INSTRUCTIONS

TYPE HCZ IMPEDANCE RELAY

Caution Before putting protective relays into service, remove all blocking which may have been 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 HCZ relay is a combination of the instantaneous impedance and directional elements of the Type HZ relay and the distance element of the Type CZ relay. This relay is used for high speed clearing of phase faults on transmission systems. It gives instantaneous protection over 80 to 90% of the protected section, and protection over the remaining 20 to 10% of the protected section, and the adjacent sections with adjustable time delay increasing with distance. (Figure 1).

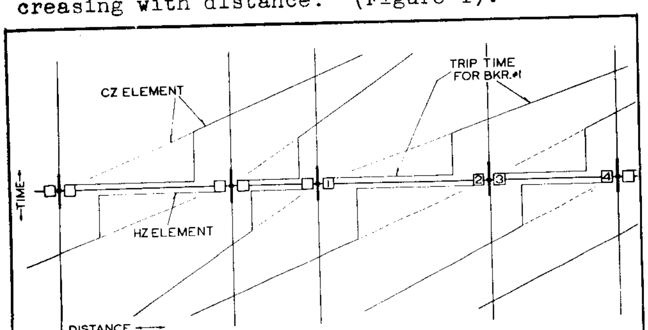

Fig. 1 — Typical Time-Distance Characteristic of the Type HCZ Relay.

CONSTRUCTION AND OPERATION

The Type HCZ relay contains an instantaneous impedance (HZ) element, a distance (CZ) element, a directional element, a fault detector element, auxiliary contactor switches, and operation indicators all mounted in a single case. The construction and operation of each of these elements is as follows.

<u>Instantaneous Impedance (HZ) Element</u>

This element is similar to the first impedance element of the Type HZ relay. It consists of a balanced beam pivoted at the center (Figure 4) and pulled downward by a current coil on the forward end to close the relay contacts. This pull is opposed by two voltage coils acting on the other end of the beam. The fluxes set up by these two potential coils are shifted out of phase with respect to each other so that a balance between current and voltage fluxes can be held within desirable limits for all phase angles.

A tap screw on the front of the element permits changing the number of turns on the current coil, and a core screw on the bottom of the element changes an air gap in the magnetic path. These two adjustments make it possible to set the impedance element so that it will operate instantaneously, for all faults occurring within 80 to 90% of the protected line section. For a fault at the balance point of the element (determined by setting) the pull of the voltage coil, which measures the IZ drop from the fault to the relay, will just equal the pull of the current coil, which receives the fault current, I. If the fault occurs inside the balance point, the IZ voltage pull will be less than the I current pull and the beam will trip closing its contacts. Conversely, if the fault occurs outside the relay balance point, the IZ voltage pull will be greater than the I current pull and the beam will not trip.

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 a short leaf spring. A small

SUPERSEDES I. L. 41-479
✱ Denotes changed from superseded issue.

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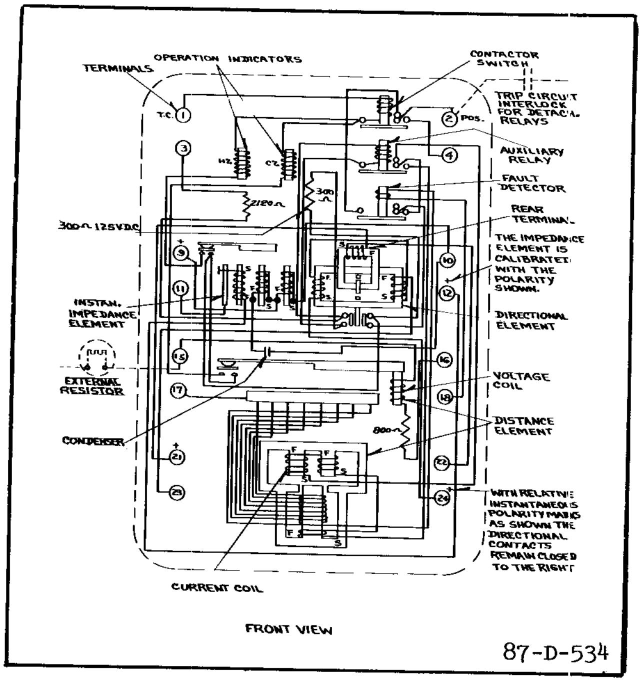


*** Fig. 2—Internal Connections of the Type HCZ Relay in the Standard Case.**

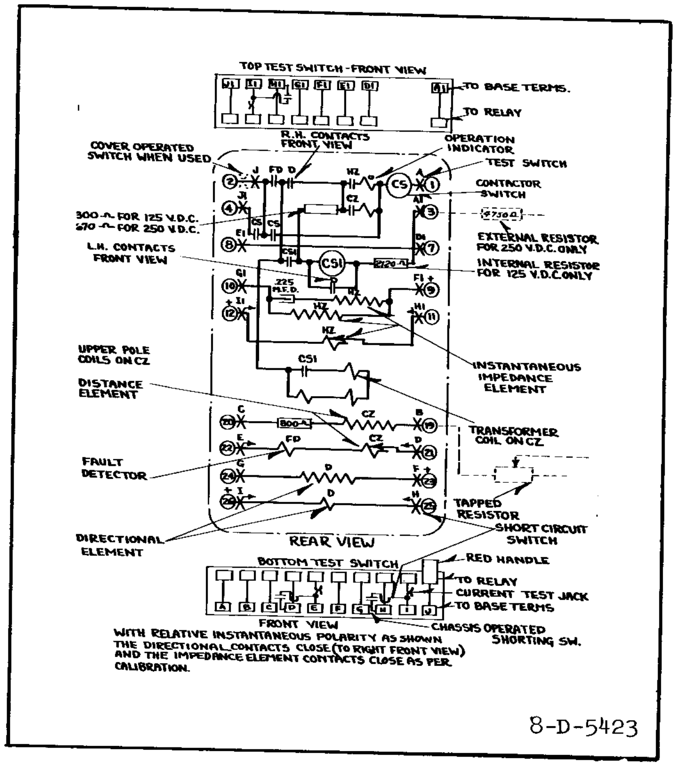
set screw determines the position of the leaf spring and provides means for adjusting the contact gap and follow.

The Distance (CZ) Element

The distance element consists of an induction-disc element operated by current, and a restraining coil and plunger assembly operated by voltage. These two elements are mechanically interconnected thru pivoted lever arms which also operate the CZ element contacts. The induction disc winds up a spiral spring to tilt the horizontal lever arm in the contact closing direction. This motion is opposed by the pull of the voltage restraining coil on a small plunger fastened to one end of the lever arm. When the pull of the spring and induction disc overcomes the voltage coil pull, the plunger snaps up and the contacts close. The operating time of the element is proportional to the speed of the current disc and magnitude of the voltage. Consequently, the closer the fault, the larger the current, and the lower the voltage; and, therefore, the faster the distance (CZ) element operates.

Directional Element

A small voltage transformer causes a large current to flow in a single-turn movable



*** Fig. 3—Internal Connections of the Type HCZ Relay in the Type FT Case.**

aluminum secondary, which current is substantially in phase with the voltage. The current coils are mounted on a magnetic frame and the current and voltage elements are assembled at right angle to each other with the one-turn voltage loop in the air gaps of the current coil flux path. The interaction of the current and voltage fluxes produces torque and rotates the loop in one of two directions, depending on the direction of power flow.

An Isolantite arm extends from the moving loop and supports a rectangular silver contact which bridges two stationary contacts located on either side of the loop. The stationary contacts are silver hemi-spheres mounted on the lower end of vertically-hanging spring leaves. The contact separation is adjustable by a small screw near the upper end of the rigid stationary contact supporting arm. One of these supporting arms hangs parallel to each of the four stationary contacts. The set screw on the lower end of this arm provides the contact follow adjustment. Two additional screws on the movement frame beneath the current coil iron limit the movement of the one-turn loop.

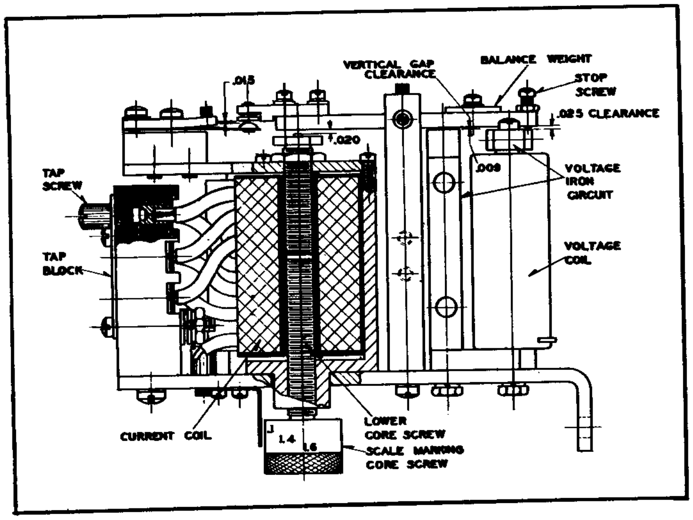


Fig. 4 — Sectional View of the Instantaneous (HZ) Element.

Fault-Detector Element

This element is a small solenoid-type switch. A small cylindrical plunger with a silver disc supported on its lower end rides up and down on a vertical guide rod in the center of the solenoid coil. The guide rod is fastened to the stationary core which in turn screws into the element frame. When the coil is energized, the silver disc moves upward bridging three cone shaped stationary contacts. The silver disc is supported on the moving plunger by a spring which permits the plunger to ride upward after the contacts have made.

The switch is used as an overcurrent fault detector by connecting its coil in the distance element current circuit and setting its contacts to pick up on 8 amperes fault current. These contacts are connected in series with the directional element and the instantaneous or distance element contacts and so prevent the relay from tripping if the fault current is less than the 8-ampere pick-up of the fault detector. They also prevent the operation of an auxiliary D-C contactor switch which in turn controls the operation of the CZ distance element.

Auxiliary Contactor Switch

The construction of this switch is similar to the fault detector switch except that the design of the moving plunger and solenoid coil is for D-C instead of A-C. The operation of this D-C auxiliary switch is controlled by the directional and fault detector elements which in turn directionally controls the CZ distance element. When sufficient fault current flows in the tripping direction to close the fault detector, the auxiliary contactor switch operates to close and seal in the upper pole circuit of the CZ distance element, permitting the disc to rotate. If the direction of the fault current reverses, a contact on the directional element shorts the auxiliary contactor switch coil, causing it to drop out. This opens the directional control circuit and allows the distance element to reset.

Contactor Switch and Operation Indicator

The coil of the contactor switch is connected in the trip circuit. When the relay contacts close, the coil is energized and its contacts short around the relay contacts, relieving them of the duty of carrying the breaker tripping current. These contacts remain closed until the trip circuit is opened by a breaker auxiliary switch. The third contact of the contactor switch is connected to a separate relay terminal to operate an alarm circuit.

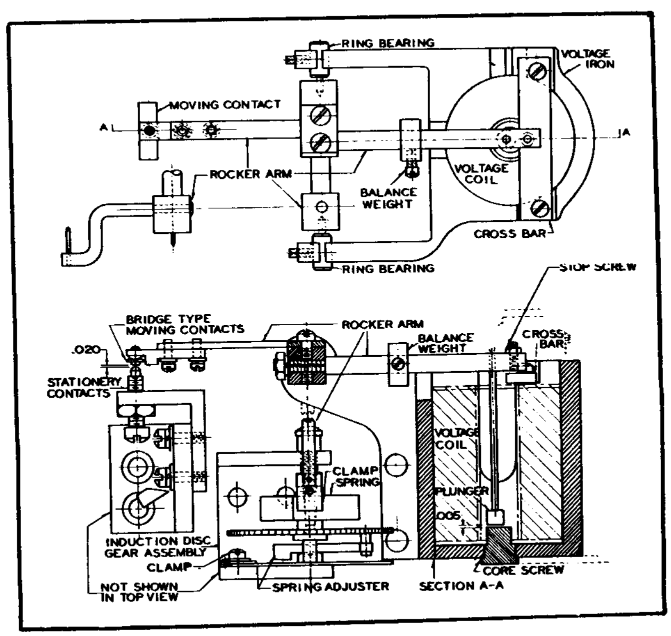


Fig. 5 — Sectional View of the Distance (CZ) Element.

Two operation indicators show white targets with the letters HZ and CZ. The HZ target operates when the trip circuit is completed through the instantaneous impedance element, and the CZ target operates when the trip circuit is completed through the distance element.

CHARACTERISTICS

The relay is available in two ranges which refers to the range of instantaneous (HZ) element. These are the 0.2 to 2.0 ohm relay for short lines and the 0.60 to 6.0 ohm relay for long lines. The following are the tap markings:

Instantaneous (HZ) element 0.2 to 2.0 ohm range:

Tap = 2, 3, 4, 6, 9. 13
Core Screw = .8, .9, 1.0, 1.1, 1.2, 1.4, 1.6

Instantaneous (HZ) element 0.6 to 6.0 ohm range:

Tap = 6.2, 9.4, 13.5, 20.8, 29.8, 45
Core Screw = .8, .9, 1.0, 1.1, 1.2, 1.3, 1.4

Distance (CZ) element - all ranges:

Current taps = 4, 5, 6.5, 8, 10, 15, 20, 25
Voltage taps on the series resistor = 125, 150, 175, 200, 250, 300, 350, 400, 500, 600, 700, 800, 1000, 1200, 1400, 1600, 1800

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 two mounting studs for the standard cases and the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

The recommended connections of relay are shown in Figs. 16 and 18. The 60° connection is used on the directional element, that is at unity power factor the current thru the directional element coil should lead the polarizing voltage by 60° as shown in the vector diagram. The star-delta auxiliary current transformer is the same as used with the type HZ relay and is described in I. L. 41-535. Figs. 17 and 19 show the external connections of the Type HCZ relay using star current for all elements.

SETTINGS

The Type HCZ relay requires two separate settings; one for the instantaneous HZ element and the other for the distance CZ element. Each will be considered below:

The following nomenclature is used in the discussion of the two settings:

Z = the line-to-neutral ohmic impedance;
For the instantaneous element, the impedance for 80 to 90% of the protected line section.

For the distance element, the ohmic line length for which the element will operate in a time determined by the choice of K.

K = constant determined by the coordinating time interval between successive relays.

Rc = the current transformer ratio.

Rv = the potential transformer ratio.

T = the instantaneous HZ element current tap.

S = the instantaneous HZ element current core screw.

Tc = the distance CZ element current tap.

Tv = the distance CZ element voltage tap on the external resistor.

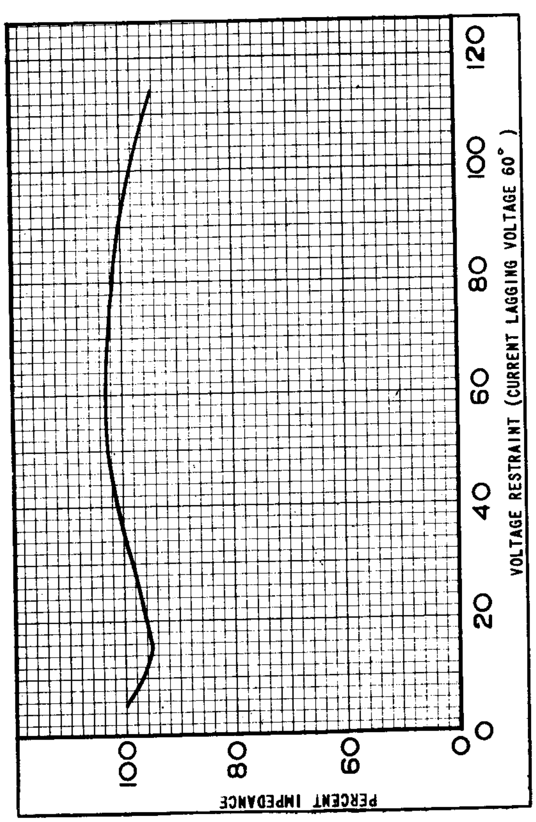


Fig. 6 — Typical Impedance Curve for the Instantaneous (HZ) Element.

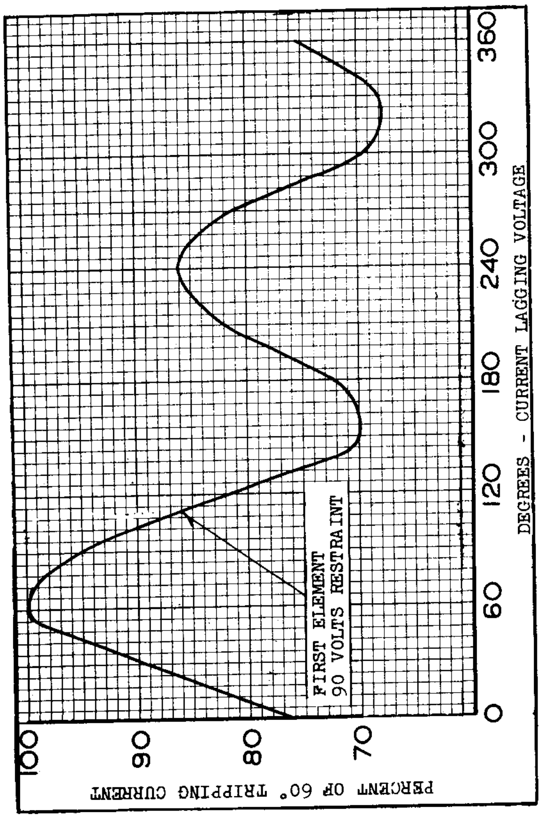


Fig. 7 — Typical Phase Angle Curve of the Instantaneous (HZ) Element.

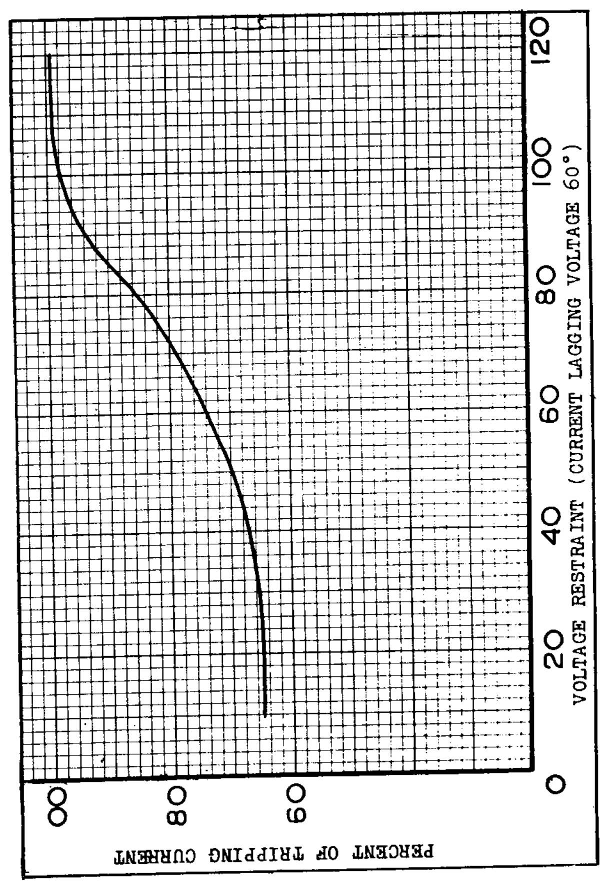


Fig. 8 — Typical Reset Curve for the Instantaneous (HZ) Relay.

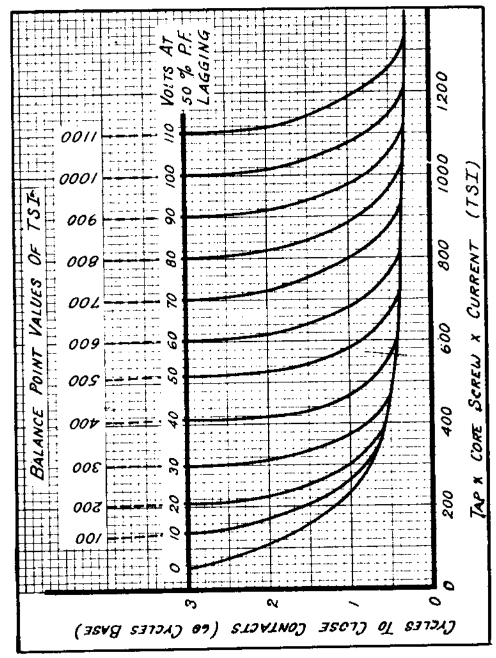


Fig. 9 — Typical Time of Operation Curves for the Instantaneous (HZ) Element.

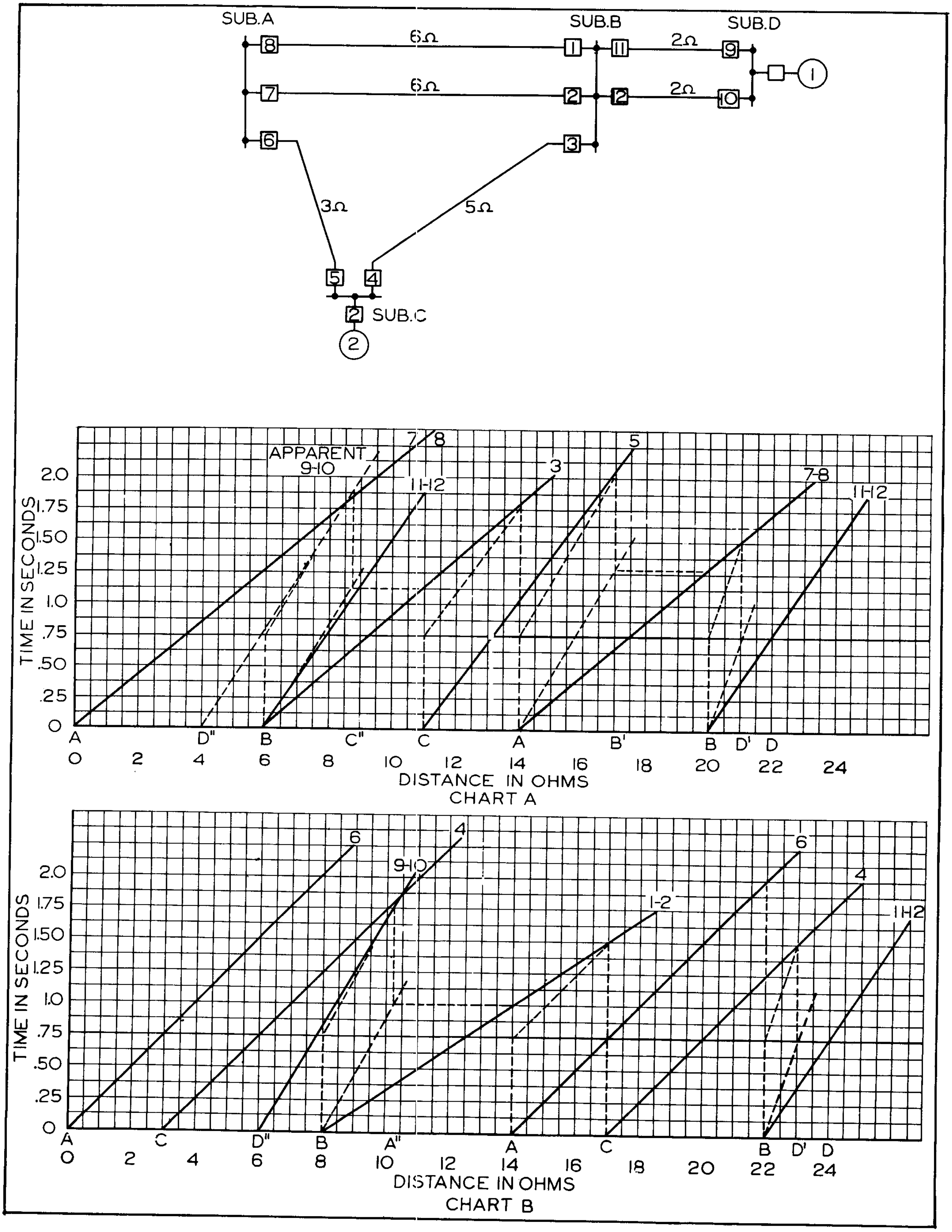


Fig. 10 — Construction of Time-Distance Chart for the System Shown.

Instantaneous (HZ) Element Setting

This element is set to give instantaneous protection over approximately 90% of the protected line section. Since the impedance of the voltage coil is the same at all times, the balance point of the element 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 settings is by the use of the following equations:

Instantaneous Element Receiving Delta Current:

$$TS = \frac{10\ Z\ Rc}{Rv} \qquad (1)$$

Instantaneous Element Receiving Star Current:

$$TS = \frac{17.3\ Z\ Rc}{Rv} \qquad (2)$$

The nomenclature is as defined above. 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 be screwed in the desired tap before removing the existing tap screw to prevent open circuiting the current transformers.

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 less than 3/4 of a 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.

The above formulas are based on the relay being used on a 60° line and are 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. 7.

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.

As an example, the instantaneous element is to be set for 90% of the line section AB which is 6 ohms long. The current transformer ratio is 200/5 star-connected with the star-delta auxiliary current transformer supplying delta current to the instantaneous element coils. The potential transformer ratio is 1000/1.

Using equation (1)

$$TS = \frac{10 \times .90 \times 6 \times 40}{1000} = 2.16$$

Set tap 2 on the .02 to 2.0 ohm relay and core screw = 1.08.

Distance (CZ) Element Setting

The distance element is set to protect the last 10 or 20% of the protected section, and to give back-up protection over the instantaneous element zone of the protected section as well as the adjacent sections. Consequently, each distance element must be carefully set to coordinate with the relays protecting these adjacent sections so as not to trip out its breaker before the adjacent line relays and breakers have had an opportunity to operate.

Before discussing this problem the individual distance element settings will be explained disregarding the question of coordination with other relays.

Individual Setting: The impedance curve and hence the time of operation of the distance element is approximately constant for fault currents in the range of 200% to 1000% of the current tap value, Figure 13. The selection of the current tap Tc should be made such that the element will operate in this range for maximum and minimum fault currents. In no case should the minimum fault current for which the relay must operate be less than 200% of the tap selected, and it is always desirable to use the highest tap possible.

With the selection of suitable current tap, Tc, the voltage tap, Tv, may be determined by using the curves of Fig. 11 or by the equation below. The use of the curves is as follows. The per cent trip current on the abscissa is the fault current thru relay in per cent of the current Tc tap chosen. The ordinate is the desired relay operating time in seconds for the fault under consideration. The point thus located will fall on or near one of the curves. The values on the curves are the voltage drop from the fault to the relay (relay volts) for Tv = 125. Knowing the actual voltage drop, the tap, Tv, is determined by the relation:

$$\text{Voltage drop} = \frac{Tv}{125} \times \text{voltage value on curve}$$

For three phase faults the voltage drop is easily calculated by multiplying the fault current by the impedance from the relay to the fault.

NOTE: The relay should not be required to operate when the drop from the relay to the fault for minimum fault is less than 5 relay volts.

The voltage tap, Tv, can also be determined by the following equation:

$$Tv = \frac{Tc \times Rc \times Z \times K}{Rv} \qquad (3)$$

where the nomenclature is as defined above. The voltage tap determined from this equation will permit the distance element to close its contacts in a time depending on the selection of K for a fault Z ohms distant from the relay. The value of .75 second is a conventional time interval between switching stations for which the distance element should be set. This value is arrived at by allowing .25 second for the relay to close its contacts and .50 second for the adjacent relay and breakers to operate. The values of K for this and other time intervals is shown in the following table:

Time Interval	Value of K for Current Transformers: Star Connected	Delta Connected
1.2	68	39
1.1	72	42
1.0	77.5	45
.9	83	48
.8	91	53
.75	96	56
.7	101	59
.6	113	65
.5	130	75
.4	152	88

The calculation of Tv from equation (3) will usually give a value in between the available taps on the voltage resistor. In these cases the selection of the nearest taps below the calculated value usually will be desirable since it gives a slightly greater operating time.

The settings on the distance element may be checked in the laboratory by means of the operating curve, Fig. 11, and a system short-circuit study. For any fault on the system which will operate the distance element, determine from the study the relay current and voltage. These quantities should be applied to the distance element coils and the time for the relay to close its contacts should check with the time from the curve.

Coordinated Settings: The problem of coordinating the settings of the Type HCZ relays to power system is best discussed by the example of Figure 10 which shows a typical system to be protected by type HCZ relays. In this example the distance elements at successive stations will be set with a time interval of .75 second between them. This value is arrived at by allowing .25 second for the relay to close its contacts and .50 second for the adjacent relays and breakers to operate.

In looking over the system of Fig. 10 several observations may be made:

1. Where a short line section follows a long line section, the slope of the time distance line of the short line is steeper and, consequently, the long line relay will require more than .75 second operating time for a fault near the end of the long line. This is necessary in order to give the long line relay not less than .75 second operating time above the short line relay setting over the entire short line section.

2. Where the adjacent section is a parallel line made up of two or more lines feeding into the same bus points, the relay backing up this adjacent section must be set considering all lines in parallel. This gives the steepest slope of the time distance line. These general observations will aid in the following construction and indicate the utility of constructing time-distance charts for coordinating the distance element settings.

The construction of the time-distance chart for the example is as follows: Since the type HCZ relays have directional elements, the relay protecting the loop, A, B, C, in one direction are coordinated in Chart A, and in the opposite direction in Chart B. The abscissa of the charts is the distance in ohms between the various substations in the direction indicated. The ordinate measures the relay operating time in seconds. Thus, any point on the slant time-distance lines indicates the operating time of the time-distance element for fault location shown by the abscissa. The relay characteristics can be plotted as straight lines only if the Tc taps are chosen as explained above.

In Chart A utilizing the observations set down above, a good starting point in the construction of the chart is to set relays 11 and 12 to protect the short 2 ohm lines between subs B and D. For a fault near B either relay 11 or 12 (depending on which line the fault occurs) should operate fast and as the fault moves toward D, this time should increase to .75 second for a fault at bus D. On the right of the chart between points B and D draw a slant line as shown representing the time-distance line of either relay 11 or 12.

Both relays 7 and 8 at sub A must protect a 6-ohm line between A and B and back up the short parallel 2-ohm lines between B and D. The effective impedance of this parallel line to relays 7 or 8 is 1 ohm which makes sub D look to the relays as if it were D'; 1 ohm from sub B and the relay 11 and 12 time-distance line moved from the .75 second point above D to the same point above D' as shown dotted in the chart. Relays 7 or 8 should be set to operate .75 second above this last-mentioned point as shown by the time-distance line of relays 7 and 8. Relays 7 and 8 must also coordinate with relay 3, but it will obviously do so since relays 11 and 12 protecting the shorter lines have a steeper time-distance line than relay 3.

In a similar manner relay 5 must be set to back up the parallel lines between subs A and B. Here sub B appears to relay 5 as 3 ohms (B') away from sub A, and the time-distance line of relays 7 and 8 appears as drawn dotted from A to a point above B' determined by the point at which the actual time-distance line of relays 7 and 8 crosses the vertical ordinate above B. The time-distance line of relay 5 is drawn then from C to a point .75 second above the dotted time-distance line of relays 7 and 8 between A and B'.

The next relay in the direction of chart A is relay 3 at sub B which must coordinate with relay 5. Consequently, its time-distance line is drawn from B to a point .75 second above relay 5 at A. The other lines shown on the left of this last line for relay 5 are a repetition of the lines determined previously for relays 11 and 12. This completes for the moment chart A.

Chart B is similarly constructed, starting again at the right side and setting first relays 11 and 12 as was done before. Then relay 4 at sub C must be set for the parallel lines between B and D as were relays 7 and 8 in chart A. This construction for relay 4 is shown in the chart. Next, relay 6 at sub A MUST be coordinated with relay 4. This does not offer any difficulty as line AC is shorter than line CB. To complete the loop, relays 1 and 2 at sub B must be set to coordinate with relay 6 as shown. This completes the determination of the time-distance lines for all the relays except 9 and 10 at sub D.

Relays 9 and 10 must coordinate with relays 1, 2 and 3 and back up the parallel lines between subs B, A and C. Also, relay 9 must coordinate with relay 12 for a fault on the line near relay 10 with breaker 10 open. In a similar manner relay 10 must coordinate with relay 11. This will give three time-distance lines, the steepest of which will determine the time-distance line for relays 9 and 10. The first of the three lines is the one determined from the time-distance line of relay 11 and 12 and has the same slope as line 11-12. The second is determined from the apparent time-distance line for relays 1 and 2. From sub D sub A appears to be 2.18 ohms from sub B (equivalent impedance of the parallel combination of the two lines AB with lines BC plus CA). On chart B sub A appears then to be at A'' and the dotted line BA'' is apparent time-distance line of relays 1 and 2. To the left of B locate D'' (2 ohms) and the second time-distance line for relay 9-10 is determined as outlined above and shown on the chart. The third line is determined from the apparent time-distance for relay 3 where C appears to be 2.72 ohms from sub B (equivalent impedance of line BC in parallel with lines AB plus AC), or at C'' on chart A. The dotted line between BC'', determined as outlined above, is then the apparent line for relay 3 which determined the third line for relay 9-10, marked "Apparent 9-10". By inspection the steepest of these three lines is the second and this is the time-distance line for relay 9-10 and shown on chart B. This completes the construction of the charts for this example.

Equation (3) can now be used to determine the voltage tap for each relay by selecting that value of Z for which the relay operates in .75 second. The value of K for this time interval is found from the table above. In the example, for relay 7, suppose that the current transformers are star-connected with a ratio 200/5, the potential transformer ratio is 200/1 and Tc = 8. From Chart B for relay 7 the relay operates in .75 second for a fault 3.5 ohms away. K for .75 second is 96.

Using equation (3):

$$Tv = \frac{8 \times 40 \times 3.5 \times 96}{200} = 538$$

Set tap 500 on the voltage resistor. After all the taps are calculated, the time-distance charts may be replotted to give the actual discrimination of the relays.

On lines where taps or parallel 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 is to increase the time of operation of the distance element. This can be seen on the time-distance chart, where the increased apparent impedance has the effect of making the fault appear more remote to the relay. In these cases the distance element setting can often be changed to give faster operating times than normally would be given if the feeders were disregarded. However, if this is done, the possibility of losing selectivity when the tapped lines are open must not be overlooked.

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, 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 contact.

* 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 wave form with an oscilloscope.

Instantaneous Impedance (HZ) Element

Refer to Figure 4. For the 60 cycle relays adjust the stop screw on the rear of the beam to give a clearance of .025 inch between the rear of the beam and the voltage iron circuit. This may be checked with a feeler gauge. With the beam in the reset position, i.e., back against the stop, adjust the gap between the adjustable iron and the beam to .009 inch. Care should be taken in this adjustment to keep the gap the same on 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 as shown in the test diagram, Figure 14 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. Make certain that the stop on the voltage side is absolutely clean, otherwise the impedance at which the beam trips may be affected, particularly at the 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.

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 strikes the bronze stop on the core screw.

It is difficult to accurately adjust the contacts by eye. A good method 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.

A further caution in regard to the contact adjustment is that too much follow or deflection of the stationary contacts will slightly delay the resetting of the high-speed element and thus the directional element contacts may get closed before the impedance contacts are open and result in unnecessary tripping.

The Distance (CZ) Element

Adjust the stop screw on the end of the rocker arm so that there is a gap of .005 inch between the core screw at the bottom of the iron and the plunger when the beam is reset. Adjust the gap by loosening the stop screw and allowing the plunger to touch the core. Then screw down the stop screw until it touches the cross bar. Then turn the stop screw an additional 1/2 revolution and lock it in place. The accuracy of this adjustment will be checked by measuring the time of operation. This measurement will be described later.

With the beam in the reset position, adjust the position of the stationary contacts so that there is a gap of .020 inch between them and the moving contacts. Check further to see that both contacts make simultaneously.

To adjust the balance of the rocker arm, loosen the clamp screw on the spring adjuster located beneath the large gear. Turn the adjuster to the right until the rocker is just about balanced. The object is to adjust the initial tension on the spring so that with the voltage coil de-energized, the weight of the plunger arm is just sufficient to hold the contact open. With this position a movement of about 1-1/2 inches of the disc should be sufficient to close the contact. When the disc is released, it should return to its initial position and open the contact. In other words, the rocker arm should be balanced so that the plunger will always return to the .005 gap position with the stop screw resting lightly against the cross bar. Extreme care should be taken to obtain a fine balance of the rocker arm. When working with the rocker arm be careful not to break or damage the jeweled ring bearings.

Check the balance of the rocker arm by applying and removing full voltage to the restraining coil at least ten times. The current coil should not be energized. The contacts should not bounce closed when the voltage is removed. A tendency of the contacts to bounce indicates that the balance of the rocker arm is too critical. In this case the spring adjuster should be turned very slightly towards the left. With the rocker arm carefully balanced, the tripping current is adjusted by passing 4 amperes thru the current coil with the tap screw in the 4 ampere tap. The voltage coil should not be energized. In order to energize this element it will be necessary to complete the directional control circuit by blocking the auxiliary contactor switch closed. Adjust the position of the balance weight on the rocker arm so that the contacts just barely close at 4 amperes ± 5%. It is important to note that during this adjustment every time the position of the balance weight is changed, the rocker arm must be rebalanced by moving the spring adjuster, as explained above. After the correct position of the weight has been determined, it should be locked in place with the set screw.

Check the time of operation of the element at the following points, using the 4 ampere tap, and measuring the voltage across the relay terminals alone:

Volts	Amperes	Time (Cycles) at 60 Cycles
0	8	22 or less
6.25	12	45

These time values should be the average of a large number of tests. The check at zero voltage shows that the element is free from friction. The check at 6.25 volts indicates the accuracy of the air gap adjustment which may be varied slightly to bring this point to the proper time.

When checking the time of operation, place the permanent magnet in the maximum damping position which is about 1/8" from the edge of the disc. The correct time of contact closure for the 6.25 volt point is obtained initially in the factory by adjusting the spring. The time is decreased by pulling more of the spring thru the spring clamp on the lever arm, thus making the effective length of the spring shorter. Whenever this adjustment is made, it will be necessary to readjust the balance of the rocker arm.

Directional Element

Check the free movement of the directional element loop with the relay in a vertical position to see that it is free from friction and properly centered. The loop should assume a vertical position with the contacts open when the element is completely de-energized.

With the loop in the vertical position adjust the front and back stationary contacts for .020 inch separation from the vertical moving contact. Adjust the contact back stop screws to just touch the stationary contacts, then back off 1/4 of a turn to give correct contact follow. Adjust the two stop screws which limit the movement of the loop (these screws are located to the rear of the current coil) so that the loop strikes these stops at the same instant the stationary contacts strike their back stop.

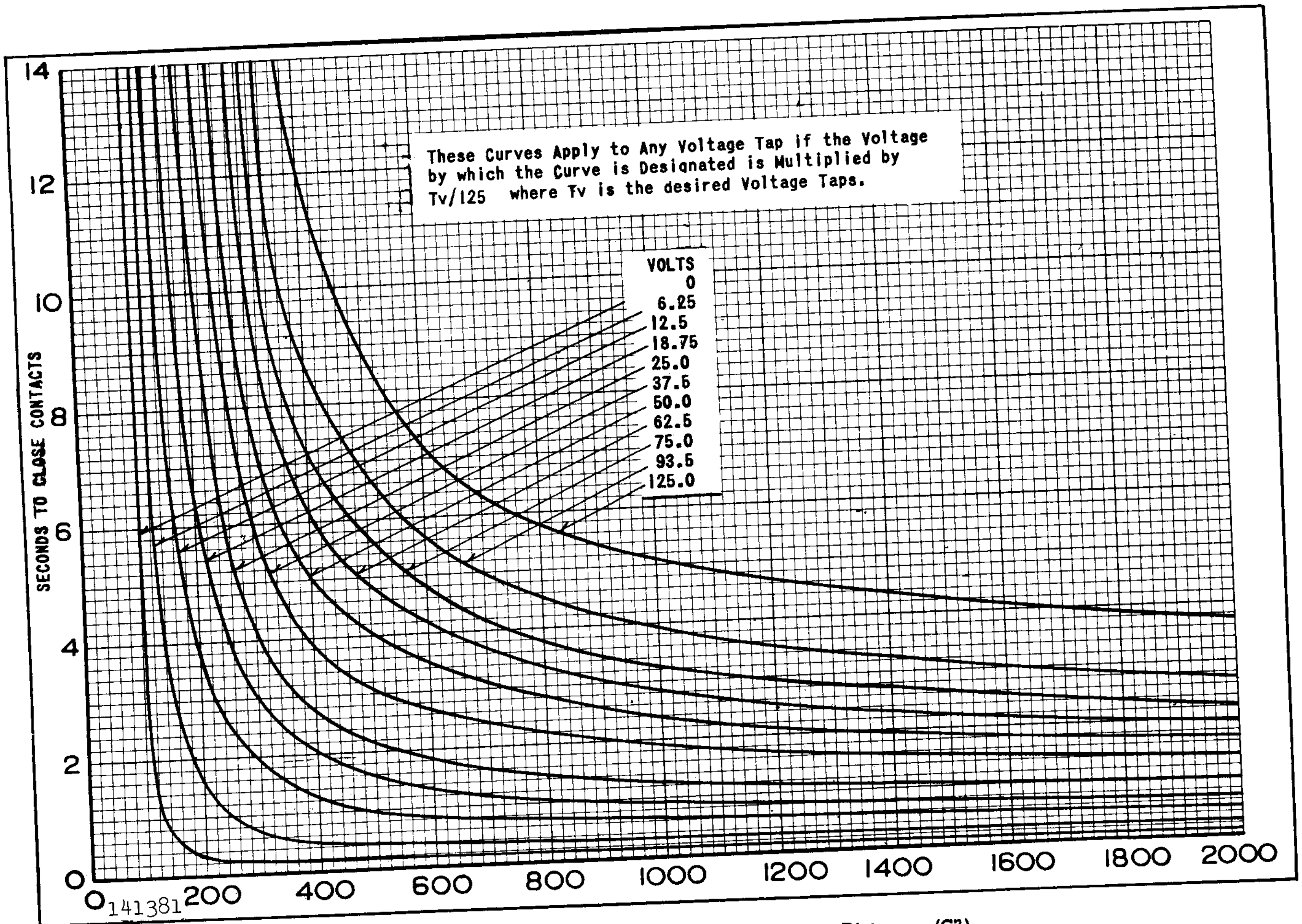


Fig. 11 — Typical Time-Ampere Curves of the Distance (CZ) Element.

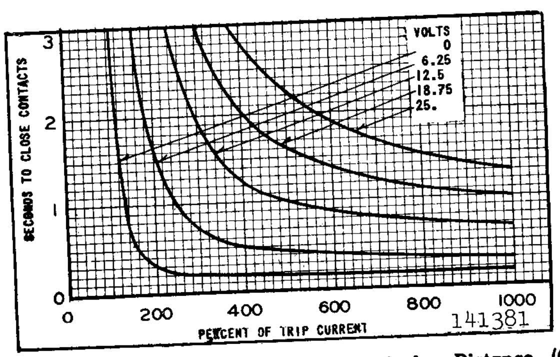


Fig. 12 — Typical Time-Ampere Curves of the Distance (CZ) Element (Enlarged).

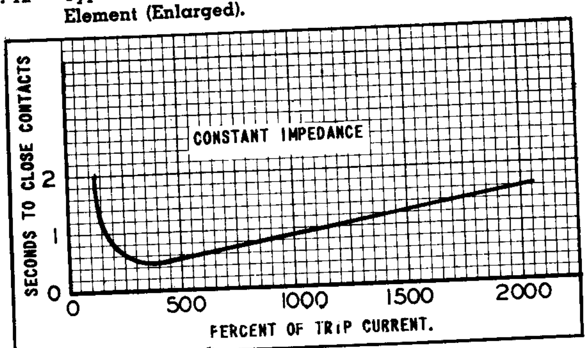
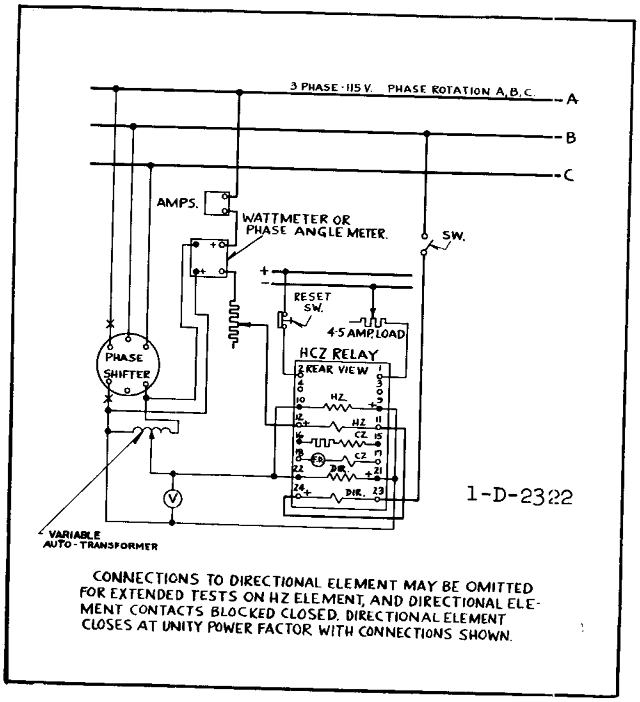


Fig. 13 — Typical Time-Ampere Curve of the Distance (CZ) Element for a Constant Given Distance.

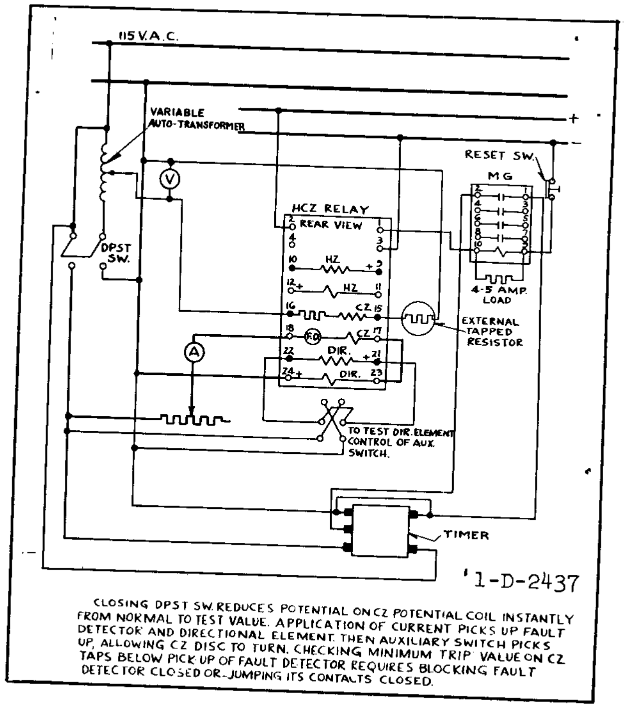
Too much follow on the directional contacts should be avoided in order to allow the directional element to reset fast enough by gravity to properly coordinate with the high speed impedance element.

Energize the loop with normal potential long enough to bring it up to temperature (about 10 or 15 minutes) and adjust the bearing screws so there is about .010 inch end play. See that the loop does not bind or strike against the iron or coil when pressed against either end jewel.

The minimum pick-up of the element is 10 amperes at 2.0 volts (unity power factor). Apply these values to the element and see that contacts make good contact in the correct direction. Reverse the direction of current to see that the contacts make good contact in the opposite direction.



* Fig. 14 — Diagram of Test Connections for the Instantaneous (HZ) Element. Relay is Shown for Standard Case. For Type FT Case Compare With Figure 3.



* Fig. 15 — Diagram of Test Connections for the Distance (CZ) Element. Relay is Shown for Standard Case For Type FT Case Compare With Figure 3.

When the directional element is energized on voltage alone, there may be a small torque which may hold contacts either open or closed. This torque is small and shows up only at high voltages with the entire absence of current. At voltages high enough to make this torque discernible, it will be found that only a fraction of an ampere in the current coils will produce wattmeter torque to insure positive action. This is mentioned because the slight torque shown on voltage alone has no significance in actual service and has no practical effect on the directional element operation.

Check the coordination of the directional and impedance contacts as follows. Set the impedance element on the maximum tap and scale setting and the CZ element on the lowest tap. Connect the relay with the correct polarity so that the right-hand (front view) directional contacts close and apply rated d-c volts to the directional control circuit. Block the fault detector in the closed position. Apply 115 volts a-c to the impedance and directional element potential coils and pass 5 amperes at unity power factor thru the current circuit. Check trip circuit to see that it is not completed when the voltage on the impedance and directional elements is suddenly applied or interrupted. Do not interrupt the current circuit. Make several such tests. The trip circuit should draw about 5 amperes d-c for this test so that the contactor switch will pick up and seal in if the elements fail to coordinate. Otherwise, a failure to coordinate is not necessarily indicated by the flicker of a lamp, since the blocking resistor will prevent the pick-up of a trip coil plunger until the auxiliary contactor falls out. This coordination test has been described for the most severe conditions. Consequently, an occasional failure to coordinate may be tolerated, since, in service, the directional element will be resetting under the positive action of reverse power flow rather than under the influence of gravity alone, as described in this test. If proper coordination is not obtained, it may be necessary to reduce the follow on the directional or impedance element contacts, as the case may be.

Fault Detector

The pick-up of the fault detector switch is changed by raising or lowering the plunger. This is done by means of two nuts on either side of the Micarta disc at the bottom of the switch. Adjust the switch to pick up at 8 amperes ± .2 amperes gradually applied current.

The drop-out value is varied by raising or lowering the core screw at the top of the switch. After the final adjustment is made, the core screw should be securely locked in place with the locknut. Adjust the switch to drop out at 6 amperes ± .5 amperes gradually applied current.

When the switch picks up at 8 amperes ± .2, there should be a slight deflection of the helical spring. Failure to obtain this slight deflection at 8 amperes ± .2 amperes indicates that the drop-out adjustment is too high and that the core screw should be lowered.

Contactor Switch (Seal-in-Switch)

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core of 1/64" when the switch is picked up. This can be done by turning the relay up-side-down or by disconnecting the switch and turning it up-side-down. Then screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the points where the play in the assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the core screw approximately one turn and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32" by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 2 amperes d-c. Test for sticking after 30 amperes have been passed through the coil.

Auxiliary Contactor Switch
(Directional Control Circuit)

The adjustments are the same as for the seal-in contactor switch except that the contact separation should be 3/64 inch. The switch should pick up at not more than 90 volts d-c. Apply 140 volts d-c to the circuit and see that the contacts drop out when the coil is shorted by the left-hand directional contacts. For the 250 volt d-c relays the pick-up should be 165 volts and the contacts should drop-out when the directional element contacts short-circuit the coil with 250 to 280 volts applied to the circuit. Energize the directional element with 50 volts and 10 amperes in phase suddenly applied. The contactor switch must operate the first time the directional contacts close without fluttering or bouncing of the contacts.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied. Test for sticking after 30 amperes d-c is passed through the coil.

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 name-plate data.

ENERGY REQUIREMENTS

The burdens of the various circuits of the 60 cycle relay are as follows:

POTENTIAL CIRCUITS AT 115 VOLTS

Circuit	Tap	V. A.	P.F. Angle
Directional Element	-	9.0	28° lag
Distance (CZ) Element	125	11.0	7° lag
	1800	0.8	0° lag
Instantaneous (HZ) Element		1.8	20° lag

CURRENT CIRCUITS AT 5 AMPERES

Circuit	Tap	V. A.	P.F. Angle
Directional Element And Fault Detector	-	4.0	45° lag
Distance (CZ) Element	4	7.5	70° lag
	25	0.75	70° lag
Instantaneous (HZ) Element	45	2.0	30° lag
	13.5	.55	30° lag

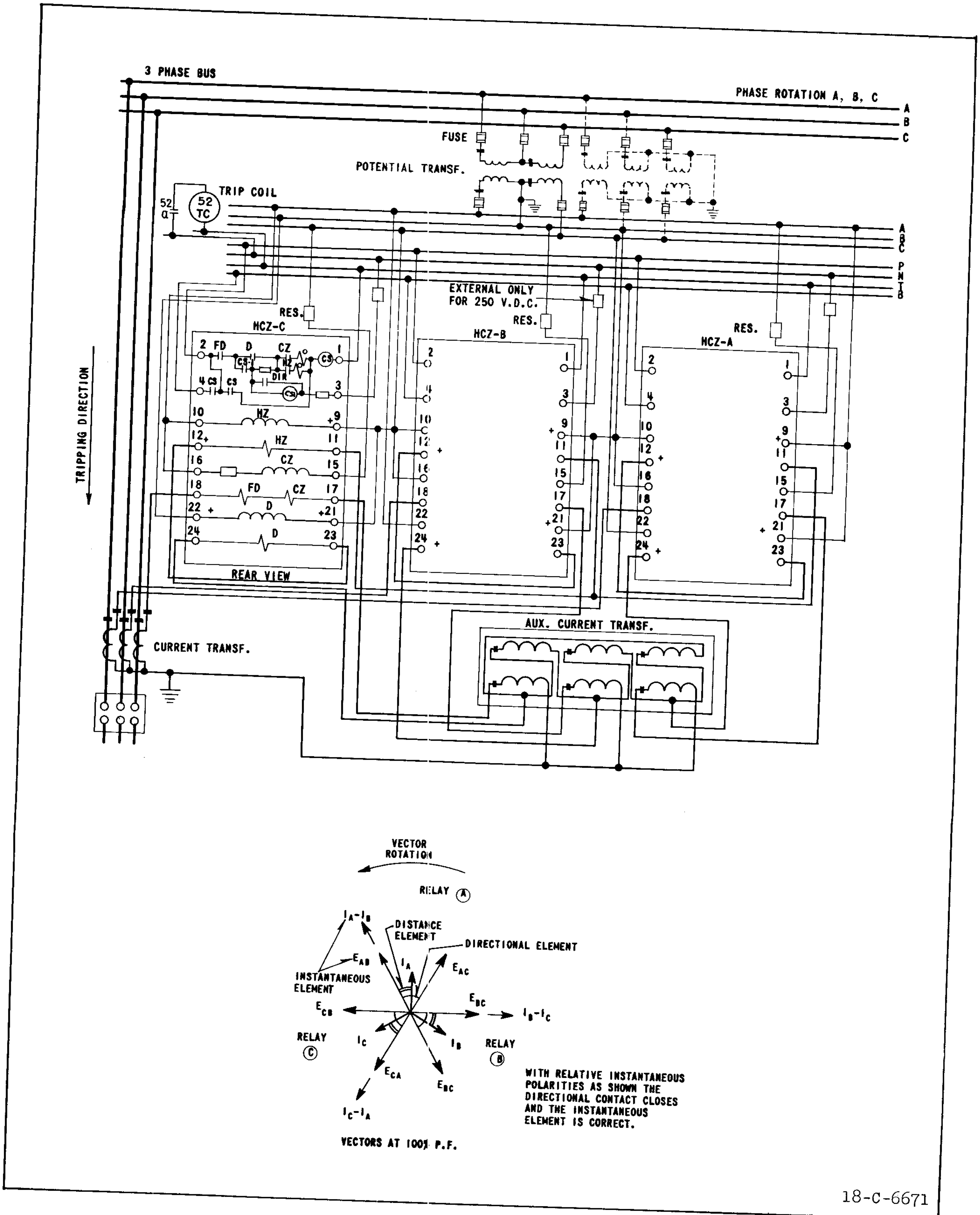


Fig. 16 — External Connections of the Type HCZ Relay in the Standard Case Using Star Current for the Directional and Distance Elements and Delta Current for the Instantaneous Element.

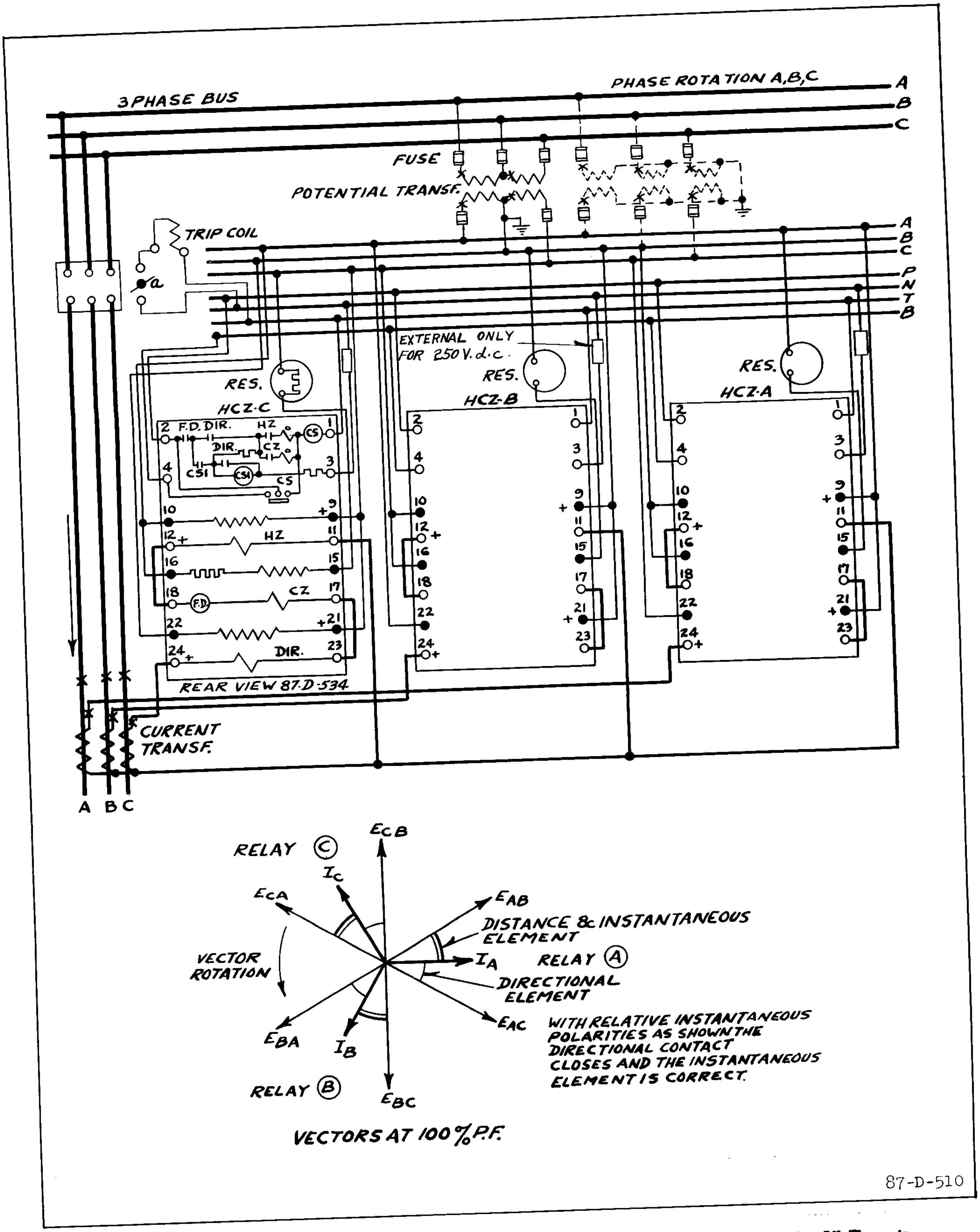
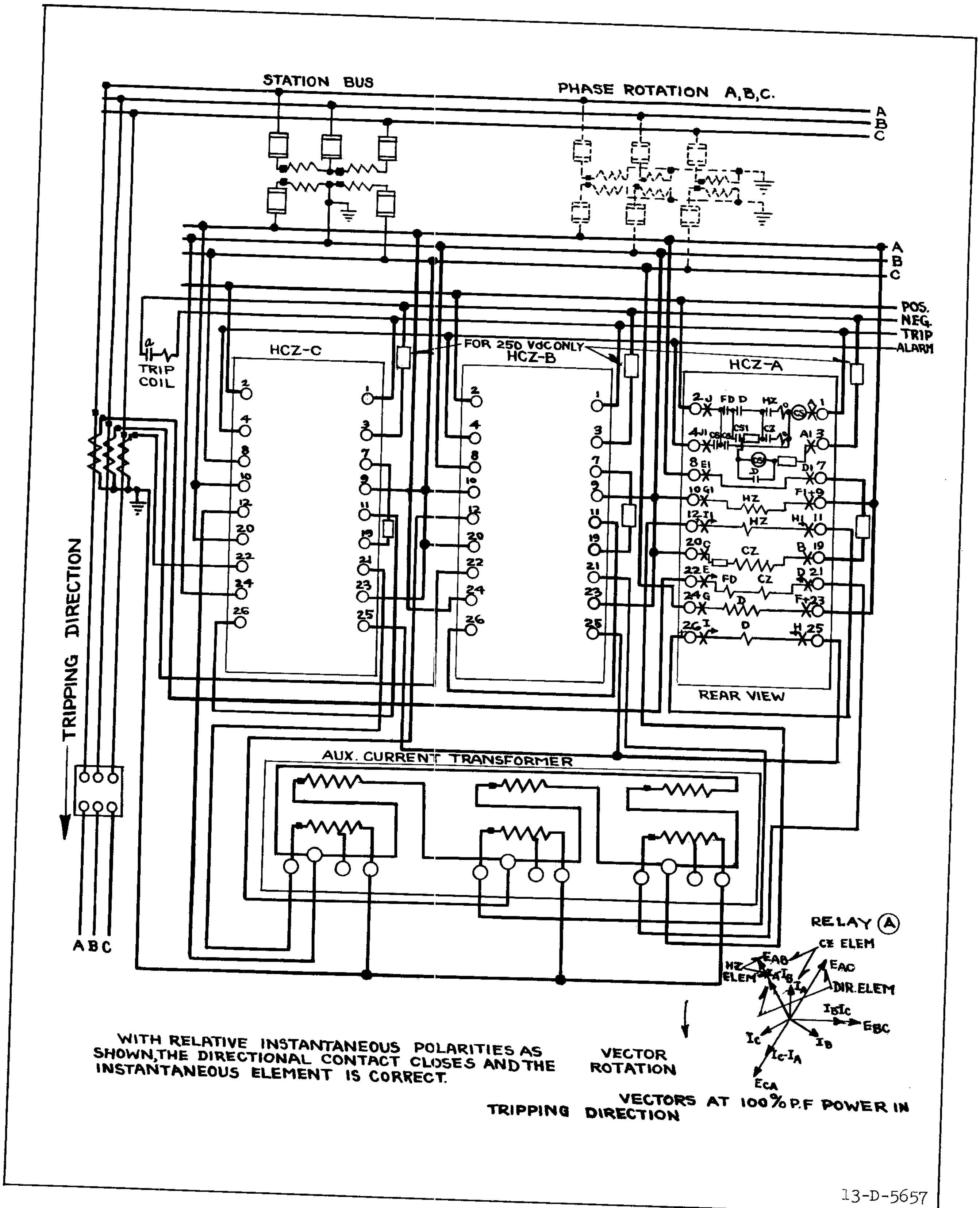


Fig. 17 — External Connections of the Type HCZ Relay in the Standard Case Using Star Current for All Elements.



* **Fig. 18 — External Connections of the Type HCZ Relay in the Standard Case Using Star Current for the Distance Element and Delta Current for the Instantaneous and Directional Elements.**

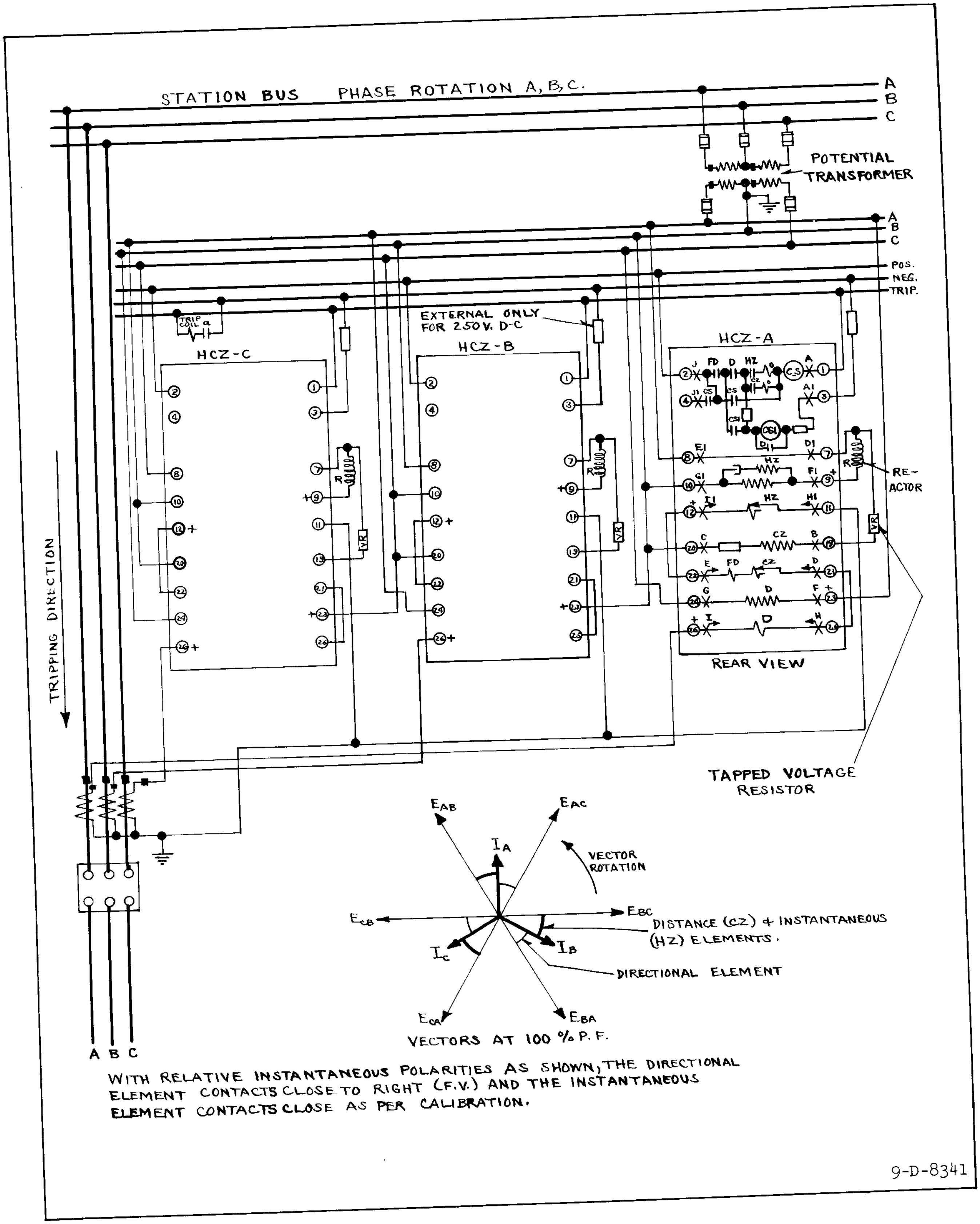


Fig. 19 — External Connections of the Type HCZ Relay in the Type FT Case Using Star Current for All Elements.

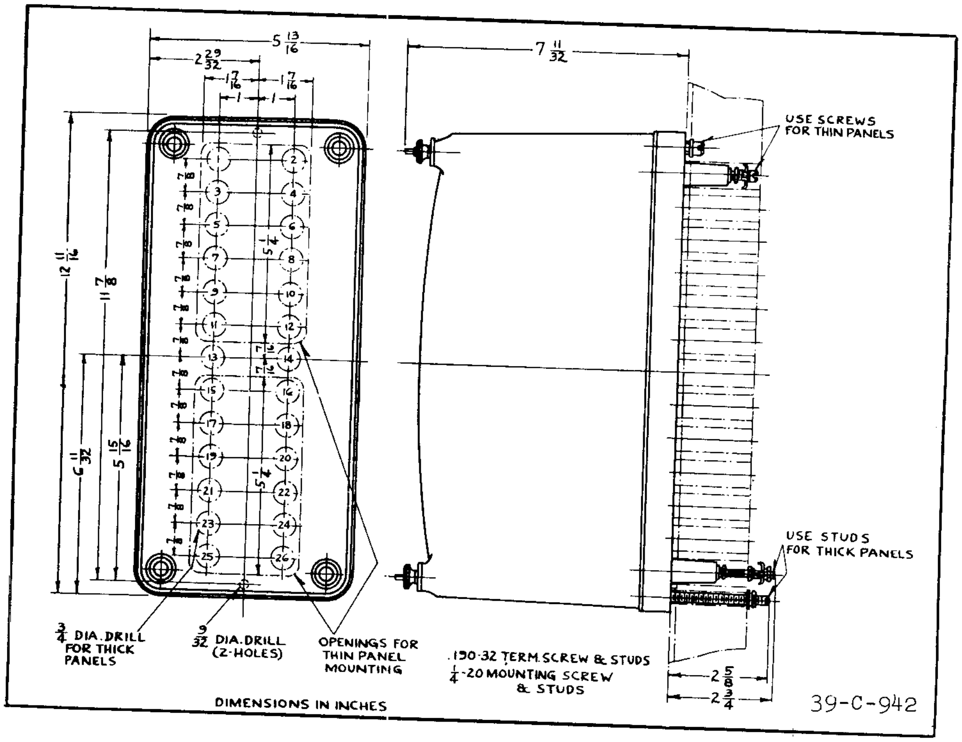


Fig. 20 — Outline and Drilling Plan for the Standard Projection Type Case. See the Internal Schematics For Terminals Supplied. For Reference Only.

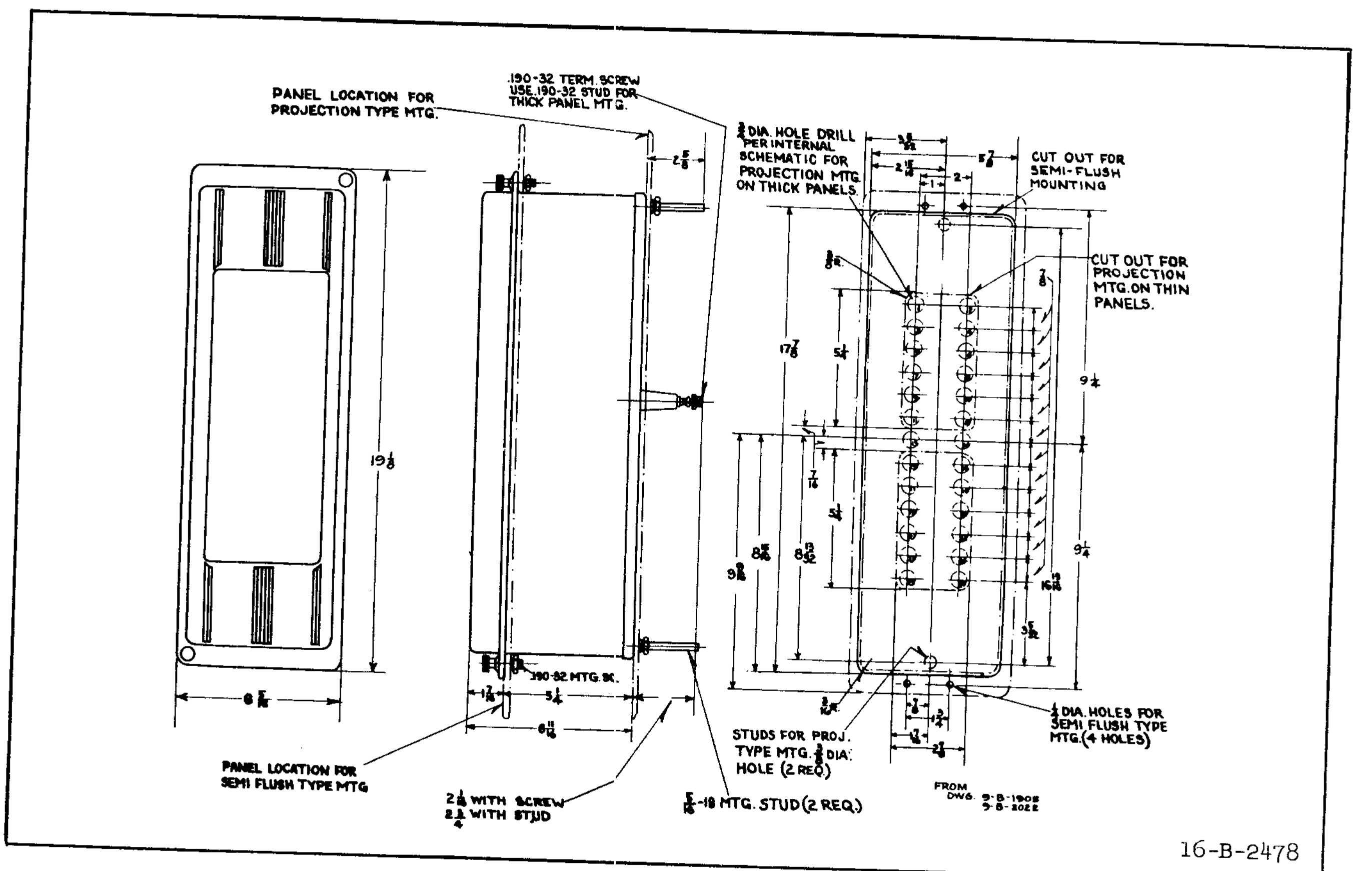


Fig. 21—Outline and Drilling Plan for the M20 Semi-flush or Projection Type FT Flexitest Case. See the Internal Schematics for Terminals Supplied. For Reference Only.

TYPE HCZ IMPEDANCE RELAY

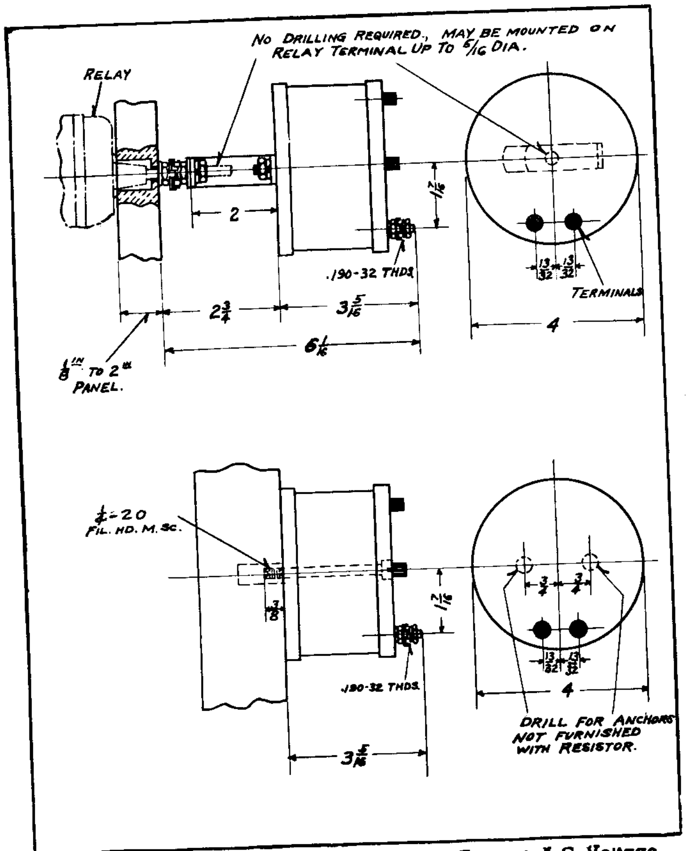


Fig. 22— Outline and Drilling Plan for the Tapped A-C Voltage Resistor for the Distance (CZ) Element. For Reference Only.

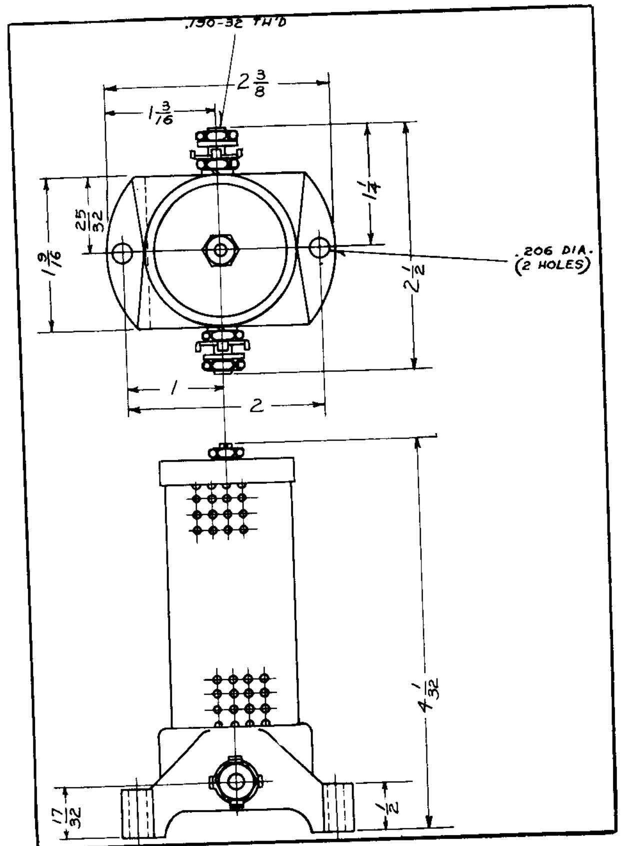


Fig. 23 — Outline and Drilling Plan for the External Control Circuit Resistor for the 250 Volt D-C Relays. For Reference Only.

pick-up should be 165 volts and the contacts should drop-out when the directional element contacts short-circuit the coil with 250 to 280 volts applied to the circuit. Energize the directional element with 50 volts and 10 amperes in phase suddenly applied. The contactor switch must operate the first time the directional contacts close without fluttering or bouncing of the contacts.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied. Test for sticking after 30 amperes d-c is passed through the coil.

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

The burdens of the various circuits of the 60 cycle relay are as follows:

POTENTIAL CIRCUITS AT 115 VOLTS

Circuit	Tap	V. A.	P.F. Angle
Directional Element	-	9.0	28° lag
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CURRENT CIRCUITS AT 5 AMPERES

Circuit	Tap	V. A.	P.F. Angle
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Distance (CZ) Element	4	7.5	70° lag
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Instantaneous (HZ) Element	45	2.0	30° lag
	13.5	.55	30° lag

WESTINGHOUSE ELECTRIC CORPORATION
METER DIVISION • NEWARK, N.J.

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INSTRUCTIONS

TYPE HCZ IMPEDANCE RELAY

Caution Before putting protective relays into service, remove all blocking which may have been 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 HCZ relay is a combination of the instantaneous impedance and directional elements of the Type HZ relay and the distance element of the Type CZ relay. This relay is used for high speed clearing of phase faults on transmission systems. It gives instantaneous protection over 80 to 90% of the protected section, and protection over the remaining 20 to 10% of the protected section, and the adjacent sections with adjustable time delay increasing with distance. (Figure 1).

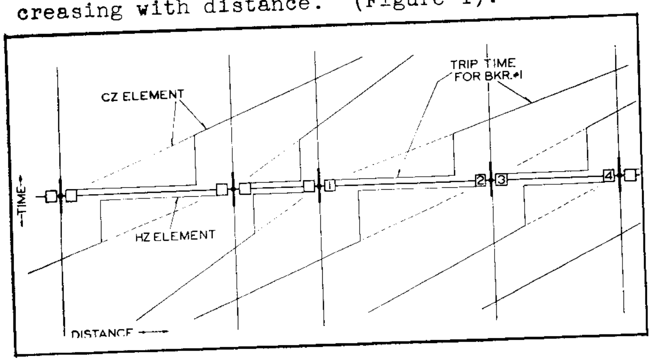


Fig. 1 — Typical Time-Distance Characteristic of the Type HCZ Relay.

CONSTRUCTION AND OPERATION

The Type HCZ relay contains an instantaneous impedance (HZ) element, a distance (CZ) element, a directional element, a fault detector element, auxiliary contactor switches, and operation indicators all mounted in a single case. The construction and operation of each of these elements is as follows.

Instantaneous Impedance (HZ) Element

This element is similar to the first impedance element of the Type HZ relay. It consists of a balanced beam pivoted at the center (Figure 4) and pulled downward by a current coil on the forward end to close the relay contacts. This pull is opposed by two voltage coils acting on the other end of the beam. The fluxes set up by these two potential coils are shifted out of phase with respect to each other so that a balance between current and voltage fluxes can be held within desirable limits for all phase angles.

A tap screw on the front of the element permits changing the number of turns on the current coil, and a core screw on the bottom of the element changes an air gap in the magnetic path. These two adjustments make it possible to set the impedance element so that it will operate instantaneously, for all faults occurring within 80 to 90% of the protected line section. For a fault at the balance point of the element (determined by setting) the pull of the voltage coil, which measures the IZ drop from the fault to the relay, will just equal the pull of the current coil, which receives the fault current, I. If the fault occurs inside the balance point, the IZ voltage pull will be less than the I current pull and the beam will trip closing its contacts. Conversely, if the fault occurs outside the relay balance point, the IZ voltage pull will be greater than the I current pull and the beam will not trip.

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 a short leaf spring. A small

SUPERSEDES I. L. 41-420D
*Denotes changed from superseded issue.

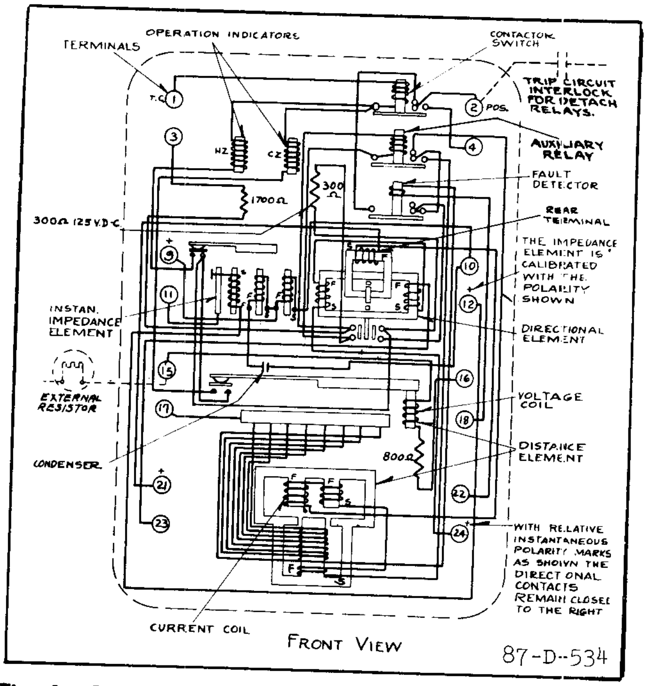


Fig. 2 — Internal Connections of the Type HCZ Relay in the Standard Case.

set screw determines the position of the leaf spring and provides means for adjusting the contact gap and follow.

The Distance (CZ) Element

The distance element consists of an induction-disc element operated by current, and a restraining coil and plunger assembly operated by voltage. These two elements are mechanically interconnected thru pivoted lever arms which also operate the CZ element contacts. The induction disc winds up a spiral spring to tilt the horizontal lever arm in the contact closing direction. This motion is opposed by the pull of the voltage restraining coil on a small plunger fastened to one end of the lever arm. When the pull of the spring and induction disc overcomes the voltage coil pull, the plunger snaps up and the contacts close. The operating time of the element is proportional to the speed of the current disc and magnitude of the voltage. Consequently, the closer the fault, the larger the current, and the lower the voltage; and, therefore, the faster the distance (CZ) element operates.

Directional Element

A small voltage transformer causes a large current to flow in a single-turn movable

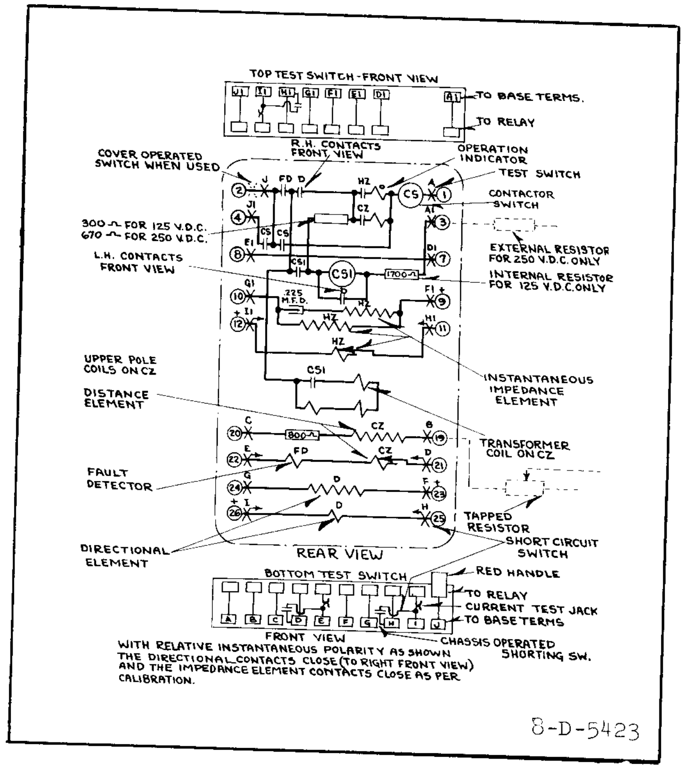


Fig. 3 — Internal Connections of the Type HCZ Relay in the Type FT Case.

aluminum secondary, which current is substantially in phase with the voltage. The current coils are mounted on a magnetic frame and the current and voltage elements are assembled at right angle to each other with the one-turn voltage loop in the air gaps of the current coil flux path. The interaction of the current and voltage fluxes produces torque and rotates the loop in one of two directions, depending on the direction of power flow.

An Isolantite arm extends from the moving loop and supports a rectangular silver contact which bridges two stationary contacts located on either side of the loop. The stationary contacts are silver hemi-spheres mounted on the lower end of vertically-hanging spring leaves. The contact separation is adjustable by a small screw near the upper end of the rigid stationary contact supporting arm. One of these supporting arms hangs parallel to each of the four stationary contacts. The set screw on the lower end of this arm provides the contact follow adjustment. Two additional screws on the movement frame beneath the current coil iron limit the movement of the one-turn loop.

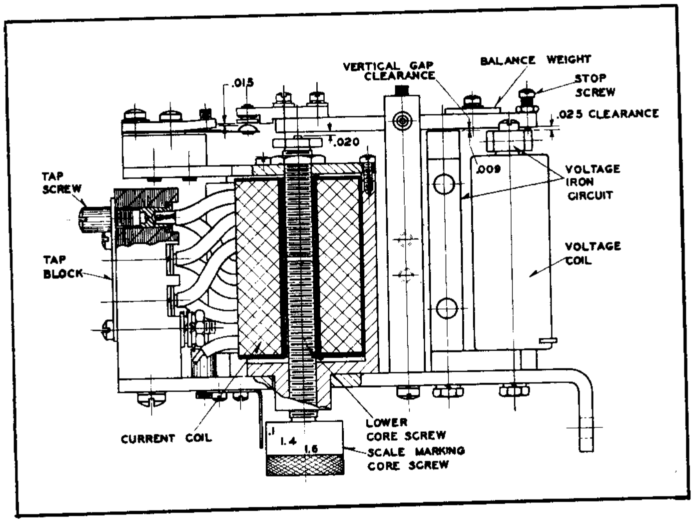


Fig. 4 — Sectional View of the Instantaneous (HZ) Element.

Fault-Detector Element

This element is a small solenoid-type switch. A small cylindrical plunger with a silver disc supported on its lower end rides up and down on a vertical guide rod in the center of the solenoid coil. The guide rod is fastened to the stationary core which in turn screws into the element frame. When the coil is energized, the silver disc moves upward bridging three cone shaped stationary contacts. The silver disc is supported on the moving plunger by a spring which permits the plunger to ride upward after the contacts have made.

The switch is used as an overcurrent fault detector by connecting its coil in the distance element current circuit and setting its contacts to pick up on 8 amperes fault current. These contacts are connected in series with the directional element and the instantaneous or distance element contacts and so prevent the relay from tripping if the fault current is less than the 8-ampere pick-up of the fault detector. They also prevent the operation of an auxiliary D-C contactor switch which in turn controls the operation of the CZ distance element.

Auxiliary Contactor Switch

The construction of this switch is similar to the fault detector switch except that the design of the moving plunger and solenoid coil is for D-C instead of A-C. The operation of this D-C auxiliary switch is controlled by the directional and fault detector elements which in turn directionally controls the CZ distance element. When sufficient fault current flows in the tripping direction to close the fault detector, the auxiliary contactor switch operates to close and seal in the upper pole circuit of the CZ distance element, permitting the disc to rotate. If the direction of the fault current reverses, a contact on the directional element shorts the auxiliary contactor switch coil, causing it to drop out. This opens the directional control circuit and allows the distance element to reset.

Contactor Switch and Operation Indicator

The coil of the contactor switch is connected in the trip circuit. When the relay contacts close, the coil is energized and its contacts short around the relay contacts, relieving them of the duty of carrying the breaker tripping current. These contacts remain closed until the trip circuit is opened by a breaker auxiliary switch. The third contact of the contactor switch is connected to a separate relay terminal to operate an alarm circuit.

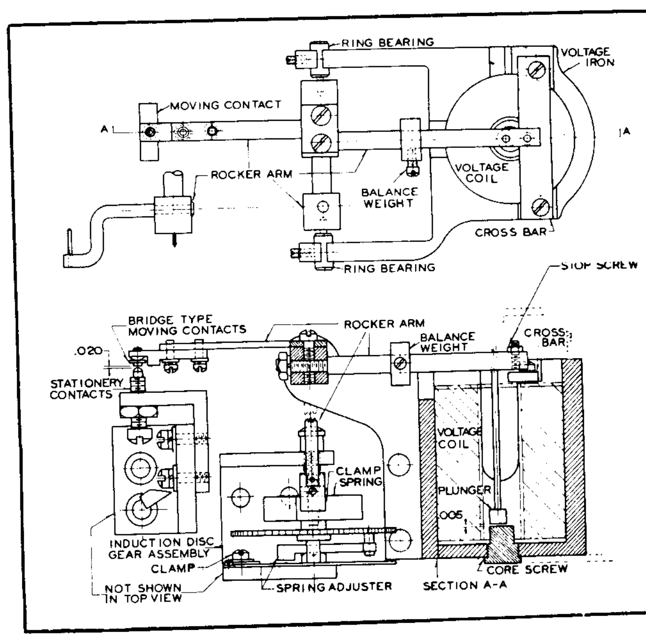


Fig. 5 — Sectional View of the Distance (CZ) Element.

Two operation indicators show white targets with the letters HZ and CZ. The HZ target operates when the trip circuit is completed through the instantaneous impedance element, and the CZ target operates when the trip circuit is completed through the distance element.

CHARACTERISTICS

The relay is available in two ranges which refers to the range of instantaneous (HZ) element. These are the 0.2 to 2.0 ohm relay for short lines and the 0.60 to 6.0 ohm relay for long lines. The following are the tap markings:

Instantaneous (HZ) element 0.2 to 2.0 ohm range:

Tap = 2, 3, 4, 6, 9. 13
Core Screw = .8, .9, 1.0, 1.1, 1.2, 1.4, 1.6

Instantaneous (HZ) element 0.6 to 6.0 ohm range:

Tap = 6.2, 9.4, 13.5, 20.8, 29.8, 45
Core Screw = .8, .9, 1.0, 1.1, 1.2, 1.3, 1.4

Distance (CZ) element - all ranges:

Current taps = 4, 5, 6.5, 8, 10, 15, 20, 25
Voltage taps on the series resistor = 125, 150, 175, 200, 250, 300, 350, 400, 500, 600, 700, 800, 1000, 1200, 1400, 1600, 1800

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 two mounting studs for the standard cases and the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

The recommended connections of relay are shown in Figs. 16 and 18. The 60° connection is used on the directional element, that is at unity power factor the current thru the directional element coil should lead the polarizing voltage by 60° as shown in the vector diagram. The star-delta auxiliary current transformer is the same as used with the type HZ relay and is described in I. L. 41-535. Figs. 17 and 19 show the external connections of the Type HCZ relay using star current for all elements.

SETTINGS

The Type HCZ relay requires two separate settings; one for the instantaneous HZ element and the other for the distance CZ element. Each will be considered below:

The following nomenclature is used in the discussion of the two settings:

Z = the line-to-neutral ohmic impedance;
For the instantaneous element, the impedance for 80 to 90% of the protected line section.

For the distance element, the ohmic line length for which the element will operate in a time determined by the choice of K.

K = constant determined by the coordinating time interval between successive relays.

Rc = the current transformer ratio.

Rv = the potential transformer ratio.

T = the instantaneous HZ element current tap.

S = the instantaneous HZ element current core screw.

Tc = the distance CZ element current tap.

Tv = the distance CZ element voltage tap on the external resistor.

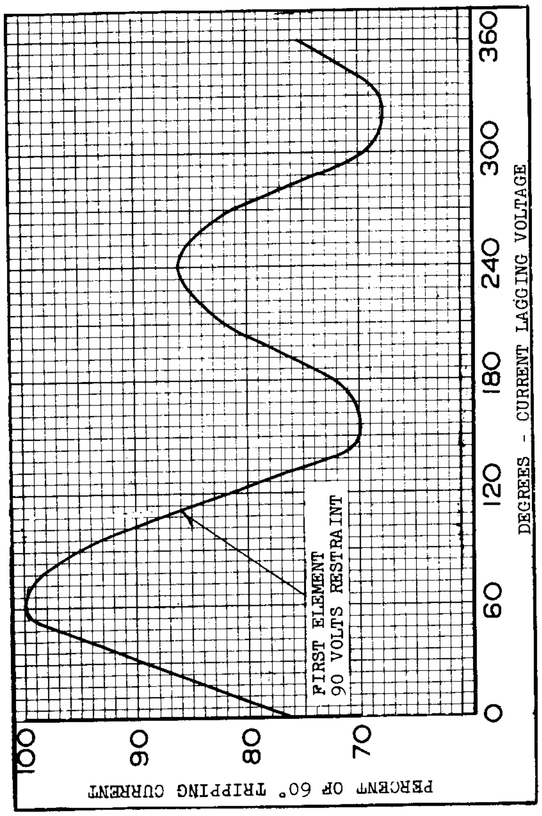


Fig. 7 — Typical Phase Angle Curve of the Instantaneous (HZ) Element.

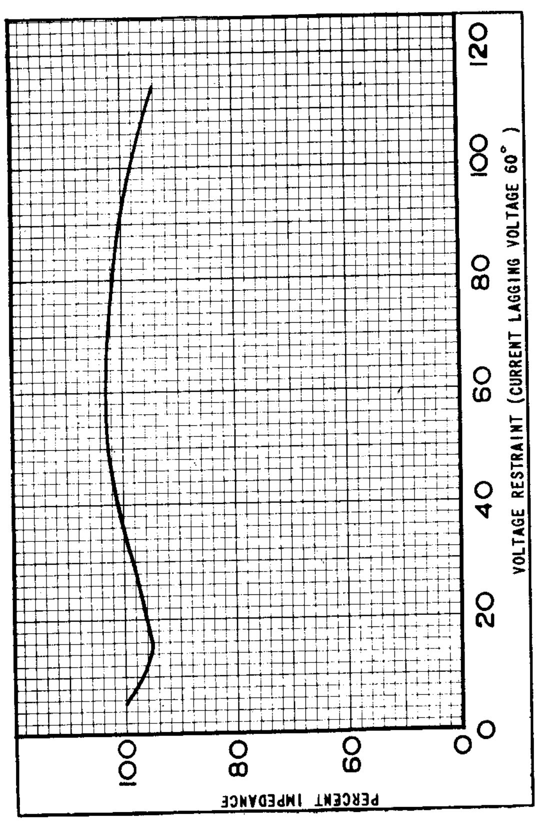


Fig. 6 — Typical Impedance Curve for the Instantaneous (HZ) Element.

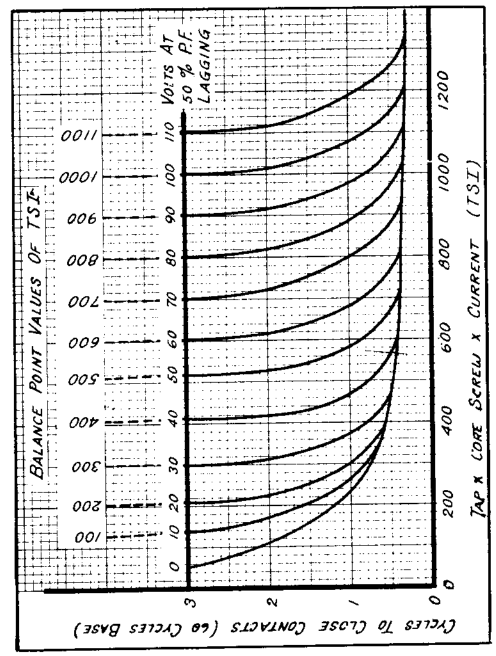


Fig. 9 — Typical Time of Operation Curves for the Instantaneous (HZ) Element.

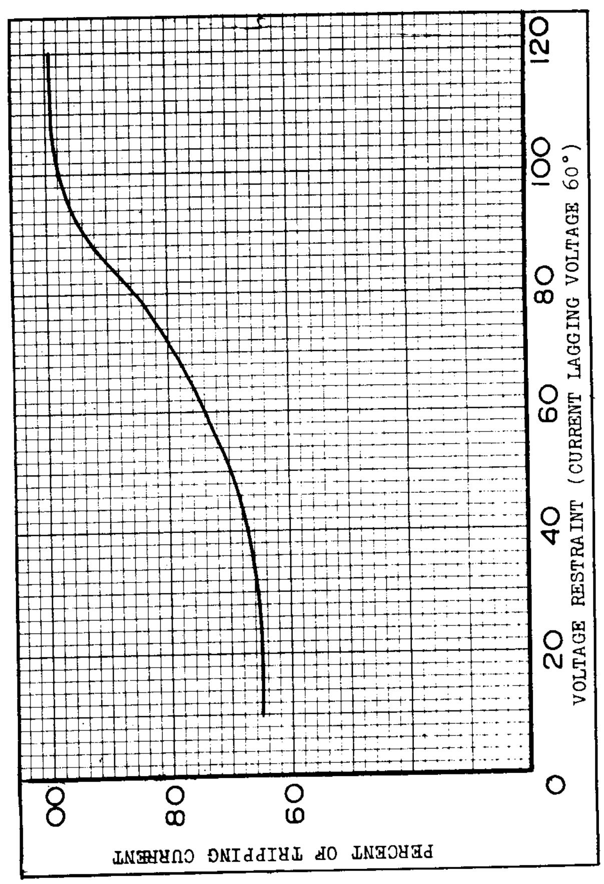


Fig. 8 — Typical Reset Curve for the Instantaneous (HZ) Relay.

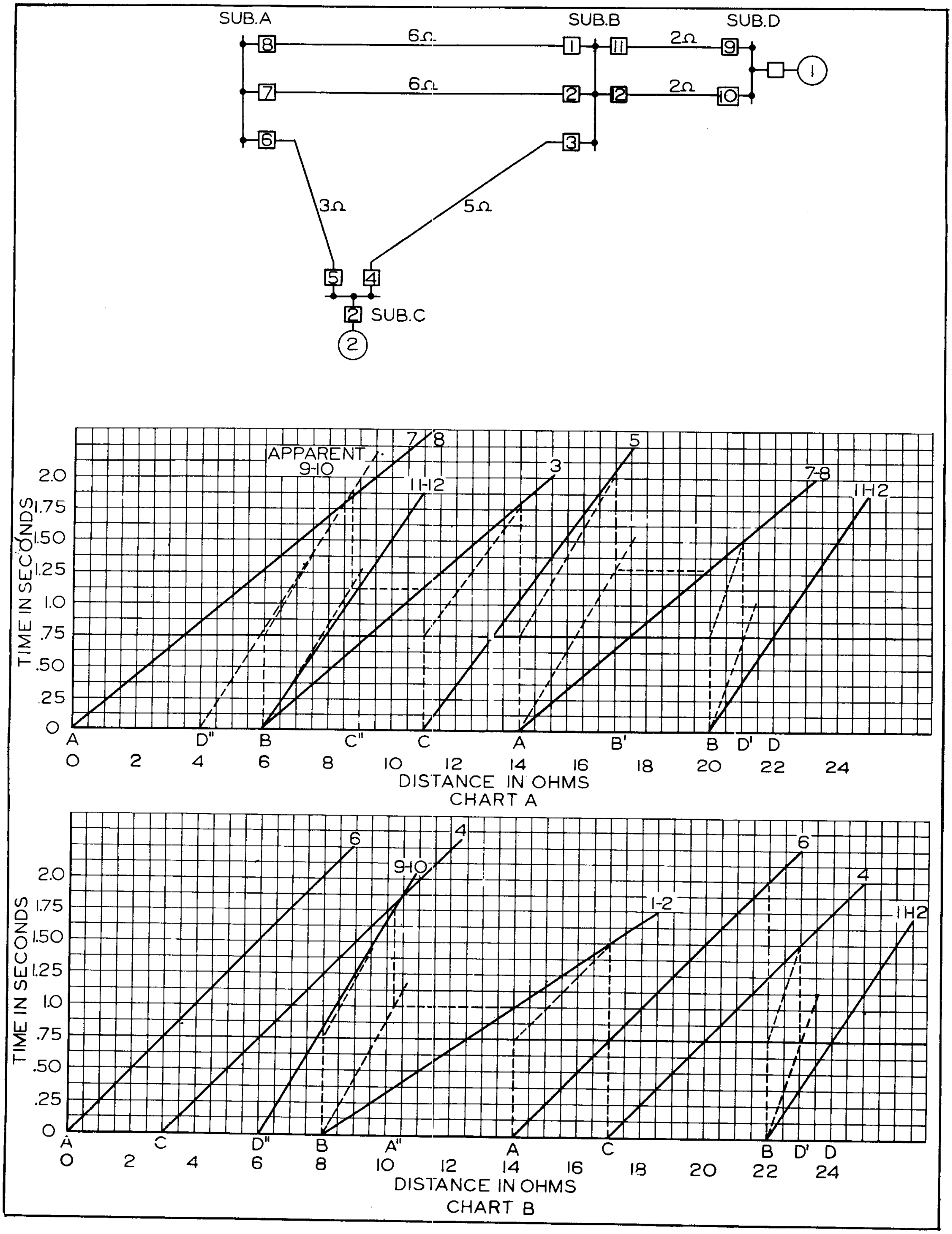


Fig. 10 — Construction of Time-Distance Chart for the System Shown.

Instantaneous (HZ) Element Setting

This element is set to give instantaneous protection over approximately 90% of the protected line section. Since the impedance of the voltage coil is the same at all times, the balance point of the element 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 settings is by the use of the following equations:

Instantaneous Element Receiving Delta Current:

$$TS = \frac{10\ Z\ Rc}{Rv} \qquad (1)$$

Instantaneous Element Receiving Star Current:

$$TS = \frac{17.3\ Z\ Rc}{Rv} \qquad (2)$$

The nomenclature is as defined above. 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 be screwed in the desired tap before removing the existing tap screw to prevent open circuiting the current transformers.

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 less than 3/4 of a 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.

The above formulas are based on the relay being used on a 60° line and are 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. 7.

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.

As an example, the instantaneous element is to be set for 90% of the line section AB which is 6 ohms long. The current transformer ratio is 200/5 star-connected with the star-delta auxiliary current transformer supplying delta current to the instantaneous element coils. The potential transformer ratio is 1000/1.

Using equation (1)

$$TS = \frac{10 \times .90 \times 6 \times 40}{1000} = 2.16$$

Set tap 2 on the .02 to 2.0 ohm relay and core screw = 1.08.

Distance (CZ) Element Setting

The distance element is set to protect the last 10 or 20% of the protected section, and to give back-up protection over the instantaneous element zone of the protected section as well as the adjacent sections. Consequently, each distance element must be carefully set to coordinate with the relays protecting these adjacent sections so as not to trip out its breaker before the adjacent line relays and breakers have had an opportunity to operate.

Before discussing this problem the individual distance element settings will be explained disregarding the question of coordination with other relays.

Individual Setting: The impedance curve and hence the time of operation of the distance element is approximately constant for fault currents in the range of 200% to 1000% of the current tap value, Figure 13. The selection of the current tap Tc should be made such that the element will operate in this range for maximum and minimum fault currents. In no case should the minimum fault current for which the relay must operate be less than 200% of the tap selected, and it is always desirable to use the highest tap possible.

With the selection of suitable current tap, Tc, the voltage tap, Tv, may be determined by using the curves of Fig. 11 or by the equation below. The use of the curves is as follows. The per cent trip current on the abscissa is the fault current thru relay in per cent of the current Tc tap chosen. The ordinate is the desired relay operating time in seconds for the fault under consideration. The point thus located will fall on or near one of the curves. The values on the curves are the voltage drop from the fault to the relay (relay volts) for Tv = 125. Knowing the actual voltage drop, the tap, Tv, is determined by the relation:

$$\text{Voltage drop} = \frac{Tv}{125} \times \text{voltage value on curve}$$

For three phase faults the voltage drop is easily calculated by multiplying the fault current by the impedance from the relay to the fault.

NOTE: The relay should not be required to operate when the drop from the relay to the fault for minimum fault is less than 5 relay volts.

The voltage tap, Tv, can also be determined by the following equation:

$$Tv = \frac{Tc \times Rc \times Z \times K}{Rv} \qquad (3)$$

where the nomenclature is as defined above. The voltage tap determined from this equation will permit the distance element to close its contacts in a time depending on the selection of K for a fault Z ohms distant from the relay. The value of .75 second is a conventional time interval between switching stations for which the distance element should be set. This value is arrived at by allowing .25 second for the relay to close its contacts and .50 second for the adjacent relay and breakers to operate. The values of K for this and other time intervals is shown in the following table:

Time Interval	Value of K for Current Transformers	
	Star Connected	Delta Connected
1.2	68	39
1.1	72	42
1.0	77.5	45
.9	83	48
.8	91	53
.75	96	56
.7	101	59
.6	113	65
.5	130	75
.4	152	88

The calculation of Tv from equation (3) will usually give a value in between the available taps on the voltage resistor. In these cases the selection of the nearest taps below the calculated value usually will be desirable since it gives a slightly greater operating time.

The settings on the distance element may be checked in the laboratory by means of the operating curve, Fig. 11, and a system short-circuit study. For any fault on the system which will operate the distance element, determine from the study the relay current and voltage. These quantities should be applied to the distance element coils and the time for the relay to close its contacts should check with the time from the curve.

Coordinated Settings: The problem of coordinating the settings of the Type HCZ relays to power system is best discussed by the example of Figure 10 which shows a typical system to be protected by type HCZ relays. In this example the distance elements at successive stations will be set with a time interval of .75 second between them. This value is arrived at by allowing .25 second for the relay to close its contacts and .50 second for the adjacent relays and breakers to operate.

In looking over the system of Fig. 10 several observations may be made:

1. Where a short line section follows a long line section, the slope of the time distance line of the short line is steeper and, consequently, the long line relay will require more than .75 second operating time for a fault near the end of the long line. This is necessary in order to give the long line relay not less than .75 second operating time above the short line relay setting over the entire short line section.

2. Where the adjacent section is a parallel line made up of two or more lines feeding into the same bus points, the relay backing up this adjacent section must be set considering all lines in parallel. This gives the steepest slope of the time distance line. These general observations will aid in the following construction and indicate the utility of constructing time-distance charts for coordinating the distance element settings.

The construction of the time-distance chart for the example is as follows: Since the type HCZ relays have directional elements, the relay protecting the loop, A, B, C, in one direction are coordinated in Chart A, and in the opposite direction in Chart B. The abscissa of the charts is the distance in ohms between the various substations in the direction indicated. The ordinate measures the relay operating time in seconds. Thus, any point on the slant time-distance lines indicates the operating time of the time-distance element for fault location shown by the abscissa. The relay characteristics can be plotted as straight lines only if the Tc taps are chosen as explained above.

In Chart A utilizing the observations set down above, a good starting point in the construction of the chart is to set relays 11 and 12 to protect the short 2 ohm lines between subs B and D. For a fault near B either relay 11 or 12 (depending on which line the fault occurs) should operate fast and as the fault moves toward D, this time should increase to .75 second for a fault at bus D. On the right of the chart between points B and D draw a slant line as shown representing the time-distance line of either relay 11 or 12.

Both relays 7 and 8 at sub A must protect a 6-ohm line between A and B and back up the short parallel 2-ohm lines between B and D. The effective impedance of this parallel line to relays 7 or 8 is 1 ohm which makes sub D look to the relays as if it were D'; 1 ohm from sub B and the relay 11 and 12 time-distance line moved from the .75 second point above D to the same point above D' as shown dotted in the chart. Relays 7 or 8 should be set to operate .75 second above this last-mentioned point as shown by the time-distance line of relays 7 and 8. Relays 7 and 8 must also coordinate with relay 3, but it will obviously do so since relays 11 and 12 protecting the shorter lines have a steeper time-distance line than relay 3.

In a similar manner relay 5 must be set to back up the parallel lines between subs A and B. Here sub B appears to relay 5 as 3 ohms (B') away from sub A, and the time-distance line of relays 7 and 8 appears as drawn dotted from A to a point above B' determined by the point at which the actual time-distance line of relays 7 and 8 crosses the vertical ordinate above B. The time-distance line of relay 5 is drawn then from C to a point .75 second above the dotted time-distance line of relays 7 and 8 between A and B'.

The next relay in the direction of chart A is relay 3 at sub B which must coordinate with relay 5. Consequently, its time-distance line is drawn from B to a point .75 second above relay 5 at A. The other lines shown on the left of this last line for relay 5 are a repetition of the lines determined previously for relays 11 and 12. This completes for the moment chart A.

Chart B is similarly constructed, starting again at the right side and setting first relays 11 and 12 as was done before. Then relay 4 at sub C must be set for the parallel lines between B and D as were relays 7 and 8 in chart A. This construction for relay 4 is shown in the chart. Next, relay 6 at sub A MUST be coordinated with relay 4. This does not offer any difficulty as line AC is shorter than line CB. To complete the loop, relays 1 and 2 at sub B must be set to coordinate with relay 6 as shown. This completes the determination of the time-distance lines for all the relays except 9 and 10 at sub D.

Relays 9 and 10 must coordinate with relays 1, 2 and 3 and back up the parallel lines between subs B, A and C. Also, relay 9 must coordinate with relay 12 for a fault on the line near relay 10 with breaker 10 open. In a similar manner relay 10 must coordinate with relay 11. This will give three time-distance lines, the steepest of which will determine the time-distance line for relays 9 and 10. The first of the three lines is the one determined from the time-distance line of relay 11 and 12 and has the same slope as line 11-12. The second is determined from the apparent time-distance line for relays 1 and 2. From sub D sub A appears to be 2.18 ohms from sub B (equivalent impedance of the parallel combination of the two lines AB with lines BC plus CA). On chart B sub A appears then to be at A'' and the dotted line BA'' is apparent time-distance line of relays 1 and 2. To the left of B locate D'' (2 ohms) and the second time-distance line for relay 9-10 is determined as outlined above and shown on the chart. The third line is determined from the apparent time-distance for relay 3 where C appears to be 2.72 ohms from sub B (equivalent impedance of line BC in parallel with lines AB plus AC), or at C'' on chart A. The dotted line between BC'', determined as outlined above, is then the apparent line for relay 3 which determined the third line for relay 9-10, marked "Apparent 9-10". By inspection the steepest of these three lines is the second and this is the time-distance line for relay 9-10 and shown on chart B. This completes the construction of the charts for this example.

Equation (3) can now be used to determine the voltage tap for each relay by selecting that value of Z for which the relay operates in .75 second. The value of K for this time interval is found from the table above. In the example, for relay 7, suppose that the current transformers are star-connected with a ratio 200/5, the potential transformer ratio is 200/1 and Tc = 8. From Chart B for relay 7 the relay operates in .75 second for a fault 3.5 ohms away. K for .75 second is 96.

Using equation (3):

$$Tv = \frac{8 \times 40 \times 3.5 \times 96}{200} = 538$$

Set tap 500 on the voltage resistor. After all the taps are calculated, the time-distance charts may be replotted to give the actual discrimination of the relays.

On lines where taps or parallel 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 is to increase the time of operation of the distance element. This can be seen on the time-distance chart, where the increased apparent impedance has the effect of making the fault appear more remote to the relay. In these cases the distance element setting can often be changed to give faster operating times than normally would be given if the feeders were disregarded. However, if this is done, the possibility of losing selectivity when the tapped lines are open must not be overlooked.

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, 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 periodically cleaned with a fine file. S#1002110 file 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 contact.

Instantaneous Impedance (HZ) Element

Refer to Figure 4. For the 60 cycle relays adjust the stop screw on the rear of the beam to give a clearance of .025 inch between the rear of the beam and the voltage iron circuit. This may be checked with a feeler gauge. With the beam in the reset position, i.e., back against the stop, adjust the gap between the adjustable iron and the beam to .009 inch. Care should be taken in this adjustment to keep the gap the same on 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 as shown in the test diagram, Figure 14. 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. Make certain that the stop on the voltage side is absolutely clean, otherwise the impedance at which the beam trips may be affected, particularly at the 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.

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 strikes the bronze stop on the core screw.

It is difficult to accurately adjust the contacts by eye. A good method 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.

A further caution in regard to the contact adjustment is that too much follow or deflection of the stationary contacts will slightly delay the resetting of the high-speed element and thus the directional element contacts may get closed before the impedance contacts are open and result in unnecessary tripping.

The Distance (CZ) Element

Adjust the stop screw on the end of the rocker arm so that there is a gap of .005 inch between the core screw at the bottom of the iron and the plunger when the beam is reset. Adjust the gap by loosening the stop screw and allowing the plunger to touch the core. Then screw down the stop screw until it touches the cross bar. Then turn the stop screw an additional 1/2 revolution and lock it in place. The accuracy of this adjustment will be checked by measuring the time of operation. This measurement will be described later.

With the beam in the reset position, adjust the position of the stationary contacts so that there is a gap of .020 inch between them and the moving contacts. Check further to see that both contacts make simultaneously.

To adjust the balance of the rocker arm, loosen the clamp screw on the spring adjuster located beneath the large gear. Turn the adjuster to the right until the rocker is just about balanced. The object is to adjust the initial tension on the spring so that with the voltage coil de-energized, the weight of the plunger arm is just sufficient to hold the contact open. With this position a movement of about 1-1/2 inches of the disc should be sufficient to close the contact. When the disc is released, it should return to its initial position and open the contact. In other words, the rocker arm should be balanced so that the plunger will always return to the .005 gap position with the stop screw resting lightly against the cross bar. Extreme care should be taken to obtain a fine balance of the rocker arm. When working with the rocker arm be careful not to break or damage the jeweled ring bearings.

Check the balance of the rocker arm by applying and removing full voltage to the restraining coil at least ten times. The current coil should not be energized. The contacts should not bounce closed when the voltage is removed. A tendency of the contacts to bounce indicates that the balance of the rocker arm is too critical. In this case the spring adjuster should be turned very slightly towards the left. With the rocker arm carefully balanced, the tripping current is adjusted by passing 4 amperes thru the current coil with the tap screw in the 4 ampere tap. The voltage coil should not be energized. In order to energize this element it will be necessary to complete the directional control circuit by blocking the auxiliary contactor switch closed. Adjust the position of the balance weight on the rocker arm so that the contacts just barely close at 4 amperes ± 5%. It is important to note that during this adjustment every time the position of the balance weight is changed, the rocker arm must be rebalanced by moving the spring adjuster, as explained above. After the correct position of the weight has been determined, it should be locked in place with the set screw.

Check the time of operation of the element at the following points, using the 4 ampere tap, and measuring the voltage across the relay terminals alone:

Volts	Amperes	Time (Cycles) at 60 Cycles
0	8	22 or less
6.25	12	45

These time values should be the average of a large number of tests. The check at zero voltage shows that the element is free from friction. The check at 6.25 volts indicates the accuracy of the air gap adjustment which may be varied slightly to bring this point to the proper time.

When checking the time of operation, place the permanent magnet in the maximum damping position which is about 1/8" from the edge of the disc. The correct time of contact closure for the 6.25 volt point is obtained initially in the factory by adjusting the spring. The time is decreased by pulling more of the spring thru the spring clamp on the lever arm, thus making the effective length of the spring shorter. Whenever this adjustment is made, it will be necessary to readjust the balance of the rocker arm.

Directional Element

Check the free movement of the directional element loop with the relay in a vertical position to see that it is free from friction and properly centered. The loop should assume a vertical position with the contacts open when the element is completely de-energized.

With the loop in the vertical position adjust the front and back stationary contacts for .020 inch separation from the vertical moving contact. Adjust the contact back stop screws to just touch the stationary contacts, then back off 1/4 of a turn to give correct contact follow. Adjust the two stop screws which limit the movement of the loop (these screws are located to the rear of the current coil) so that the loop strikes these stops at the same instant the stationary contacts strike their back stop.

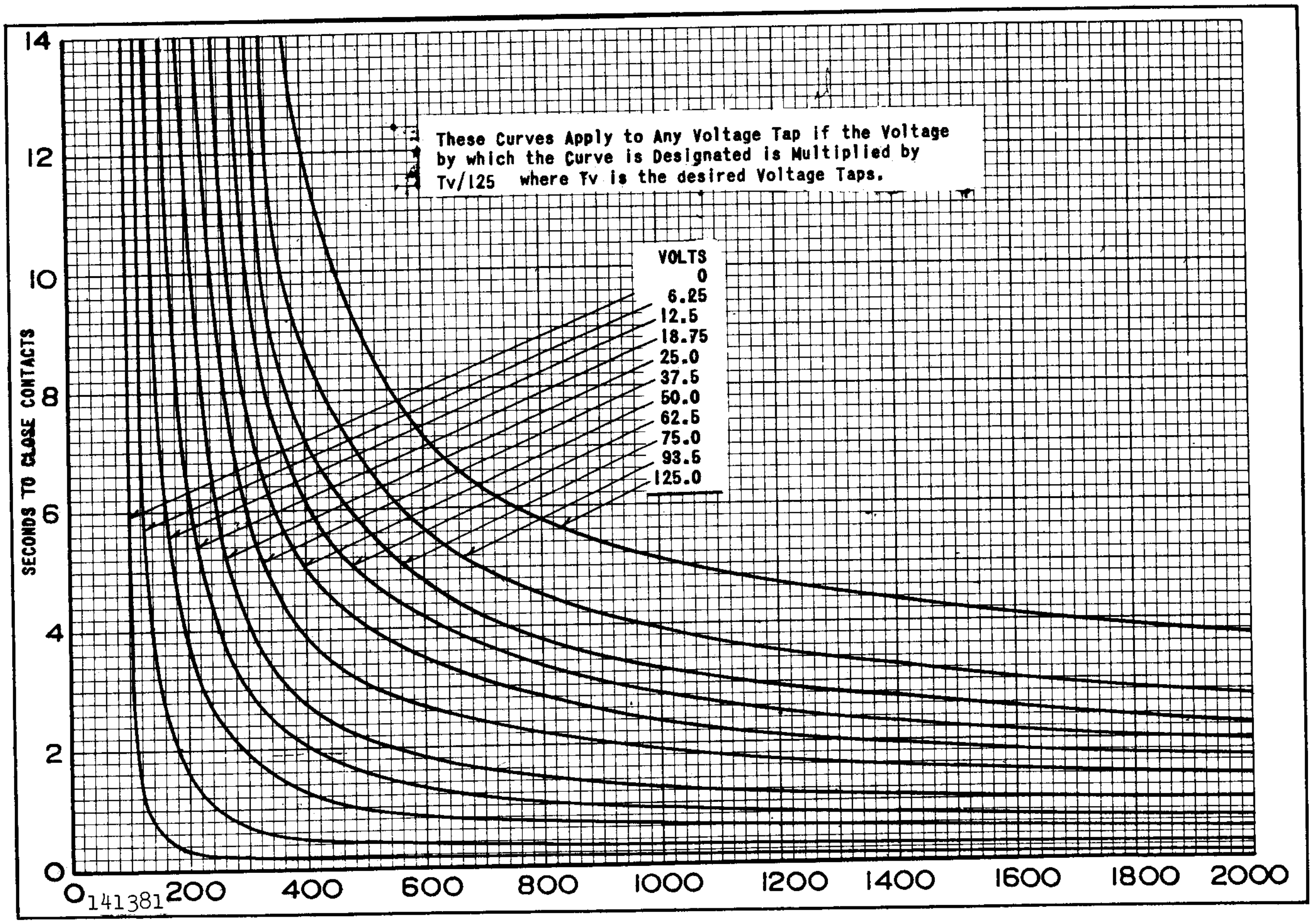


Fig. 11 — Typical Time-Ampere Curves of the Distance (CZ) Element.

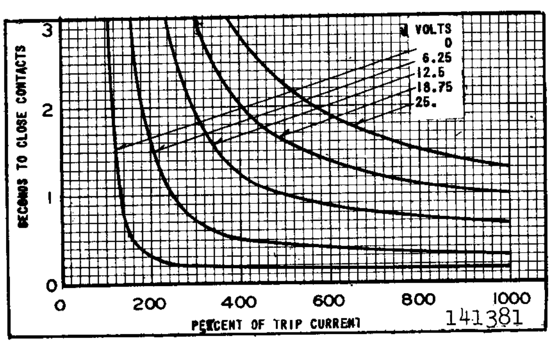


Fig. 12 — Typical Time-Ampere Curves of the Distance (CZ) Element (Enlarged).

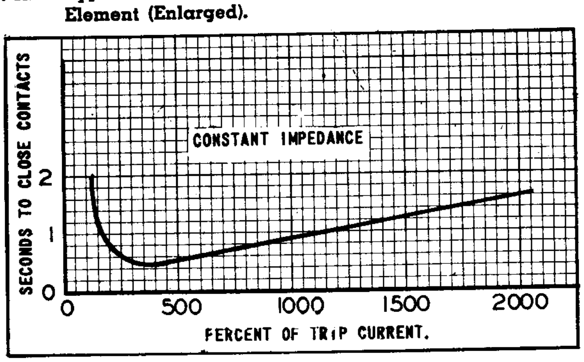
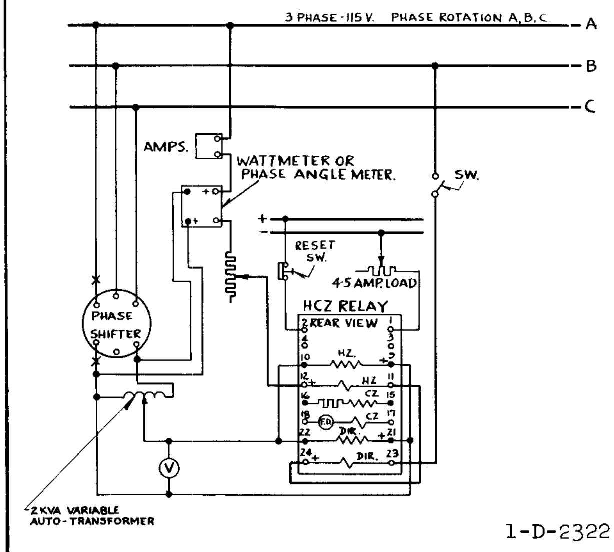


Fig. 13 — Typical Time-Ampere Curve of the Distance (CZ) Element for a Constant Given Distance.

Too much follow on the directional contacts should be avoided in order to allow the directional element to reset fast enough by gravity to properly coordinate with the high speed impedance element.

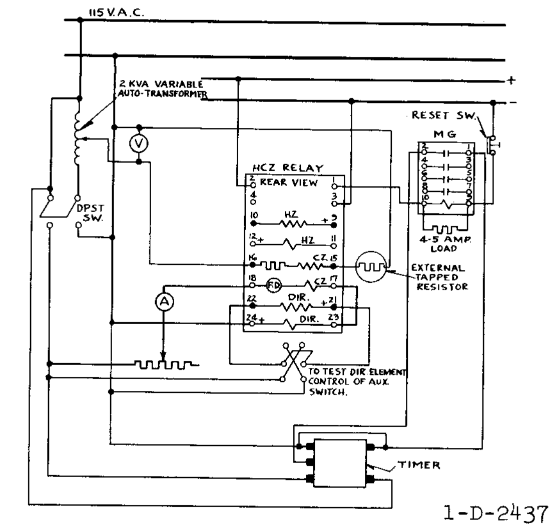
Energize the loop with normal potential long enough to bring it up to temperature (about 10 or 15 minutes) and adjust the bearing screws so there is about .010 inch end play. See that the loop does not bind or strike against the iron or coil when pressed against either end jewel.

The minimum pick-up of the element is 10 amperes at 2.0 volts (unity power factor). Apply these values to the element and see that contacts make good contact in the correct direction. Reverse the direction of current to see that the contacts make good contact in the opposite direction.



CONNECTIONS TO DIRECTIONAL ELEMENT MAY BE OMITTED FOR EXTENDED TESTS ON HZ ELEMENT, AND DIRECTIONAL ELEMENT CONTACTS BLOCKED CLOSED. DIRECTIONAL ELEMENT CLOSES AT UNITY POWER FACTOR WITH CONNECTIONS SHOWN.

✱ Fig. 14 — Diagram of Test Connections for the Instantaneous (HZ) Element. Relay is Shown for Standard Case. For Type FT Case Compare With Figure 3.



CLOSING DPST SW. REDUCES POTENTIAL ON CZ POTENTIAL COIL INSTANTLY FROM NORMAL TO TEST VALUE. APPLICATION OF CURRENT PICKS UP FAULT DETECTOR AND DIRECTIONAL ELEMENT. THEN AUXILIARY SWITCH PICKS UP, ALLOWING CZ DISC TO TURN. CHECKING MINIMUM TRIP VALUE ON CZ TAPS BELOW PICK UP OF FAULT DETECTOR REQUIRES BLOCKING FAULT DETECTOR CLOSED OR JUMPING ITS CONTACTS CLOSED.

✱ Fig. 15 — Diagram of Test Connections for the Distance (CZ) Element. Relay is Shown for Standard Case For Type FT Case Compare With Figure 3.

When the directional element is energized on voltage alone, there may be a small torque which may hold contacts either open or closed. This torque is small and shows up only at high voltages with the entire absence of current. At voltages high enough to make this torque discernible, it will be found that only a fraction of an ampere in the current coils will produce wattmeter torque to insure positive action. This is mentioned because the slight torque shown on voltage alone has no significance in actual service and has no practical effect on the directional element operation.

Check the coordination of the directional and impedance contacts as follows. Set the impedance element on the maximum tap and scale setting and the CZ element on the lowest tap. Connect the relay with the correct polarity so that the right-hand (front view) directional contacts close and apply rated d-c volts to the directional control circuit. Block the fault detector in the closed position. Apply 115 volts a-c to the impedance and directional element potential coils and pass 5 amperes at unity power factor thru the current circuit. Check trip circuit to see that it is not completed when the voltage on the impedance and directional elements is suddenly applied or interrupted. Do not interrupt the current circuit. Make several such tests. The trip circuit should draw about 5 amperes d-c for this test so that the contactor switch will pick up and seal in if the elements fail to coordinate. Otherwise, a failure to coordinate is not necessarily indicated by the flicker of a lamp, since the blocking resistor will prevent the pick-up of a trip coil plunger until the auxiliary contactor falls out. This coordination test has been described for the most severe conditions. Consequently, an occasional failure to coordinate may be tolerated, since, in service, the directional element will be resetting under the positive action of reverse power flow rather than under the influence of gravity alone, as described in this test. If proper coordination is not obtained, it may be necessary to reduce the follow on the directional or impedance element contacts, as the case may be.

Fault Detector

The pick-up of the fault detector switch is changed by raising or lowering the plunger. This is done by means of two nuts on either side of the Micarta disc at the bottom of the switch. Adjust the switch to pick up at 8 amperes ± .2 amperes gradually applied current.

The drop-out value is varied by raising or lowering the core screw at the top of the switch. After the final adjustment is made, the core screw should be securely locked in place with the locknut. Adjust the switch to drop out at 6 amperes ± .5 amperes gradually applied current.

When the switch picks up at 8 amperes ± .2, there should be a slight deflection of the helical spring. Failure to obtain this slight deflection at 8 amperes ± .2 amperes indicates that the drop-out adjustment is too high and that the core screw should be lowered.

Contactor Switch (Seal-in-Switch)

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core of 1/64" when the switch is picked up. This can be done by turning the relay up-side-down or by disconnecting the switch and turning it up-side-down. Then screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the points where the play in the assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the core screw approximately one turn and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32" by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 2 amperes d-c. Test for sticking after 30 amperes have been passed through the coil.

Auxiliary Contactor Switch
(Directional Control Circuit)

The adjustments are the same as for the seal-in contactor switch except that the contact separation should be 3/64 inch. The ✱ switch should pick up at not more than 90 volts d-c. Apply 140 volts d-c to the circuit and see that the contacts drop out when the coil is shorted by the left-hand directional contacts. For the 250 volt d-c relays the pick-up should be 165 volts and the contacts should drop-out when the directional element contacts short-circuit the coil with 250 to 280 volts applied to the circuit. Energize the directional element with 50 volts and 10 amperes in phase suddenly applied. The contactor switch must operate the first time the directional contacts close without fluttering or bouncing of the contacts.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied. Test for sticking after 30 amperes d-c is passed through the coil.

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

The burdens of the various circuits of the 60 cycle relay are as follows:

POTENTIAL CIRCUITS AT 115 VOLTS

Circuit	Tap	V. A.	P.F. Angle
Directional Element	-	9.0	28° lag
Distance (CZ) Element	125	11.0	7° lag
	1800	0.8	0° lag
Instantaneous (HZ) Element		1.8	20° lag

CURRENT CIRCUITS AT 5 AMPERES

Circuit	Tap	V. A.	P.F. Angle
Directional Element And Fault Detector	-	4.0	45° lag
Distance (CZ) Element	4	7.5	70° lag
	25	0.75	70° lag
Instantaneous (HZ) Element	45	2.0	30° lag
	13.5	.55	30° lag

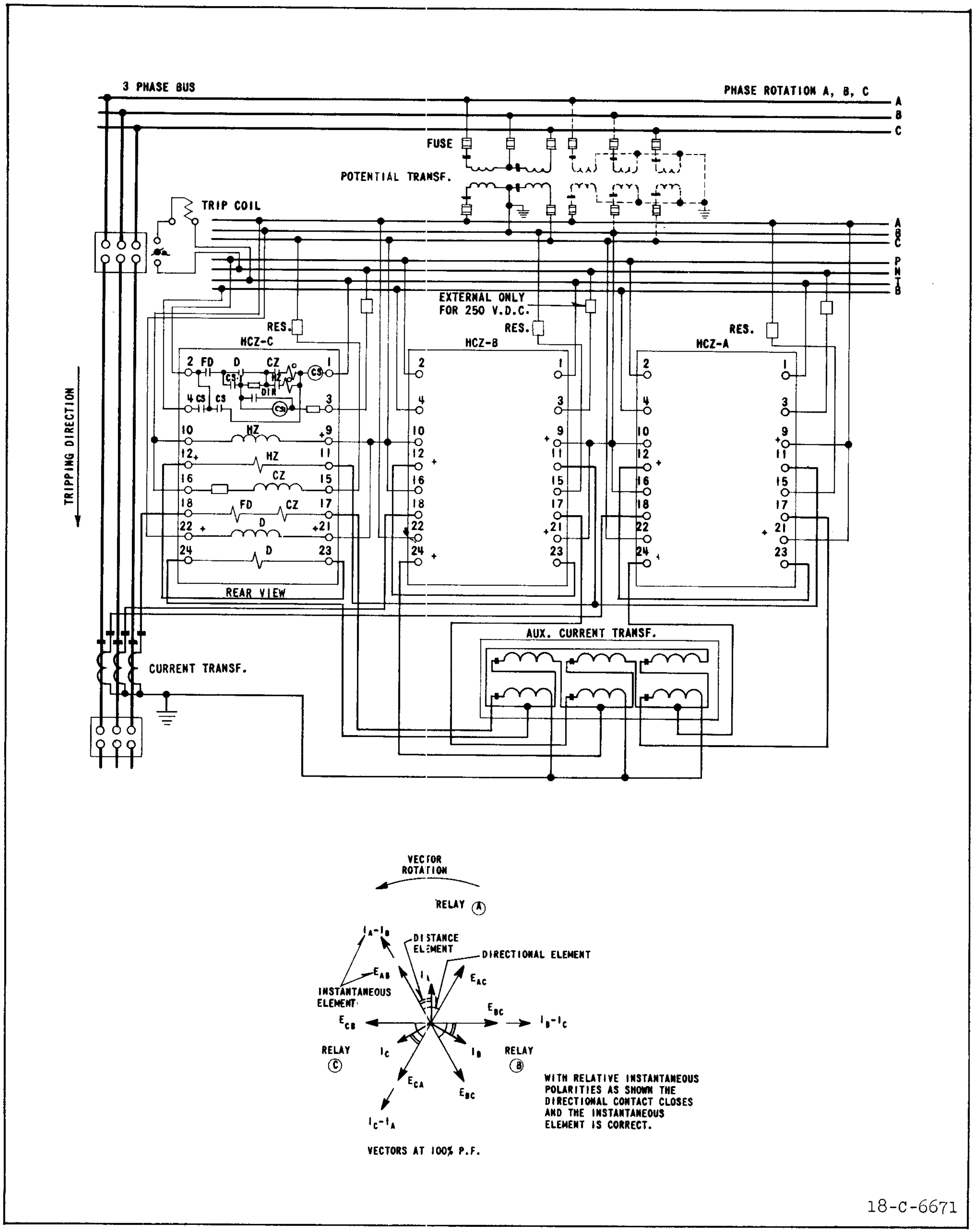


Fig. 16 — External Connections of the Type HCZ Relay in the Standard Case Using Star Current for the Directional and Distance Elements and Delta Current for the Instantaneous Element.

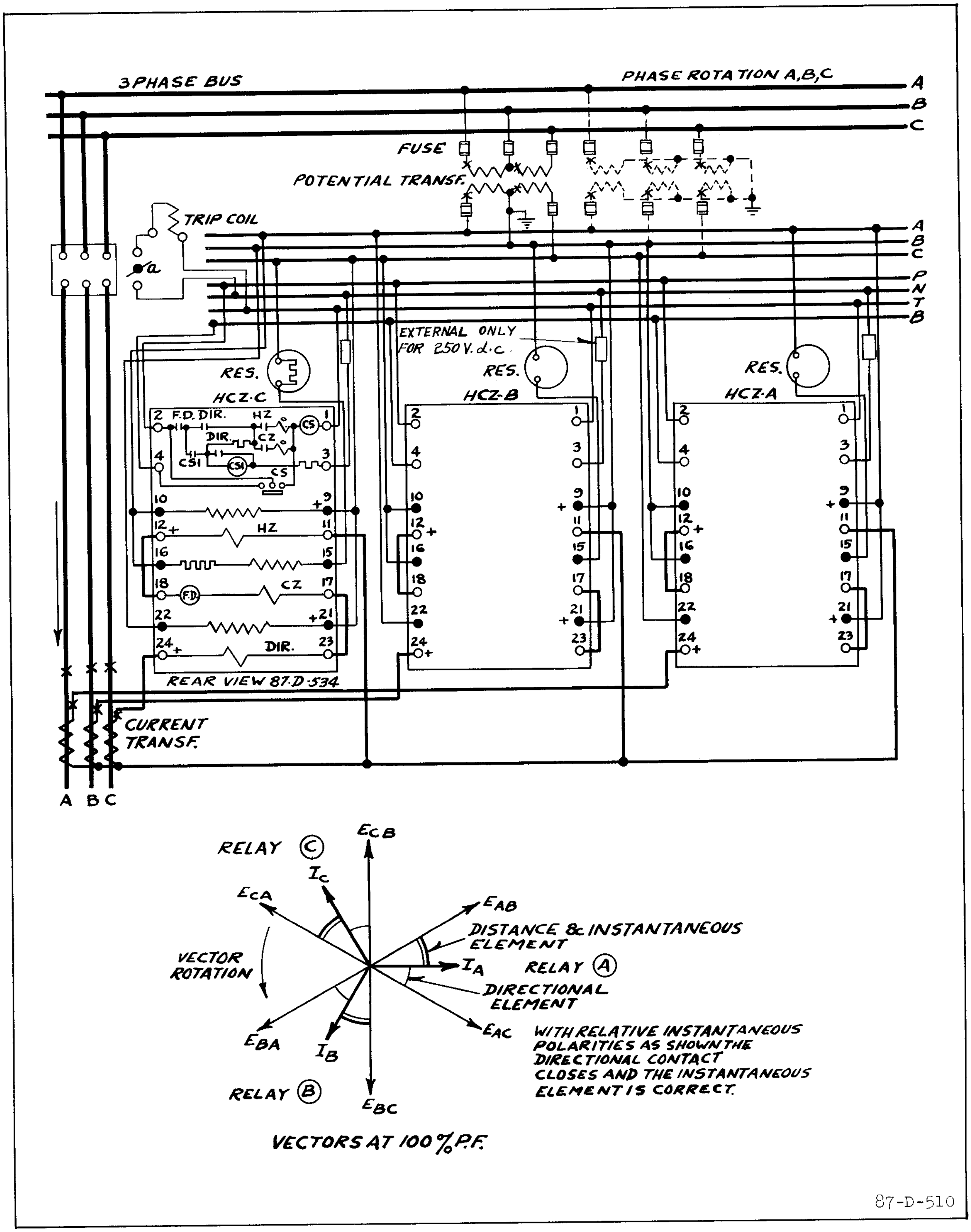


Fig. 17 — External Connections of the Type HCZ Relay in the Standard Case Using Star Current for All Elements.

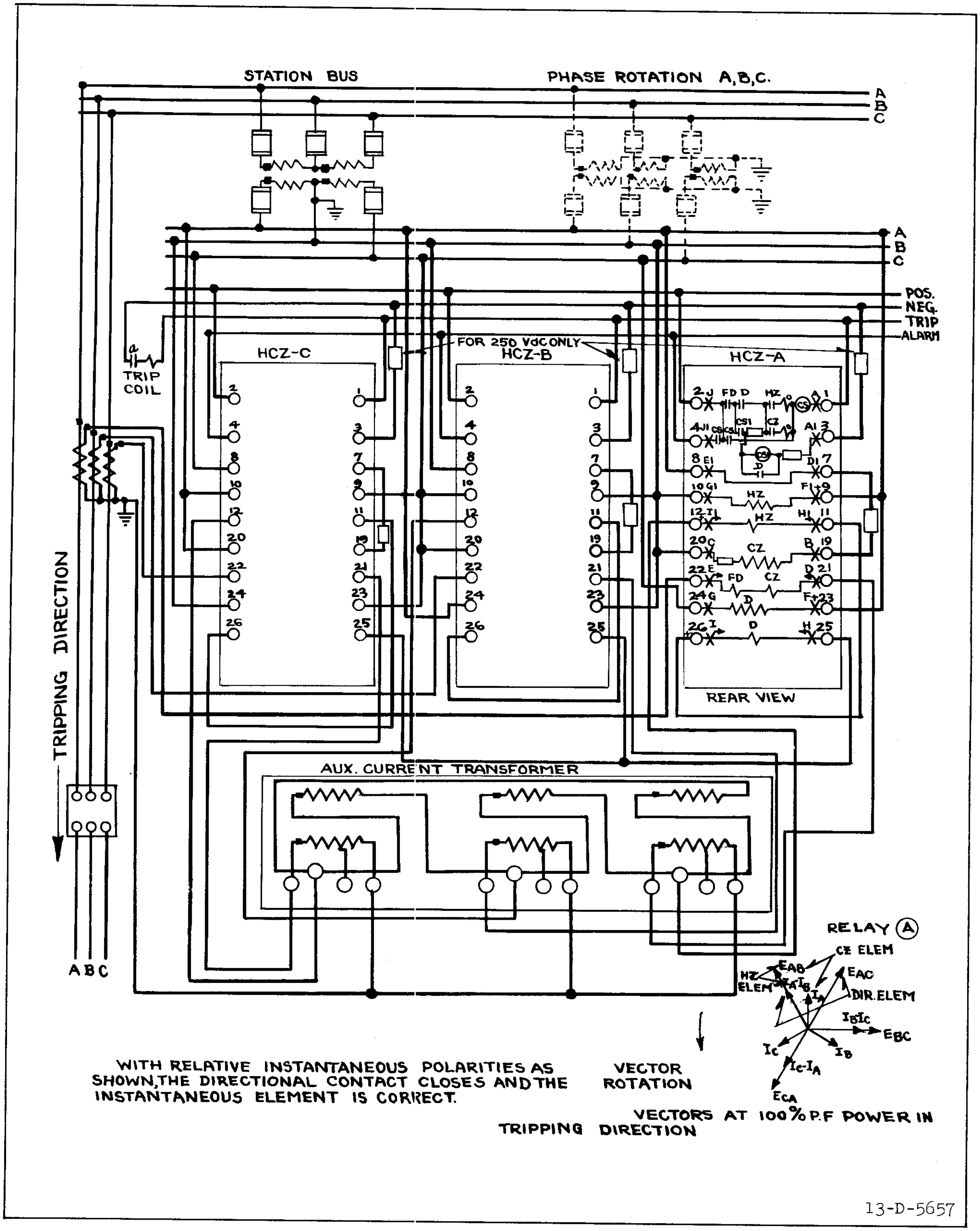


Fig. 18 — External Connections of the Type HCZ Relay in the Type FT Case Using Star Current for the Directional and Distance Elements and Delta Current for the Instantaneous Element.

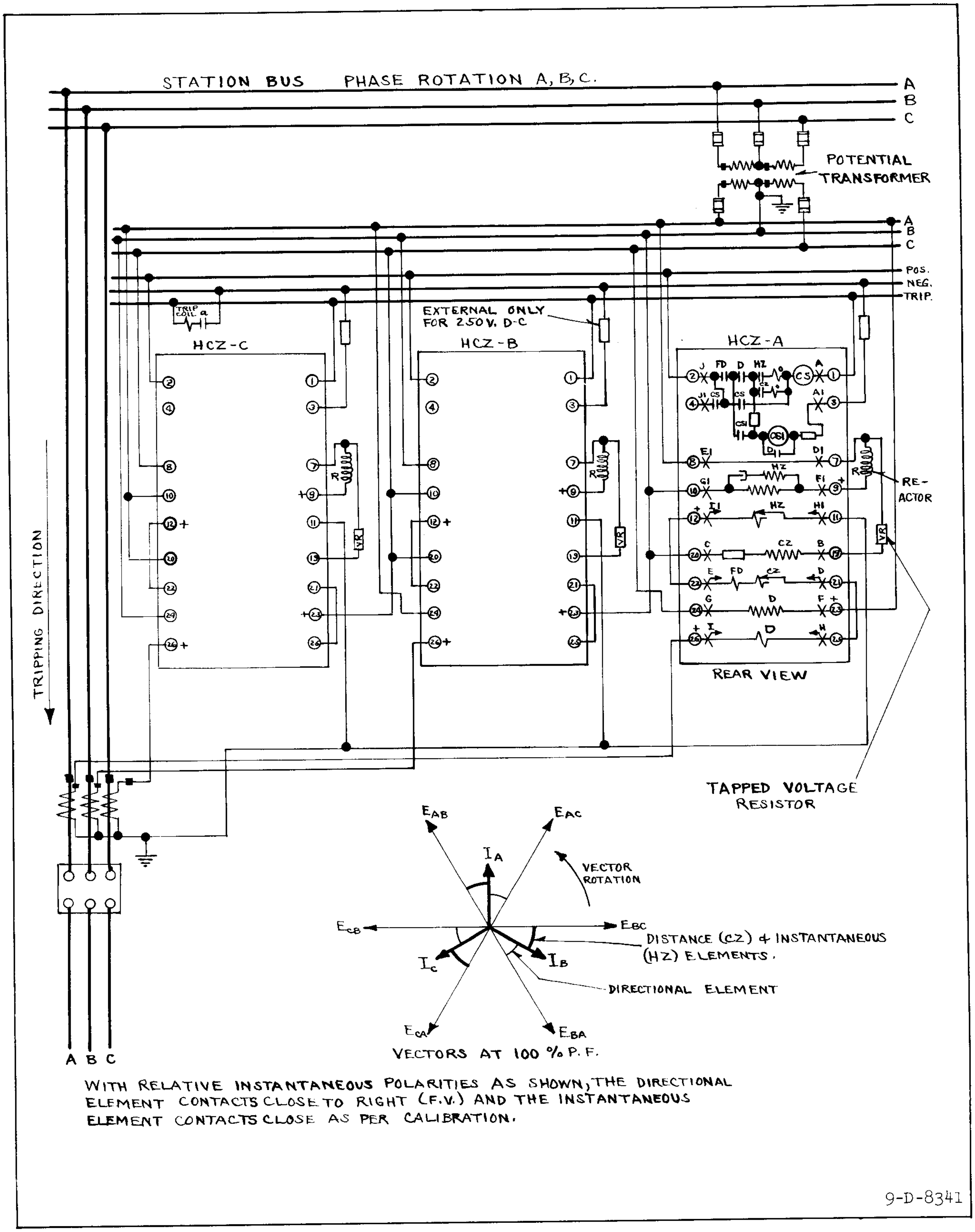


Fig. 19 — External Connections of the Type HCZ Relay in the Type FT Case Using Star Current for All Elements.

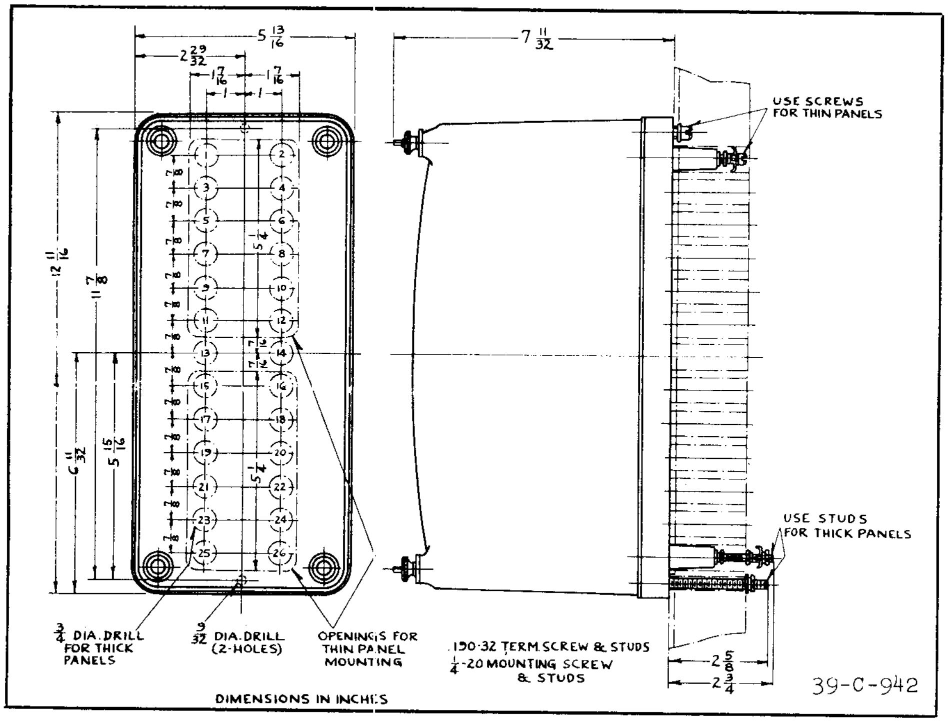


Fig. 20 — Outline and Drilling Plan for the Standard Projection Type Case. See the Internal Schematics For Terminals Supplied. For Reference Only.

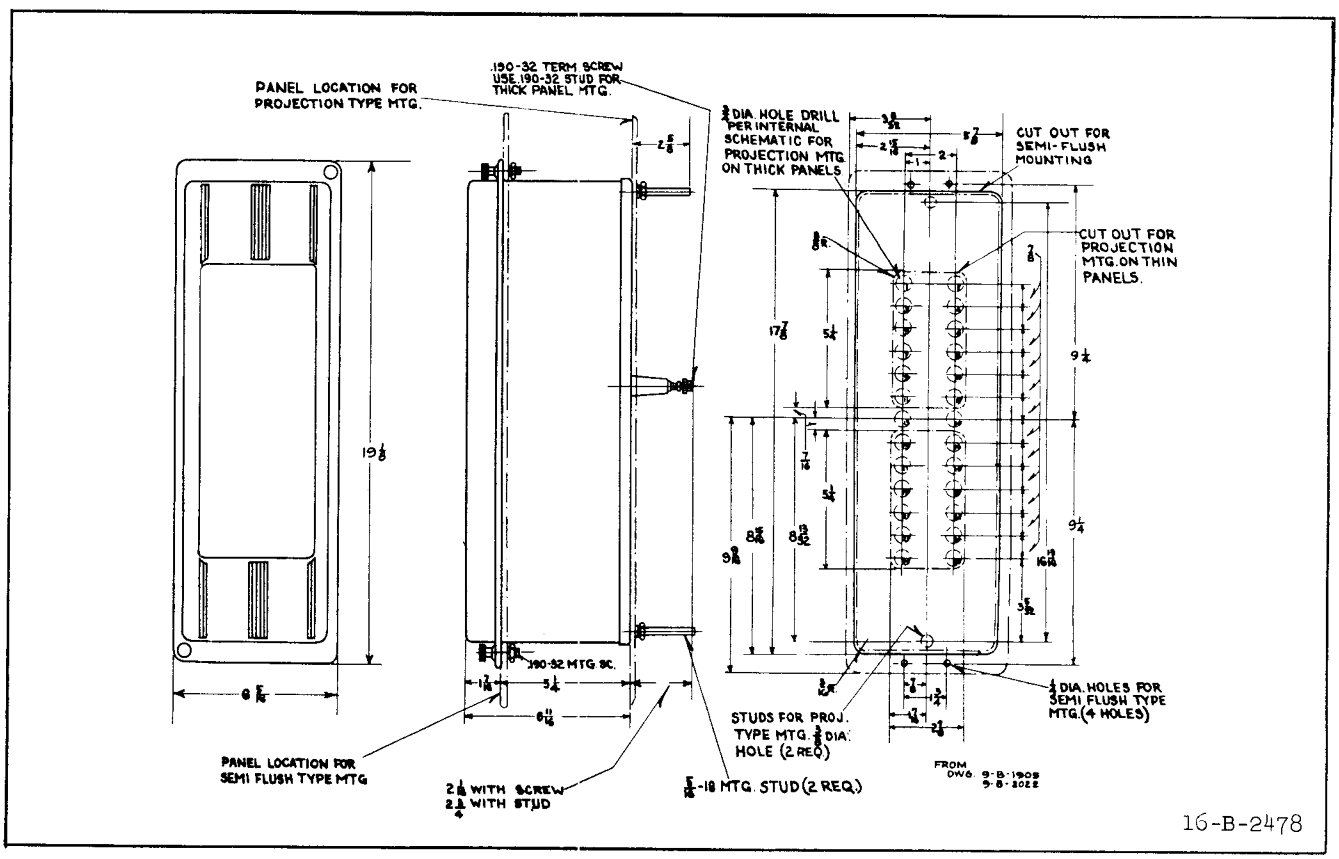


Fig. 21—Outline and Drilling Plan for the M20 Semi-flush or Projection Type FT Flexitest Case. See the Internal Schematics for Terminals Supplied. For Reference Only.

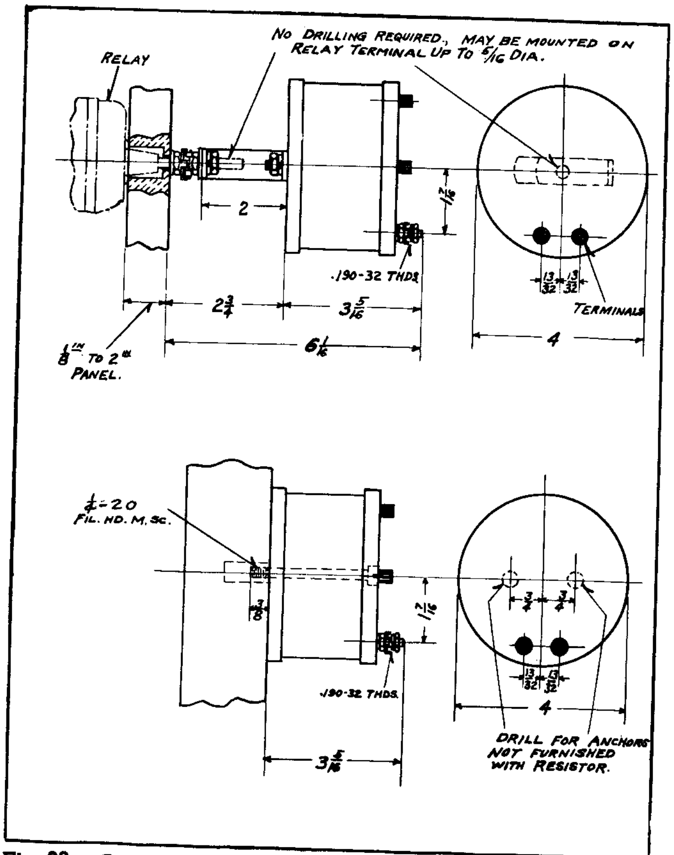


Fig. 22—Outline and Drilling Plan for the Tapped A-C Voltage Resistor for the Distance (CZ) Element. For Reference Only.

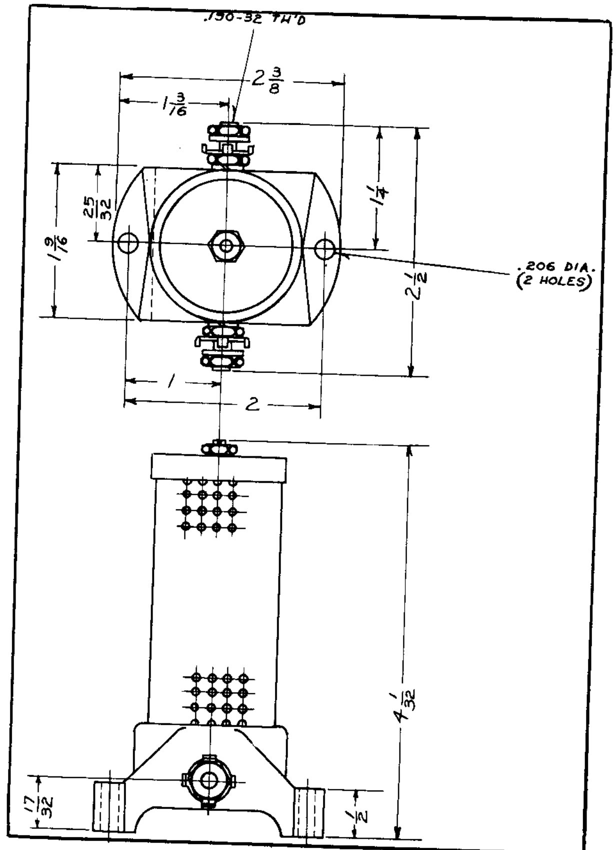


Fig. 23 — Outline and Drilling Plan for the External Control Circuit Resistor for the 250 Volt D-C Relays. For Reference Only.

pick-up should be 165 volts and the contacts should drop-out when the directional element contacts short-circuit the coil with 250 to 280 volts applied to the circuit. Energize the directional element with 50 volts and 10 amperes in phase suddenly applied. The contactor switch must operate the first time the directional contacts close without fluttering or bouncing of the contacts.

Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied. Test for sticking after 30 amperes d-c is passed through the coil.

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

The burdens of the various circuits of the 60 cycle relay are as follows:

POTENTIAL CIRCUITS AT 115 VOLTS

Circuit	Tap	V. A.	P.F. Angle
Directional Element	-	9.0	28° lag
Distance (CZ) Element	125	11.0	7° lag
	1800	0.8	0° lag
Instantaneous (HZ) Element		1.8	20° lag

CURRENT CIRCUITS AT 5 AMPERES

Circuit	Tap	V. A.	P.F. Angle
Directional Element And Fault Detector	-	4.0	45° lag
Distance (CZ) Element	4	7.5	70° lag
	25	0.75	70° lag
Instantaneous (HZ) Element	45	2.0	30° lag
	13.5	.55	30° lag

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