IN CHECKED FOR 36 FAULT CLRRENT AS THE MHO UNIT ITSELF COMPENSATES FOR MEDUCED (66.88) FAULT CURRENT MAGNITUDE ON PHASE-TO-PHASE FAULT.

MHO UNIT WARRIAN OPERATING TIME

17.9 SET No-1078.

ANGLE OF MAX. TORQUE-80°
RILAY VC. ACE BEFORE FAULT-1220. SOURCE PHASE MAGLE-TANGLE OF MAXIMAM 110 ROULE.

2 Str NG = 508 2 Str NG = 508 2 Str NG = 108

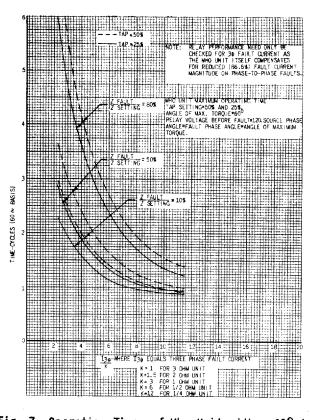


Fig. 6 Operating Times of Mho Unit with a 60° Angle of Maximum Torque and a 100% Tap Setting

6 9 10 12 14 16 18

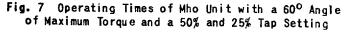
132-MERE 136 ECLALS HIREE PHASE HAULT CURRENT

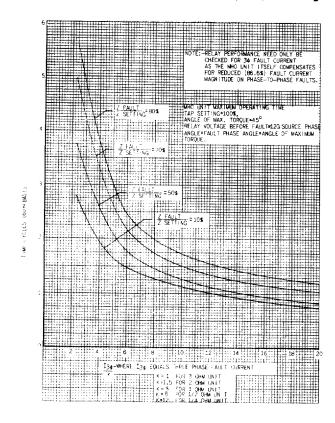
K = 1 FOR 3 OWN UNIT

K = 1 FOR 3 OWN UNIT

K = 5 FOR 1 OWN UNIT

K = 6 FOR 1 2 OWN UNIT





rig. 8 Operating Times of Mho Unit with a 45° Angle of Maximum Torque and a 100% Tap Setting

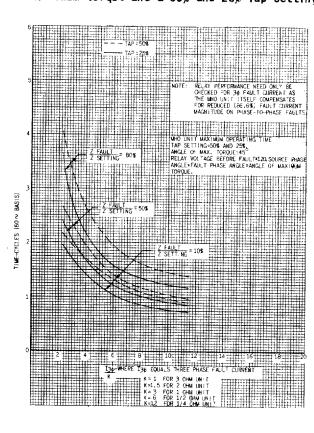


Fig. 9 Operating Times Mho Unit with a 45<sup>o</sup> Angle of Maximum Torque and 50% and 25% Tap Settings

present at the inception of a fault is important. Transient overreach is the tendency of the mho unit, under transient system conditions, to close its contacts momentarily for a fault impedance greater than its impedance setting. The magnitude of the mho unit's transient overreach is directly proportional to the degree of asymmetry in the fault current, and is also proportional to the circuit angle, (the angle of the system from the point of the fault to the source of generation). Maximum transient overreach is obtained when the fault occurs at that instant in either half of the cycle which produces maximum asymmetry, or maximum d-c offset of the fault current wave. If the fault occurs midway between these two instants, there is no offset current, and hence, no transient overreach. Fig. 10 shows the maximum transient overreach of the Type GYC mho unit as a function of the circuit angle.

The speed of operation of the mho unit is similarly a function of the instant in the cycle at which the fault occurs. It is also necessarily a function of the angle of the fault impedance, the magnitude of the fault impedance, the magnitude of the fault current, the angle of the circuit, and the tap setting and angle of maximum torque of the mho unit. The time data are presented in Fig's. 6, 7, 8 and 9 in terms of these variables. Maximum operating times are obtained when the fault occurs at that instant in the cycle which produces zero d-c offset current. Conversely, minimum operating

times are obtained when the fault occurs at that instant in the cycle which produces maximum d-c offset currents.

#### TIME OVERCURRENT UNIT

The inverse time-current characteristics of the Type GYC51 time overcurrent unit are shown in Fig. 11.

The very inverse time-current characteristics of the Type GYC53 time overcurrent unit are shown in Fig. 12.

The extremely inverse time-current characteristics of the Type GYC77 time overcurrent unit are shown in Fig. 13.

The total operating time of the Type GYC relay second zone is the summation of the mho unit pickup time, the time overcurrent operating time, and the one cycle transfer auxiliary unit pickup time.

## INSTANTANEOUS OVERCURRENT UNIT

The pickup current of the instantaneous overcurrent unit is adjustable over a 4:1 range. The contacts reset at approximately 90 to 95 per cent of a-c pickup current.

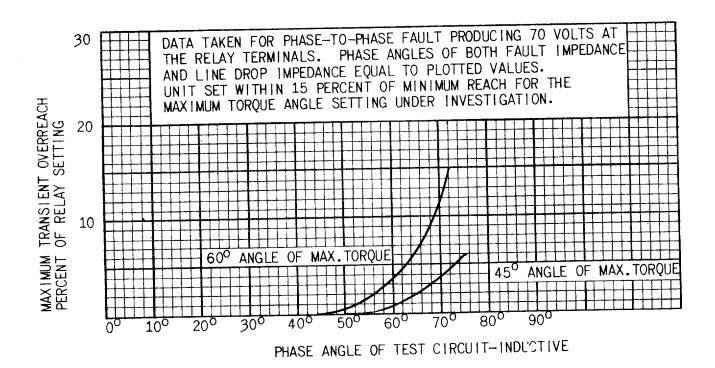


Fig. 10 Maximum Transient Overreach of Type GYC Who Unit versus Phase Angle of Test Circuit

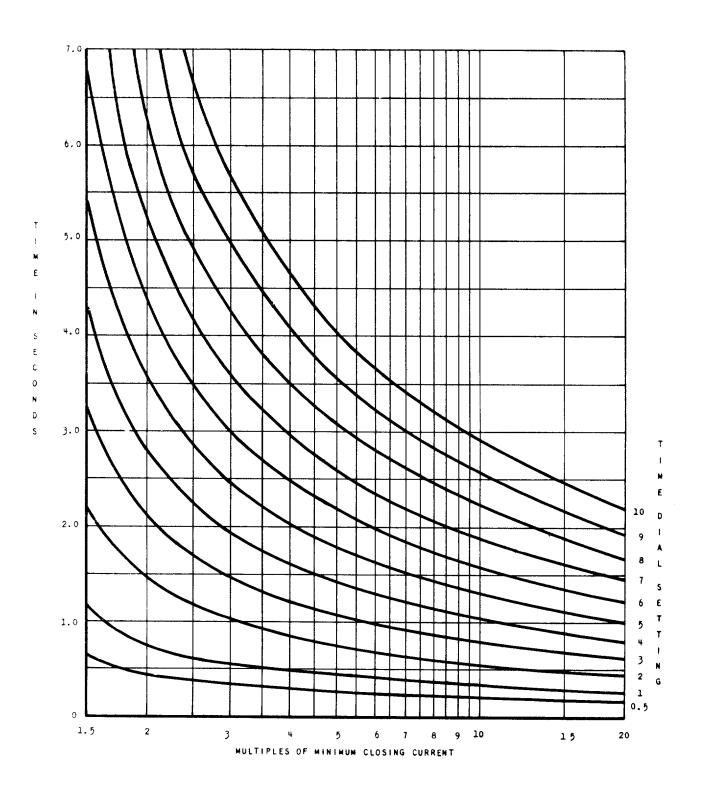


Fig. II Inverse Time-Current Characteristics of Time Overcurrent Unit of Type GYC51 Relay

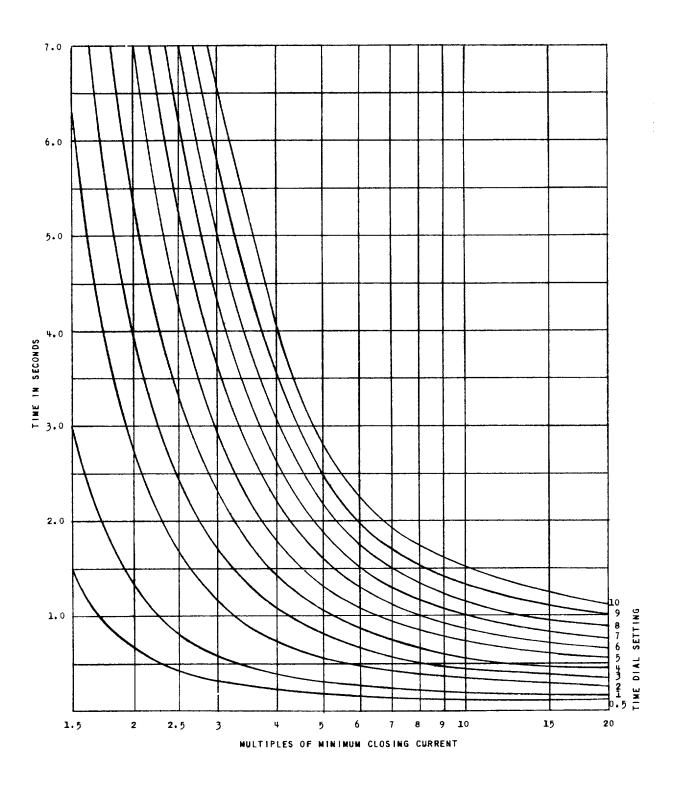


Fig. 12 Very Inverse Time-Current Characteristics of Time Overcurrent Unit of Type GYC53 Relay

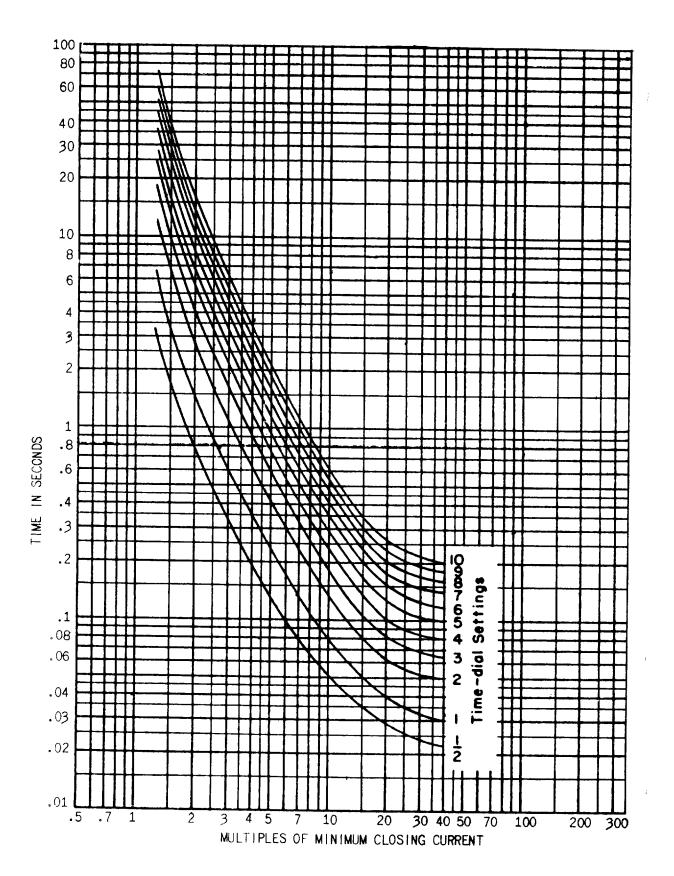


Fig. 13 Extremely Inverse Time-Current Characteristics of Time Overcurrent Unit of Type GYC77 Relay

#### TAPPED AUTOTRANSFORMER

The ohmic reach of the mho unit may be adjusted by means of taps on the autotransformer. The autotransformer is tapped in one per cent steps from zero to one hundred per cent, and these taps are brought to the right-hand tap block. The tap setting of the two taps marked No. 1 determine the first or instantaneous zone, and the tap setting of the two taps marked No. 2 determine the second or time delayed zone.

The tap setting required to protect a zone Z ohms long, where Z is the positive phase sequence phase to neutral impedance expressed in secondary terms, is determined by the following equation:

# OUTPUT TAP = $\frac{\text{(INPUT TAP)(MIN.OHMS)} COS(\emptyset-\theta)}{Z}$

The minimum ohms of the mho unit can be found on the relay nameplate.

The input tap setting is generally 100 per cent. There are times, however, when this setting does not allow fine enough adjustment of the mho unit reach. In these instances 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 INPUT lead, which is under the hexagonal stud in the top tap (10 per cent), to one of the other taps on the upper half of the tap block.

For a numerical example of the relay tap settings, refer to the "Calculations" section of this book.

#### MHO UNIT TRANSFER AUXILIARY

The mho unit transfer auxiliary, A, is a telephone-type relay whose coil and contacts are shown in the internal connection diagrams of Fig's. 15 and 16. Fig's. 1 and 2 show the unit mounted in the middle right of the relay. The transfer unit is used to change the tap setting of the mho unit, and thereby provide a second step of distance relay protection. Its operation is controlled by the time overcurrent unit, TOC, as shown by the internal connection diagrams of Fig's. 15 and 16, and the external connection diagram of Fig. 14. The circuit opening contacts of the transfer auxiliary provide the trip circuit for faults in the first, or instantaneous, step of line protection. If the fault is beyond the first zone of protection, after a time delay the time overcurrent unit picks up, providing the fault current is of sufficient magnitude.

Closing of the TOC contact energizes the transfer auxiliary which performs three functions. First, the transfer relay opens the circuit opening "A" contacts in the zone 1 trip circuit. Second, the transfer auxiliary changes the setting of the mho unit by switching the mho unit from its No. 1 tap setting on the autotransformer to its No. 2 tap setting. This extends the reach of the mho unit, and enables it to operate for faults in the second zone of distance protection. Third, the transfer relay closes the circuit closing "A" contacts in the zone 2 trip circuit.

The operating time of the transfer auxiliary unit is one cycle.

#### RATINGS

The Types GYC51, GYC53 and GYC77 are rated 120 volts, 5 amperes 60 cycle and 125/250 volts dc.

The angle of maximum torque of the mho unit can be set at either 60 or 45 degrees voltage leading current. The reach of the mho unit is rated on the basis of its 60 degree angle of maximum torque setting. The GYC mho unit is available in ohmic ranges of 0.25-2.5, 0.5-5, 1-10, 2-20 and 3-30 ohms phase to neutral. When the mho unit is set for a 45 degree angle of maximum torque, its minimum and maximum reaches are increased approximately 37 per cent. The reach of the mho unit can be adjusted in one per cent steps.

The time overcurrent unit of the Type GYC relay is rated 4-16 amperes. The time overcurrent unit of the Type GYC51 relay has an inverse time characteristic. The time overcurrent unit of the Type GYC53 relay has a very inverse time characteristic. The time overcurrent unit of the Type GYC77 relay has an extremely inverse time characteristic. The continuous current rating of the induction disk 4-16 ampere unit is 10 amperes or tap value, whichever is greater.

The instantaneous overcurrent unit of the Type GYC relay is rated 4-16 amperes. The continuous current rating of this unit is 12 amperes.

A dual control circuit rating of 125 and 250 volts dc is provided in the Type GYC relay.

The combination target and seal-in units have a dual rating of 0.2/2.0 amperes. The tap selected is determined by the current drawn by the trip coil.

The 0.2 ampere tap of the seal-in unit is for use with trip coils that operate on currents ranging from 0.2 to 2.0 amperes at the minimum control voltage. It is not good practice to use the 0.2 ampere tap where the trip current is greater than 2 amperes since the coil impedance, Table I, may reduce the trip current to so low a value that the breaker will not be tripped.

The 2 ampere tap of the seal-in unit should be used with trip coils that take 2 amperes or more at minimum control voltage, provided the tripping current does not exceed 30 amperes at the maximum control voltage. If the tripping current exceeds 30 amperes, an auxiliary relay should be used, the connections being such that the tripping current does not pass through the contacts or the target and seal-in coils of the protective relay.

The current-closing rating of the contacts is 30 amperes for voltages not exceeding 250 volts. The current-carrying ratings are affected by the selection of the tap on the target and seal-in coil as indicated in Table I.

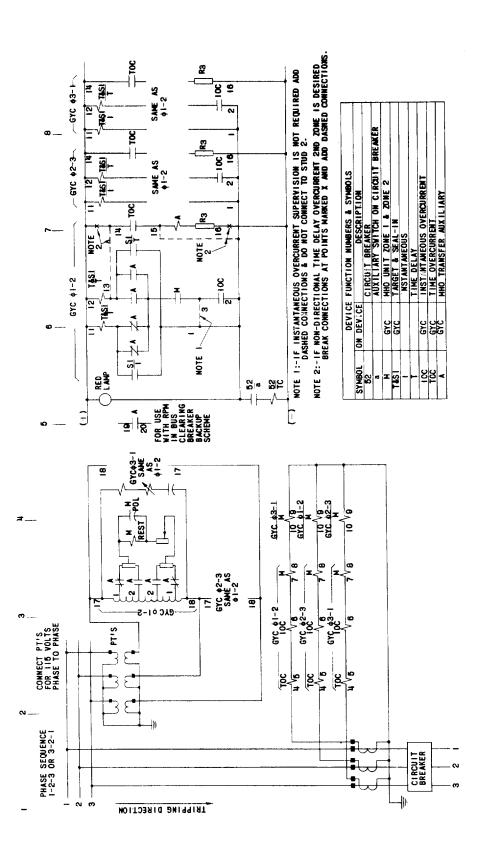


Fig. 14 Typical Wiring Diagram for Type GYC Relay

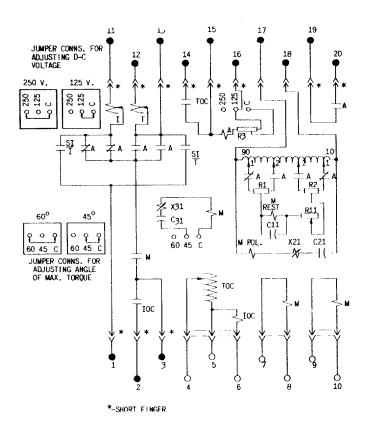


Fig. 15 Internal Connections for the Type GYC51 and Type GYC53 Relays

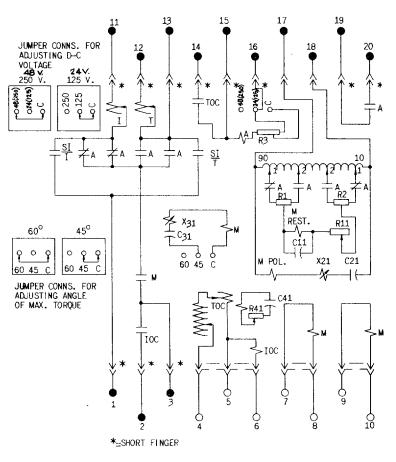


Fig. 16 Internal Connections for the Type GYC77 Relay

\* Denotes change since superseded issue.

TABLE I TARGET AND SEAL-IN UNIT

	2 Amp Tap	0.2 Amp Tap
Resistance-d-c-ohms Impedance-60 cycle-ohms	0.13 0.53	7 52
Tripping Duty-Amperes Continuous Current-Amperes	30 3	5 0.3

Though the contacts of the relay will close and carry momentarily 30 amperes dc, the breaker trip circuit should always be opened by an auxiliary switch or suitable means. It cannot be opened by the tripping relay contacts or by the seal-in unit contacts.

#### BURDENS

#### CURRENT CIRCUITS

#### A. Mho Unit

The mho unit current burden imposed on each CT by a three-phase terminal of three GYC relays at 5 amperes and rated frequency:

TABLE II

Ohmic Range	Freq.	R	х	z	VA
0.25-25 0.5 -5 1-10 2-20 3-30	60 60 60 60	.01 .01 .020 .035 .052	.001 .002 .007 .027 .061	0.01 0.01 0.021 0.043 0.08	0.25 0.25 0.5 1.1 2.0

The above burden was measured under phaseto-phase fault conditions which yields higher burden readings than balanced three-phase conditions.

#### B. Time Overcurrent Unit

The time overcurrent unit burden imposed on each CT by a three-phase terminal of three GYC relays at 5 amperes and rated frequency.

TABLE III

Relay	Range	Freq.	Тар	R	Х	Z	VA
GYC51 GYC53 GYC77	4-16	60 60 60		0.10 0.04 0.025		0.08	8.8 2.1 1.25

#### INSTANTANEOUS OVERCURRENT UNIT

The instantaneous overcurrent unit burden imposed on each CT by a three-phase terminal of three GYC relays at 5 amperes and rated frequency:

TABLE IV

Range Amperes	Freq.	Тар	R	х	Z	VA
4-16	60	4	0.044	0.094	0.104	2.6

#### POTENTIAL CIRCUIT

The maximum potential burden imposed on each P.T. by a three-phase terminals of three GYC relays at 120 volts and rated frequency for the 0.25, 0.5, 1, 2 and 3 ohm mho units is as follows:

TABLE V

	Freq.	Watts	Vars	VA
Restraint Polarizing Transformer	60 60 60	8.3 14.6 0.6	-0.9 * -7.5 * 1.1	8.3 16.4 1.2
Total Relay	60	23.5	-7.3 *	24.6

\* Leading reactive power (current leading voltage)

The potential burden of the mho unit is altered by changing the restraint tap setting in order to choose the proper reach.

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

WATTS = 15.2 + 
$$\left[\frac{\text{No. 1 Tap (\%)}}{100}\right]^2$$
 (8.3)  
VARS = -6.4 -  $\left[\frac{\text{No. 1 Tap (\%)}}{100}\right]^2$  (0.9)

VARS = -6.4 - 
$$\left[\frac{\text{No. 1 Tap (\%)}}{100 \bullet}\right]^2$$
 (0.9)

# DESCRIPTION

# GENERAL CONSTRUCTION

#### THE MHO UNIT

The mho unit of the Type GYC relay is of the four pole induction cylinder construction. The schematic connections for this unit are shown in Fig. 17. The two side poles, energized with phase-

to-phase voltage, produce the polarizing flux which interacts with the flux produced in the back pole. The back pole is 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:

$$T = 0 = EI \cos (\emptyset - \theta) - KE^2$$

Where E is the phase-to-phase voltage

- I is the delata current e.g.  $(I_1 I_2)$
- $\emptyset$  is the angle of maximum torque of the relay.
- $\theta$  is the power factor angle.
- K is a design constant

Dividing through by  $\boldsymbol{E^2}$  and transposing reduces the equation to:

$$\frac{I}{E} \cos (\emptyset - \theta) = Y \cos (\emptyset - \theta) = K$$

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.

#### TIME OVERCURRENT UNIT

These units are of the induction-disk construction type. The disk is actuated by a current operating coil on a laminated iron structure. This laminated structure is of the U-magnet type for the GYC51 and GYC53 relays, while it is of the wattmetric type for the GYC77 relay, as shown in Fig's. 1 and 2 respectively. A capacitor and variable resistor connected in series with the inner coil on the upper laminated structure of the wattmetric type make up its phase-shifting circuit. The disk shaft carries the moving contact which completes the "A" transfer unit circuit when it touches the stationary contact. The disk shaft is restrained by a spiral spring to give the proper contact closing current. The motion of the disk is retarded by a permanent magnet acting on the disk to give the correct time delay.

# INSTANTANEOUS OVERCURRENT UNIT

The overcurrent unit is of the plunger-type construction with the moving contacts fastened directly to a Textolite\* support molded onto the plunger rod. The armature is adjustable on the plunger rods to vary the pick-up over a range of 4:1. The magnet frame and stationary contact assembly, as well as the lower stop post for the plunger rod, are fastened to a Textolite mounting plate.

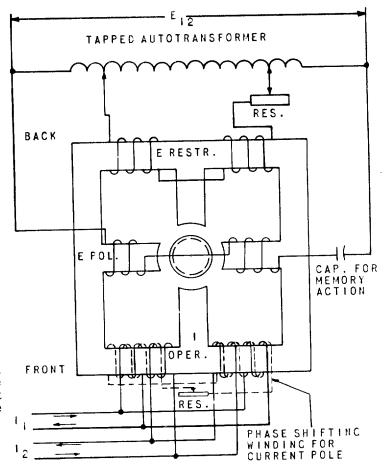


Fig. 17 Schematic Connections of the Mho Unit Associated with Phase I-2 (Top View)

#### SEAL-IN UNIT

Two target and seal-in units are mounted at the top of the relay as shown in Fig's. 1 and 2. The left hand, or "I", seal-in unit has its coil in series and its contacts in parallel with the zone one, or instantaneous, trip contacts. The right hand, or "T", seal-in unit has its coil in series and its contacts in parallel with the zone two, or time delay, trip contacts. When the first or second zone trip contacts close, their respective seal-in units pick-up and seal-in. When the seal-in unit picks-up, it raises a target into view which latches up and remains exposed until released by pressing a button beneath the lower left corner of the relay cover.

#### CASE

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

The case has study or screw connections at both ends for external connections. The electrical connections between the relay units and the case study 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 study 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.

To draw out the relay unit, the cover is removed and the plug is drawn out. Shorting bars are provided in the case to automatically 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.

# 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 the relay, an examination should be made for any damage sustained during shipment. If injury or damage resulting from rough handling is evident, a claim should be filed at once with the transportation company and the nearest Sales Office of the General Electric Company notified promptly.

Reasonable care should be exercised in un-

packing 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.

# INSTALLATION

#### INSPECTION

Before placing a relay into service, the following mechanical adjustments should be checked, and faulty conditions corrected according to instructions in the ADJUSTMENTS subsection of this section or under the MAINTENANCE section.

The armature and contacts of the target and seal-in units 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 units.

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

There should be no noticeable friction in the rotating structure of the mho unit. The mho unit moving contact should just return to the backstop when the relay is de-energized, and in the vertical position.

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 zone's contacts successively by hand and allowing trip current to pass through the contacts and the target and seal-in element. The target should promptly appear. Closure of the time overcurrent unit's contact should energize the "A" transfer auxiliary.

CAUTION: Examine the tap blocks with great care to make sure the tap lead terminals do not come in contact with adjacent terminals, tap hole shoulders, mounting screw heads, the case or other grounded parts. This may cause a portion f the tapped autotransformer to be shorted or grounded, the result from this being eventual failure of the transformer. The transformer tap leads should be placed horizontally on the tap block with the leads coming out rather than in toward the relay.

#### **ADJUSTMENTS**

#### MHO UNIT

The mho unit is properly calibrated at the factory and it is not advisable to disturb these calibrations. If it is desirable to check the factory calibration, refer to the ELECTRICAL CHECK TESTS subsection of the INSTALLATION section. If it is necessary to change the calibration of the relay, refer to the MAINTENANCE section of this book where detailed instructions are given under the SERVICING subsection.

The reach of the mho unit can be adjusted in one per cent steps by the positioning of the autotransformer tap leads on the relay right hand tap block. To determine the proper tap setting of the mho unit, a procedure similar to that outlined in the CALCULATIONS section should be followed.

The angle of maximum torque of the relay can be set at either 60 or 45 degrees, voltage leading current, by the positioning of a tap lead on the relay left hand tap block.

#### TIME OVERCURRENT UNIT

The time and current settings of the time overcurrent unit can be made easily and quickly. Each time value shown in Fig's. 11, 12 and 13 indicates the time for the time overcurrent unit contacts to close with a particular time-dial setting when the current is a prescribed number of times the current-tap setting.

The current at which the contacts operate may be changed by changing the position of the tap plug in the tap block at the top of the relay. Screw the tap plug firmly into the tap marked for the desired current (below which the unit is not to operate).

When changing the current setting of the unit, remove the bottom connecting plug to short the

current-transformer secondary circuit. Next, screw the tap plug into the tap marked for the desired current and then replace the connecting plug.

The pickup of the unit for any current tap is adjusted by means of a spring-adjusting ring. The ring may be turned by inserting a tool in the notches around the edge. By turning the ring, the operating current of the unit may be brought into agreement with the tap setting employed, if for some reason, this adjustment has been disturbed. This adjustment also permits any desired setting intermediate between the various tap settings to be obtained. The unit is adjusted at the factory to close its contacts from any time-dial position at a minimum current within five per cent of the tap plug setting. The unit resets at 90 per cent of the minimum closing value.

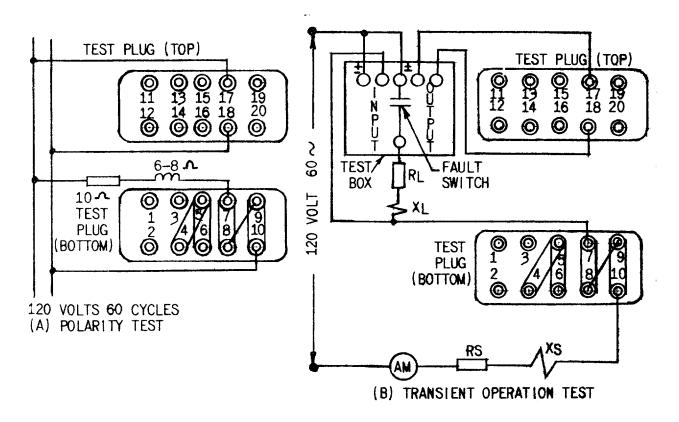
The setting of the time dial determines the length of time the unit requires to close its contacts when the current reaches the predetermined value. The contacts are just closed when the dial is set on 0. When the dial is set on 10, the disk must travel the maximum amount to close the contacts and therefore this setting gives the maximum time setting.

The primary adjustment for the time of operation of the unit is made by means of the time dial. However, further adjustment is obtained by moving the permanent magnet along its supporting shelf; moving the magnet in toward the back of the unit decreases the time, while moving it out increases the time.

If selective action of two or more relays is required, determine the maximum possible short-circuit current of the line and then choose a time value for each relay that differs sufficiently to insure the proper sequence in the operation of the several circuit breakers. Allowance must be made for the time involved in opening each breaker after the relay contacts close. For this reason, unless the circuit time of operation is known with accuracy, there should be a difference of about 0.5 second (at the maximum current) between relays whose operation is to be selective. An example of the selection of the second zone time setting is given in the CAL-CULATIONS section.

#### INSTANTANEOUS OVERCURRENT UNIT

The moving contact of the instantaneous overcurrent unit is operated directly by the movement of the plunger assembly in the calibrating tube. The unit may be set to operate at any point within the range shown on the nameplate by turning the armature on the plunger rod. The armature is held securely at the desired setting by means of an internal locking spring which requires no adjustment. For each unit the number on the nameplate associated with a given mark on the calibrating tube is the current value at which the unit will just pick up if the bottom of the armature is set to line up with the mark.



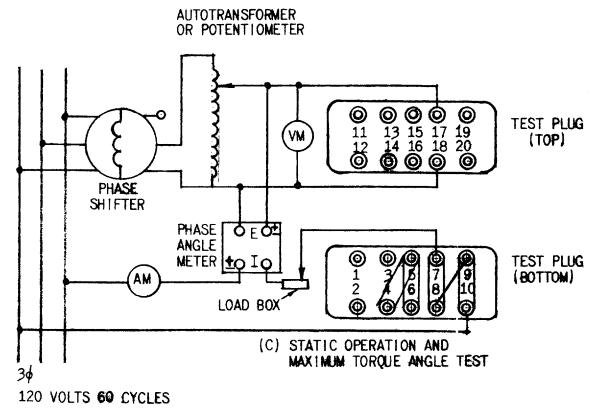


Fig. 18 Test Connections for Type GYC Relay Using Test Plugs XLA12A

#### TARGET AND SEAL-IN UNIT

The choice of tap on the target and seal-in unit is described under RATINGS.

The tap screw is the screw holding the right-hand stationary contact of the seal-in unit. To change the tap setting, first remove the connecting plug. Then, take a screw from the left-hand stationary contact and place it in the desired tap. Next, remove the screw from the other tap and place it in the left-hand contact. This procedure is necessary to prevent the right-hand stationary contact from getting out of adjustment. Screws should not be in both taps at the same time as pickup for d-c will be the higher tap value.

#### MHO UNIT TRANSFER AUXILIARY

The transfer auxiliary control circuit of the Type GYC relay is dual rated. Choice of either a 125 volt dc or a 250 volt dc rating can be obtained by positioning of a tap lead on the relay left-hand tap block.

#### ELECTRICAL CHECK TESTS

#### MHO UNIT

Before the relay is put into service, the mho unit should be given a partial check to determine that the factory adjustments have not been disturbed. It is the purpose of the tests outlined in this subsection to check these factory calibrations. If these CHECK tests indicate it is necessary to change the relay calibration, refer to the MAINTENANCE section of this book where detained instructions are given under the SERVICING subsection.

#### a. Mho Unit Test Equipment

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. 19. In Fig. 19  $R_S^{\phantom{1}} + j X_S^{\phantom{1}}$  is the source impedance,  $S_F^{\phantom{1}}$  is the fault switch and  $R_L^{\phantom{1}} + j X_L^{\phantom{1}}$  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  $R_L^{\phantom{1}} + j X_L^{\phantom{1}}$  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,  $X_L^{\phantom{1}}$ , and the test resistor with enough taps so that the combination may be made to match any line.

For convenience in field testing the fault switch and tapped autotransformer of Fig. 19 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.

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. 6158546) be arranged with the Type XLA test plugs as shown in Fig. 18B. This circuit is similar to that shown in Fig. 19 except that the source impedance  $R_{\rm S}$  + jX $_{\rm S}$  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  $R_{\rm S}$  + jX $_{\rm S}$  is only necessary when the mho unit is being tested for characteristics affected by the fault transients, such as overreach and operating time. Such tests are not considered necessary at the time of installation or during periodic testing. Tests of this nature are described in the MAINTENANCE section under SERVICING.

IMPORTANT: The test resistor has a one minute current rating of 10 amperes. Excessive currents should not flow through this resistor for extended periods of time.

#### b. Testing the Mho Unit

The manner in which the mho unit tap settings are determined is described in the CALCULATIONS section, and the manner in which the tap settings are made is discussed in the ADJUSTMENTS subsection of this INSTALLATION section. It is the purpose of the electrical tests in this section to

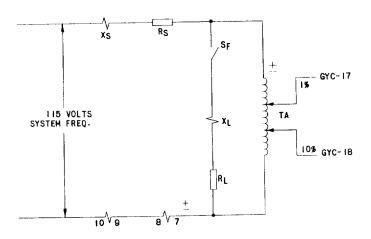


Fig. 19 Mho Unit Test Connections

check the factory calibrations of the mho unit and/or the ohmic pickup of the mho unit at the settings which have been made for a particular line section.

NOTE: Before making pickup or phase-angle checks, the mho unit should be allowed to heat up for approximately 15 minutes energized with rated voltage alone.

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,  $\mathbf{X}_{L}$ , and relay angle of maximum reach. The line reactance,  $\mathbf{X}_{L}$ , selected should be the test reactor tap nearest above twice the mho unit reach at the test reactor tap angle. From Fig. 20 it is seen that twice the relay reach at the angle of the test reactor impedance is:

$$2Z_{\text{Relay}} = 2 \frac{100 \text{ Z min.}}{\text{No. 1 tap}} \cos (\emptyset - \theta)$$

Where  $\theta$  is the angle of the test reactor impedance and  $\theta$  is the relay angle of maximum reach. The test box autotransformer per cent tap for the mho unit pickup is given by:

$$\% \tan = \frac{2Z_{Relay}}{Z_{L}} \quad x \quad (100)$$

As an illustration of the above instructions, the per cent tap required on the test box autotransformer to check a mho unit that has been factory calibrated for a 3 ohm minimum reach and 60 degree angle of maximum torque will be calculated. In determining the reactor tap setting to use, it may be assumed that the angle  $\theta$  of the test reactor impedance is 80 degrees. From the above, twice the relay reach at the angle of the test-reactor impedance is:

$$2Z_{\text{Relay}} = 2 \frac{300}{100} \cos (80-60) = 5.64 \text{ ohms}$$

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 VI shows the angles for each of the reactor taps.

TABLE VI

TAP	ANGLE	cos (Ø-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 ohm tap is 86 degrees.

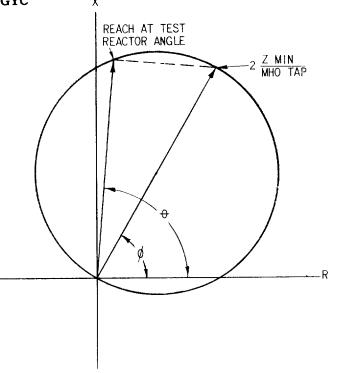


Fig. 20 Reach of the Who Unit at the Angle of the Test Reactor

Therefore:

$$2Z_{Relay} = 2 \frac{300}{100} \cos (86 - 60) = 5.4 \text{ ohms}$$

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:

$$Z_{L} = \frac{X_{L}}{\sin 86} = 6.115$$

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 cal-ibrated 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. It should not be necessary to check the ohmic pickup at more than two impedance angles to ascertain the accuracy of the angle of maximum torque setting. These two points and the origin would then define the circular characteristic of the mho unit under test.

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. 20 where it is seen, for example, at the zerodegree position that a two or three degree error in phase angle will cause a considerable apparent error in reach. Secondly, the effect of the control spring should be considered since the mho unit can only have a perfectly circular characteristic when the control spring torque is negligible. For any normal level of polarizing voltage, the control spring may be neglected but in testing the 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 will be low with the result being that the control spring torque will no longer be negligible. The result of the control spring at low polarizing voltages is to cause the reach of the mho unit to be somewhat reduced.

In addition to the above tests on the mho unit, it should also be checked for directional action with the test box circuit of Fig. 18B. The fault resistor, R<sub>L</sub>, should be zero and the test reactor should be set on the 0.5 ohm tap. A load box should be used as the source impedance to regulate the current. The mho unit should be set with a 60 degree angle of maximum torque setting, and a 100 per cent tap setting. With the fault switch closed, the test box set for 7 percent, and the load box adjusted for a 60 ampere fault current, the mho unit should close its contacts.

With the current connections at the relay terminals 7 and 10 reversed from that shown in Fig. 18B and no voltage applied to the relay the mho unit contact should remain open from 0 to 60 amperes.

#### OVERCURRENT UNITS

Before the relay is put into service, the overcurrent units should be given a partial check to determine that the factory adjustments have not been disturbed. The pickup current of both the time overcurrent unit and the instantaneous overcurrent unit should be checked. The time dial of the time overcurrent unit will be set at zero before the relay leaves the factory. It is necessary to change this setting to open the time overcurrent unit contacts.

The operating time of the time overcurrent unit should be checked for one or more time dial settings.

#### OVERALL TEST

A short test which will check the polarities of the relay connections as well as mho unit open circuits is described below. The performance of this test on all relays of the terminal yields a good though not infallible check of the connections. Open the trip circuit to prevent an unintentional circuit breaker trip. Take special care to record the mho unit tap setting and angle of maximum torque setting. Set the angle of maximum torque to 45 degrees. Remove the lower connection plug, thereby disconnecting the relay current circuits. With full voltage applied, the mho unit should have strong restraint

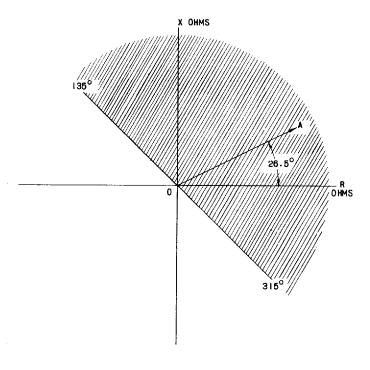


Fig. 21 Directional Characteristic of Mho Unit with Zero % Tap Setting and 45° Angle of Maximum Torque

torque to the right against the backstop (greater than that due to the control spring along). Replace the lower connection plug, and open one of the No. 1 tap leads. The mho unit should then be directional about the 135-315 degree line on a R-X diagram. If the angle of the apparent load impedance as determined from the real and lagging reactive power flow into the protected line, lies in the shaded area of Fig. 21, the mho unit should close its contacts. If the angle of this apparent impedance lies in the unshaded area, the mho unit should remain open. In the latter case, if the voltage connections of the mho unit are reversed by means of an appropriately connected test plug, the mho unit should then close its contacts.

For example, if the real power flow into the protected setion is 1000 KW, and the lagging reactive power flow into the protected section is 500 KVARS, then the angle of the apparent load impedance is the angle whose tangent is 0.5, or 26.5 degrees voltage leading current. This apparent impedance lies then in the shaded area of Fig. 21, and the mho unit should operate.

After this test has been completed, care must be taken to return the taps which determine the mho unit angle of maximum torque and reach settings to their proper positions.

#### MOUNTING

The relay should be mounted in a vertical

surface. The outline and panel drilling is shown in Fig. 25.

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, as described in the SERVICING subsection of the MAINTENANCE section.

#### LOCATION

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

#### CONNECTIONS

The internal connection diagram for the Types GYC51 and GYC53 relays is shown in Fig. 15. The internal connection diagram for the Type GYC77 relay is given in Fig. 16. A typical external connection diagram for the Type GYC relay is shown in Fig. 14.

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.

# **CALCULATIONS**

## IMPORTANT CONSIDERATIONS

Before proceeding to the example of calculations for relay settings, it is well to discuss some of the salient factors that should be considered.

#### a. Arc Resistance

The extent to which fault arc resistance exists depends on the fault itself. If the fault results from a ground wire which falls across the phase conductors, the arc resistance could be zero. If the fault results from a lightning surge which causes a flashover, the arc resistance may be appreciable. The resistance of an arc due to the latter phenomenon is given approximately by the following expression:

$$R_A = \frac{50}{I} (\overline{KV} + 28vt)$$

where:  $R_A$  = arc resistance in primary ohms

KV = system line to line voltage in kv

v = wind velocity in miles per hour

t = length of time in seconds that arc persists

li should be noted that the above equation is

based on empirical data and that the quantity in parenthesis is proportional to the length of the arc. The latter is so because the initial arc length is roughly proportional to the kv rating of the line and the elongation of the arc with time will depend on the wind velocity. In considering the effect of arc resistance on distance relays, the value

$$R_A = 50 \frac{\overline{KV}}{I}$$

#### b. Secondary Impedance

The GYC mho unit is calibrated in terms of secondary phase to neutral impedance. This may be obtained from the primary impedance by the use of the following equation:

$$Z_{sec} = Z_{pri} \frac{CT \ ratio}{PT \ ratio}$$

where

Z<sub>pri</sub> = primary phase to neutral impedance in

Z<sub>sec</sub> = secondary phase to neutral impedance in ohms

#### c. First Zone Reach

The instantaneous first zone is usually set to reach 80 to 90 per cent of the protected line section. The exact setting will depend on how accurately the line impedance is known and the overreach characteristic, as given in Fig. 10. Also important is the phase angle of the protected line section relative to the angle of maximum torque of the relay (45 or 60 degrees) and the effects of arc resistance.

Referring to Fig. 22 which illustrates the characteristic of the mho unit set for a 45 degree angle of maximum torque, OB represents the protected line and OA is 90 per cent of OB. Thus, the relay is set to protect 90 per cent of the protected line on 1st zone. If the arc resistance for a fault at A is given by AC, then the impedance as seen by the relays at 0 for such a fault would be OC. This is outside of the relay 1st zone characteristic and would be tripped by second zone.

If the protected line has an impedance that plots to the left of the crest of the mho circle, such as  $\overline{OD}$ , then the effect of fault resistance  $\overline{FE}$  for a fault at  $\overline{F}$  is to bring the total impedance into the tripping circle. This situation can result with the 45 degree setting only when the line impedance angle is greater than 67.5 degrees; with the 60 degree setting only when the line impedance angle is greater than 75 degrees. If such a situation is encountered, the relay reach setting may be reduced enough to compensate for it.

It is not recommended that any attempt be made to take advantage of arc resistance to justify a longer 1st zone reach setting, because certainfaults will have very little arc resistance and for this condition the relays may reach too far. The reach of the relay at any given impedance angle in terms of its reach at the set angle is given by the following expression:

$$Z_R = Z_M \cos (\theta - \emptyset)$$

where:

 $\emptyset$  = maximum torque angle of relay (45 or 60 degrees).

 $\theta$  = angle of impedance to the fault.

Z<sub>M</sub> = relay set reach in secondary ohms at angle of maximum torque.

 $\mathbf{Z}_{\mathbf{R}}$  = relay reach in secondary ohms at impedance angle  $\boldsymbol{\theta}_{\star}$ 

#### d. Second Zone Reach

It is recommended that the second zone reach be set so that it does not reach beyond the instantaneous first zone units on adjoining circuits. Such settings make it unnecessary to coordinate

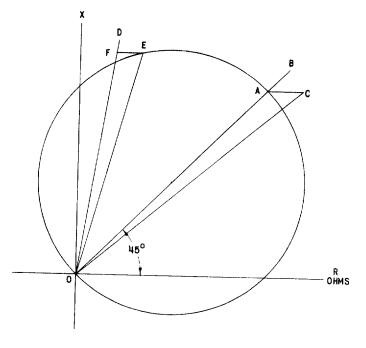


Fig. 22 Effect of Arc Resistance on Impedance Seen by Mho Unit

overcurrent units on adjoining lines. This is particularly advantageous on parallel circuits having weak infeeds where coordination of overcurrent units may not be possible. It is also advantageous on series circuits with no infeeds where coordination of overcurrent units may require long time settings.

It is, however, desirable to set the second zone reach as far as possible within the above limits as indicated in the EXAMPLE subsection of this CALCULATIONS section. The reach of the mho unit is not switched to second zone until some set time delay after the fault occurs. Therefore, there will be no memory action associated with second zone tripping. It is for this reason that it is desirable to set the second zone reach as far as possible in order to provide for positive operation on second zone faults that result in rather low voltages at the relays and which in turn may cause the relay reach to pull back.

Aside from this consideration, it is well known that infeeding currents at the remote terminal make a fault on an adjoining line appear to be further from the relay than actually is the case. This may

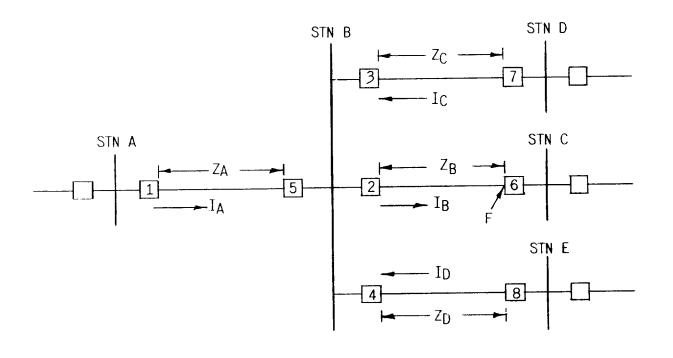


Fig. 23 Portion of a Typical 69KV Sub-Transmission System

be observed from Fig. 23. For a fault at F, the impedance as seen by the relays at circuit breaker #1 is:

$$Z_B \left(\frac{I_B}{I_A}\right) + Z_A$$

Since  $I_B = I_A + I_C + I_D$ , it is apparent that  $I_B$  is greater than  $I_A$  and the impedance as seen by the relays will be somewhat larger than the actual impedance. If  $I_B / I_A = K_B$ , then  $Z_A + K_B (Z_B)$  is the impedance as seen by the relays at breaker #1 for a fault at F.

On a system similar to that illustrated in Fig. 23, the second zone reach setting at breaker #1 should not overreach the first zone of the relays at breakers 2, 3 and 4 unless second zones are coordinated on a time basis. If it is desired to set the second zone at breaker #1 to reach just short of the first zone settings at breakers 2, 3 and 4 including the effects of infeed the following equation should be used:

2nd Zone Reach = 0.9 
$$Z_A + \frac{KPZ}{100}$$

where Z = impedance of adjoining line section.

K = minimum infeed factor for the same adjoining line section. P = 1st zone setting in per cent of line length for the same adjoining line section.

It should be noted that for the system shown in Fig. 23, KPZ may be  $(K_B)$   $(P_B)$   $(Z_B)$  or  $(K_C)$   $(P_C)$   $(Z_C)$  or  $(K_D)$   $(P_D)$   $(Z_D)$ . In order to be sure not to overreach, it is necessary to evaluate all of these products and select the smallest one in establishing the second zone reach. Furthermore, in evaluating all of these products, it is necessary to use the lowest value of K which may be expected. For example, if we consider the line between stations B and C, and assume that the first zone at 2 is set for 90 per cent of  $Z_B$ , the  $P_B$  = 90.

As defined,  $K_B = \frac{I_B}{I_A}$ , but it should be obtained for the minimum  $I_B$  and maximum  $I_A$  that might occur simultaneously, such as if breaker 3 or 4 were open. The lines to stations D and E should be similarly examined and the KPZ products obtained. In this case the lowest of the three products would be used.

#### **EXAMPLE**

As an example, let us consider a 69 KV line with 6 + j16 primary ohms impedance with three

adjoining sections having KPZ as given in the following table:

TABLE VII

SECTION	K	P	Z
Line B	1.1	85	9+j24
Line C	1.6	90	8+j20
Line D	1.4	90	17+j40

PT Ratio = 69,000/115 = 600/1 CT Ratio = 300/5 = 60/1

Consider that Fig. 23 represents the system and that the line to be protected is between stations A and B. The terminal under consideration is at circuit breaker #1.

#### FIRST ZONE REACH SETTING

Assume for this example that it is desired to set the first zone at breaker #1 to protect 90 per cent of the line. Assume further that the minimum fault current through circuit breaker #1 for a three phase fault at the balance point is 2500 primary amperes. This yields a maximum arc resistance

$$R_{A} = \frac{50x69}{2500} = 1.38 \text{ primary ohms}$$

$$R_{A} = 1.38 \frac{60}{600} = 0.138 \text{ secondary ohms}$$

The first zone must be set to reach  $0.9(6+j16) = 15.35 | 69.4^{\circ}$  primary phase to neutral ohms.

$$Z_{\text{sec}} = \frac{60}{600} (15.35 \lfloor 69.4^{\circ} \rfloor) = 1.54 \lfloor 69.4^{\circ} \rfloor$$

Use the relay with the 1.0 ohm minimum phase to neutral reach and set angle of maximum torque at 60 degrees.

Calculate first zone tap from the following equation:

1st zone tap = 
$$\frac{[Input Tap (\%)] 1.0 Cos(69.4^{\circ}-60^{\circ})}{1.54}$$

1st zone tap = (0.64)(input tap)

Set input tap at 100 per cent and first zone tap at 64 per cent.

It will be noted that the maximum arc resistance (0.138 secondary ohms) is only a very small percentage of the first zone reach setting of the relay and hence, the effects will be negligible.

#### SECOND ZONE REACH SETTING

From the data given in the table, it will be noted that line B has the smallest KPZ product (for minimum K), which is:

$$K_B P_B Z_B = 1.1 (85) (9+j24) = 841 + j2240$$

It is interesting to note that in this case the smallest KPZ product does not occur on the shortest line section.

The second zone reach should be set for:

$$Z_{\text{sec}} = \frac{60}{600} \ 0.9 \left[ (6+j16) + \frac{(841 + j2240)}{100} \right]$$

$$Z_{sec} = 3.68$$
 |  $69.4^{\circ}$  phase to neutral ohms

Calculate second zone tap setting as follows:

2nd zone tap in per cent = 
$$\frac{\text{Input Tap (\%)} \quad 1.0 \cos (69.4^{\circ} - 60^{\circ})}{3.68}$$

2nd zone tap = (input tap) (0.268)

Set input tap at 100 per cent

2nd zone tap at 27 per cent

With regard to the arc resistance, assume for this example a wind velocity of 10 miles per hour and a second zone time of 0.5 seconds. Assume, too, that the minimum fault current through breaker #1 for a line B fault at the second zone balance point is 1500 amperes. Thus, the maximum arc resistance

$$R_{A} = \frac{50}{1500} \qquad \boxed{69 + 28(10) (0.5)}$$

 $R_A = 6.98 \text{ primary ohms}$ 

$$R_A = \frac{60}{600}$$
 6.98 = 0.698 secondary ohms

Here again the arc resistance will have only a small affect on the reach of the relay.

#### SECOND ZONE TIME SETTING

It is necessary to set the second zone time at circuit breaker #1 so that a fault on any of the lines just beyond station B will cause either circuit breakers 2, 3 or 4 to trip on first zone before the overcurrent unit at circuit breaker #1 can close its contacts. This must be done for the condition of maximum fault current through circuit breaker #1.

Assume for this example that the maximum current through breaker #1 for a three phase fault at station B is 2400 amperes. Let the minimum current be 1200 amperes.

Thus

$$I_{\min} = \frac{1200}{60} = 20 \text{ secondary amperes}$$

$$I_{\text{max}} = \frac{2400}{60} = 40 \text{ secondary amperes}$$

Assume further that the relay plus breaker times at breakers 2, 3 and 4 for first zone operation is 0.12 seconds and that a minimum coordinating time of 0.30 seconds is desired. Under these conditions the overcurrent unit operating time at breaker #1 must be 0.42 seconds at a maximum fault current of 40 secondary amperes.

Since distance protection on the adjoining circuits was assumed, a rather definite second zone time appears desirable. Thus, the relay with the inverse time should be selected. From Fig. 11 which gives the time current characteristics of

the inverse unit, it will be noted that at 6.7 times pickup on time dial #1, the operating time is approximately 0.4 seconds. With the pickup set at 6.0 amperes the maximum fault of 40 secondary amperes will be 6.7 times pickup. Therefore, a setting of tap 6 and time dial #1 would give the desired operating time to close approximation. At minimum fault current (20 amperes or 3.3 times pickup) an operating time of about 0.5 will result.

It is important to note that the pickup of the overcurrent unit must always be set above maximum full load current.

#### **MAINTENANCE**

#### PERIODIC TESTS

An operation test and an inspection of each relay unit and seal-in unit are recommended at least once every six months. The inspection of the relay should be made as outlined in the INSPECTION subsection of the INSTALLATION section. The check tests should be those described in the ELECTRICAL CHECK TESTS subsection of the INSTALLATION section. These check tests may be made very quickly if the test box autotransformer settings for each relay terminal are determined ahead of time. In that case, it is only necessary to insert the test plugs in each relay in succession and observe relay contact operation when the fault switch is closed. Frequent CALIBRATION tests are not considered necessary since the calibration of the

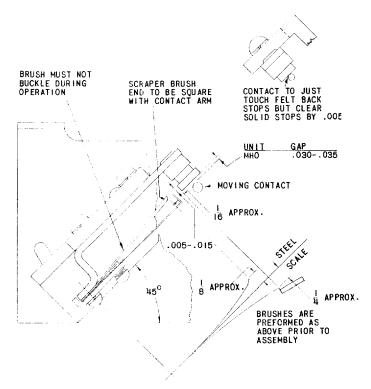


Fig. 24 Mho Unit Contact Adjustment

relay does not change appreciably with time. If it is found that the relay does not check test correctly, recalibration may be made according to the procedures set forth under SERVICING in this section.

#### 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

#### MHO UNIT

#### a. Contact Adjustment

The contacts of the mho unit should have an 0.032 inch gap when open, and should have no wipe beyond that due to the compressibility of the felt backstop. Fig. 24 illustrates the mho unit contact adjustments required to obtain proper operation. The gaps should be set by suitable thickness gages.

#### b. Control Spring Adjustment

After the GYC relay has been mounted in its test stand, the control spring of the mho unit should be adjusted so that the moving contact will just return to the right backstop when the relay is deenergized. It should be set so that if the backstop were removed, the moving contact would not move

further to the right. This adjustment should be made by using the control spring adjusting arm at the top rear of the mho unit. First loosen the set screw on the front of the top pivot support, and then rotate the control spring adjusting arm so as to return the contact arm to the backstop. Tighten the set screw permitting 1/64 inch end play to the shaft. The clutch should then be slipped mechanically and the reset position of the contact observed. This test should be repeated, and the control spring adjusted so that the moving contact will return to the backstop for all cup positions.

#### c. Clutch Setting

The clutch of the mho unit is set to slip when a force of from 45 to 55 grams is applied to the moving contact assembly at the moving contact. This setting can also be obtained by means of the following electrical test. Set the mho unit to have a 100 per cent tap setting and an angle of maximum torque of 45 degrees. The test connections of Fig. 18C should be used. Adjust the voltage to lead the current by 225 degrees, (180 degrees away from the angle of maximum torque). At this angle the restraint and operating torques are additive. The unit will develop a strong restraint to the right. The point at which the clutch slips will be a function of the current. It is recommended that the current be raised above the slipping point and then decreased to the point where the clutch ceases to slip. This value should be between 10 to 15 amperes for the 3 ohm unit. The clutch slip current of the other mho unit ohmic ranges is inversely proportional to the ratio of the unit's minimum reach to the 3 ohm unit reach.

The clutch on the mho unit 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, rotate the collar on the shaft through the number of half turns necessary to obtain the correct pressure. Moving the collar down increases the clutch pressure. The collar should then be locked by means of the set screw which seats itself in a groove provided on the shaft. Care should be taken to seat the set screw in this groove rather than tighten it against the threaded shaft.

#### d. Polarity

To check the polarity of the mho unit, the connections of Fig. 18A may be used. With these connections and the mho unit No. 1 taps on 100 per cent, the mho unit contacts should remain open. The correct polarity for the mho unit is indicated by the closing of the left-hand contact of the mho unit when one of the No. 1 tap leads is removed from the autotransformer tap block.

#### e. Directional

To check the directional action of the mho unit, the connections of Fig. 18C should be used. Set the mho unit's No. 1 taps on 100 per cent and its

angle of maximum torque at 60 degrees, voltage leading current. With the connections of Fig. 18C, adjust the phase shifter so that the phase angle meter reads 300 degrees, current leading voltage. With 1.5 volts applied to the potential circuit, the mho unit contact should be closed at 60 amperes. With the current connections at the relay terminals 7 and 10 reversed from that shown in Fig. 18C and voltage removed from the relay, the contact of the mho unit should remain open from 0 to 60 amperes.

If the mho unit fails to perform properly at these high current levels, the inner stator, or core, should be adjusted to the left or right a small amount. To accomplish this, first loosen the hex head nut in the bottom rear of the mho unit. This nut clamps the core positioning bracket. Once this nut is loosened, the core can be moved from side to side by means of the core adjusting screw mounted on the rear of the mho unit mounting plate. This adjusting screw is accessible from the right side of the relay. If the mho unit contact fails to close at the high current level, turn the core adjusting screw slightly clockwise. If the mho unit contact fails to open properly at the high current level, turn the core adjusting screw slightly counter-clockwise. After an adjustment of the screw in either direction, back it off slightly in the opposite direction to relieve tension on the screw.

#### f. Recalibration

Before pickup or phase angle checks are made, the mho unit should be allowed to heat up for approximately 15 minutes energized with rated voltage alone. When cold the relay tends to underreach by 3 or 4 per cent. If the relay is permitted to warm up, the error due to temperature will be less than one per cent.

If the pickup of the mho unit is to be calibrated by test, use the connections of Fig. 18C. Carefully calibrated meters are an absolute necessity if the relay calibration tests are to be carried out successfully. Set the mho unit calculated reach, Z, by means of the No. 1 taps. Set the angle tap to the desired angle of maximum torque. Adjust the voltage to the desired level. When setting low values of impedance, it is advisable to use approximately 55 volts to avoid excessive currents. Adjust the phase angle to the angle of maximum torque of the mho unit. Increase the current to determine the mho unit pickup current. The impedance calculated from the ratio of the voltage and current readings with the connections of Fig. 18C corresponds to the phase-to-phase impedance, and is double the phase-to-neutral or relay impedance ZR.

If the contact does not close at the correct current, the setting of the rheostat,  $R_{11}$ , should be changed. Rotating the rheostat setting clockwise decreases the pick-up current.

If angular settings are to be checked, use the connections of Fig. 18C 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 60 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 45 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.

#### g. Transient Tests

If a test is desired showing the operation of the relay under transient conditions, the circuit shown in Fig. 18B 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<sub>S</sub>, X<sub>S</sub>, the ammeter and the relay current coils in series, should be equal to the secondary impedance from the generated 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 mho unit is satisfactory for detecting closure of the contacts.

#### TIME OVERCURRENT UNIT

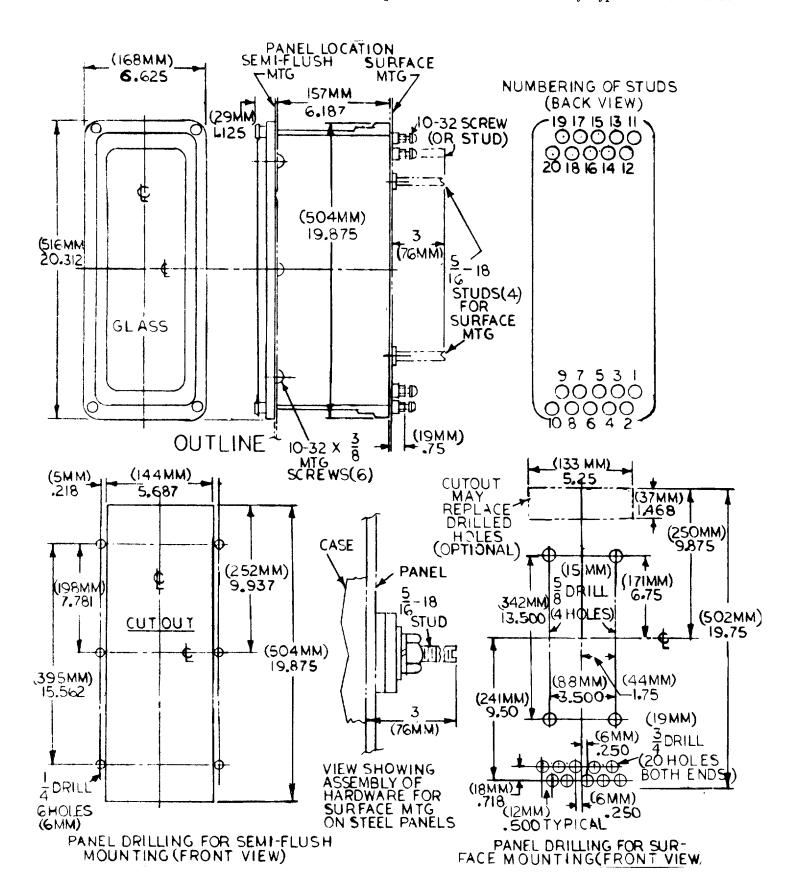
The lower jewel may be tested for cracks by exploring its surface with the point of a fine needle. If it is necessary to replace the jewel, a new pivot should be screwed into the bottom of the shaft at the same time. The jewel should be turned up until the disk is centered in the air gaps, after which it should be locked in this position by the set screw provided for this purpose.

## 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.



\* Fig. 25 (K-6209276-3) Outline and Panel Drilling Dimensions for Type GYC Relay



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