Westinghouse

TYPE CZ IMPEDANCE RELAY

INSTRUCTIONS

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 CZ relay is an impedance type relay in which the time of operation is proportional to the distance between the relay and the fault. In effect, the construction makes it a voltage-restrained overcurrent relay with adjustable time delay increasing with distance. The relay is used for phase fault protection on transmission lines. It is supplied with an induction-type directional element.

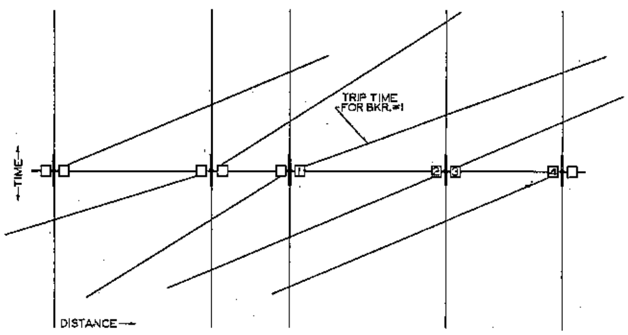

Figure 1
Typical Time-Distance Characteristic of the CZ Relay.

CONSTRUCTION AND OPERATION

The type CZ relay consists of an impedance element, a directional element a contactor switch, and an operation indicator. The construction and operation of each of these elements is as follows:

Impedance Element

The impedance element consists of an induction-disc element operated by current, and a restraining coil and plunger assembly operated by voltage. The construction details are shown in figure 2. These two elements are mechanically interconnected thru pivoted lever arms which also operate the 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 the magnitude of the voltage. Consequently, the closer the fault, the larger the current, and the lower the voltage; and, therefore, the faster the impedance element operates.

The induction disc of the overcurrent element is a thin aluminum disc mounted on a vertical shaft which is supported on the lower end by a steel ball bearing riding between concave sapphire jewel surfaces, and on the upper end by a stainless steel pin. The moving disc is rotated by an electromagnet in the rear and damped by a permanent magnet in the front. The operating torque is obtained by the circuit arrangement shown in figure 3. The main pole coil of the element acts as a transformer and induces a voltage in a secondary coil. Current from this secondary coil flows thru the upper pole coil and thus produces torque in the disc by the reaction between the fluxes of the upper and lower poles.

A rectangular silver contact is flexibly fastened on the free end of the lever arm. As the arm trips, the contact bridges two silver stationary contact screws. The stationary contact screws permit adjustment of the contacts.

Directional Element

This element is similar to the overcurrent element except for the quantities used to rotate the disc and the contact assembly. The two upper poles of the electromagnet are in series with the impedance element current coil, and the lower pole by polarizing voltage. The fluxes produced by these two electrical quantities cause rotation of the disc in a direction depending on the phase angle between the current and voltage. As fault power reverses, the current in the relay reverses while the polarizing voltage remains fixed, thus directional torque is obtained.

The rotation of the disc is limited in the opening direction to a few degrees by a projecting stop on the disc which strikes the element frame and in the closing direction by the rigid moving arm striking the stationary contact arm.

The moving contact assembly consists of a rigid counter-weighted arm fastened to an insulated section of the disc shaft. A leaf spring fastened to the shaft end of the arm with a silver contact attached to the free end of the leaf spring. When the moving contact strikes the stationary contact, the spring deflects to provide the required contact follow. The electrical connection is made from the moving contact thru the arm and spiral spring. One end of the spring fastens to the arm, and the other to a slotted spring adjuster disc which in turn fastens to the element frame.

The stationary contact consists of a right angle bracket fastened to the element frame thru a Micarta insulating block. A contact screw projects thru the outer end of the bracket and provides adjustable contact separation.

To prevent the relay from operating for faults in the non-tripping direction, the

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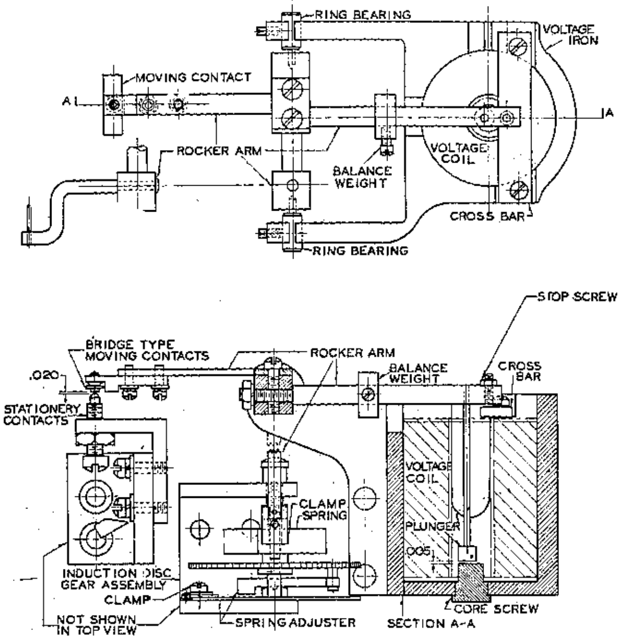
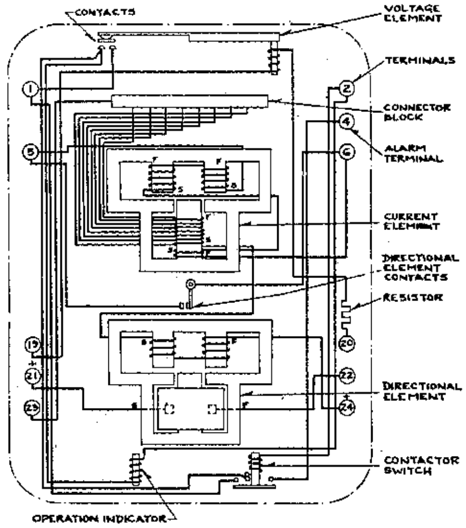


Figure 2
Sectional View of the Impedance Element.



FRONT VIEW
WITH RELATIVE INSTANTANEOUS POLARITIES
AS SHOWN THE DIRECTIONAL CONTACT CLOSES.

Figure 3
Internal Connections of the Directional Type CZ Relay.

directional element contacts are connected in the upper pole circuit of the impedance current element. This means that the overcurrent element cannot operate unless the power flow is in a predetermined direction. This is known as directional control of the overcurrent element.

Contactor Switch

The contactor switch is a small solenoid-type d-c. switch, the coil of which is connected in the trip circuit. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward, the disc bridges three silver stationary contacts. These contacts seal around the main relay contact thereby 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.

Operation Indicator

The operation indicator is a small solenoid coil connected in the trip circuit. When the coil is energized, a spring restrained armature releases a white target which falls by gravity to show the completion of the trip circuit.

CHARACTERISTICS

The standard 4 to 25 ampere type CZ relay has the following taps:

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.

The relays in the older style case have an additional 30 ampere current tap.

A special 1 to 6 ampere range relay has been made for use with external fault detectors where minimum fault current is below or about the same value as load current. The taps are:

Current taps - 1, 2, 3, 4, 5, 6.

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. Either of these studs may be utilized for grounding the metal base. 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 the relay are shown in figure 10. The 30° connection is used on the directional element; that is, at unity power factor the current thru the directional element should lead the polarizing voltage by 30° as shown in the vector diagram.

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

The relay is shipped with the operation indicator and the contactor switch connected in parallel. This circuit has a resistance of approximately 0.25 ohms and is suitable for all trip currents above 2.25 amperes d-c. If the trip current is less than 2.25 amperes, there is no need for the contactor switch and it should be disconnected. To disconnect the coil, remove the lower lead on the front stationary contact of the contactor switch and this lead should be fastened (dead-ended) under the small filister-head screw located in the Micarta base of the contactor switch. The operation indicator will operate for trip currents above 0.2 amperes d-c. The resistance of its coil is approximately 2.8 ohms. When using the contactor switch it is necessary to use an auxiliary switch on the circuit breaker so that when the circuit breaker is tripped, the tripping circuit will be opened by this switch.

SETTINGS

The type CZ relay requires two settings on the impedance (distance) element, one for the overcurrent element and the other for the voltage element.

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

Z = the line-to-neutral ohmic impedance or ohmic line length for which the distance element will operate in a time determined by the choice of K.

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

R_c= the current transformer ratio.

R_v= the potential transformer ratio.

T_c= the distance element current tap.

T_v= the distance element voltage tap on the external resistor.

The impedance element is set to protect the line section and to give back-up protection over the adjacent sections. Consequently, each impedance (distance) element must be carefully set to coordinate with the relay protecting the adjacent section 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 impedance element settings will be explained, disregarding the question of selection or coordination with other relays.

Individual Settings: The impedance curve and hence the time of operation of the element is approximately constant for fault currents in the range of 200% to 1000% of the current tap value, Figure 7. The selection of the current tap, T_c, 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 a suitable current tap, T_c, the voltage tap, T_v, may be determined by using the curves of figure 5 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 the relay in per cent of the current T_c 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 $T_v = 125$. Knowing the actual voltage drop, the tap, T_v, is determined by the relation:

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

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, T_v, can also be determined by the following equation:

$$T_v = \frac{T_c \times R_c \times Z \times K}{R_v} \qquad (1)$$

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 distance 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 T_v from equation (1) 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, figure 5, 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 CZ relays to power system is best discussed by the example of figure 4 which shows a typical system to be protected by type CZ relays. In this example the distance elements at successive stations will be set with a time interval of .75 second between them.

In looking over the system of figure 4 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 CZ relays have directional elements, the

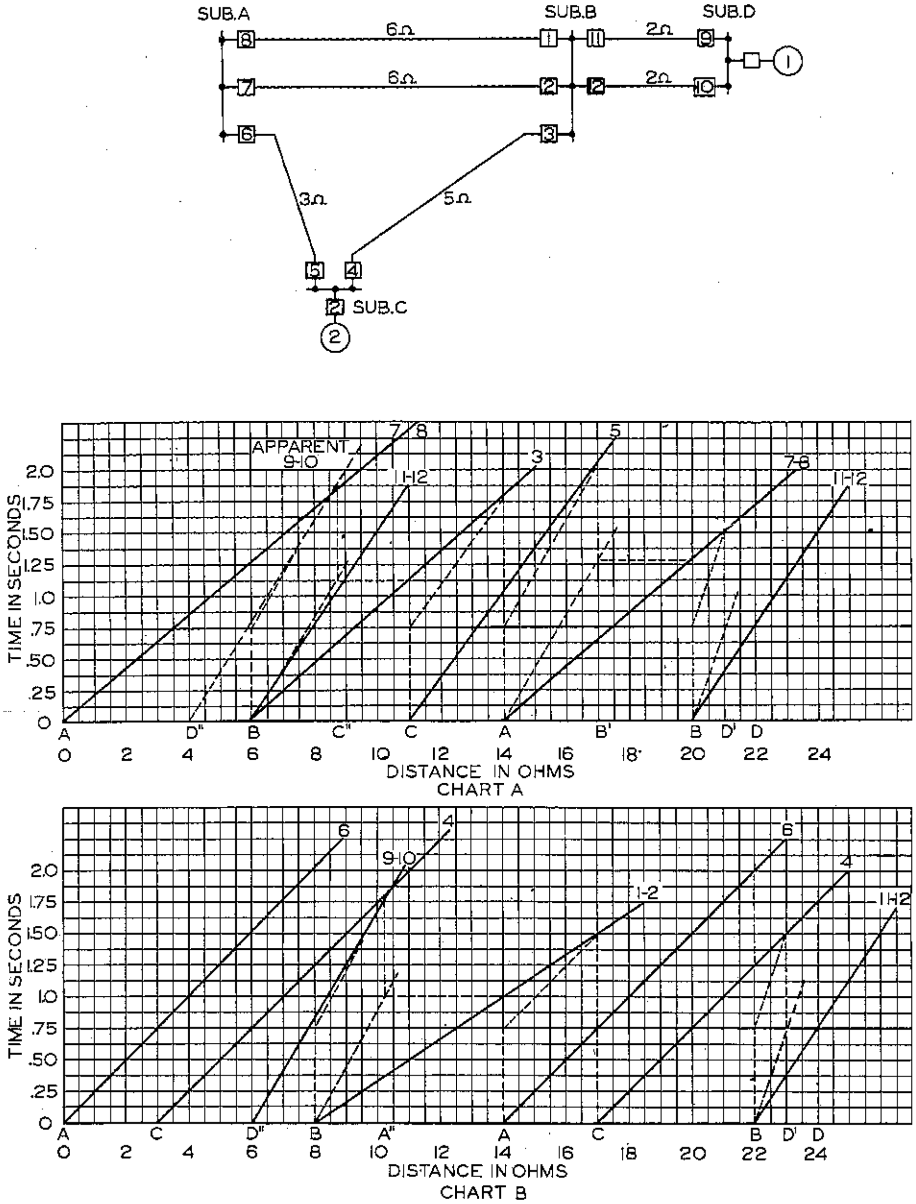


Figure 4
Construction of Time-Distance Chart for the System Shown.

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 T_c 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 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 $T_c = 8$. 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 (1):

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

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 loosing selectivity when the tapped lines are open must not be overlooked.

ADJUSTMENTS AND MAINTENANCE

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.

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed or the relay taken apart for repairs, the following instructions should be followed in reassembling and setting it.

Impedance 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 deenergized, 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

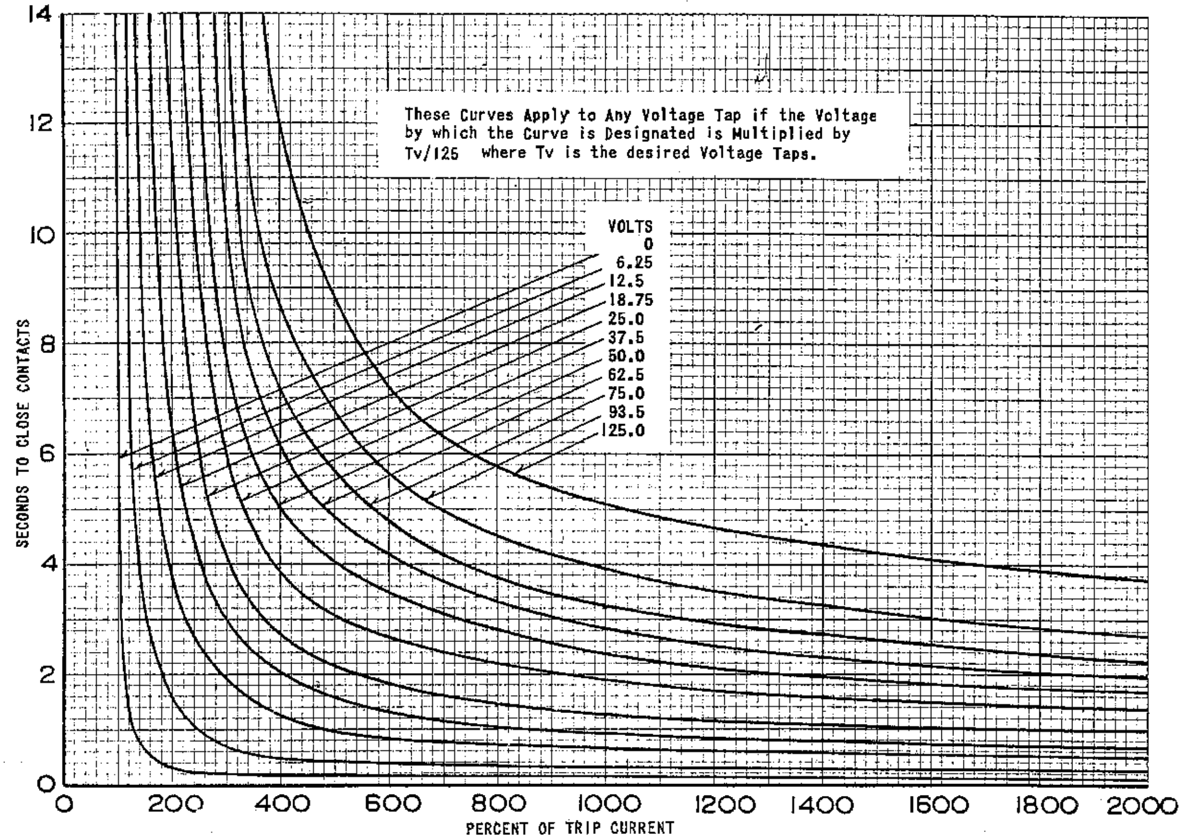


Figure 5
Typical Time-Ampere Curves of the Impedance Element.

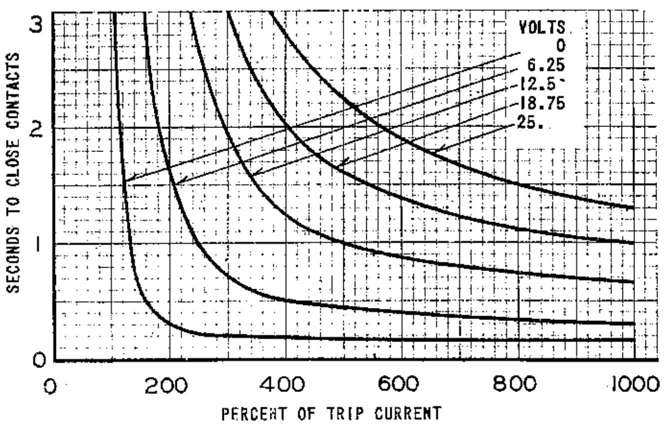


Figure 6
Typical Time-Ampere Curves of the Impedance Element (Enlarged).

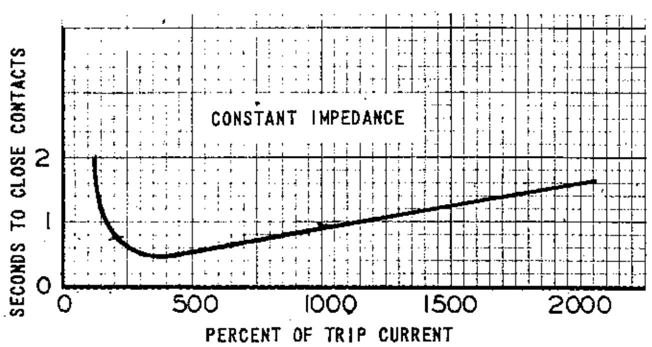


Figure 7
Typical Time-Ampere Curve of the Impedance Element for a Constant Given Distance.

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 directional contacts closed (in the directional type relays only). 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 several 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
25	48	75

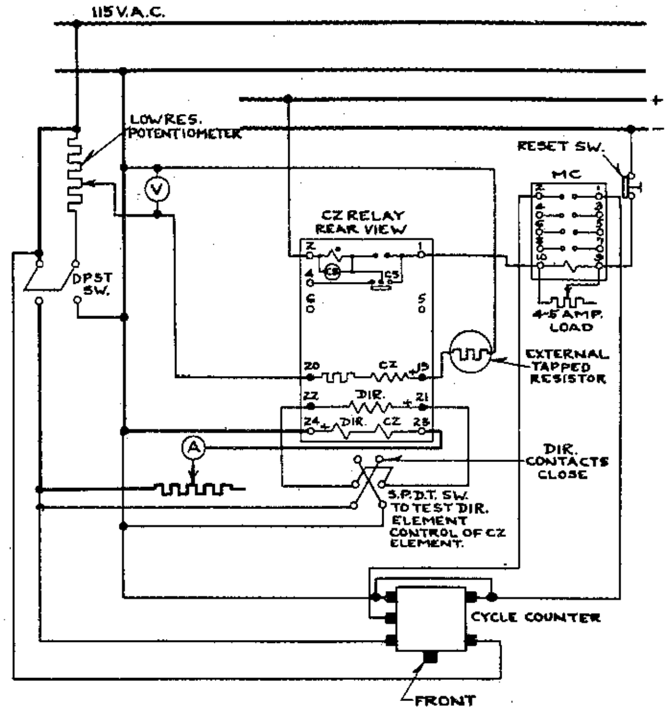


Figure 8
Diagram of Test Connections.

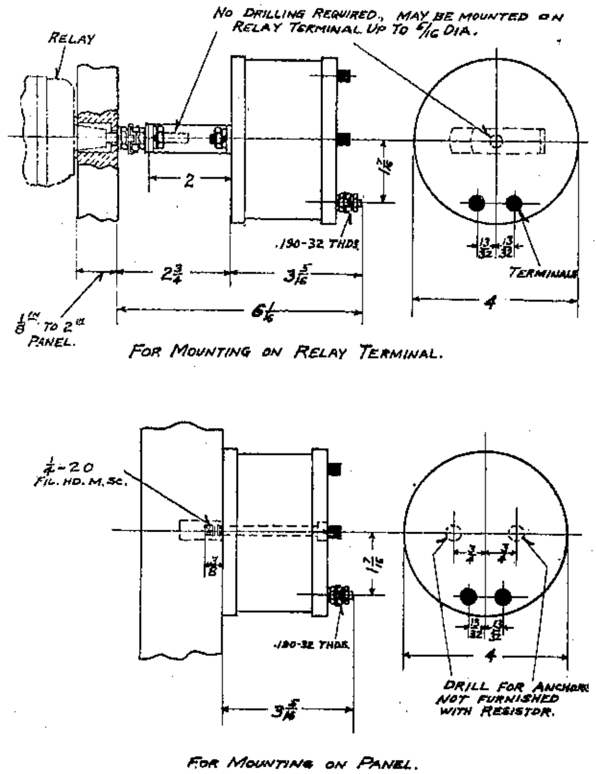


Figure 9
Outline and Drilling Plan for the Tapped a-c. Voltage Resistor for the Distance (CZ) Element.

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 is obtained 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.

For the special 1 to 6 ampere range relay the adjustments and calibration are the same as above except use tap 1 and one-fourth of the ampere values above.

Directional Element

The upper bearing screw should be screwed down until there is only .002 or .003 inch clearance between it and the shaft, and then securely locked in position with the lock nut. This adjuster can be made best by carefully screwing the top bearing screw until the disc fails to turn freely and then backing up a fraction of a turn. Great care must be taken in this adjustment to prevent damage to the bearings.

Adjust the stationary contact so that there is 1/32 inch separation between the moving contact and the stationary contact when the stop on the disc is against the right-hand side of the movement frame (front-view). This contact separation will reduce the time of operation of the directional element to a minimum. No harm will result if the directional contacts rebound closed momentarily after a fault is cleared, because the impedance contacts will be in the open position.

The tension of the spiral spring on the element should be just sufficient to return the disc to the stop and thus hold the contacts in the open position. In many applications there is no objection to having the contacts closed when the relay is deenergized. This can be done by shifting the spring adjuster, but the tension on the spring should never be enough to prevent the contacts from taking their proper position, either open or closed, during the time of short circuit when the forces acting on the disc are small.

There is an adjustable magnetic vane on either side of the upper pair of poles, which is intended to balance the current circuit. The normal adjustment is to disconnect the control spring and remove all potential from the voltage coil. Then, apply heavy currents to the current coils. Adjust the balancing vanes until there is no pronounced torque in either direction. This same adjustment may be used to positively close the contacts on current alone. This may be desired on some installations in order to insure that the relay will always trip the breaker even tho the potential may be zero.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core of 1/64 inch 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 moving core screw until the moving

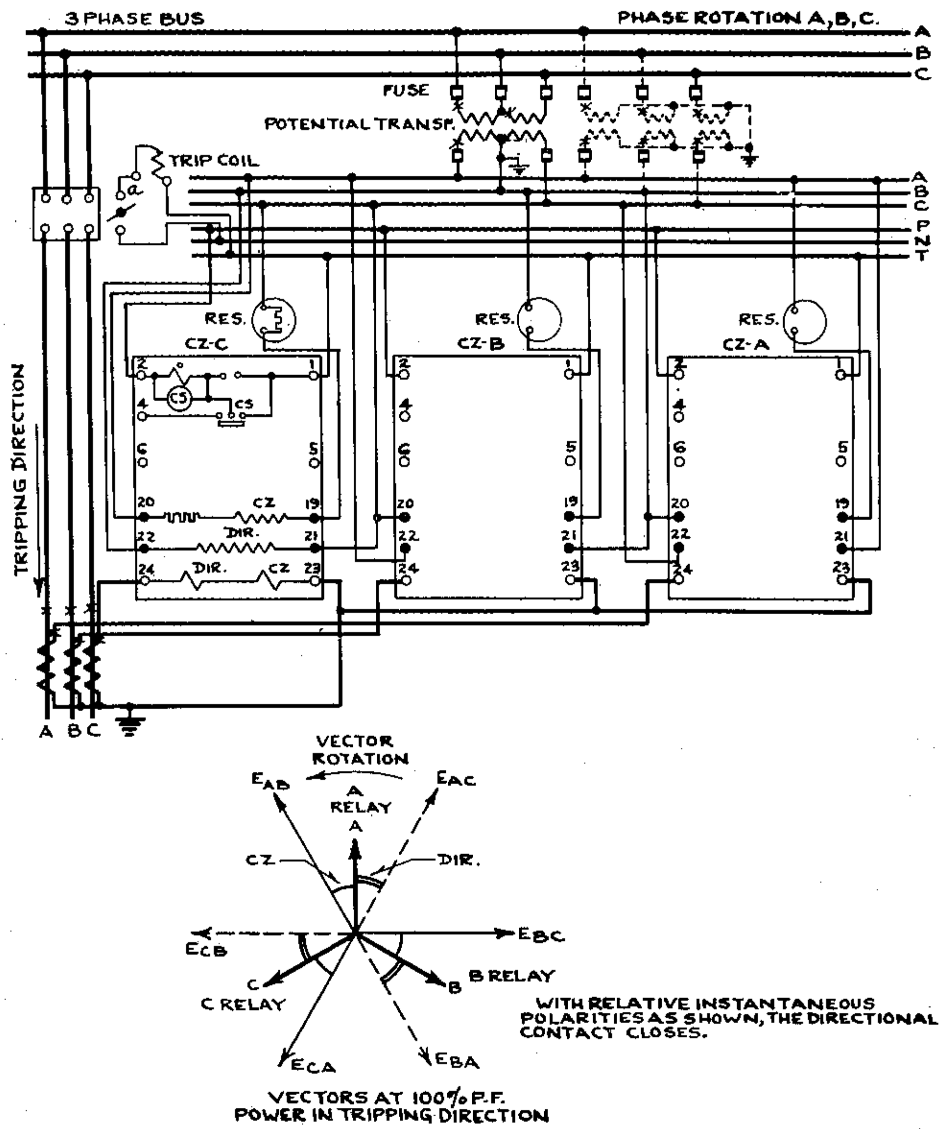


Figure 10
External Connections Using Star Current for All Elements.

core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point 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 inch by means of two small nuts on either side of the Micarta disc. The switch should pick up and seal in at 2 amperes d-c. Test to see that it does not stick when 30 amperes d-c. have been passed thru the coil.

Operation Indicator

Adjust the indicator to operate at 0.2 ampere d-c. gradually applied. Test for sticking after 30 amperes d-c. is passed thru the coil. Adjustments may be made by loosening the two screws on the under side of the assembly and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced with new springs, they should be weakened slightly by stretching just beyond their elastic limit.

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	-	23.0	81° lag
Impedance Element	125	11.0	7° lag
	1800	0.8	0°

CURRENT CIRCUITS AT 5 AMPERES

Circuit	Tap	V.A.	P.F.Angle
Directional Element	-	1.0	75° lag
Impedance Element	4	7.5	70° lag
	25	0.75	70° lag

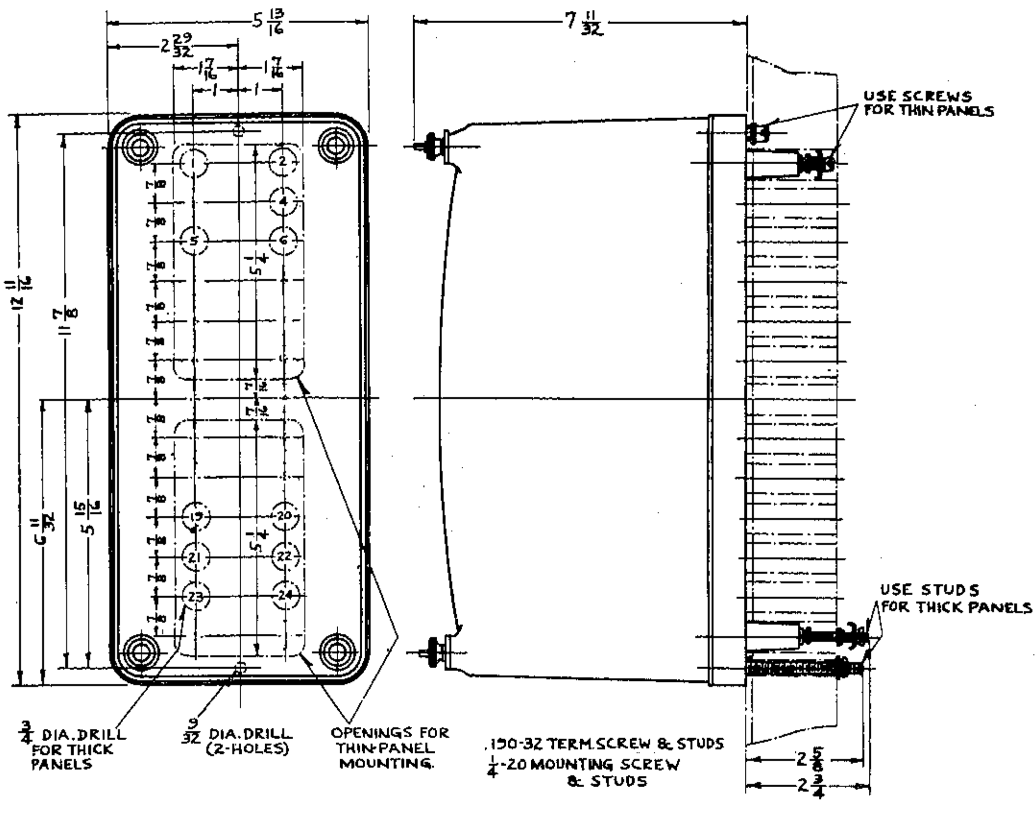


Figure 11
Outline and Drilling Plan for the Standard Projection Type Case.

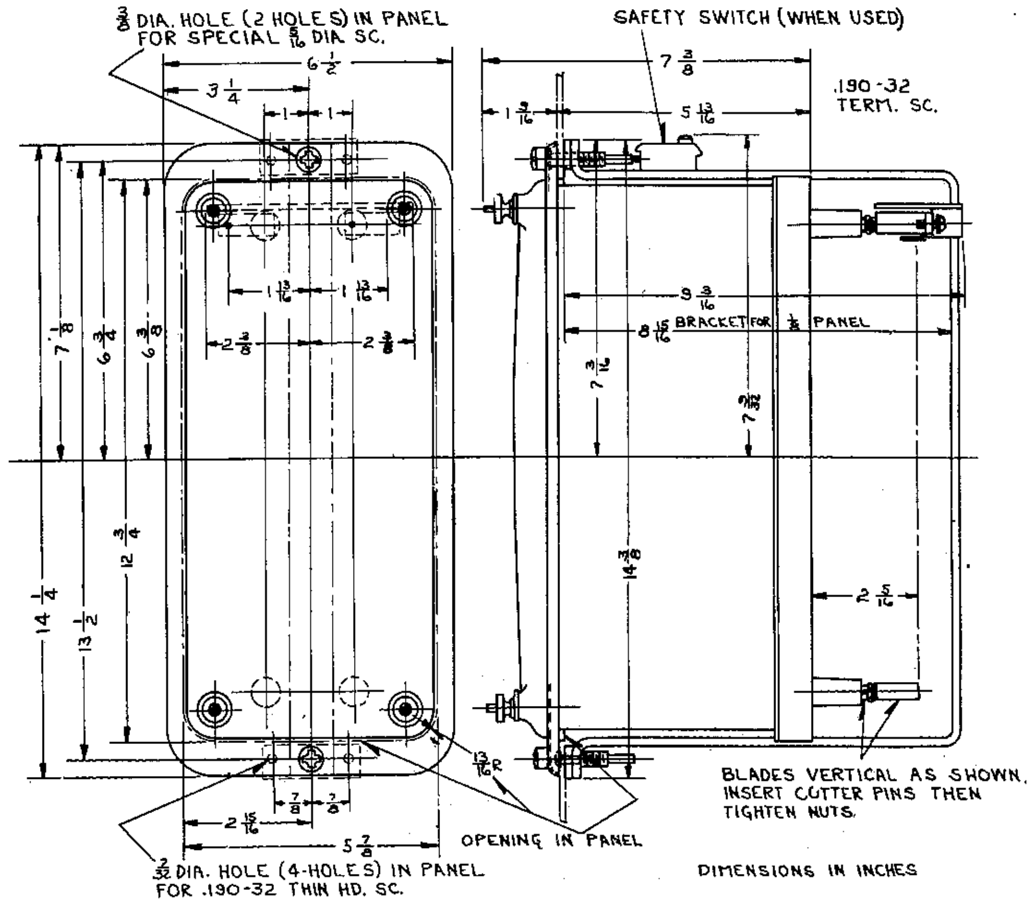


Figure 12
Outline and Drilling Plan for the Standard Semi-Flush Plug-In Case for 1/8" Panel Mounting.

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