INSTALLATION • OPERATION • MAINTENANCE
INSTRUCTIONS

TYPE HZ-4 DISTANCE RELAY

CAUTION Before putting protective relays into service, remove all blocking inserted for the purpose of securing the parts during shipment. Make sure that all moving parts operate freely. Inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The type HZ-4 relay is a three-zone distance relay for transmission line protection. This relay has provisions for off-setting only the third impedance unit to avoid tripping on load ohms. The particular application for this relay is on heavily loaded transmission lines where there is little, if any, difference in magnitude between minimum load ohms and the ohmic setting for the third impedance unit and yet the first and second zones do not need the offset.

CONSTRUCTION

The type HZ-4 relay contains three beam-type impedance units, an offset transformer with its angular displacement resistor, a directional unit, a synchronous timer, four contactor switches, and three operation indicators.

Impediance Units

Construction details of these units are shown in Fig. 1. A balanced beam is pulled downward on the contact end by a current coil and on the other end by two voltage coils. The fluxes of these two potential coils are shifted out of phase with respect to each other to produce a steady pull so that practically a constant balance can be obtained regardless of the phase angle between the current and voltage coil fluxes. A tap screw on the front of the unit permits changing the number of turns on the current coil, and a core screw on the bottom of the unit changes an air gap in the magnetic path. These two adjustments make it possible to set the unit.

On the instantaneous first unit (Z1) a rectangular silver contact is flexibly fastened on the forward end of the beam. As the beam trips, the contact bridges two silver stationary hemispherical contacts mounted on the free end of two short leaf springs. A small set screw determines the position of each leaf spring and provides means for adjusting the contact gap.

On the second and third units (Z2 and Z3) the moving contact is a thin-walled silver shell practically filled with tungsten powder. When this contact strikes the rigid stationary contact, the movement of the tungsten powder creates sufficient friction to absorb practically all of the energy of impact and thus the tendency of the contact to bounce is reduced to a minimum. The moving contact is loosely mounted on the unit beam and held in place by a leaf spring. The construction is such that the beam continues to move slightly after the contacts close deflecting the spring which provides the required contact follow. This spring should have zero tension on the contact when the beam is in the reset position. Current is conducted into the moving contact by means of a flexible metal ribbon.

On both the second and third unit beams a thin-walled cylinder filled with tungsten powder is mounted near the rear end of the beam. This acts as a counterweight and tends to damp out vibrations in the beam in the manner described above for the unit contacts.

Synchronous Timer

The timer is a small synchronous motor which operates from the current circuit thru a saturating transformer, and drives a moving contact arm thru a gear train. The contact on the moving arm is a cylindrical silver sleeve,

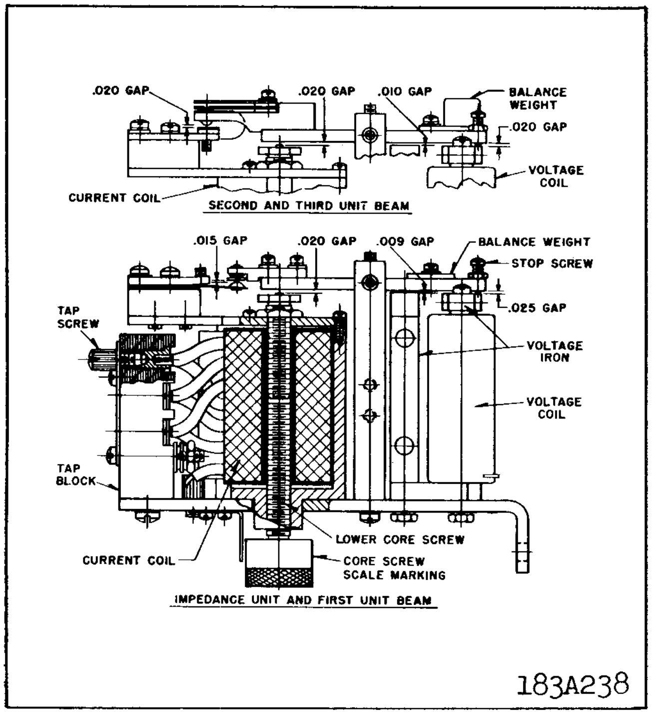

Fig. 1 Sectional View of the Impedance Units.

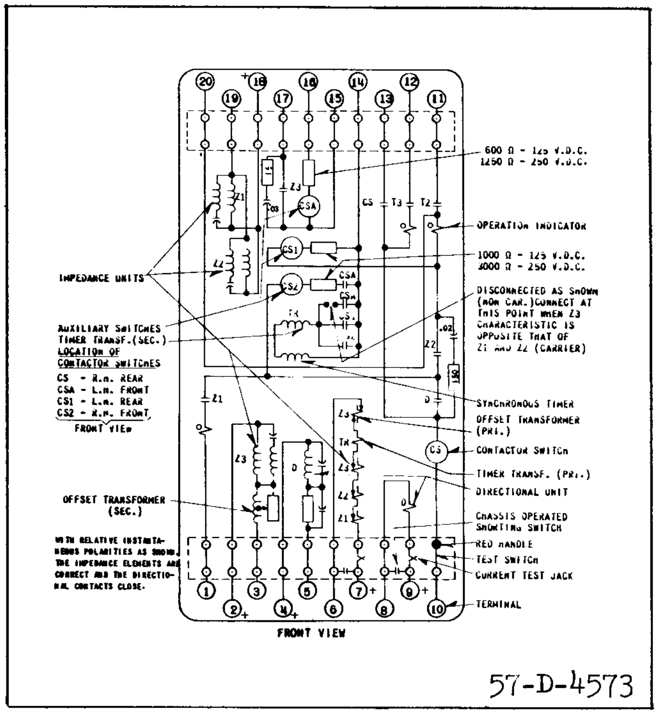

Fig. 2 Internal Schematic of the Type HZ-4 Relay in the Type FT42 Case.

loosely fitted on the moving arm. In making contact, this sleeve rolls across two vertically projecting stationary butt contacts to bridge the gap between them. Two sets of stationary contacts are mounted in Micarta insulating blocks which are adjustable around a semi-circular calibrated guide. The maximum time settings are 3.0 seconds for the 60 cycle timer and 3.6 seconds for the 50 cycle timer.

The synchronous motor has a floating rotor which is in mesh with the gear train only when energized. The rotor falls out instantly when the motor is deenergized, allowing a spring to reset the moving arm.

The time delay on the synchronous timer for the second and third impedance units is adjustable from 0 to 180 cycles (50 or 60 cycle-basis.) T-3 must be set beyond T-2 by a minimum of 25 cycles.

Directional Unit

The directional unit is made up of five basic parts: the die-cast aluminum frame, the electromagnet, the molded cover assembly, the moving element assembly, and the bridge and upper bearing pin assembly. The lower bearing pin and the magnetic core with its adjustment lever are mounted on the frame. The electromagnet has two series-connected voltage coils mounted diametrically opposite one another, two series-connected current coils mounted diametrically opposite one another and two magnetic plugs accessible through the cover. The moving element consists of a spring and contact arm assembly and a double aluminum loop mounted on a shaft which has end jewels for the top and bottom bearings. This shaft rides between the bottom steel bearing pin mounted in the frame and a similar pin in the bridge that mounts on the two longer studs of the electromagnet. The stops for the moving element are mounted on the cover and are easily accessible for the adjustment of the contact travel. The spring adjuster seats on the molded cover and is attached to the contact through a spriral spring. The moving contact is made of two thin-walled silver shells practically filled with tungsten powder and mounted back to back on a thin leaf spring. The stationary silver contacts are mounted on the molded cover. The electrical connection is made from the stationary contact to the moving contact, through the spiral spring and

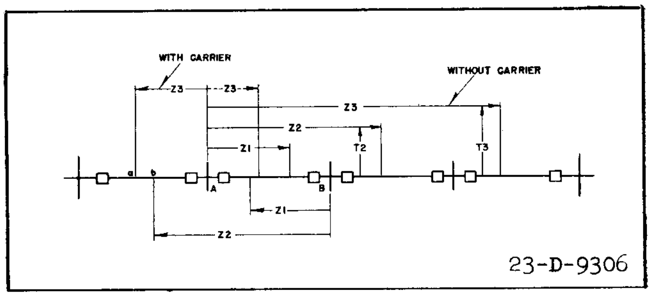

Fig. 3 Typical Settings of the Type HZ-4 Relay in Terms of Line Length.

spring adjuster to the spring adjuster clamp. The magnetic bias of the unit is controlled by a small lever arm extending to the front on the bottom of the unit and two magnetic plugs accessible through the cover. These plugs afford control of the sensitivity at the higher currents.

Auxillary Contactor Switches

These are small solenoid-type d-c switches. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upwards the disc bridges three silver stationary contacts.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring-restrained armature releases the white target which falls by gravity to indicate completion of the trip circuit. The indicator can be reset from outside of the case.

Offset Transformer

An offset transformer, with its angular displacement resistor, is located on the back of the subbase. The addition of the offset transformer makes it possible to displace the impedance circle characteristics of the third impedance unit as plotted on "R" and "X" coordinates, from a circle with the center at the origin to a circle with the center displaced.

OPERATION

The relay measures the impedance of the line to which it is connected by measuring the ratio of the current and voltage supplied to it.

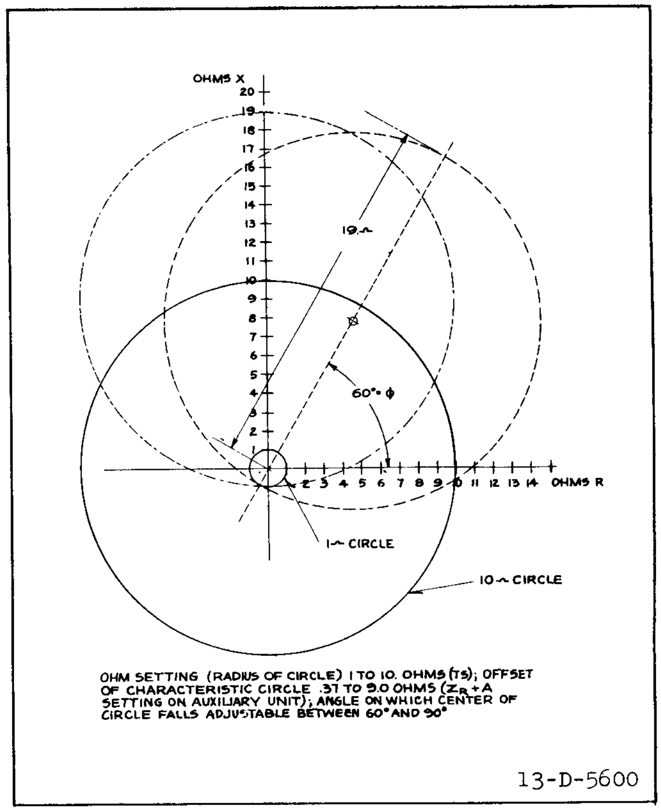

Fig. 4 Operating Characteristics and Ranges of Zone Three of the Type HZ-4 Relay.

The relay is connected to receive a current and voltage proportional to those existing on the high-tension line. With a fault in zone 1, Fig. 3, a given amount of current, I, will flow from the relay location to the fault. With zero voltage existing at the fault, phase-to-neutral voltage at the relay location must be equal to the drop in the line due to the current, I, or equal to IZ where Z is the impedance to neutral of the line from the relay location to the point of fault in primary ohms. When considering a three-phase fault, the line voltage would equal $\sqrt{3}$ IZ, the delta current would equal $\sqrt{3}$ I and the ratio would be $\frac{\sqrt{3}\,IZ}{\sqrt{3}\,I} = Z$. When considering a two-phase fault with zero voltage existing at the fault, the delta voltage of the faulted phases at the relay location equals the voltage drop of the loop or I x 2Z, the delta current of the faulted phases equals 2I, and the ratio would be $\frac{2IZ}{2I} = Z$. Thus, for phase faults, the ratio of delta voltage to delta current is used to indicate the location of the fault. This ratio is constant for any value of current as the delta voltage is proportional to the current times the line impedance. By using the turns ratio of the potential transformers and current transformers this Z can be converted from primary ohms to secondary ohms.

$$Z \text{ secondary} = Z \text{ primary} \frac{R_c}{R_v}$$

The relay uses delta voltage and delta current; therefore, Z relay equals Z secondary. Therefore, if the first impedance unit of the tyle HZ-4 relay is adjusted by the core screw and taps on the current coil for a value of current such that the pull of the current coil is just equal to the potential restraint for a fault at the end of zone 1 in Fig. 3, the beam will be balanced for a fault at that point for any value of current. Now, if the fault occurs to the right of this balance point, the beam will not trip as the voltage pull is the greater due to a larger amount of impedance and correspondingly larger potential restraint than the beam is balanced for. The second impedance unit is adjusted to balance for a fault at the end of zone 2, and, therefore operates for faults anywhere up to this point. Likewise, the third impedance unit is adjusted to balance for a fault at the end of zone 3 and operates for faults in all three zones.

The type HZ-4 relay is a modified impedance relay that is identical to the conventional balanced beam impedance relay except that the third unit restraint is produced by the potential and current instead of by potential alone. The mixing of the current and the potential to produce restraint torque is done in the offset transformer and the resultant energy is fed into potential coils of the beam impedance unit. This additional energy will shift the center of the impedance circle away from the origin of the R-X diagram as shown in Fig. 4. This allows longer settings for zone three without including the swing vector or load impedance vector.

In the directional unit, torque is produced by interaction of current and voltage fluxes which develop forces on the two aluminum loops. The resulting torque is substantially free of vibrations, because of double-frequency torques that are produced on the two loops are equal and opposite in sign. The magnetic design of the unit is such that the maximum torque occurs when the current leads the voltage 35 to 40 degrees. This is the condition at which the voltage and current fluxes are 90° apart. The flux in each pole face is lagged on the outside edges. This produced a torque, caused by the small power factor angle of the moving element. The adjustable magnetic bias which is built into the core controls the distribution of the fluxes so that the electrical center of the unit may be shifted to give optimum operating conditions.

The trip circuit for each of the three zones, consists of the following contacts: First Zone, directional and first impedance unit; Second Zone, directional, second impedance and timer (first set of contacts) unit: Third Zone, directional and timer (second set of contacts) unit. The coil of one of the contactor switches CS is in series with all of the contacts above and with the trip coil of the breaker. When the trip coil is energized the contactor switch contacts seal around the relay contacts, thereby relieving them of the duty of carrying the tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker. An auxiliary switch on the circuit breaker must be provided so that when the circuit-breaker is tripped, the tripping circuit will be opened by this switch.

When the relay is used without carrier the synchronous timer is directionally controlled; that is, it operates only for a fault in the tripping direction and within the reach of the third impedance unit. Upon the occurrence of such a fault, the directional (D) and third impedance (Z3) units close their contacts. The operation of Z3 energizes an auxiliary contactor switch CSA. The contacts of CSA in conjunction with the directional unit contact complete a d-c circuit through another auxiliary contactor switch CS1. The contacts of CS1 in turn connect the synchronous timer motor to the saturating transformer.

CHARACTERISTICS

The type HZ-4 relay is available in two impedance ranges.

1. 0.6-6.0 ohms (nominal range of first impedance unit).

2. 0.2-2.0 ohms (nominal range of first impedance unit).

The third impedance unit has a range of 1 to 10 ohms impedance circle radius, with 0.37 to 9.0 ohms impedance circle center displacement over a phase angle from 60° to 90° current lag.

The tap and core screw markings of the two ranges are as follows:

0.6 - 6.0 Ohm Relay

Unit	Taps					
Z1, Z2, Z3	6.2	9.4	13.5	20.8	29.8	45
	Core Screw Marking					
Z1	0.8	1.0	1.2	1.4		
Z2, Z3	1.4	1.6	1.8	2.0	2.2	

0.2 - 2.0 Ohm Relay

Unit	Taps					
Z1	2	3	4	6	9	13
Z2	3.1	4.2	6.2	9.1	13	20
Z3	6.2	9.4	13.5	20.8	29.8	45
	Core Screw Marking					
Z1	0.8	1.0	1.2	1.4	1.6	
Z2, Z3	1.4	1.6	1.8	2.0	2.2	

Offset Transformer

Coarse Ohms Taps (Z_R)

0.0 1.9 3.7 5.6 7.5

Fine Ohms Taps (A)

0.0 0.37 0.75 1.1 1.5

Phase Angle Adjustment

60° to 90° current lag.

The phase angle for circle displacement is normally set at 75° unless otherwise specified.

The time delay on the synchronous timer for the second and third impedance unit is adjustable in calibrated steps of 20 cycles from zero to 180 cycles.

Both 50 cycle and 60 cycle relays are available. The relays are not interchangeable as different coils and timers are used.

Minimum Voltage Requirement

The minimum length of line to which the type HZ-4 relay can be applied must be long enough to produce at least 5 volts on the relay when a short circuit exists at the balance point of the first unit and minimum short circuit in flowing. If the voltage on the relay becomes less than 5 volts, the forces become too small to assure fast and positive action. The minimum voltage limit for the second zone is 10 volts.

SETTINGS

The type HZ-4 relay requires a setting for each of the three impedance units and on the synchronous timer for Second and Third Zone timer. The following nomenclature will be used:

Z = the line-to-neutral ohmic impedance of the protected line from the relay to the desired balance point.

For the First Unit = 80 to 90% of the protected section

For the Second Unit = Approx. 50% into the adjacent section.

For the Third Unit = Approx. 25% into the third line section (without carrier).

When carrier is used, see the section entitled, "HZ-4 Carrier Setting of Z_3".

Since the impedance of the voltage circuit of the relay is the same at all times, the balance point of the unit is adjusted by changing the pull on the current coil. This is done by taps (T) on the current coil winding, and by the core screw (S) which varies the magnetic air gap for the current flux.

The most satisfactory method of arriving at the tap setting is by the use of the following formula:

(1) $$TS = \frac{10 Z_0 R_c}{R_v}$$

where

T = The impedance unit current tap value.

S = The impedance unit current core screw value. The values appear as a series of

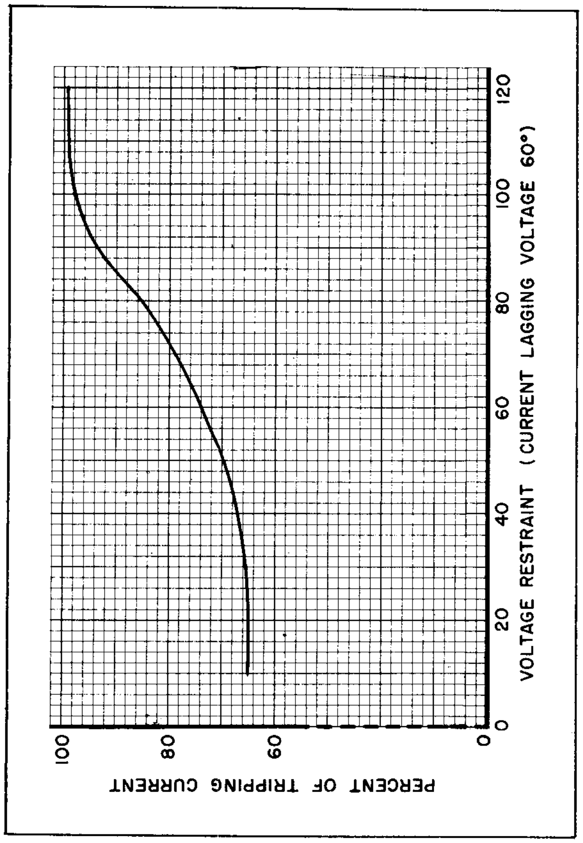

Fig. 7 Typical Reset Curves for the First Unit.

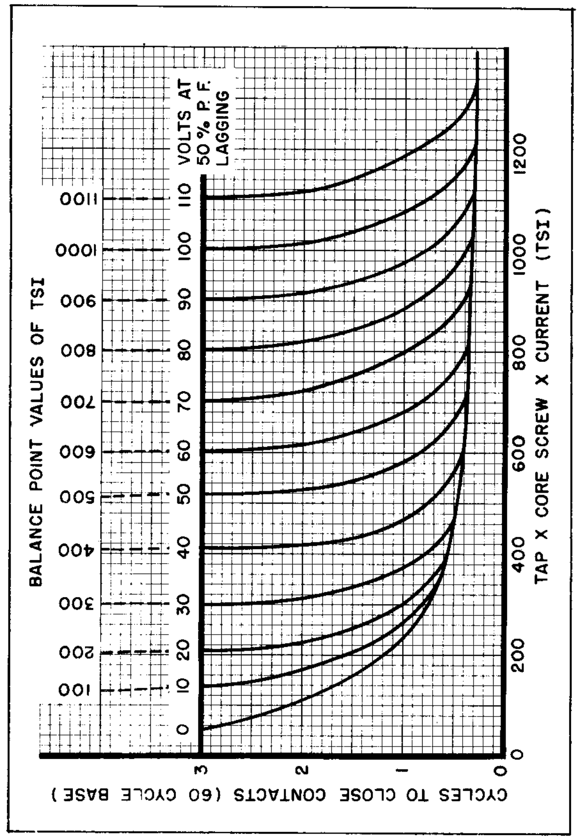

Fig. 8 Typical Time of Operation Curves for the First Unit.

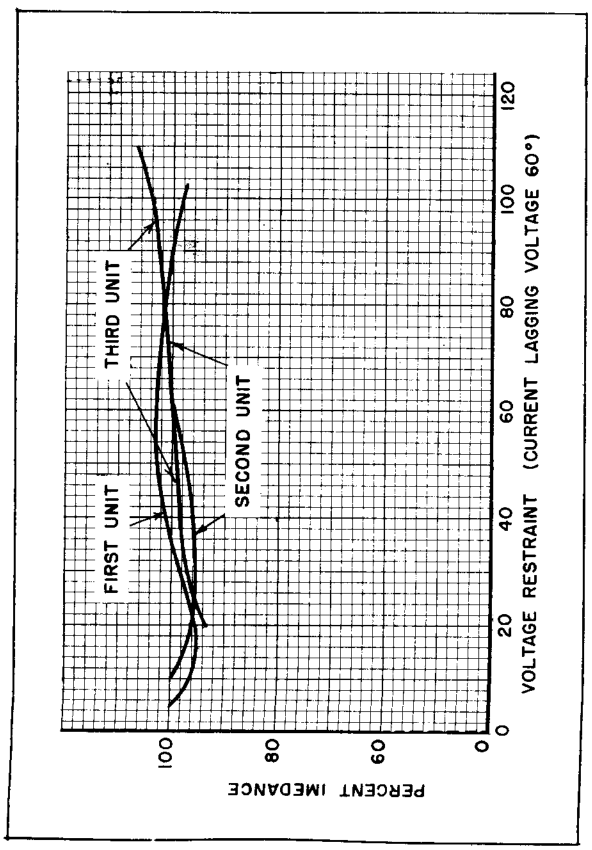

Fig. 5 Typical Impedance Curves for all Three Units.

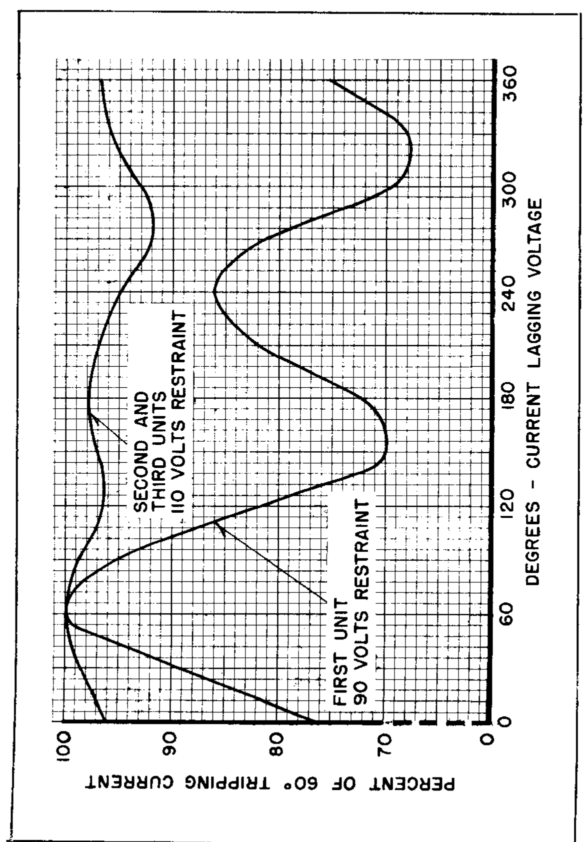

Fig. 6 Typical Phase Angle Curves for all Three Units.

dots on the drum of the lower core screw adjusting knob.

Z_O = Radius of circle, in ohms primary.

R_C = The current transformer ratio.

R_V = The potential transformer ratio.

The tap, T, is obtained by dividing the TS product by S to give an available tap number. When changing taps, the extra tap screw should by screwed in the desired tap before removing existing tap screw to prevent open circuiting the current transformers.

For first impedance unit the above formula is based on the relay being used on a 60° line and is correct for lines of that angle. For lines other than 60° a slight error is introduced which may be as much as 8% and 6% on 40° and 80° lines, respectively. However, the formula relay setting can be corrected for lines other than 60° by using the curve of Fig. 6. The scale reading should be decreased so that the current to trip the beam at the line angle is equal to the current to trip on a 60° line. This does not affect the second and third impedance units, since they are practically independent of phase angle having a flat phase angle curve as shown in Fig. 6.

First Impedance Unit

As an example of the formula setting set the first impedance unit to protect a 60° 110 KV line 53.5 miles long. The line to neutral impedance is .75 ohm per mile. The current transformer ratio is 600/5, and the potential transformer ratio is 1000/1. The first unit is to protect 80% of the line section or for a balance point .80 x 53.5 x .75 = 32 ohms away. Then

$$TS = \frac{10 \times 32 \times 120}{1000} = 38.4$$

Set tap = 29.9 and core screw = 1.29 on a 0.6 to 6.0 ohm relay.

The setting for the second impedance unit is obtained in the same manner, using the proper value of Z, and the proper constant in the formula.

Third Impedance Unit

When the balance impedance has been determined, the phase angle and magnitude of the minimum load ohms and the phase angle and magnitude of the minimum synchronizing surge ohms from which the system can recover should be determined or estimated to complete the analysis.

It will expedite the application by plotting the transmission line characteristics on "R" and "X" coordinates. An operating circle should then be drawn of a diameter and location to fulfill the following conditions:

1. The circle must pass through the point of the vector Z and must completely enclose the vector Z.

2. The circle must not enclose the point of the vector of minimum load ohms or of minimum synchronizing surge ohms from which the system can recover.

3. The angular displacement of the center of the circle must be within 60° to 90° current lagging phase angle.

After the operating circle for relay action has been obtained, it is necessary to adjust the relay characteristics to match this circle.

The radius of the circle in ohms should be measured and the impedance element set in accordance with the previous formula (1).

From the operating circle, previously constructed, measure the displacement of the center of the circle from the intersection of the "R" and "X" axis in magnitude and angle.

The offset transformer should be set in accordance with the formula:

$$(2) \qquad Z_R + A = \frac{Z_D R_C}{R_V K}$$

where

Z_R = Offset Transformer tap value.

A = Offset Transformer tap value.

Z_D = Displacement of the center of the operating circle in ohms primary.

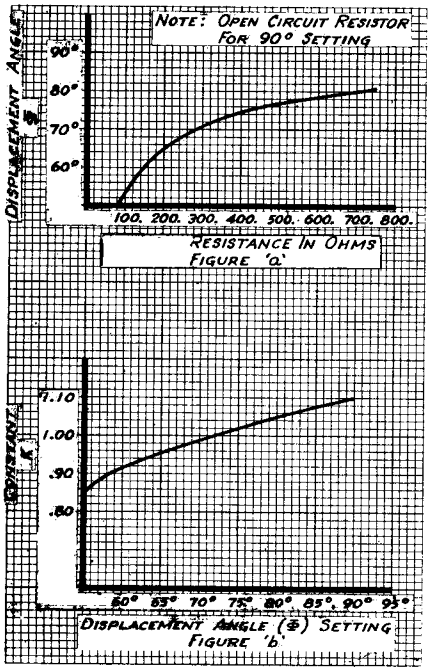

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Fig. 9 Adjustment Curve for the Angular Displacement of the Operating Circle Center of Zone Three by Varying the Angular Displacement Resistor.

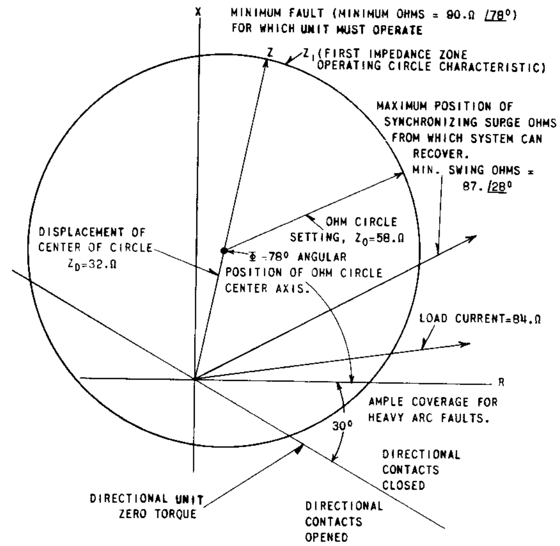

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Fig. 10 Transmission Line and Relay Characteristics of Zone Three Plotted on R and X Coordinates in Primary Ohms.

K = Constant determined from Curve Fig. 9b

R_c = The current transformer ratio.

R_v = The potential transformer ratio.

ϕ = Angular Displacement

When changing the Z_R or A tap with the relay energized, the current terminals of the offset transformer should be shorted before unscrewing the tap screw to prevent open circuiting the transformers.

Normally the Z_D setting is from 0 to 75% of the Z_0 setting. The angular displacement (ϕ) may be varied by adjusting the resistor above the offset transformer in accordance with the curve of Fig. 9a for a fault at the desired balance point. A slight change in the scale value or in the transformer setting from that calculated may be required so that the relay will just trip for the simulated fault at the balance point.

As an example of the formula setting, set the third impedance unit to protect 25% of the third line section. Assume that the three sections are of equal length and similar to the line used in zone one setting calculations. Since 100% of a line section is 40 ohms, the balance point of the third unit equals 2.25 x 40 = 90 ohms away. The phase angle and the magnitude of the minimum synchronizing surge ohms from which the system can recover should be determined.

Plot the transmission line characteristics on "R" and "X" coordinates as shown in Fig. 10. An operating circle should then be drawn of a diameter and location to fulfill the conditions previously stated.

The radius of the circle in ohms should be measured and the impedance unit set in accordance using formula (1):

$$(1) \qquad TS = \frac{10 Z_0 \, RC}{R_v}$$

$$TS = \frac{10 \times 58.0 \times 600/5}{1000/1} = 69.6$$

T will be set on 45 (Relay Tap Setting)
S will be set on 1.55 (Relay Core Setting)

The displacement angle used in drawing the operating circle should be set on the relay by adjusting the resistor mounted above its offset transformer in accordance with the curve of Fig. 9a. In Fig. 10 the angle used was 78 degrees; therefore, the resistor should be adjusted to 600 ohms.

The distance expressed in ohms impedance between the center of the modified impedance circle and the intersection of the "R" and "X" axis should be measured from Fig. 10, and the offset transformer set using formula (2):

$$(2) \qquad Z_R + A = \frac{Z_D\ R_c}{R_v K}$$

$$Z_R + A = \frac{32 \times 600/5}{1000/1 \times 1.04} = 3.69 \text{ ohms}$$

Z_R should be set on 3.7 ohms.

A should be set on 0 ohm.

The time delay on the synchronous timer is set to coordinate with the relays backed up by the second and third impedance units. The setting is made by moving each stationary contact assembly to the desired position as indicated by the scale.

On lines where taps or paralleled feeders supply fault power to the adjacent sections, the apparent impedance to the relay backing up the adjacent section is greater than the actual impedance. The reason for this is that the relay does not measure the additional fault current supplied by the other feeders, but at the same time, this current does increase the voltage drop from the fault to the relay. This increases the apparent impedance to the adjacent section by the ratio of the total current to the relay current. The effect on the relay impedance units is to back up the balance point of the second and third impedance units. In order to extend the range of back-up protection under these conditions, the second unit can be set for a balance point further than the 150% normally recommended, provided it is made to time select with the adjacent section relay second unit. Similarly, the third unit can be set further than normal if it is made to select with the second and third units of the adjacent relay which it overlaps.

The formula settings are sufficiently accurate for most installations. Where it is desired to set the balance point more accurately the tap and scale values may be checked by applying to the relay the voltage, current, and phase angle conditions which will be impressed on it for a fault at the desired balance point. A slight change in the scale value from that calculated may be required so that the relay will just trip for the simulated fault at the balance point.

The particular setting of one unit may have some influence on the adjacent unit. The factory calibration of the core screw is made with taps cascaded as indicated in the section, "Electrical Check Points."

The numbers on the core screw appear in ascending order as the core screw is screwed into the core. In some cases, a question of doubt may arise whether the scale setting is correct, or is out by one full turn of the core screw. In such a case, the point may be verified by turning the core screw all the way in. Then back out the core screw until the highest scale marking just comes under the end of the pointer. This will occur in approximately one turn. To prevent such doubt it is recommended that the core screw setting be made by thus locating the highest scale marking and then continuing to back it off until the desired value appears exactly under the end of the pointer. Sufficiently accurate setting can be made by interpolating between the marked points when necessary.

HZ-4 Carrier Setting of Z_3

When the relay is used with carrier, the third zone unit must operate in a reverse direction from Z1 and Z2 whenever the modified distance characteristic is used. This is done to assure proper carrier blocking for external faults in the adjacent line section with a setting of Z3 which will not pick up on load or surge ohms. This can be accomplished by merely reversing the polarity of the Z3 potential circuit.

The method of arriving at the proper setting is shown in Fig. 3 which also shows the normal settings of Z1, Z2, and Z3 when used without carrier. When the HZ-4 relay is used with carrier, the ohmic reach of Z3 at station A in the direction away from line AB should be greater than the reach of Z2 (from station B) past the local station bus (at A). Thus any fault in the zone Ab which picks up Z2 at B will also pick up Z3 at station A to block tripping at B. The zone ab is for a safety factor to insure that carrier will always be started at A before carrier tripping can be set up at B. For this service, Z3 should be set to reach out of the line 50% farther than the reach of Z2 (at B) past the station A Bus. In Fig. 5 this means Aa should be 150% of Ab. The reach of Z3 into the line section AB as shown is not critical.

When the Z3 setting is reversed, the second contact of the CSA must be connected in parallel with the CS1 contact to control the timer. This provides third zone back-up protection for lines away from the line protected by zone one and two. Thus the timer is controlled by Z2 and D or Z3 only.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT case information refer to I.L. 41-076.

CONNECTIONS

Impediance Units

The impedance to the balance point is measured from the point where the potential transformers are connected to the protected line. For protecting transmission lines, the relays should receive potential from potential transformers connected directly to the line at the point from which the impedance is to be measured.

In some applications a power transformer bank forms part of the transmission line, and potential transformers are available only on the bus side of the bank. In this case the relays may be set thru the bank to protect the line only if the bank impedance is not too large as compared with the line impedance. If the bank impedance is too large in comparison with the line impedance, the 80 or 90% setting of the first unit may cover only a very small percentage of the transmission line or in some cases not cover any of the line section. For the same reason the second and third units will offer considerably less back-up protection over the adjacent lines. In order to use the potential transformers on the bus side of the bank under this condition, Type KX compensators are used and the impedance measured from the line side of the bank to the balance points. The type KX compensators operate from the current transformers and provide voltage compensation equivalent to the drop in the power bank. The setting of the KX compensator is covered by I.L. 41-861.

The above discussion assumes that power is fed thru the bank to faults on the line. Where a power transformer connects to a high tension transmission line and does not supply power to a line fault, low-tension potential transformers may be used without compensation. Then, the impedance to the balance point is measured from the point where the power bank connects to the protected line.

The conventional star connection of current transformer is not satisfactory where accurate distance relay protection is desired. With this connection the balance points of the impedance units shift about 15% depending upon whether a phase-to-phase, a three phase or a double ground fault is involved. That is, if the balance point were adjusted at 80% for a three phase fault, then for a double ground fault the shift may be more or less than plus or minus 15% of the 80% setting, depending upon the ratio of the zero sequence impedance to the negative sequence impedance of the system from the source of power to the fault.

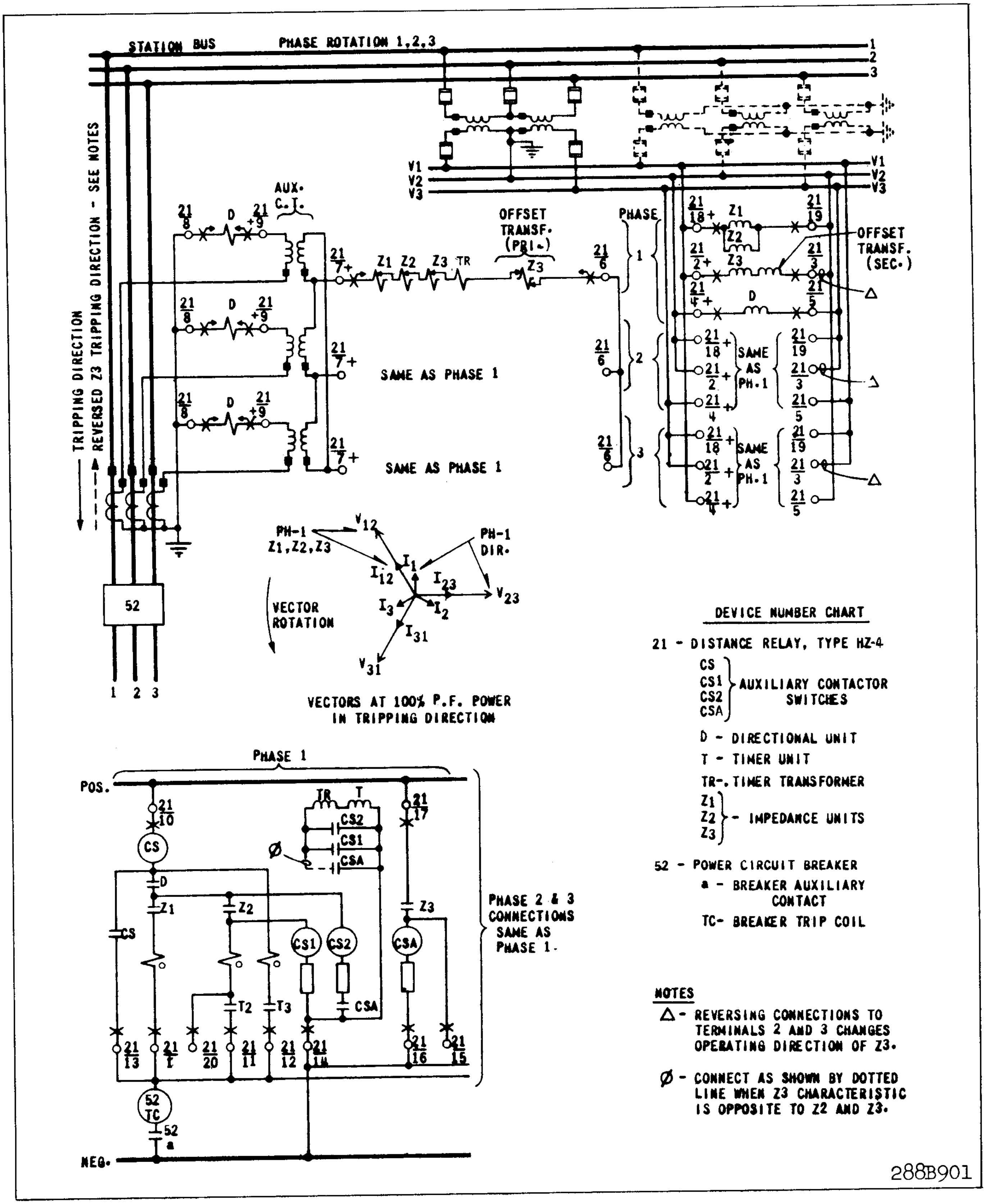


Fig. 11 External Schematic of the Type HZ-4 Relay for Phase Protection of a Three Phase Transmission Line.

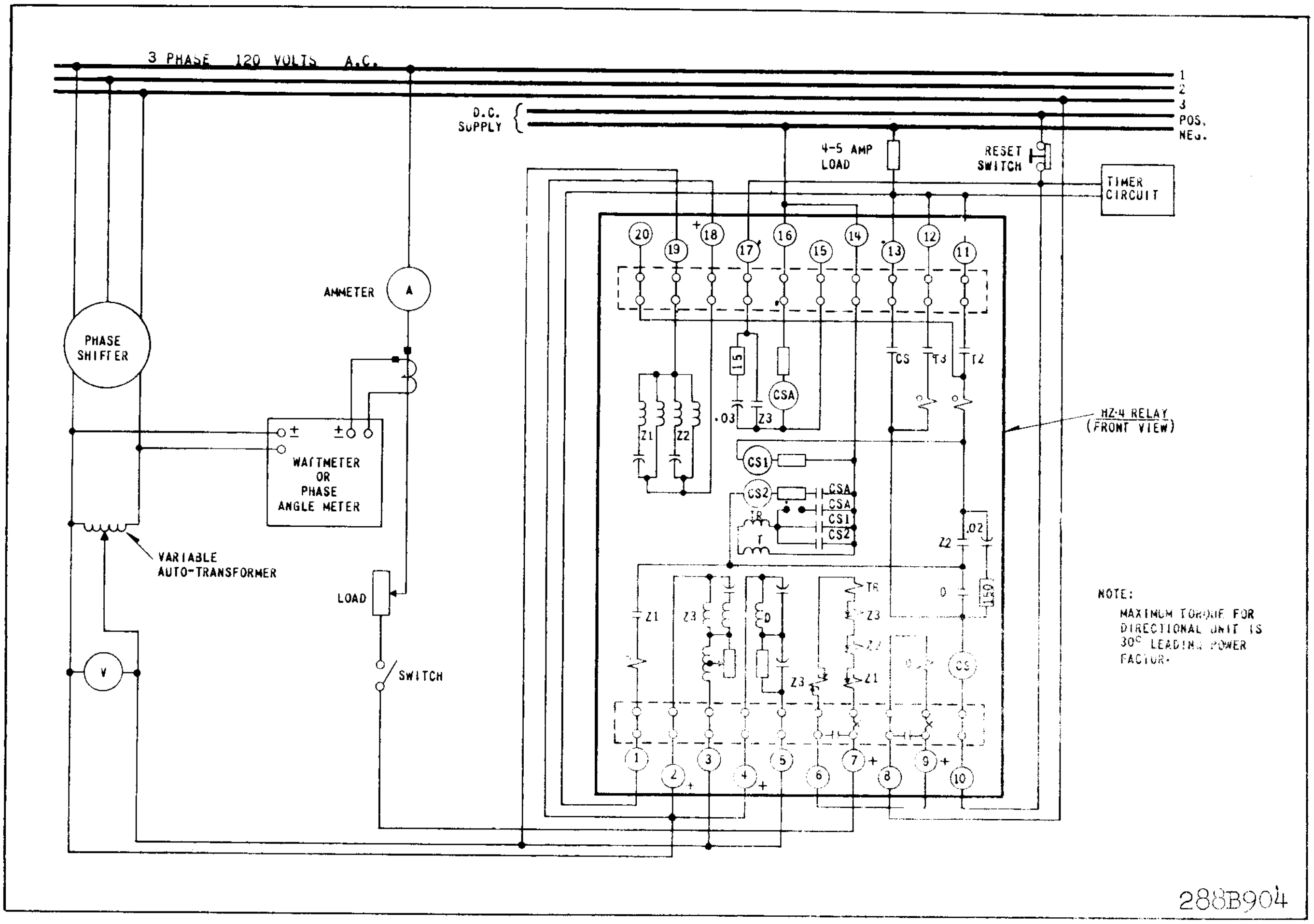


Fig. 12 Diagram of Test Connections for the Type HZ-4 Relay.

This error can be entirely eliminated by making use of the vector difference between the line current, (i.e. delta currents) for actuating the relay.

The most common method is to connect the main current transformers in star and use a set of auxiliary 5/5 ratio transformers to supply delta currents to the elements, as shown in Fig. 11. The delta voltages used on the impedance units of the relays should be in phase with the delta currents at unity power factor.

Directional Unit

The magnetic design of the unit and potential circuit is such that maximum torque occurs when the current leads the voltage by approximately 30 degrees. Thus, the directional unit coils should be connected to receive current that leads the voltage by 90 degrees when the line power factor is 100 percent. This will result in operation at approximately the maximum torque angle for transmission line faults.

Trip Circuit

The contactor switch operates on a minimum of 1.0 ampere, but the trip circuit should draw at least 4 or 5 amperes in order to reduce the time of the operation of the switch to a minimum and provide more positive operation. If the type HZ-4 relay is used to trip an auxiliary multi-contact relay, provision should be made for loading down the trip circuit with a resistor in parallel with the operating coils of the auxiliary relay. Also, since the total trip circuit resistance in the relay is approximately 1.0 ohm, care must be taken to see that the breaker trip coil will receive enough current when low voltage control is used.

The main contacts on the impedance units and directional unit will safely close 30 amperes at 250 volts d-c, and the switch contacts will safely carry this current long enough to trip a breaker.

ELECTRICAL CHECK POINTS

To check the electrical operation of the relay, the following instruction should be followed. Connect the relay per Fig. 12 and make the following settings. (At regular maintenance periods the settings of each particular relay with the voltage and current expected at the balance point should be used, if available. During factory testing, the settings are cascaded as indicated below.)

IMPEDANCE UNITS

.2 to 2 Ohm Relay

ZONE	T	S	Z_R	A	Ø
Z_1	3	1.2			
Z_2	20	1.8			
Z_3	45	1.8	5.6	0.0	75°

IMPEDANCE UNITS

.6 to 6 Ohm Relay

ZONE	T	S	Z_R	A	Ø
Z_1	29.8	1.2			
Z_2	45	1.6			
Z_3	45	1.8	5.6	0.0	75°

CAUTION: The relay voltage should be of good wave form. The combination of a phase shifter and autotransformer may give an output voltage of poor wave form if the magnetizing current of the autotransformer is high in proportion to the impedance of the phase shifter used. In case of doubt, check the output voltage waveform with an oscilloscope.

Directional Unit

With 120 volts and 5 amperes in phase, the directional unit should be closed. The contacts should open when the current lags the voltage by approximately 60 degrees.

Impediance Units

With 60 volts on the relay, increase the current until the contacts just close. This current (which will vary slightly from this value if suddenly applied) should be approximately:

.2 to 2 Ohm Relay

Z-3 I = 4.4 amp. at 75° lag I (non-carrier)
Z-3 I = 4.4 amps. at 255° lag I (carrier)
Z-2 I = 16.7 amps. at 60° lag I

.6 to 6 Ohm Relay

Z-3 I = 4.4 amps. at 75° lag I (non-carrier)
Z-3 I = 4.4 amps. at 255° lag I (carrier)
Z-2 I = 8.4 amps. at 60° lag I

With 35 volts on the relay, Z-1 should trip when the following currents are applied.

.2 to 2 Ohm Relay

Z-1 I = 22.4 amps. at 60° lag I

.6 to 6 Ohm Relay

Z-1 I = 9.8 amps. at 60° lag I

With the D contact closed, the tripping of Z-3 should cause CSA switch to pick up, and CS-1 switch in turn. The operation of CS1 should start the timer. When Z-1, Z-2 and timer T-2, or T-3 contacts close, the CS switch should operate and seal around all the contacts. The CS and CS-1 are not continuously rated; therefore, care should be taken not to overheat these auxiliary switches. The checking of the timer unit will depend on standard time device used. Generally this check is made independently of the trip circuit to avoid circuitry complications. The timer should operate with 3.5 amperes in the timer transformer and with the contacts of CS-1 closed or shorted. An auxiliary relay, as used in the trip circuit, should be used to seal in the timer circuit.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed or the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended because of the danger of embedding small particles in the face of the soft silver and thus impairing the contacts.

Impediance Units

The voltage circuit on the first impedance unit is designed to have a peaked phase angle curve. This design in conjunction with the contact arrangement enables the first zone to operate with a 5 volt balance point voltage.

The voltage circuit on the second and third impedance units is designed to have a comparatively flat phase angle curve. This is accomplished by energizing the two coils with currents that are essentially equal and 90° out of phase. The gaps as shown in Fig. 1 are nominal dimensions. The actual gaps on any particular relay may vary a few thousandths from these values.

If the voltage circuits have been disassembled, the gaps referred to in Fig. 1 provide a nominal starting point for calibration. This is accomplished as follows:

First Impediance Unit

Refer to Fig. 1. Adjust the stop screw on the rear of the beam to give a clearance of .025 inch between the beam and the voltage iron circuit. With the beam in the reset position; i.e., with the stop screw against the vertical gap for .009 inch between the adjustable iron and the beam. Care should be taken in this adjustment to keep the gap the same as both sides. Also, with the beam in the same position adjust the gap between the front end of the beam and the stop in the upper core screw to .020 inch.

The beam should be balanced as follows. Connect the relay with polarities as shown in the test diagram, Fig. 12. With any tap and scale setting, check the impedance measured by the relay with 35 volts potential restraint. Apply 5 volts restraint and adjust the balance weight on the beam until the beam just trips with 1/7 of the current required to trip with 35 volts restraint.

The stationary contacts should be adjusted to give .015 inch clearance between them and the silver bridge on the beam when the beam is in the reset position. The bridge should be made to touch both contacts simultaneously, and deflect the contact springs at least .010 inch before the beam strides the bronze stop on the core screw.

A good method of adjusting the contacts consists in first adjusting one of the contacts to the correct gap and then applying just sufficient current to trip the beam against a restraint of about 5 volts. While the beam is in this position, that is, lightly pressing on the one contact, the other contact should be slowly adjusted upward by means of the set screw until it just touches the silver bridge without lifting it off the other contact. The trip circuit should be energized so that the lighting of a lamp or the tripping of an auxiliary relay will show when both contacts are made.

Second Impediance Unit

Refer again to Fig. 1. Adjust the stop screw on the moving beam for .020 inches clearance between the rear of the beam and the voltage iron. With the beam in this position, adjust the vertical gap for .010 inches clearance between the adjustable iron and the beam, also adjust for .020 inches clearance between the front of the beam and the stop on the upper core screw.

The stationary contact should be adjusted for an .020 inch gap when the beam is in the reset position. When the beam is in the operated position there should be a .015 inch deflection of the moving contact. The spring that carries the moving contact should lie flat on the Micarta arm with no initial tension on the contact. The flexible pigtail should be at least 3/32 inches from the end of the stationary contact.

With the connections as shown in the test diagram, Fig. 12, and using any tap and scale setting, check the impedance measured by the relay with 60 volts potential restraint. Apply 10 volts restraint and adjust the balance weight or vibration damper on the second unit until the beam just trips with 1/6 of the current required to trip with the 60 volts restraint.

Third Impedance Unit

Mechanical adjustments of the beam and contact are the same as for the second unit except for the vibration damper.

The third impedance unit beam should be balanced by adjusting the balance weight so that in the de-energized condition, the beam will reset, thus leaving its contact open. Do not introduce excessive resetting torque, but only enough to reset the unit.

Calibration of Impedance Units

The current required to operate the impedance units against any given voltage is obtained from the equation:

$$(3) \qquad I = \frac{10E}{TS}$$

It is essential that the polarity be as given, otherwise an error will be introduced particularly for the first unit. Fig. 6 shows the variation of tripping current for a given voltage as the phase angle between current and voltage is varied. To make sure that the relay is operating at 60° lag and not 240° the current leads can be reversed which will cause the first impedance unit beam to operate at a smaller current if the original connections were correct.

The current required to operate the third impedance unit, with offset, is obtained from the equation:

$$(4) \qquad I = \frac{E}{\frac{TS}{10} + (Z_R + A)\,K}$$

Fig. 5 shows the general shape of the impedance curves for different ohm settings. These curves are obtained by tripping the beam against different voltages for a constant T and S setting and then plotting the ratio E/I in percent calibrating voltage impedance against the voltage. The lower voltage points (5 to 15 volts) are considerably affected by the mechanical balance of the beam, while the higher points are but little influenced.

Accurate time tests on the instantaneous unit and directional unit can only be taken with the aid of an oscillograph or high speed timer. The cycle counter is of use only in timing the synchronous timer and in timing the high-speed units near the "balance point" where the time may be several cycles.

Fig. 8 shows the time of operation in cycles (data taken on 60 cycle relay) of the first impedance unit for various balance points. By using these curves the operating speed of the HZ-4 element can be determined for any value of current and voltage applied to the element.

Directional Unit

The upper bearing screw should be screwed down until there is only three to four thousandths of an inch clearance between it and the shaft, and then securely locked in position with the lock nut. This adjustment can be made best by carefully screwing down the top bearing screw until the double loop fails to turn freely and then backing up 1/8 of a turn. Great care must be taken in making this adjustment to prevent damage to the bearings.

The front contact spring should be positioned in the center of the .020 inch slot of the aluminum guard by means of the small adjusting screw located on the nut plate that holds the spring on the moving element. The travel of the moving contact is limited by the stationary contacts mounted on the molded cover. The contact gap should be adjusted as follows: With the moving contact centered between the studs, close the gaps by advancing the two front stationary contacts. Then back off the right-hand stationary contact .035 inch and lock both contacts in place. The complete moving element is limited in travel by two stop screws, located on the molded cover. These should be adjusted so that the moving contact just barely misses the stationary contact stops front and rear respectively when energized in the opening and closing directions with 120 volts and 5.0 amperes at maximum torque. The right-hand stationary contact should just touch the moving contact when energized as above and then should be turned 1/6th of a turn to obtain .005 inch contact follow. Too much follow should be avoided to insure proper coordination. The spring should be adjusted so that the contact closes with approximately 1.0 volts and 5 amperes at maximum torque.

A small lever arm extending to the front on the bottom of the unit and the plugs accessible through the molded cover control the magnetic bias of the electromagnet. The lever should be adjusted so that the unit will operate with 30 amperes and 0.1 to 0.4 volt at the maximum torque angle. Before or after this adjustment, short the voltage coils and check to insure that the contacts do not close on 60 amperes momentarily applied. Raising the right-hand plug under these conditions will produce torque to the right when considering the front moving contact. The unit can be adjusted to just remain open under these conditions or adjusted to operate with 60 amperes and 0.1 to 0.4 volt at the maximum torque angle.

Contactor Switch (Sealed-In Switch) CS

Adjust the stationary core of the switch for clearance between the stationary core and the moving core of .025 inch when the switch is picked up. This can be done by disconnecting the switch, turning it up-side-down and screwing up the core screw until the contact just separates. Then back off the core screws approximately one turn and lock in place. This prevents the moving core from striking and sticking to the stationary core because of the residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1.0 ampere direct current. Test for sticking after passing 30 amperes direct current through the coil.

Contactor Switch CSA

The adjustments are the same as for the seal-in contactor switch "CS" except that the contact clearance should be 1/32 inch. For 125 volt d-c relays, apply 80 volts d-c to Nos. 16 and 17 terminals. Similarly for 250 volt d-c relays, apply 160 volts d-c to Nos. 16 and 17 terminals. See that the switch picks up and closes its contact positively when the contact of the third impedance unit is made. The switch coil is continuously rated.

Contactor Switches CS-1 and CS-2

The adjustments are the same as for the seal-in contactor switch CS except that the contact separation should be 1/32 inch. For 125 volt d-c relays apply 60 volts d-c positive to Nos. 10 and 17 terminals and negative to Nos. 14 and 16 terminals. Similarly for 250 volt d-c relays use a test voltage of 120 volts d-c. See that switch CS-1 picks up and closes its contact positively when the directional and Z-2 impedance unit contacts are made. See that CS-2 picks up and closes its contacts when the directional unit and Z-3 impedance unit contacts are made. These switch coils are intermittently rated, and therefore care should be exercised so as not to overheat the coils.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere direct current gradually applied. Test for sticking after passing 30 amperes direct current through the coil.

Synchronous Timer

When testing the synchronous timer, complete the transformer circuit by a jumper around the contacts on the contactor switch CS-1 or CS-2 rather than operating the switch on d-c. Test the motor with 3.5 amperes through the current circuit of the relay. This is the minimum current at which it will run in synchronism.

Timing Tests

The d-c trip circuit should be loaded with a resistor to draw approximately 5 amperes and an auxiliary relay should be used to operate the timer circuit if time tests are to be taken. There is a slight vibration of the beam and contacts because of the pulsating pull on the current side of the instantaneous unit. This vibration may prevent positive stopping of the timing device unless an auxiliary type MG relay is used. The loading resistor will cause the contactor switch to seal in and simulates the actual service condition when a circuit breaker is to be tripped. This type of circuit is also necessary when timing T-2 or T-3.

CAUTION Make certain that the stops on the rear and front of each beam are absolutely clean, otherwise the impedance at which the beam trips may be affected, particularly at low voltages. The stop can be easily cleaned by drawing a piece of clean white paper between the beam and the stop while the beam is firmly pressed down.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMENTS

POTENTIAL CIRCUITS AT 120 VOLTS, 60 CYCLES

Circuit	V.A.	P.F. Angle
Z-1 and Z-2 together	4.2	3° lag
Z-3 Displacement angle 90°	2.4	48° lag
Displacement angle 60°	2.3	29° lag
Directional Unit	6.6	19° lead

POTENTIAL CIRCUITS AT 120 VOLTS, 50 CYCLES

Circuit	V.A.	P.F. Angle
Z-1 and Z-2 together	3.9	15° lead
Z-3 Displacement angle 90°	2.2	40° lag
Displacement angle 60°	2.0	26° lag
Directional Unit	6.4	9° lead

CURRENT CIRCUITS AT 60 CYCLES †

Circuit	Amps.	V.A.	P.F. Angle
Impedance			
T = 45, S = 1.8			
Z_R = 7.5, A = 0.0	8.66	30	51° lag
Directional Unit	5	2.0	50° lag

†The burdens of the current circuits, at 50 cycles, are slightly less than the above values.

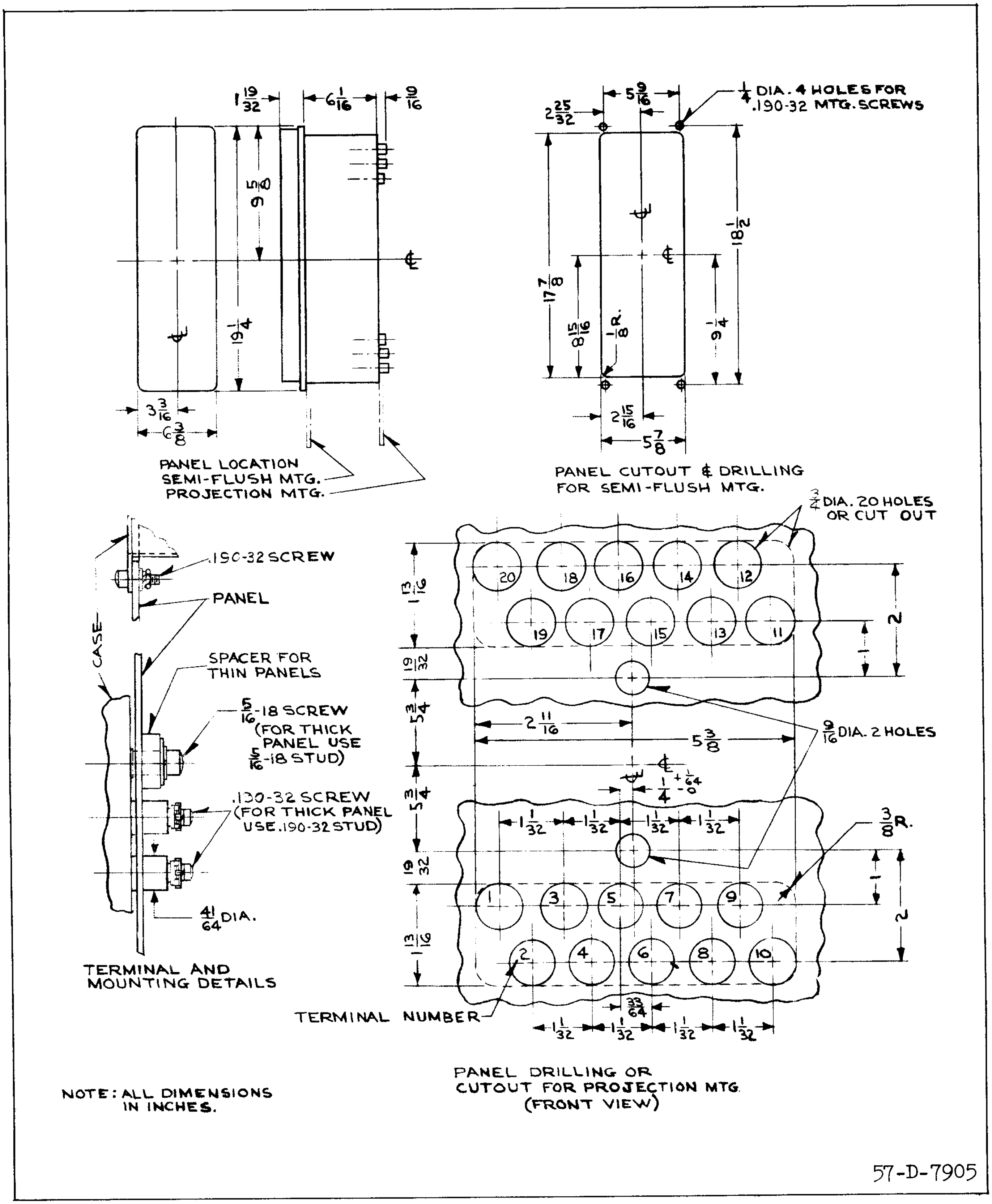


Fig. 13 Outline and Drilling Plan of the Type HZ-4 Relay in the Type FT42 Case.

WESTINGHOUSE ELECTRIC CORPORATION
METER DIVISION • NEWARK, N.J.
Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE HZ-4 DISTANCE RELAY

CAUTION Before putting protective relays into service, remove all blocking inserted for the purpose of securing the parts during shipment. Make sure that all moving parts operate freely. Inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The type HZ-4 relay is a three-zone distance relay for transmission line protection. This relay has provisions for off-setting only the third impedance unit to avoid tripping on load ohms. The particular application for this relay is on heavily loaded transmission lines where there is little, if any, difference in magnitude between minimum load ohms and the ohmic setting for the third impedance unit and yet the first and second zones do not need the offset.

CONSTRUCTION

The type HZ-4 relay contains three beam-type impedance units, an offset transformer with its angular displacement resistor, a directional unit, a synchronous timer, four contactor switches, and three operation indicators.

Impedance Units

Construction details of these units are shown in Fig. 1. A balanced beam is pulled downward on the contact end by a current coil and on the other end by two voltage coils. The fluxes of these two potential coils are shifted out of phase with respect to each other to produce a steady pull so that practically a constant balance can be obtained regardless of the phase angle between the current and voltage coil fluxes. A tap screw on the front of the unit permits changing the number of turns on the current coil, and a core screw on the bottom of the unit changes an air gap in the magnetic path. These two adjustments make it possible to set the unit.

On the instantaneous first unit (Z1) a rectangular silver contact is flexibly fastened on the forward end of the beam. As the beam trips, the contact bridges two silver stationary hemispherical contacts mounted on the free end of two short leaf springs. A small set screw determines the position of each leaf spring and provides means for adjusting the contact gap.

On the second and third units (Z2 and Z3) the moving contact is a thin-walled silver shell practically filled with tungsten powder. When this contact strikes the rigid stationary contact, the movement of the tungsten powder creates sufficient friction to absorb practically all of the energy of impact and thus the tendency of the contact to bounce is reduced to a minimum. The moving contact is loosely mounted on the unit beam and held in place by a leaf spring. The construction is such that the beam continues to move slightly after the contacts close deflecting the spring which provides the required contact follow. This spring should have zero tension on the contact when the beam is in the reset position. Current is conducted into the moving contact by means of a flexible metal ribbon.

On both the second and third unit beams a thin-walled cylinder filled with tungsten powder is mounted near the rear end of the beam. This acts as a counterweight and tends to damp out vibrations in the beam in the manner described above for the unit contacts.

Synchronous Timer

The timer is a small synchronous motor which operates from the current circuit thru a saturating transformer, and drives a moving contact arm thru a gear train. The contact on the moving arm is a cylindrical silver sleeve,

SUPERSEDES I.L. 41-469.1
*Denotes change from superseded issue.

EFFECTIVE SEPTEMBER 1958

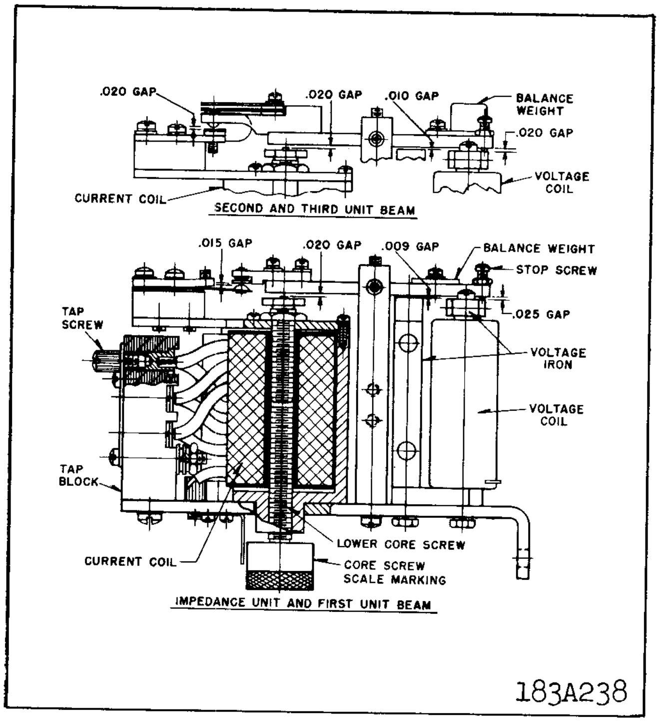
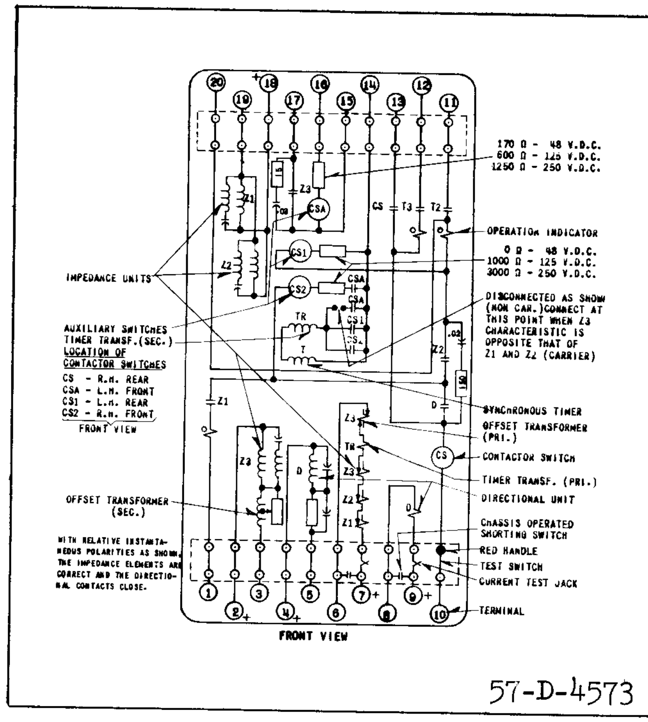


Fig. 1 Sectional View of the Impedance Units.



* *Fig. 2 Internal Schematic of the Type HZ-4 Relay in the Type FT42 Case.*

loosely fitted on the moving arm. In making contact, this sleeve rolls across two vertically projecting stationary butt contacts to bridge the gap between them. Two sets of stationary contacts are mounted in Micarta insulating blocks which are adjustable around a semi-circular calibrated guide. The maximum time settings are 3.0 seconds for the 60 cycle timer and 3.6 seconds for the 50 cycle timer.

The synchronous motor has a floating rotor which is in mesh with the gear train only when energized. The rotor falls out instantly when the motor is deenergized, allowing a spring to reset the moving arm.

The time delay on the synchronous timer for the second and third impedance units is adjustable from 0 to 180 cycles (50 or 60 cycle-basis.) T-3 must be set beyond T-2 by a minimum of 25 cycles.

Directional Unit

The directional unit is made up of five basic parts: the die-cast aluminum frame, the electromagnet, the molded cover assembly, the moving element assembly, and the bridge and upper bearing pin assembly. The lower bearing pin and the magnetic core with its adjustment lever are mounted on the frame. The electromagnet has two series-connected voltage coils mounted diametrically opposite one another, two series-connected current coils mounted diametrically opposite one another and two magnetic plugs accessible through the cover. The moving element consists of a spring and contact arm assembly and a double aluminum loop mounted on a shaft which has end jewels for the top and bottom bearings. This shaft rides between the bottom steel bearing pin mounted in the frame and a similar pin in the bridge that mounts on the two longer studs of the electromagnet. The stops for the moving element are mounted on the cover and are easily accessible for the adjustment of the contact travel. The spring adjuster seats on the molded cover and is attached to the contact through a spriral spring. The moving contact is made of two thin-walled silver shells practically filled with tungsten powder and mounted back to back on a thin leaf spring. The stationary silver contacts are mounted on the molded cover. The electrical connection is made from the stationary contact to the moving contact, through the spiral spring and

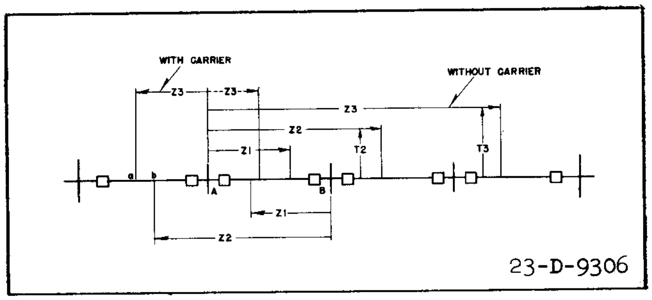


Fig. 3 Typical Settings of the Type HZ-4 Relay in Terms of Line Length.

spring adjuster to the spring adjuster clamp. The magnetic bias of the unit is controlled by a small lever arm extending to the front on the bottom of the unit and two magnetic plugs accessible through the cover. These plugs afford control of the sensitivity at the higher currents.

Auxiliary Contactor Switches

These are small solenoid-type d-c switches. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upwards the disc bridges three silver stationary contacts.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring-restrained armature releases the white target which falls by gravity to indicate completion of the trip circuit. The indicator can be reset from outside of the case.

Offset Transformer

An offset transformer, with its angular displacement resistor, is located on the back of the subbase. The addition of the offset transformer makes it possible to displace the impedance circle characteristics of the third impedance unit as plotted on "R" and "X" coordinates, from a circle with the center at the origin to a circle with the center displaced.

OPERATION

The relay measures the impedance of the line to which it is connected by measuring the ratio of the current and voltage supplied to it.

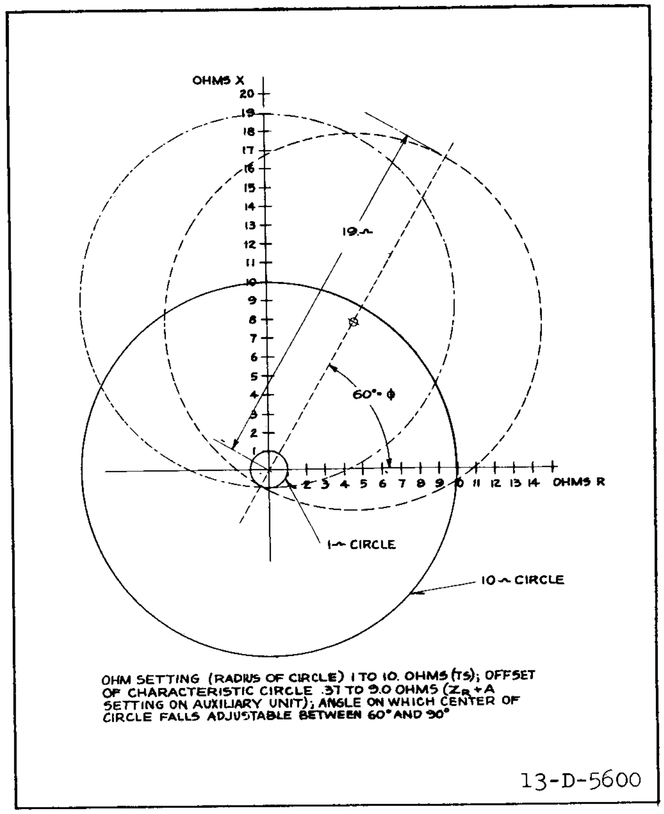


Fig. 4 Operating Characteristics and Ranges of Zone Three of the Type HZ-4 Relay.

The relay is connected to receive a current and voltage proportional to those existing on the high-tension line. With a fault in zone 1, Fig. 3, a given amount of current, I, will flow from the relay location to the fault. With zero voltage existing at the fault, phase-to-neutral voltage at the relay location must be equal to the drop in the line due to the current, I, or equal to IZ where Z is the impedance to neutral of the line from the relay location to the point of fault in primary ohms. When considering a three-phase fault, the line voltage would equal $\sqrt{3}$ IZ, the delta current would equal $\sqrt{3}$ I and the ratio would be $\frac{\sqrt{3}\ IZ}{\sqrt{3}\ I} = Z$. When considering a two-phase fault with zero voltage existing at the fault, the delta voltage of the faulted phases at the relay location equals the voltage drop of the loop or I x 2Z, the delta current of the faulted phases equals 2I, and the ratio would be $\frac{2IZ}{2I} = Z$. Thus, for phase faults, the ratio of delta voltage to delta current is used to indicate the location of the fault. This ratio is constant for any value of current as the delta voltage is proportional to the current times the line impedance. By using the turns ratio of the potential transformers and current transformers this Z can be converted from primary ohms to secondary ohms.

$$Z \text{ secondary} = Z \text{ primary} \frac{R_c}{R_v}$$

The relay uses delta voltage and delta current; therefore, Z relay equals Z secondary. Therefore, if the first impedance unit of the tyle HZ-4 relay is adjusted by the core screw and taps on the current coil for a value of current such that the pull of the current coil is just equal to the potential restraint for a fault at the end of zone 1 in Fig. 3, the beam will be balanced for a fault at that point for any value of current. Now, if the fault occurs to the right of this balance point, the beam will not trip as the voltage pull is the greater due to a larger amount of impedance and correspondingly larger potential restraint than the beam is balanced for. The second impedance unit is adjusted to balance for a fault at the end of zone 2, and, therefore operates for faults anywhere up to this point. Likewise, the third impedance unit is adjusted to balance for a fault at the end of zone 3 and operates for faults in all three zones.

The type HZ-4 relay is a modified impedance relay that is identical to the conventional balanced beam impedance relay except that the third unit restraint is produced by the potential and current instead of by potential alone. The mixing of the current and the potential to produce restraint torque is done in the offset transformer and the resultant energy is fed into potential coils of the beam impedance unit. This additional energy will shift the center of the impedance circle away from the origin of the R-X diagram as shown in Fig. 4. This allows longer settings for zone three without including the swing vector or load impedance vector.

In the directional unit, torque is produced by interaction of current and voltage fluxes which develop forces on the two aluminum loops. The resulting torque is substantially free of vibrations, because of double-frequency torques that are produced on the two loops are equal and opposite in sign. The magnetic design of the unit is such that the maximum torque occurs when the current leads the voltage 35 to 40 degrees. This is the condition at which the voltage and current fluxes are 90° apart. The flux in each pole face is lagged on the outside edges. This produced a torque, caused by the small power factor angle of the moving element. The adjustable magnetic bias which is built into the core controls the distribution of the fluxes so that the electrical center of the unit may be shifted to give optimum operating conditions.

The trip circuit for each of the three zones, consists of the following contacts: First Zone, directional and first impedance unit; Second Zone, directional, second impedance and timer (first set of contacts) unit: Third Zone, directional and timer (second set of contacts) unit. The coil of one of the contactor switches CS is in series with all of the contacts above and with the trip coil of the breaker. When the trip coil is energized the contactor switch contacts seal around the relay contacts, thereby relieving them of the duty of carrying the tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker. An auxiliary switch on the circuit breaker must be provided so that when the circuit-breaker is tripped, the tripping circuit will be opened by this switch.

When the relay is used without carrier the synchronous timer is directionally controlled; that is, it operates only for a fault in the tripping direction and within the reach of the third impedance unit. Upon the occurrence of such a fault, the directional (D) and third impedance (Z3) units close their contacts. The operation of Z3 energizes an auxiliary contactor switch CSA. The contacts of CSA in conjunction with the directional unit contact complete a d-c circuit through another auxiliary contactor switch CS1. The contacts of CS1 in turn connect the synchronous timer motor to the saturating transformer.

CHARACTERISTICS

The type HZ-4 relay is available in two impedance ranges.

1. 0.6-6.0 ohms (nominal range of first impedance unit).

2. 0.2-2.0 ohms (nominal range of first impedance unit).

The third impedance unit has a range of 1 to 10 ohms impedance circle radius, with 0.37 to 9.0 ohms impedance circle center displacement over a phase angle from 60° to 90° current lag.

The tap and core screw markings of the two ranges are as follows:

0.6 - 6.0 Ohm Relay

Unit	Taps					
Z1, Z2, Z3	6.2	9.4	13.5	20.8	29.8	45

	Core Screw Marking				
Z1	0.8	1.0	1.2	1.4	
Z2, Z3	1.4	1.6	1.8	2.0	2.2

0.2 - 2.0 Ohm Relay

Unit	Taps					
Z1	2	3	4	6	9	13
Z2	3.1	4.2	6.2	9.1	13	20
Z3	6.2	9.4	13.5	20.8	29.8	45

	Core Screw Marking				
Z1	0.8	1.0	1.2	1.4	1.6
Z2, Z3	1.4	1.6	1.8	2.0	2.2

Offset Transformer

Coarse Ohms Taps (Z_R)

0.0 1.9 3.7 5.6 7.5

Fine Ohms Taps (A)

0.0 0.37 0.75 1.1 1.5

Phase Angle Adjustment

60° to 90° current lag.

The phase angle for circle displacement is normally set at 75° unless otherwise specified.

The time delay on the synchronous timer for the second and third impedance unit is adjustable in calibrated steps of 20 cycles from zero to 180 cycles.

Both 50 cycle and 60 cycle relays are available. The relays are not interchangeable as different coils and timers are used.

Minimum Voltage Requirement

The minimum length of line to which the type HZ-4 relay can be applied must be long enough to produce at least 5 volts on the relay when a short circuit exists at the balance point of the first unit and minimum short circuit in flowing. If the voltage on the relay becomes less than 5 volts, the forces become too small to assure fast and positive action. The minimum voltage limit for the second zone is 10 volts.

SETTINGS

The type HZ-4 relay requires a setting for each of the three impedance units and on the synchronous timer for Second and Third Zone timer. The following nomenclature will be used:

Z = the line-to-neutral ohmic impedance of the protected line from the relay to the desired balance point.

For the First Unit = 80 to 90% of the protected section

For the Second Unit = Approx. 50% into the adjacent section.

For the Third Unit = Approx. 25% into the third line section (without carrier).

When carrier is used, see the section entitled, "HZ-4 Carrier Setting of Z_3".

Since the impedance of the voltage circuit of the relay is the same at all times, the balance point of the unit is adjusted by changing the pull on the current coil. This is done by taps (T) on the current coil winding, and by the core screw (S) which varies the magnetic air gap for the current flux.

The most satisfactory method of arriving at the tap setting is by the use of the following formula:

$$TS = \frac{10 Z_0 R_c}{R_v} \quad (1)$$

where

T = The impedance unit current tap value.

S = The impedance unit current core screw value. The values appear as a series of

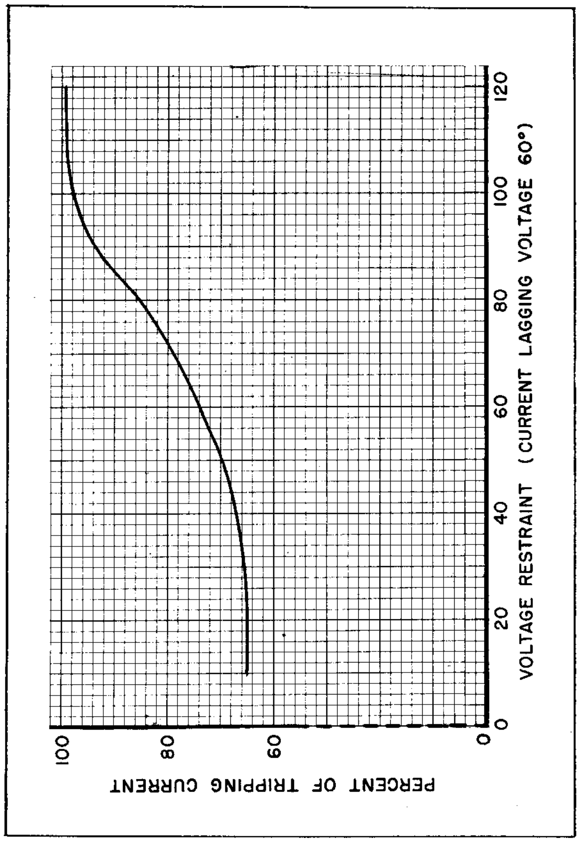


Fig. 7 Typical Reset Curves for the First Unit.

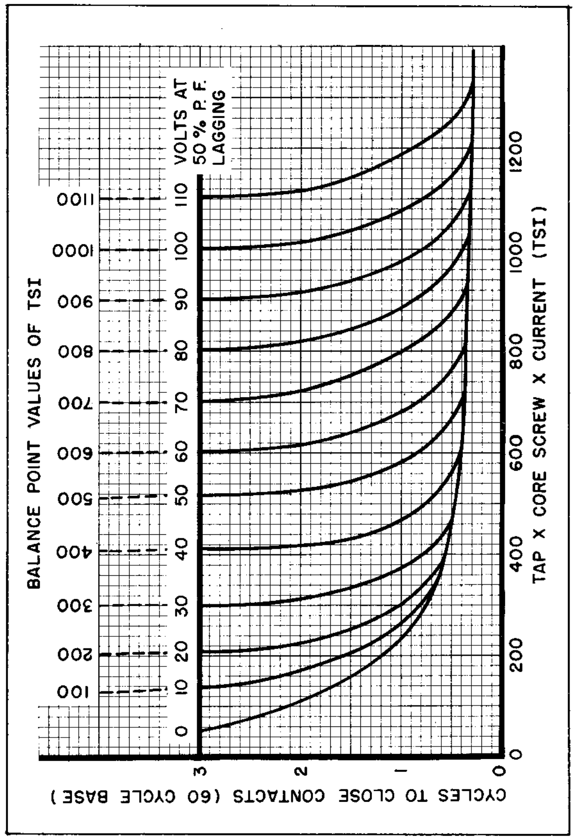


Fig. 8 Typical Time of Operation Curves for the First Unit.

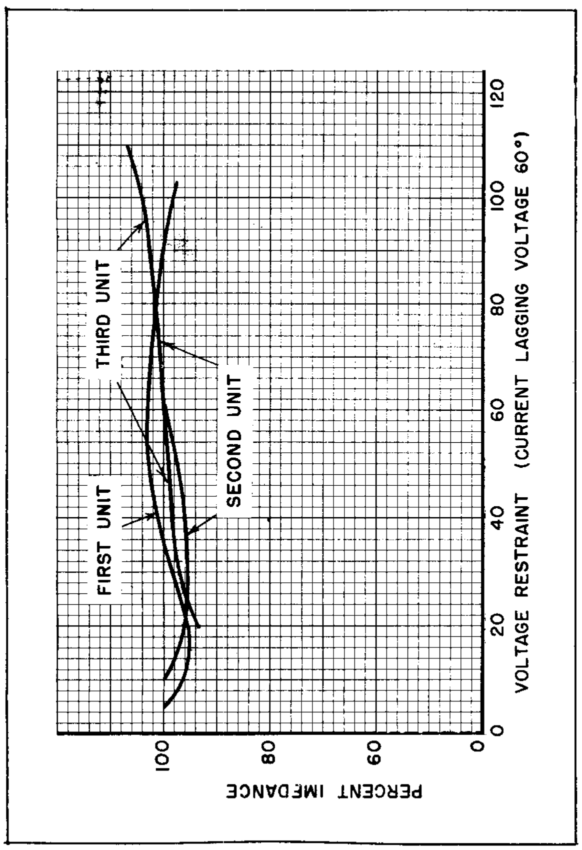


Fig. 5 Typical Impedance Curves for all Three Units.

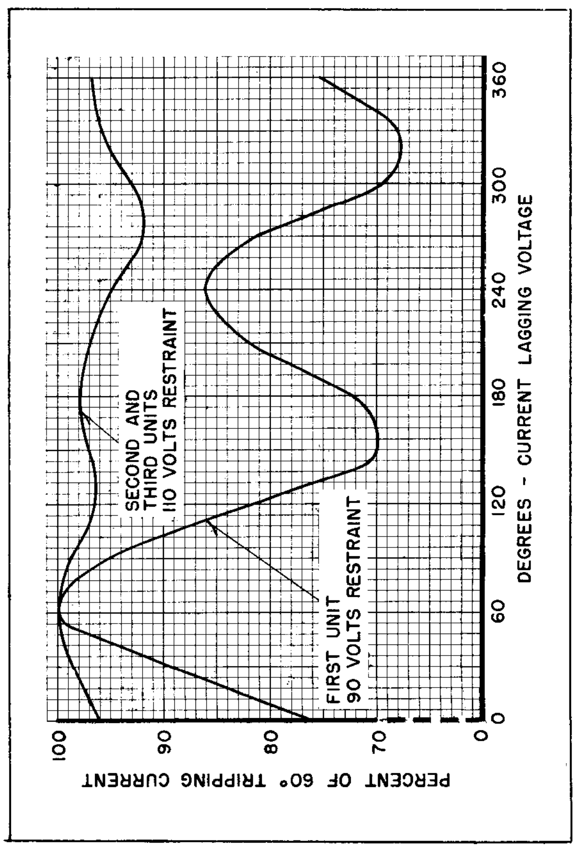


Fig. 6 Typical Phase Angle Curves for all Three Units.

dots on the drum of the lower core screw adjusting knob.

Z_O = Radius of circle, in ohms primary.

R_C = The current transformer ratio.

R_V = The potential transformer ratio.

The tap, T, is obtained by dividing the TS product by S to give an available tap number. When changing taps, the extra tap screw should by screwed in the desired tap before removing existing tap screw to prevent open circuiting the current transformers.

For first impedance unit the above formula is based on the relay being used on a 60° line and is correct for lines of that angle. For lines other than 60° a slight error is introduced which may be as much as 8% and 6% on 40° and 80° lines, respectively. However, the formula relay setting can be corrected for lines other than 60° by using the curve of Fig. 6. The scale reading should be decreased so that the current to trip the beam at the line angle is equal to the current to trip on a 60° line. This does not affect the second and third impedance units, since they are practically independent of phase angle having a flat phase angle curve as shown in Fig. 6.

First Impedance Unit

As an example of the formula setting set the first impedance unit to protect a 60° 110 KV line 53.5 miles long. The line to neutral impedance is .75 ohm per mile. The current transformer ratio is 600/5, and the potential transformer ratio is 1000/1. The first unit is to protect 80% of the line section or for a balance point .80 x 53.5 x .75 = 32 ohms away. Then

$$TS = \frac{10 \times 32 \times 120}{1000} = 38.4$$

Set tap = 29.9 and core screw = 1.29 on a 0.6 to 6.0 ohm relay.

The setting for the second impedance unit is obtained in the same manner, using the proper value of Z, and the proper constant in the formula.

Third Impedance Unit

When the balance impedance has been determined, the phase angle and magnitude of the minimum load ohms and the phase angle and magnitude of the minimum synchronizing surge ohms from which the system can recover should be determined or estimated to complete the analysis.

It will expedite the application by plotting the transmission line characteristics on "R" and "X" coordinates. An operating circle should then be drawn of a diameter and location to fulfill the following conditions:

1. The circle must pass through the point of the vector Z and must completely enclose the vector Z.

2. The circle must not enclose the point of the vector of minimum load ohms or of minimum synchronizing surge ohms from which the system can recover.

3. The angular displacement of the center of the circle must be within 60° to 90° current lagging phase angle.

After the operating circle for relay action has been obtained, it is necessary to adjust the relay characteristics to match this circle.

The radius of the circle in ohms should be measured and the impedance element set in accordance with the previous formula (1).

From the operating circle, previously constructed, measure the displacement of the center of the circle from the intersection of the "R" and "X" axis in magnitude and angle.

The offset transformer should be set in accordance with the formula:

$$(2) \qquad Z_R + A = \frac{Z_D R_C}{R_V K}$$

where

Z_R = Offset Transformer tap value.

A = Offset Transformer tap value.

Z_D = Displacement of the center of the operating circle in ohms primary.

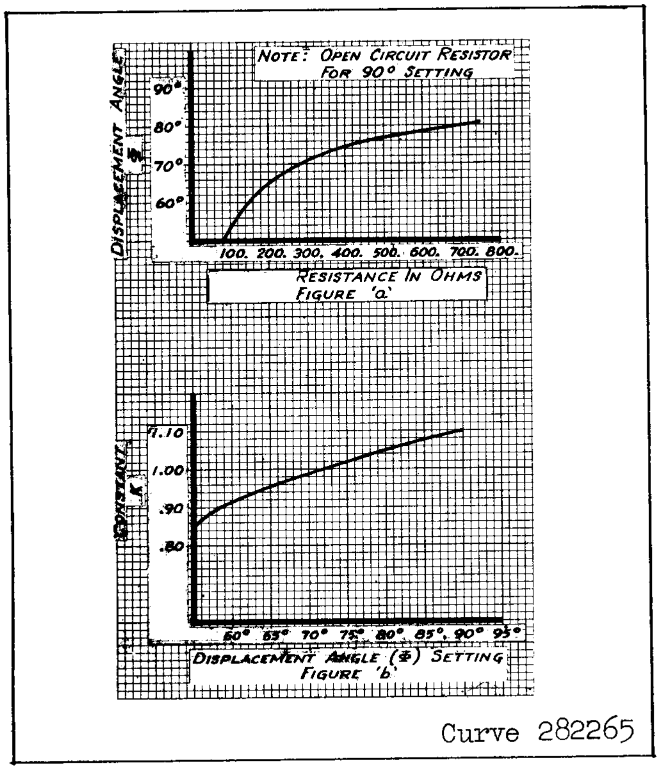
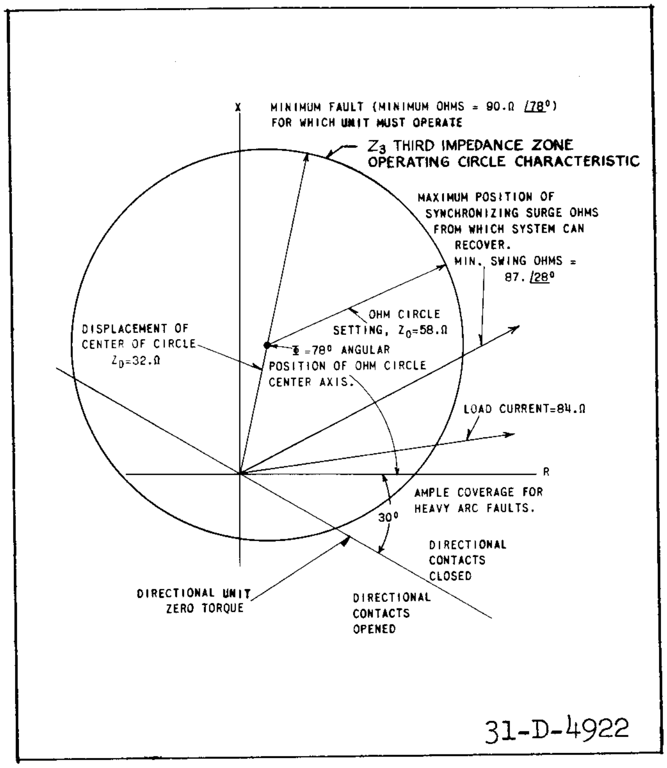


Fig. 9 Adjustment Curve for the Angular Displacement of the Operating Circle Center of Zone Three by Varying the Angular Displacement Resistor.



✱ *Fig. 10 Transmission Line and Relay Characteristics of Zone Three Plotted on R and X Coordinates in Primary Ohms.*

K = Constant determined from Curve Fig. 9 b

R_C = The current transformer ratio.

R_V = The potential transformer ratio.

ϕ = Angular Displacement

When changing the Z_R or A tap with the relay energized, the current terminals of the offset transformer should be shorted before unscrewing the tap screw to prevent open circuiting the transformers.

Normally the Z_D setting is from 0 to 75% of the Z_0 setting. The angular displacement (ϕ) may be varied by adjusting the resistor above the offset transformer in accordance with the curve of Fig. 9a for a fault at the desired balance point. A slight change in the scale value or in the transformer setting from that calculated may be required so that the relay will just trip for the simulated fault at the balance point.

As an example of the formula setting, set the third impedance unit to protect 25% of the third line section. Assume that the three sections are of equal length and similar to the line used in zone one setting calculations. Since 100% of a line section is 40 ohms, the balance point of the third unit equals 2.25 x 40 = 90 ohms away. The phase angle and the magnitude of the minimum synchronizing surge ohms from which the system can recover should be determined.

Plot the transmission line characteristics on "R" and "X" coordinates as shown in Fig. 10. An operating circle should then be drawn of a diameter and location to fulfill the conditions previously stated.

The radius of the circle in ohms should be measured and the impedance unit set in accordance using formula (1):

$$TS = \frac{10 Z_0 \, RC}{R_V} \qquad (1)$$

$$TS = \frac{10 \times 58.0 \times 600/5}{1000/1} = 69.6$$

T will be set on 45 (Relay Tap Setting)
S will be set on 1.55 (Relay Core Setting)

The displacement angle used in drawing the operating circle should be set on the relay by adjusting the resistor mounted above its offset transformer in accordance with the curve of Fig. 9a. In Fig. 10 the angle used was 78 degrees; therefore, the resistor should be adjusted to 600 ohms.

The distance expressed in ohms impedance between the center of the modified impedance circle and the intersection of the "R" and "X" axis should be measured from Fig. 10, and the offset transformer set using formula (2):

$$Z_R + A = \frac{Z_D R_c}{R_v K} \qquad (2)$$

$$Z_R + A = \frac{32 \times 600/5}{1000/1 \times 1.04} = 3.69 \text{ ohms}$$

Z_R should be set on 3.7 ohms.

A should be set on 0 ohm.

The time delay on the synchronous timer is set to coordinate with the relays backed up by the second and third impedance units. The setting is made by moving each stationary contact assembly to the desired position as indicated by the scale.

On lines where taps or paralleled feeders supply fault power to the adjacent sections, the apparent impedance to the relay backing up the adjacent section is greater than the actual impedance. The reason for this is that the relay does not measure the additional fault current supplied by the other feeders, but at the same time, this current does increase the voltage drop from the fault to the relay. This increases the apparent impedance to the adjacent section by the ratio of the total current to the relay current. The effect on the relay impedance units is to back up the balance point of the second and third impedance units. In order to extend the range of back-up protection under these conditions, the second unit can be set for a balance point further than the 150% normally recommended, provided it is made to time select with the adjacent section relay second unit. Similarly, the third unit can be set further than normal if it is made to select with the second and third units of the adjacent relay which it overlaps.

The formula settings are sufficiently accurate for most installations. Where it is desired to set the balance point more accurately the tap and scale values may be checked by applying to the relay the voltage, current, and phase angle conditions which will be impressed on it for a fault at the desired balance point. A slight change in the scale value from that calculated may be required so that the relay will just trip for the simulated fault at the balance point.

The particular setting of one unit may have some influence on the adjacent unit. The factory calibration of the core screw is made with taps cascaded as indicated in the section, "Electrical Check Points."

The numbers on the core screw appear in ascending order as the core screw is screwed into the core. In some cases, a question of doubt may arise whether the scale setting is correct, or is out by one full turn of the core screw. In such a case, the point may be verified by turning the core screw all the way in. Then back out the core screw until the highest scale marking just comes under the end of the pointer. This will occur in approximately one turn. To prevent such doubt it is recommended that the core screw setting be made by thus locating the highest scale marking and then continuing to back it off until the desired value appears exactly under the end of the pointer. Sufficiently accurate setting can be made by interpolating between the marked points when necessary.

HZ-4 Carrier Setting of Z_3

When the relay is used with carrier, the third zone unit must operate in a reverse direction from Z1 and Z2 whenever the modified distance characteristic is used. This is done to assure proper carrier blocking for external faults in the adjacent line section with a setting of Z3 which will not pick up on load or surge ohms. This can be accomplished by merely reversing the polarity of the Z3 potential circuit.

The method of arriving at the proper setting is shown in Fig. 3 which also shows the normal settings of Z1, Z2, and Z3 when used without carrier. When the HZ-4 relay is used with carrier, the ohmic reach of Z3 at station A in the direction away from line AB should be greater than the reach of Z2 (from station B) past the local station bus (at A). Thus any fault in the zone Ab which picks up Z2 at B will also pick up Z3 at station A to block tripping at B. The zone ab is for a safety factor to insure that carrier will always be started at A before carrier tripping can be set up at B. For this service, Z3 should be set to reach out of the line 50% farther than the reach of Z2 (at B) past the station A Bus. In Fig. 5 this means Aa should be 150% of Ab. The reach of Z3 into the line section AB as shown * is not critical, but should be at least 20% of the offset ohms.

When the Z3 setting is reversed, the second contact of the CSA must be connected in parallel with the CS1 contact to control the timer. This provides third zone back-up protection for lines away from the line protected by zone one and two. Thus the timer is controlled by Z2 and D or Z3 only.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT case information refer to I.L. 41-076.

CONNECTIONS

Impedance Units

The impedance to the balance point is measured from the point where the potential transformers are connected to the protected line. For protecting transmission lines, the relays should receive potential from potential transformers connected directly to the line at the point from which the impedance is to be measured.

In some applications a power transformer bank forms part of the transmission line, and potential transformers are available only on the bus side of the bank. In this case the relays may be set thru the bank to protect the line only if the bank impedance is not too large as compared with the line impedance. If the bank impedance is too large in comparison with the line impedance, the 80 or 90% setting of the first unit may cover only a very small percentage of the transmission line or in some cases not cover any of the line section. For the same reason the second and third units will offer considerably less back-up protection over the adjacent lines. In order to use the potential transformers on the bus side of the bank under this condition, Type KX compensators are used and the impedance measured from the line side of the bank to the balance points. The type KX compensators operate from the current transformers and provide voltage compensation equivalent to the drop in the power bank. The setting of the KX compensator is covered by I.L. 41-861.

The above discussion assumes that power is fed thru the bank to faults on the line. Where a power transformer connects to a high tension transmission line and does not supply power to a line fault, low-tension potential transformers may be used without compensation. Then, the impedance to the balance point is measured from the point where the power bank connects to the protected line.

The conventional star connection of current transformer is not satisfactory where accurate distance relay protection is desired. With this connection the balance points of the impedance units shift about 15% depending upon whether a phase-to-phase, a three phase or a double ground fault is involved. That is, if the balance point were adjusted at 80% for a three phase fault, then for a double ground fault the shift may be more or less than plus or minus 15% of the 80% setting, depending upon the ratio of the zero sequence impedance to the negative sequence impedance of the system from the source of power to the fault.

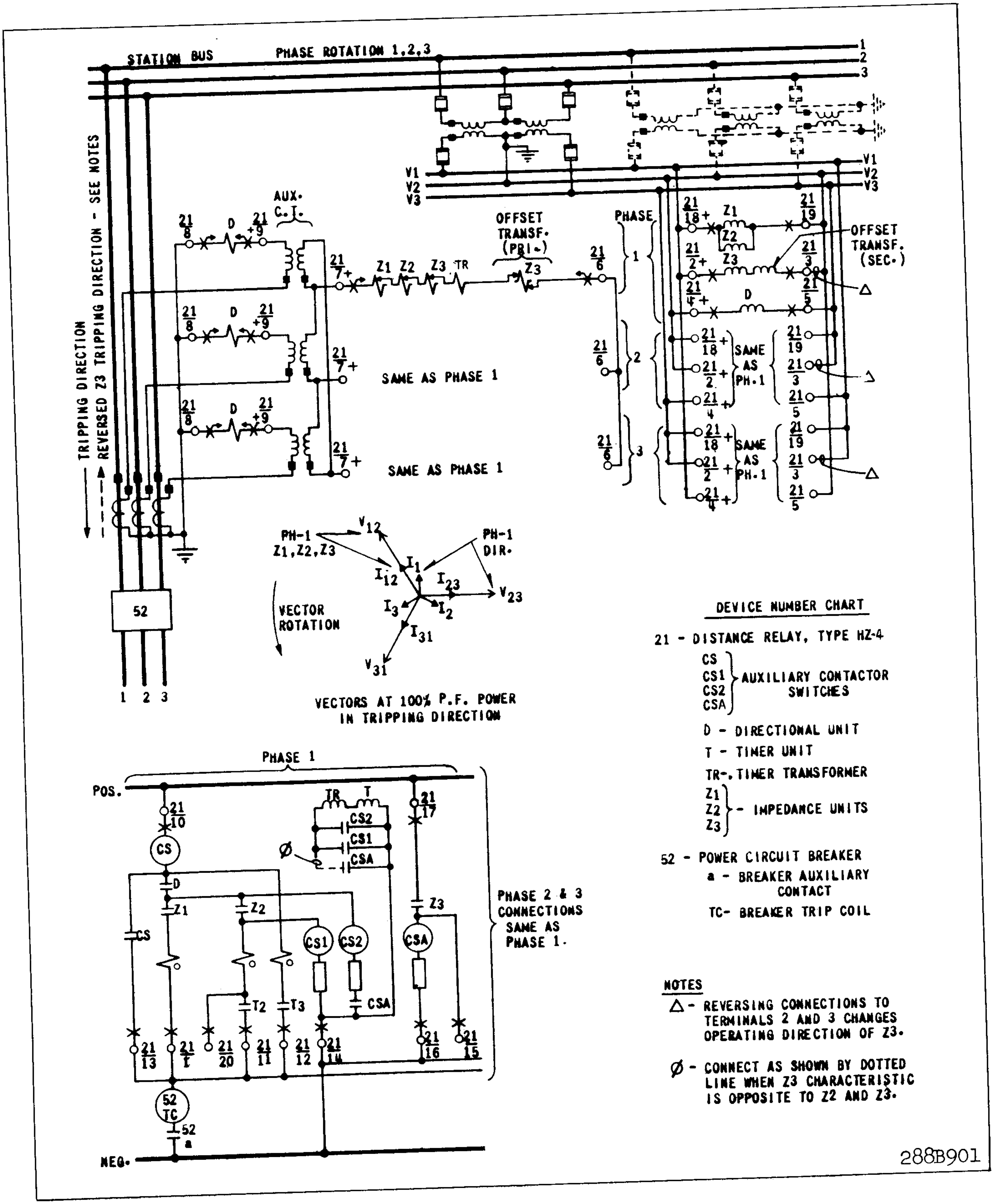


Fig. 11 External Schematic of the Type HZ-4 Relay for Phase Protection of a Three Phase Transmission Line.

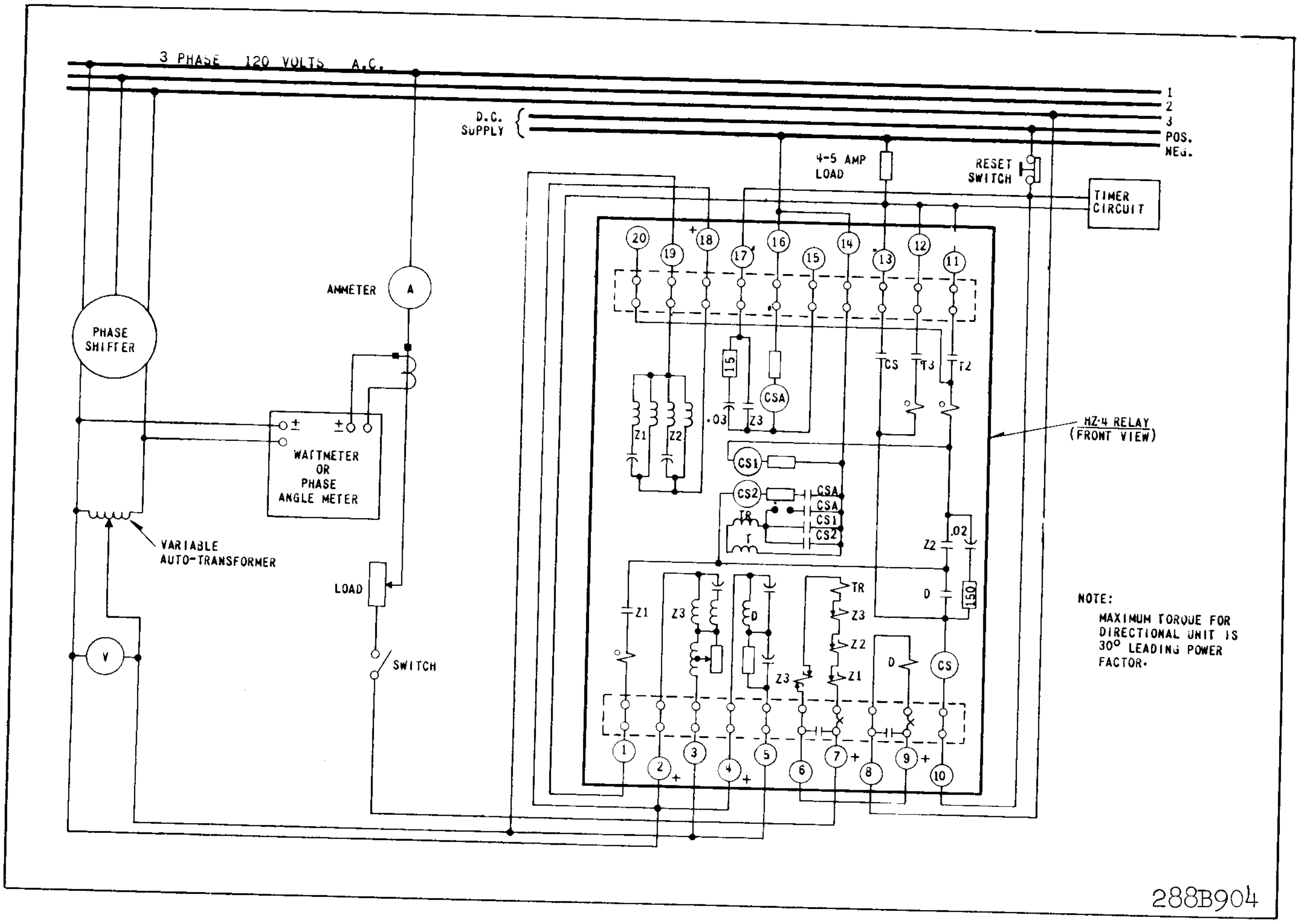


Fig. 12 Diagram of Test Connections for the Type HZ-4 Relay.

This error can be entirely eliminated by making use of the vector difference between the line current, (i.e. delta currents) for actuating the relay.

The most common method is to connect the main current transformers in star and use a set of auxiliary 5/5 ratio transformers to supply delta currents to the elements, as shown in Fig. 11. The delta voltages used on the impedance units of the relays should be in phase with the delta currents at unity power factor.

Directional Unit

The magnetic design of the unit and potential circuit is such that maximum torque occurs when the current leads the voltage by approximately 30 degrees. Thus, the directional unit coils should be connected to receive current that leads the voltage by 90 degrees when the line power factor is 100 percent. This will result in operation at approximately the maximum torque angle for transmission line faults.

Trip Circuit

The contactor switch operates on a minimum of 1.0 ampere, but the trip circuit should draw at least 4 or 5 amperes in order to reduce the time of the operation of the switch to a minimum and provide more positive operation. If the type HZ-4 relay is used to trip an auxiliary multi-contact relay, provision should be made for loading down the trip circuit with a resistor in parallel with the operating coils of the auxiliary relay. Also, since the total trip circuit resistance in the relay is approximately 1.0 ohm, care must be taken to see that the breaker trip coil will receive enough current when low voltage control is used.

The main contacts on the impedance units and directional unit will safely close 30 amperes at 250 volts d-c, and the switch contacts will safely carry this current long enough to trip a breaker.

ELECTRICAL CHECK POINTS

To check the electrical operation of the relay, the following instruction should be followed. Connect the relay per Fig. 12 and make the following settings. (At regular maintenance periods the settings of each particular relay with the voltage and current expected at the balance point should be used, if available. During factory testing, the settings are cascaded as indicated below.)

IMPEDANCE UNITS

.2 to 2 Ohm Relay

ZONE	T	S	Z_R	A	Ø
Z_1	13	1.2			
Z_2	20	1.8			
Z_3	45	1.8	5.6	0.0	75°

IMPEDANCE UNITS

.6 to 6 Ohm Relay

ZONE	T	S	Z_R	A	Ø
Z_1	29.8	1.2			
Z_2	45	1.6			
Z_3	45	1.8	5.6	0.0	75°

CAUTION: The relay voltage should be of good wave form. The combination of a phase shifter and autotransformer may give an output voltage of poor wave form if the magnetizing current of the autotransformer is high in proportion to the impedance of the phase shifter used. In case of doubt, check the output voltage waveform with an oscilloscope.

Directional Unit

With 120 volts and 5 amperes in phase, the directional unit should be closed. The contacts should open when the current lags the voltage by approximately 60 degrees.

Impedance Units

With 60 volts on the relay, increase the current until the contacts just close. This current (which will vary slightly from this value if suddenly applied) should be approximately:

.2 to 2 Ohm Relay

Z-3 I = 4.4 amp. at 75° lag I (non-carrier)
Z-3 I = 4.4 amps. at 255° lag I (carrier)
Z-2 I = 16.7 amps. at 60° lag I

.6 to 6 Ohm Relay

Z-3 I = 4.4 amps. at 75° lag I (non-carrier)
Z-3 I = 4.4 amps. at 255° lag I (carrier)
Z-2 I = 8.4 amps. at 60° lag I

With 35 volts on the relay, Z-1 should trip when the following currents are applied.

.2 to 2 Ohm Relay

Z-1 I = 22.4 amps. at 60° lag I

.6 to 6 Ohm Relay

Z-1 I = 9.8 amps. at 60° lag I

With the D contact closed, the tripping of Z-3 should cause CSA switch to pick up, and CS-1 switch in turn. The operation of CS1 should start the timer. When Z-1, Z-2 and timer T-2, or T-3 contacts close, the CS switch should operate and seal around all the contacts. The CS and CS-1 are not continuously rated; therefore, care should be taken not to overheat these auxiliary switches. The checking of the timer unit will depend on standard time device used. Generally this check is made independently of the trip circuit to avoid circuitry complications. The timer should operate with 3.5 amperes in the timer transformer and with the contacts of CS-1 closed or shorted. An auxiliary relay, as used in the trip circuit, should be used to seal in the timer circuit.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed or the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be cleaned periodically. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended because of the danger of embedding small particles in the face of the soft silver and thus impairing the contacts.

Impedance Units

The voltage circuit on the first impedance unit is designed to have a peaked phase angle curve. This design in conjunction with the contact arrangement enables the first zone to operate with a 5 volt balance point voltage.

The voltage circuit on the second and third impedance units is designed to have a comparatively flat phase angle curve. This is accomplished by energizing the two coils with currents that are essentially equal and 90° out of phase. The gaps as shown in Fig. 1 are nominal dimensions. The actual gaps on any particular relay may vary a few thousandths from these values.

If the voltage circuits have been disassembled, the gaps referred to in Fig. 1 provide a nominal starting point for calibration. This is accomplished as follows:

First Impedance Unit

* Refer to Fig. 1. Adjust the stop screw on the rear of the beam to give a clearance of .025 inch between the beam and the voltage iron circuit. With the beam in the reset position; i.e., with the stop screw against the vertical gap for .009 inch between the adjustable iron and the beam. Also, with the beam in the same position adjust the gap between the front end of the beam and the stop in the upper core screw to .020 inch.

The beam should be balanced as follows. Connect the relay with polarities as shown in the test diagram, Fig. 12. With any tap and scale setting, check the impedance measured by the relay with 35 volts potential restraint. Apply 5 volts restraint and adjust the balance weight on the beam until the beam just trips with 1/7 of the current required to trip with 35 volts restraint.

The stationary contacts should be adjusted to give .015 inch clearance between them and the silver bridge on the beam when the beam is in the reset position. The bridge should be made to touch both contacts simultaneously, and deflect the contact springs at least .010 inch before the beam strides the bronze stop on the core screw.

A good method of adjusting the contacts consists in first adjusting one of the contacts to the correct gap and then applying just sufficient current to trip the beam against a restraint of about 5 volts. While the beam is in this position, that is, lightly pressing on the one contact, the other contact should be slowly adjusted upward by means of the set screw until it just touches the silver bridge without lifting it off the other contact. The trip circuit should be energized so that the lighting of a lamp or the tripping of an auxiliary relay will show when both contacts are made.

Second Impedance Unit

Refer again to Fig. 1. Adjust the stop screw on the moving beam for .020 inches clearance between the rear of the beam and the voltage iron. With the beam in this position, adjust the vertical gap for .010 inches clearance between the adjustable iron and the beam, also adjust for .020 inches clearance between the front of the beam and the stop on the upper core screw.

The stationary contact should be adjusted for an .020 inch gap when the beam is in the reset position. When the beam is in the operated position there should be a .015 inch deflection of the moving contact. The spring that carries the moving contact should lie flat on the Micarta arm with no initial tension on the contact. The flexible pigtail should be at least 3/32 inches from the end of the stationary contact.

With the connections as shown in the test diagram, Fig. 12, and using any tap and scale setting, check the impedance measured by the relay with 60 volts potential restraint. Apply 10 volts restraint and adjust the balance weight or vibration damper on the second unit until the beam just trips with 1/6 of the current required to trip with the 60 volts restraint.

Third Impedance Unit

Mechanical adjustments of the beam and contact are the same as for the second unit except for the vibration damper.

The third impedance unit beam should be balanced by adjusting the balance weight so that in the de-energized condition, the beam will reset, thus leaving its contact open. Do not introduce excessive resetting torque, but only enough to reset the unit.

Calibration of Impedance Units

The current required to operate the impedance units against any given voltage is obtained from the equation:

$$I = \frac{10E}{TS} \qquad (3)$$

It is essential that the polarity be as given, otherwise an error will be introduced particularly for the first unit. Fig. 6 shows the variation of tripping current for a given voltage as the phase angle between current and voltage is varied. To make sure that the relay is operating at 60° lag and not 240° the current leads can be reversed which will cause the first impedance unit beam to operate at a smaller current if the original connections were correct.

The current required to operate the third impedance unit, with offset, is obtained from the equation:

$$I = \frac{E}{\frac{TS}{10} + (Z_R + A)\,K} \qquad (4)$$

Fig. 5 shows the general shape of the impedance curves for different ohm settings. These curves are obtained by tripping the beam against different voltages for a constant T and S setting and then plotting the ratio E/I in percent calibrating voltage impedance against the voltage. The lower voltage points (5 to 15 volts) are considerably affected by the mechanical balance of the beam, while the higher points are but little influenced.

Accurate time tests on the instantaneous unit and directional unit can only be taken with the aid of an oscillograph or high speed timer. The cycle counter is of use only in timing the synchronous timer and in timing the high-speed units near the "balance point" where the time may be several cycles.

Fig. 8 shows the time of operation in cycles (data taken on 60 cycle relay) of the first impedance unit for various balance points. By using these curves the operating speed of the HZ-4 element can be determined for any value of current and voltage applied to the element.

Directional Unit

The upper bearing screw should be screwed down until there is only three to four thousandths of an inch clearance between it and the shaft, and then securely locked in position with the lock nut. This adjustment can be made best by carefully screwing down the top bearing screw until the double loop fails to turn freely and then backing up 1/8 of a turn. Great care must be taken in making this adjustment to prevent damage to the bearings.

The front contact spring should be positioned in the center of the .020 inch slot of the aluminum guard by means of the small adjusting screw located on the nut plate that holds the spring on the moving element. The travel of the moving contact is limited by the stationary contacts mounted on the molded cover. The contact gap should be adjusted as follows: With the moving contact centered between the studs, close the gaps by advancing the two front stationary contacts. Then back off the right-hand stationary contact .035 inch and lock both contacts in place. The complete moving element is limited in travel by two stop screws, located on the molded cover. These should be adjusted so that the moving contact just barely misses the stationary contact stops front and rear respectively when energized in the opening and closing directions with 120 volts and 5.0 amperes at maximum torque. The right-hand stationary contact should just touch the moving contact when energized as above and then should be turned 1/6th of a turn to obtain .005 inch contact follow. Too much follow should be avoided to insure proper coordination. The spring should be adjusted so that the contact closes with approximately 1.0 volts and 5 amperes at maximum torque.

A small lever arm extending to the front on the bottom of the unit and the plugs accessible through the molded cover control the magnetic bias of the electromagnet. The lever should be adjusted so that the unit will operate with 30 amperes and 0.1 to 0.4 volt at the maximum torque angle. Before or after this adjustment, short the voltage coils and check to insure that the contacts do not close on 60 amperes momentarily applied. Raising the right-hand plug under these conditions will produce torque to the right when considering the front moving contact. The unit can be adjusted to just remain open under these conditions or adjusted to operate with 60 amperes and 0.1 to 0.4 volt at the maximum torque angle.

Contactor Switch (Seal-In Switch) CS

Adjust the stationary core of the switch for clearance between the stationary core and the moving core of .025 inch when the switch is picked up. This can be done by disconnecting the switch, turning it up-side-down and screwing up the core screw until the contact just separates. Then back off the core screws approximately one turn and lock in place. This prevents the moving core from striking and sticking to the stationary core because of the residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 1.0 ampere direct current. Test for sticking after passing 30 amperes direct current through the coil.

Contactor Switch CSA

The adjustments are the same as for the seal-in contactor switch "CS" except that the contact clearance should be 1/32 inch. For 125 volt d-c relays, apply 80 volts d-c to Nos. 16 and 17 terminals. Similarly for 250 volt d-c relays, apply 160 volts d-c to Nos. 16 and 17 terminals. See that the switch picks up and closes its contact positively when the contact of the third impedance unit is made. The switch coil is continuously rated.

Contactor Switches CS-1 and CS-2

The adjustments are the same as for the seal-in contactor switch CS except that the contact separation should be 1/32 inch. For 125 volt d-c relays apply 60 volts d-c positive to Nos. 10 and 17 terminals and negative to Nos. 14 and 16 terminals. Similarly for 250 volt d-c relays use a test voltage of 120 volts d-c. See that switch CS-1 picks up and closes its contact positively when the directional and Z-2 impedance unit contacts are made. See that CS-2 picks up and closes its contacts when the directional unit and Z-3 impedance unit contacts are made. These switch coils are intermittently rated, and therefore care should be exercised so as not to overheat the coils.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere direct current gradually applied. Test for sticking after passing 30 amperes direct current through the coil.

Synchronous Timer

When testing the synchronous timer, complete the transformer circuit by a jumper around the contacts on the contactor switch CS-1 or CS-2 rather than operating the switch on d-c. Test the motor with 3.5 amperes through the current circuit of the relay. This is the minimum current at which it will run in synchronism.

Timing Tests

The d-c trip circuit should be loaded with a resistor to draw approximately 5 amperes and an auxiliary relay should be used to operate the timer circuit if time tests are to be taken. There is a slight vibration of the beam and contacts because of the pulsating pull on the current side of the instantaneous unit. This vibration may prevent positive stopping of the timing device unless an auxiliary type MG relay is used. The loading resistor will cause the contactor switch to seal in and simulates the actual service condition when a circuit breaker is to be tripped. This type of circuit is also necessary when timing T-2 or T-3.

CAUTION Make certain that the stops on the rear and front of each beam are absolutely clean, otherwise the impedance at which the beam trips may be affected, particularly at low voltages. The stop can be easily cleaned by drawing a piece of clean white paper between the beam and the stop while the beam is firmly pressed down.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

ENERGY REQUIREMENTS

POTENTIAL CIRCUITS AT 120 VOLTS, 60 CYCLES

Circuit	V.A.	P.F. Angle
Z-1 and Z-2 together	4.2	3° lag
Z-3 Displacement angle 90°	2.4	48° lag
Displacement angle 60°	2.3	29° lag
Directional Unit	6.6	19° lead

POTENTIAL CIRCUITS AT 120 VOLTS, 50 CYCLES

Circuit	V.A.	P.F. Angle
Z-1 and Z-2 together	3.9	15° lead
Z-3 Displacement angle 90°	2.2	40° lag
Displacement angle 60°	2.0	26° lag
Directional Unit	6.4	9° lead

CURRENT CIRCUITS AT 60 CYCLES †

Circuit	Amps.	V.A.	P.F. Angle
Impedance			
T = 45, S = 1.8			
Z_R = 7.5, A = 0.0	8.66	30	51° lag
Directional Unit	5	2.0	50° lag

†The burdens of the current circuits, at 50 cycles, are slightly less than the above values.

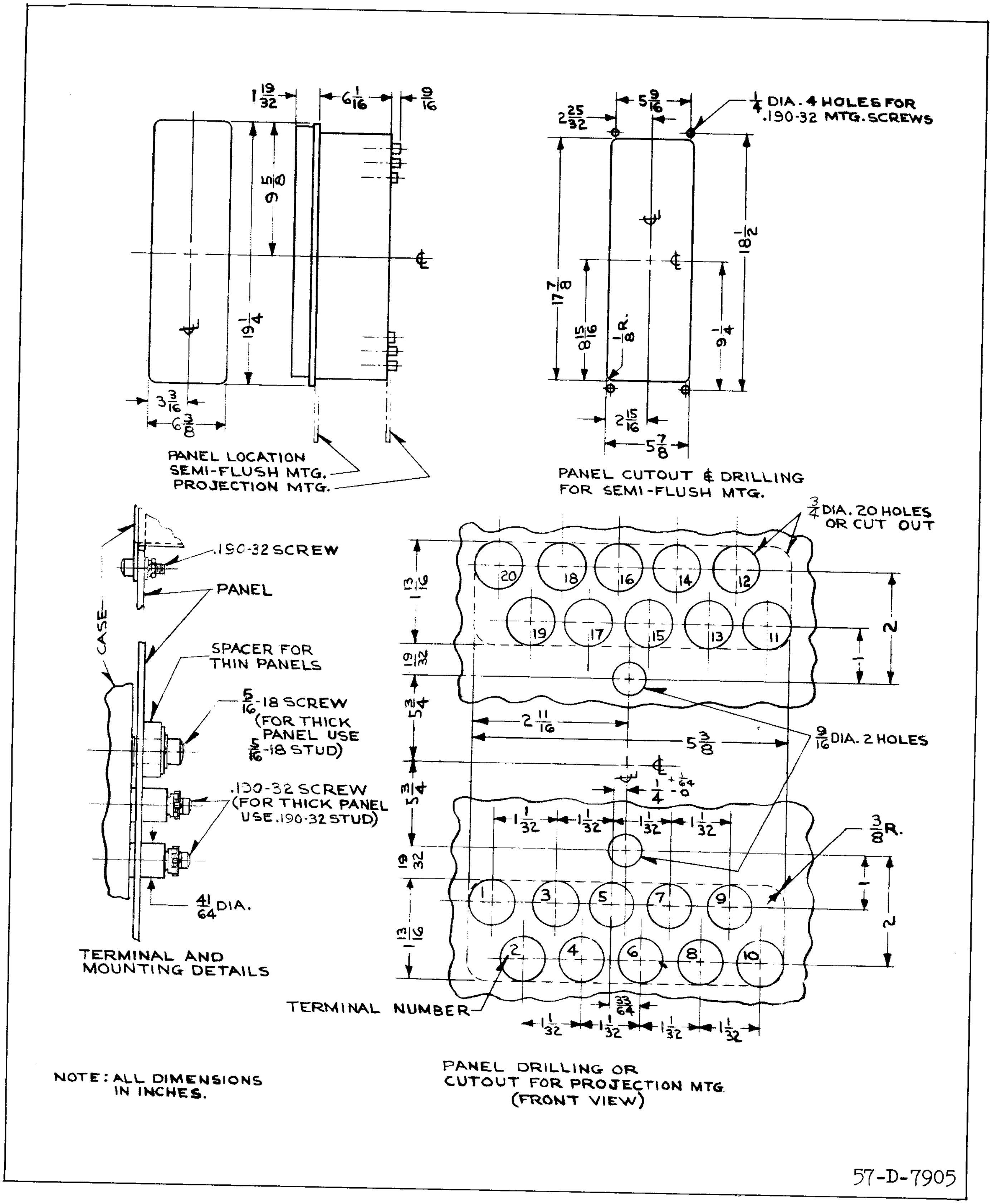


Fig. 13 Outline and Drilling Plan of the Type HZ-4 Relay in the Type FT42 Case.

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