Buffalo Service
Mr. John Atkinson,
Service Manager

Westinghouse

Type HCZ Impedance Relay

INSTRUCTIONS

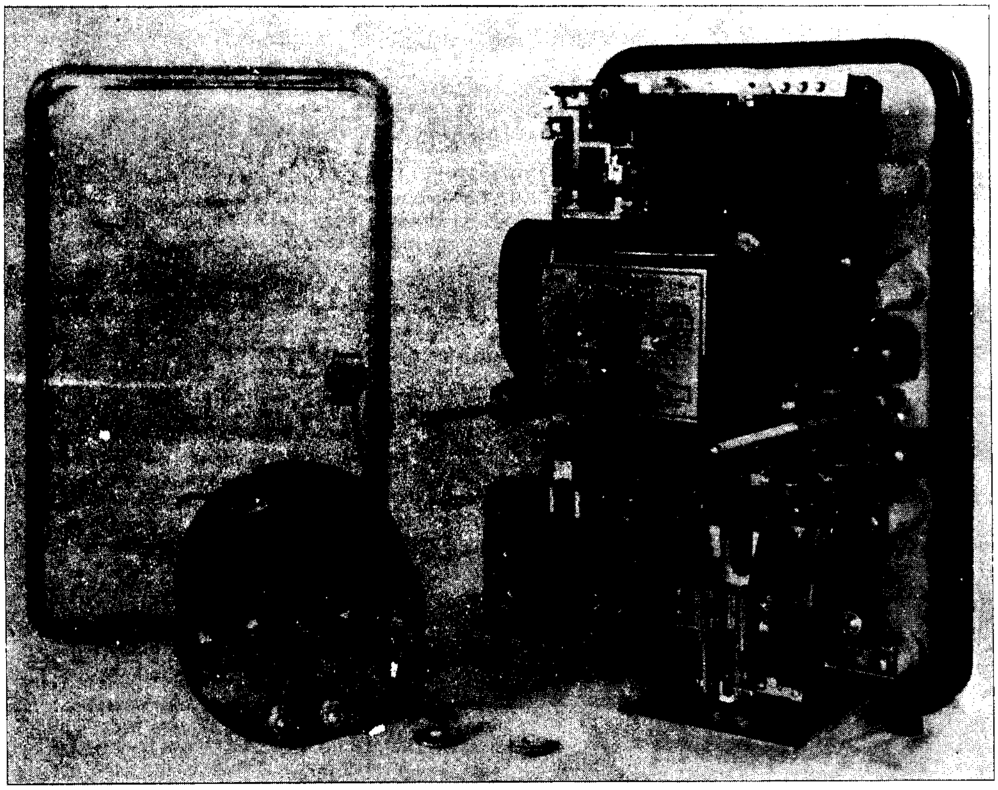

Fig. 1 - The latest Westinghouse relay, Type HCZ, combining the best features of the Type HZ and Type CZ Relays.

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.

The type HCZ relay is a combination of the high-speed element of the HZ relay and the distance element of the CZ impedance relay. The directional element is of the HZ high-speed type.

It has a time-distance characteristic which is a combination of the HZ and CZ relay, as shown in Fig. 2. For a fault within the first 80% of the distance to the next switching point, the time of operation is constant, or nearly so, for any given line and has a minimum value of about one-half cycle. For faults beyond this point, the time of clearing varies directly as the distance between the relay and the fault.

It is made in two ranges--one capable of being adjusted from .2 to 2 secondary ohms, and the other from .6 to 6 ohms.

CONSTRUCTION

Fundamentally, an impedance relay requires two sets of contacts in series; one on a distance-measuring element, and the other one a directional element. But, in order to provide for numerous practical requirements, the HCZ relay contains the following elements, shown schematically in Fig. 3.

Instantaneous Impedance Element (HZ)
Distance Element (CZ)
Directional Element (HZ)
Auxiliary Contactor
Fault Detector (Instantaneous Over-Current Coil)
Contactor Switch
Operation Indicator

The instantaneous impedance element protects the first zone of the section of transmission line, which zone consists of 80 or 90 per cent

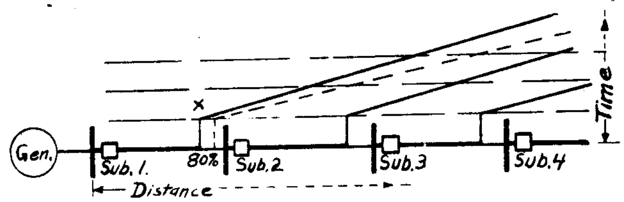

Fig. 2 - The Time-Distance Characteristic

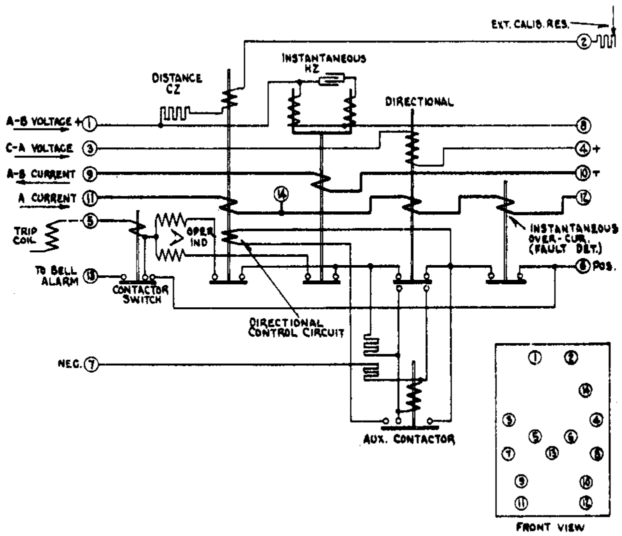

Fig. 3 - The Elements of the HCZ Relay

of the distance to the next switching station. It consists of a balanced beam of silicon steel which is pulled downward on the forward end by the current coil. The pull of the current coil is opposed by two voltage coils acting on the other end of the beam. The contacts of the instantaneous element are in series with the contacts on the directional element so that the breaker can be tripped only in case the power flow is in the proper direction.

The distance element is a timing device whose time of operation depends upon the distance to the fault. Its principal object is to secure proper discrimination when a fault is close to the next switching station. It consists of an induction disc which winds up a spring which, in turn, pulls on the core of a voltage restraining coil. When the pull of the spring overcomes the pull of the coil, the core snaps away and the contacts are closed. Thus the time required for the contacts to close on this element depends upon how fast the current turns the disc and how low the voltage drops. Obviously, the closer the trouble, the heavier the current and the lower the voltage, and it follows that the time of operation is proportional to the distance to the trouble. The contacts on this element are also in series with the directional element.

The Directional Element. The directional element of this relay is similar to the high-speed element used in the type HZ relay. A small voltage transformer causes a large current to flow in a one-turn, movable secondary, which current is substantially in phase with the voltage. This aluminum secondary loop is placed in a field produced by the current, and a torque is produced which rotates the loop one direction or the other, depending upon the direction of the power flow. The movement of the loop closes two contacts in each direction of travel. This element has true wattmeter characteristics and is extremely fast.

The directional element has its contacts in series with the two impedance elements (high-speed and distance), and it also, through the auxiliary contactor switch, exerts "directional control" on the current coil of the distance element. By this is meant that the distance element disc cannot begin to turn until power flows away from the switching station. The torque on the disc is produced by the interaction of the flux from the lower and upper poles. The lower pole is energized by the main current circuit. A secondary coil on this same pole acts as a transformer coil and produces a current which flows through the upper pole coils to energize them. This is the direction control circuit, and it is completed by contacts operated by the directional element. When these contacts are closed, the disc can turn, provided, of course, there is current enough in the main circuit.

Auxiliary Contactor. The directional element does not close the directional control circuit directly, but works through a small auxiliary contactor. When the tripping contacts of the directional element are closed, either due to outgoing load current or fault current, the auxiliary contactor is energized, sealing itself in and closing the directional control circuit on the distance element. (This operation is also supervised by the action of the fault detector described next.)

If a fault occurs in a direction to cause current to flow towards the bus, the back contacts of the directional element are closed. This de-energizes the coil on the auxiliary contactor and its contacts open. This opens the directional control circuit on the distance element and allows it to return to its de-energized position.

Fault Detector. (Instantaneous Over-Current Coil) This accessory is added to improve the performance of the relay in a number of minor ways. It is a simple over-current relay adjusted to operate at 8 amperes and reset at 5 amperes. Its contacts are in series with the other contacts, and it will, therefore, keep the trip circuit open except when a heavy current flows in the line. This accomplishes two desirable results: First, it prevents the auxiliary contactor from operating, and thus relieves the battery of a constant though small drain; second, it prevents the relay from operating if the A-C. potential on the impedance elements should be lost due to the blowing of a pair of potential transformer fuses or an improper switching operation.

There is one objection to the use of this relay element; namely, it will prevent the instantaneous impedance element from tripping the breaker if the short circuit current should be less than the 8 ampere setting on the over-current coil. If this is an important consideration, the contacts of the over-current coil may be permanently short circuited.

The Contactor Switch. Following past practice in the design of protective relays and in order to increase the capacity and certainty of action of the trip contacts, a special direct current contactor switch is in series with the main contacts of the relay and with the trip coil of the breaker. When the relay contacts close, the coil becomes energized and seals the switch contacts. This shunts all the main relay contacts, thereby relieving them of duty of carrying the trip current. These contacts will not open under any circumstances until the tripping circuit is opened by the auxiliary switch on the breaker.

The contactor switch operates on a minimum of 1.0 ampere, but the trip circuit should draw at least 3 to 5 amperes in order to reduce the time of operation of the switch to a minimum and provide more positive operation. If the type HCZ relay is used to trip an auxiliary multi-contact relay, provision should be made for loading down the trip circuit with a resistor in parallel with the operating coils of the auxiliary relay. Also, since the total trip circuit resistance in the relay is approximately 3.8 ohms, care must be taken to see that the breaker trip coil will receive enough current when low voltage control is used. A control battery of less than 24 volts will probably be unsatisfactory.

OPERATION

The instantaneous element measures the impedance of the line to which it is connected by measuring the ratio of the current and voltage supplied to it. The relay is connected to receive a current and voltage proportional to those existing on a high tension line. With a fault at X in Fig. 2, a given amount of current, I, will flow from the relay location to the fault. With zero voltage existing at the fault, the voltage back at the relay must be proportional to the drop in the line due to current, I, or proportional to IZ, where Z is the impedance to neutral of the line from the relay to the point of fault. The ratio of the current to the voltage applied to the relay is constant for any value of current as the voltage on the relay is equal to the current times the line impedance. Therefore, if the instantaneous element of the type HCZ relay is adjusted by the core screw and taps on the current coil for a value of current such that the pull of the current coil is just equal to the potential restraint for a fault at X, the beam will be balanced for a fault at that point for any value of current. Now, if the fault occurs to the left of X, the pull of the current coil will be greater than that of the potential coil and the beam will trip. If the fault occurs to the right of X, the beam will not trip as the voltage pull is greater due to a larger amount of impedance and correspondingly larger potential restraint. It is customary to set this balance point at 80 per cent of the distance from the relay to the next switching point so as to allow a margin of safety.

The same reasoning applies to the distance element except that instead of a definite balance point, the element has a definite time of operation for every position of a fault even though the value of the current should vary.

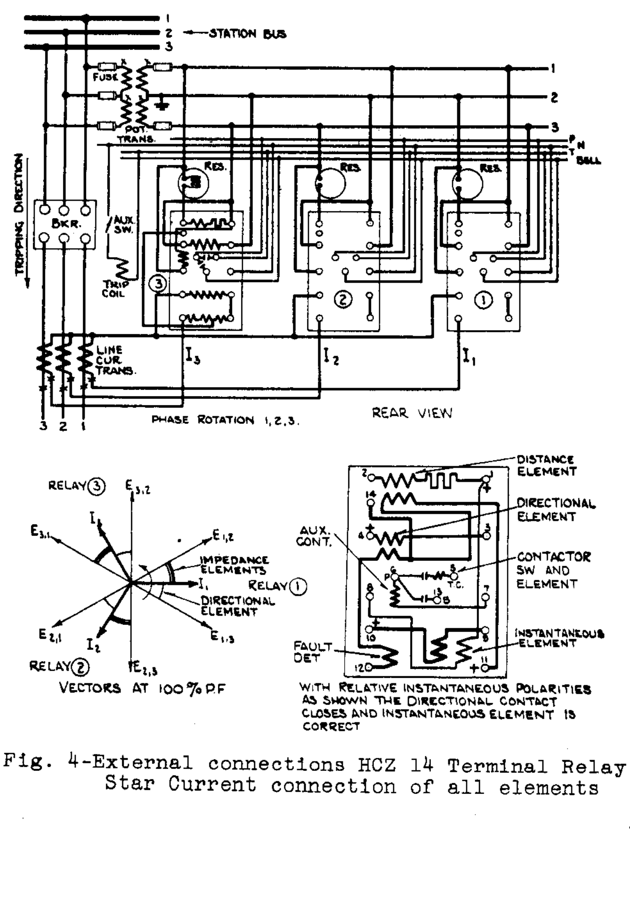

Fig. 4-External connections HCZ 14 Terminal Relay
Star Current connection of all elements

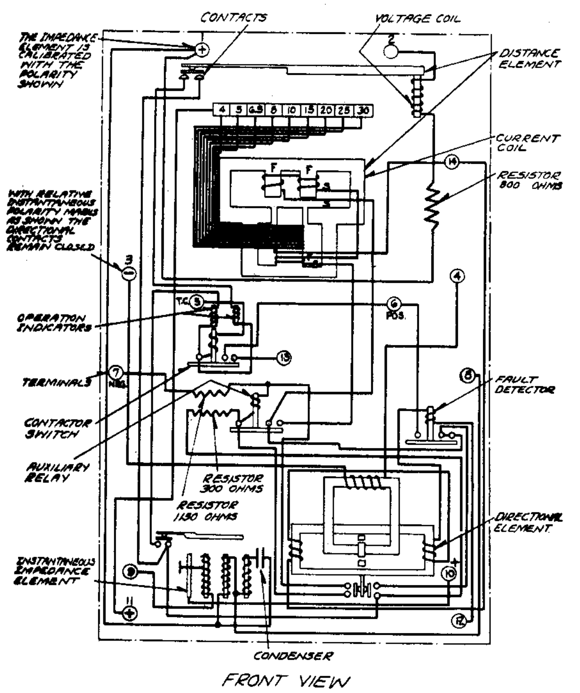

Fig. 5-Relay-Type HCZ 14 Terminals-Wiring Diagram

INSTALLATION

The HCZ relay should be mounted in a location free from dampness, excessive heat, or excessive vibration, and must not be subject to severe jars. After the relay has been properly mounted, take off the cover and remove the blocking from the various elements. Do not disturb the adjustments of the relay other than as herein mentioned. If they are disturbed during installation, it will, in some cases, seriously change the characteristics of the relay, preventing proper operation.

Connect the relay in the circuit according to Fig. 4 unless some other diagram has been provided. Care must be taken to insure correct polarity. This diagram shows the conventional connection with star-connected current transformers. Other connections are sometimes used, and for this reason an extra terminal (14) is provided on certain styles of relay, as shown in the internal diagram, Fig. 5.

The directional element for the type HCZ relay should be so connected that the current will lead the voltage by 30° when the line power factor is 100%. There are two reasons for this connection, both of which relate to the conditions which exist at times of single phase short circuits. The first advantage is that the relay voltage is obtained from one of the phases which is not in trouble and is, therefore, high. The second reason, and the really important one, is that with this connection, the phase relations during time of trouble can never be distorted to such a point that the directional element will operate backwards.

The following method should be used to insure that relays are properly connected. Connect the current coils of a single-phase wattmeter in series with the current winding of the relay. With power flowing in either direction, if the current is lagging so that the power factor is between 100% and 50%, select a pair of voltage leads which give the highest reading on the wattmeter. The two leads selected should be connected to the directional element potential terminals. The front contacts (right hand front view) should close when power flows away from the bus.

SETTING THE RELAY

Instantaneous Element

The instantaneous element is adjusted only by varying the pull on the armature of the current coil. There are two of these adjustments: one in the number of turns (T), and the other the air gap between the core and the armature (S). The simple equation is $TS = KZ_b$. In this equation Z_b is the length of the balanced zone; it must not be confused with the total Z used when calculating the setting of the distance element. For easy reference, all the equations are tabulated and it is suggested that this tabulation be carefully followed.

For star-connected current transformers, the formula is $TS = 17.3\ Z_b\ R_c/R_v$; where Z_b is the impedance to neutral of the balanced zone, R_c is the current transformer ratio, and R_v is the potential transformer ratio. By solving this equation the value of TS is obtained. Pick out a suitable value of T on which to adjust the current tap, then pick out a value of S which will give the desired product, TS. For example, take a 110,000 volt line 75 miles long with a current transformer ratio of 200/5 and an impedance to neutral of .75 ohm per mile. Then the total Z = .75 x 75 = 56.2 ohms. Then Z_b = .8 x 56.2 = 45 ohms (to the balance point). R_c = 40and R_v = 1,000. Then TS = 17.3 x 45 x 40/1,000 = 31.2. From this it appears that T = 20.8 or T = 29.8 might be suitable. Try them both, S = 31.2/20.8 = 1.50 and S = 31.2/29.8 = 1.04. The S scale does not run up to a value of 1.50 so the proper value is S = 1.04, which is on the scale and can be interpolated between 1.0 and 1.1. The answer to this example is T = 29.8 and S = 1.04.

The calibration on the instantaneous core screws (S) is a series of dots which pass around the large head in a spiral manner. To set on any particular number, the screw should be turned until the mark corresponding to that number is exactly under the end of the pointer. Accurate setting can be made by interpolating between the marked points, for a line impedance which requires such settings.

Distance Element

The distance element introduces a time delay inthe operation of its breaker and before making any calculations it is necessary to fix upon the time interval which it is desired that the relay should give. Following the practice of other types of relays, it will probably be desirable to use a time interval between consecutive circuit breakers of .5 or .6 second, depending upon the time required for the circuit breakers to open and the margin of safety desired. The adjustments on this element consist of taps on the current coil and a tapped resistor in series with the potential coil. The marking on the current adjustment, T_c, represents approximately the minimum current which will cause the disc to turn. This relay element will give the best results if the short circuit has a value of at least twice the tap setting which is used. Therefore, the first step is to determine by calculation the minimum possible short circuit current. The value of current adjustment, T_c, should then be picked out which is less than half of this value. The relay will operate very well between 200% and 1500% of this value, T_c, but it will operate better if a value can be chosen such that the short circuit current, with the fault at the far end of the section, is always between 300% and 1000% of T_c. Additional precautions necessary in determining T_c, T_v, and K are discussed in a following paragraph. After having selected a value of T_c, the proper voltage adjustment can then be determined from the fundamental formula $T_v = K\ T_c\ Z$. Takin into account the current and potential transform ers, the formula will be $T_v = K\ T_c\ Z\ R_c/R_v$. This value of T_v is marked on the external resistor which accompanies the relay. The value of K depends upon the current transformer connections and upon the time interval which is desired, and both of these values are in the table of formula:

Z = impedance to neutral of the full length section of line to be protected. Sometimes the Z actually used in setting the distance element is less than the impedance of the line due to the presence of parallel sections or short adjacent sections, or the necessity for cooperation with other types of relays. This is discussed under the heading, Interference Between Relays. This does not apply to Z_b used in setting the instantaneous element.

Z_b = impedance (to neutral) to the balance point of the instantaneous element. The recommend ed Z_b = .8 Z

R_c = ratio of current transformers

R_v = ratio of potential transformers

INSTANTANEOUS ELEMENT:

T = the marking on the current coil taps. It is proportional to the number of turns.

S = the marking on the scale of the core adjusting screw. The greater the number, the greater the pull of the current.

DISTANCE ELEMENT:

T_v = the potential coil series resistance tap value. The lower the tap value, the greater the pull of the restraining coil and the longer the relay time.

T_c = the current coil tap value. It represents the minimum current which will cause the disc to turn. For a given current flow, the greater the tap that is used, the less the pull and the longer the time.

K' = arbitrary constant the value of which determines the time interval between successive relays on the system.

	Recommended values of:	
Time Interval	K'_s Star Connection	K'_d Delta Connection
1.5	57	33
1.4	60	35
1.3	64	37
1.2	68	39
1.1	72	42
1.0	77.5	45
.9	83	48
.8	91	53
.7	101	59
.6	113	65
.5	130	75
.4	152	88

INSTANTANEOUS ELEMENT	Star Current	Delta Current	(1-Phase) Relay Test
Fundamental Equation (3 phase short circuit)	$TS = \frac{K_s Z_b R_c}{R_v}$	$TS = \frac{K_d Z_b R_c}{R_v}$	$TS = KZ_b$
Same with value of K supplied.	$TS = \frac{17.3\ Z_b R_c}{R_v}$	$TS = \frac{10\ Z_b R_c}{R_v}$	$TS = 10\ Z_b$

When an auxiliary current transformer is used to obtain delta current, its coil ratio should be included as a factor in the numerator of the equation, see paragraph on auxiliary transformer.

DISTANCE ELEMENT			
Fundamental Equation (3 phase short circuit)	$T_v = \frac{K'_s T_c R_c}{R_v}$	$T_v = \frac{K'_d T_c Z R_c}{R_v}$	(use curve) $T_v = K'_d T_c Z$

RANGE OF RELAY ADJUSTMENT

These relays may be manufactured in several ranges. The instantaneous element makes use of the first element in the HZ relay. This has the following marked values of S: .8 - .9 - 1.0 - 1.1 - 1.2 - 1.3 - 1.4. The scale is continuous so that intermediate values may be obtained, and is the same in relays of all ranges.

The relay having a nominal secondary ohm rating of .2 to 2 has fixed current tap values as follows: T = 2 - 3 - 4 - 6 - 9 - 13.

The relay having a nominal secondary ohm rating of .6 to 6 ohms has taps as follows: T = 6.2 - 9.4 - 13.5 - 20.8 - 29.8 - 45.

The distance element makes use of the CZ relay element and has the following current taps: T_c = 4 - 5 - 6.5 - 8 - 10 - 15 - 20 - 25 - 30. Special relays have taps of 1 - 2 - 3 - 4 - 5 - 6.

The voltage taps on the series resistor are: T_v = 125 - 150 - 175 - 200 - 250 - 300 - 350 - 400 - 500 - 600 - 700 - 800 - 1000 - 1200 - 1400 - 1600 - 1800.

READJUSTING AND TESTING

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

Adjusting the Instantaneous Element

Refer to Fig. 6. Adjust the stop screw on the rear of the beam to give a clearance of ".025 between the rear of the beam and the voltage iron circuit. With the beam in this position, that is, back against the stop, adjust the gap vertically to obtain ".009 between the adjustable iron and the beam. Also, with the beam in the same position, adjust the gap between the front end of the beam and the stop in the upper core screw to ".020.

The stationary contacts should be adjusted to give .015" clearance between them and the silver bridge in the beam when the beam is back against the stop. The bridge should be made to touch both contacts simultaneously, and deflect the contact spring at least .010" before the beam strikes the bronze stop on the core screw. If the previous adjustments are correct, this deflection figures out to be .014".

CAUTION: Care should be exercised in adjusting the stationary contacts to see that too much "follow" in the deflection of the stationary contacts is not allowed as this will slightly delay the resetting of the high-speed element and thus the directional element contacts may get closed before the impedance contacts are opened and result in incorrect tripping. Make certain that the stop on the voltage side is absolutely clean, otherwise the impedance at which the beam trips may be considerably affected. The stop can be easily cleaned by drawing a piece of paper or cloth under it while it is firmly pressed down.

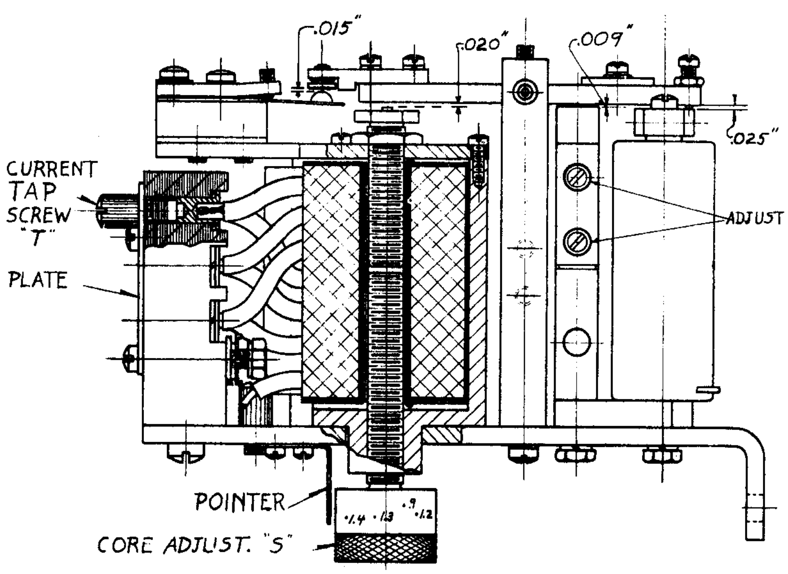

Fig. 6 - Instantaneous Element

Adjusting the Distance Element

Adjust the stop screw on the rocker arm so that there is a gap of .005" between the core screw and the plunger when the beam is reset. With the beam in this position, adjust the position of the stationary contacts so that there is a gap of .020" between them and the moving contacts. Also, see that both contacts make simultaneously. The factory method for adjusting the gap to .005" is shown in Fig. 7. If a dial micrometer is available, it can easily be clamped to the relay so that this measurement may be made. If a micrometer is not available, it is better not to attempt to adjust this gap, although the following method, if carefully done, will be approximately correct. With the stop screw loose and the plunger touching the core, screw down the stop screw till it just touches the plate. Then turn the screw down one-half revolution and lock it. The screw has 100 threads per inch so that one-half turn is equivalent to .005". Check this by measuring the time of operation as described in the last paragraph of this section.

When working with the rocker arm, be careful not to break the jeweled ring bearings.

Extreme care should be taken to obtain a fine balance of the rocker arm member. Loosen the clamp screw on spring adjuster and turn adjuster to the left so the rocker is just about balanced. The object is to adjust the initial tension on the spring so that with the voltage coils unexcited the weight of the plunger arm is just barely sufficient to hold the contacts open. Under this condition, a movement of about 1-1/2" of the disc should be sufficient to close the contacts. When the disc is allowed to return to its initial position, the contacts should open of their own accord. In other words, the plunger arm should be balanced so that the plunger will always return to a position with the stop screw lightly against the cross bar.

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. If any tendency to bounce occurs, it indicates that the balance of the rocker arm is too critical. The spring adjuster should be turned very slightly in the clockwise direction from above.

After the rocker arm has been properly balanced, the tripping current should be adjusted. The directional control circuit must be closed either by blocking the auxiliary contactor in the upper position or by putting a jumper between the front and left-hand terminal of this contactor. First, place the current tap screw in the 4 ampere position and leave the voltage coil unexcited. Adjust the position of the balance weight on the rocker arm so that the contacts just barely close at 4 amperes plus or minus 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 previously. After the correct position of the weight has been found, it should be locked securely in place with the set screw.

Finally, the relay should be checked by measuring its time of operation at several points as follows, using the 4 ampere tap and measuring the voltage across the coil alone:

Volts	Amperes	Time (Cycles)
0	8	22 or less
6.25	12	45
25.	48	75

These time values should be the average of a number of tests. The check at zero voltage shows that the relay 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 proper time.

Adjusting the Directional Element

With the relay in the vertical position, check the aluminum loop to see that it is properly centered and free to swing between the pole pieces. The loop should assume a vertical position when de-energized. With the loop vertical adjust the stationary contacts, both in front and in the rear, to give about 1/32" contact separation. The total contact travel should be 1/16", possibly less. The

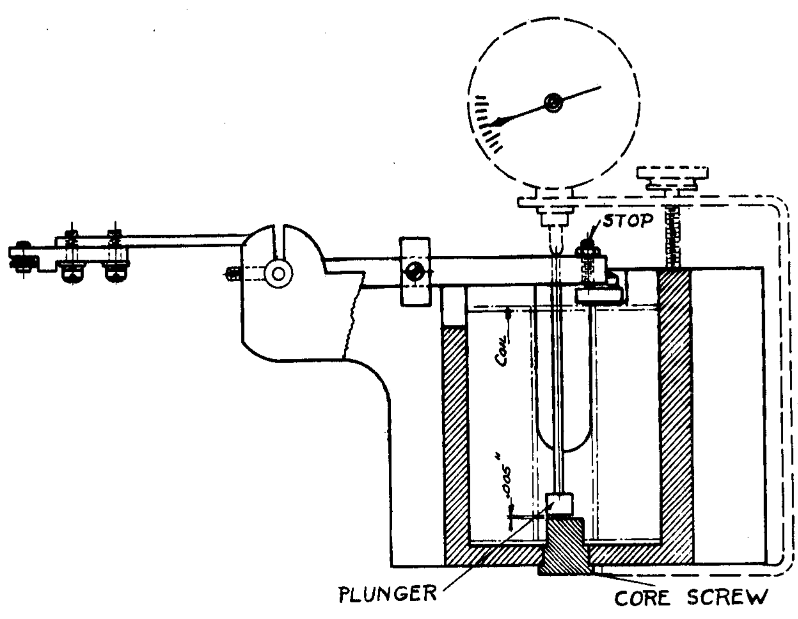

Fig. 7 - Adjusting the Air Gap

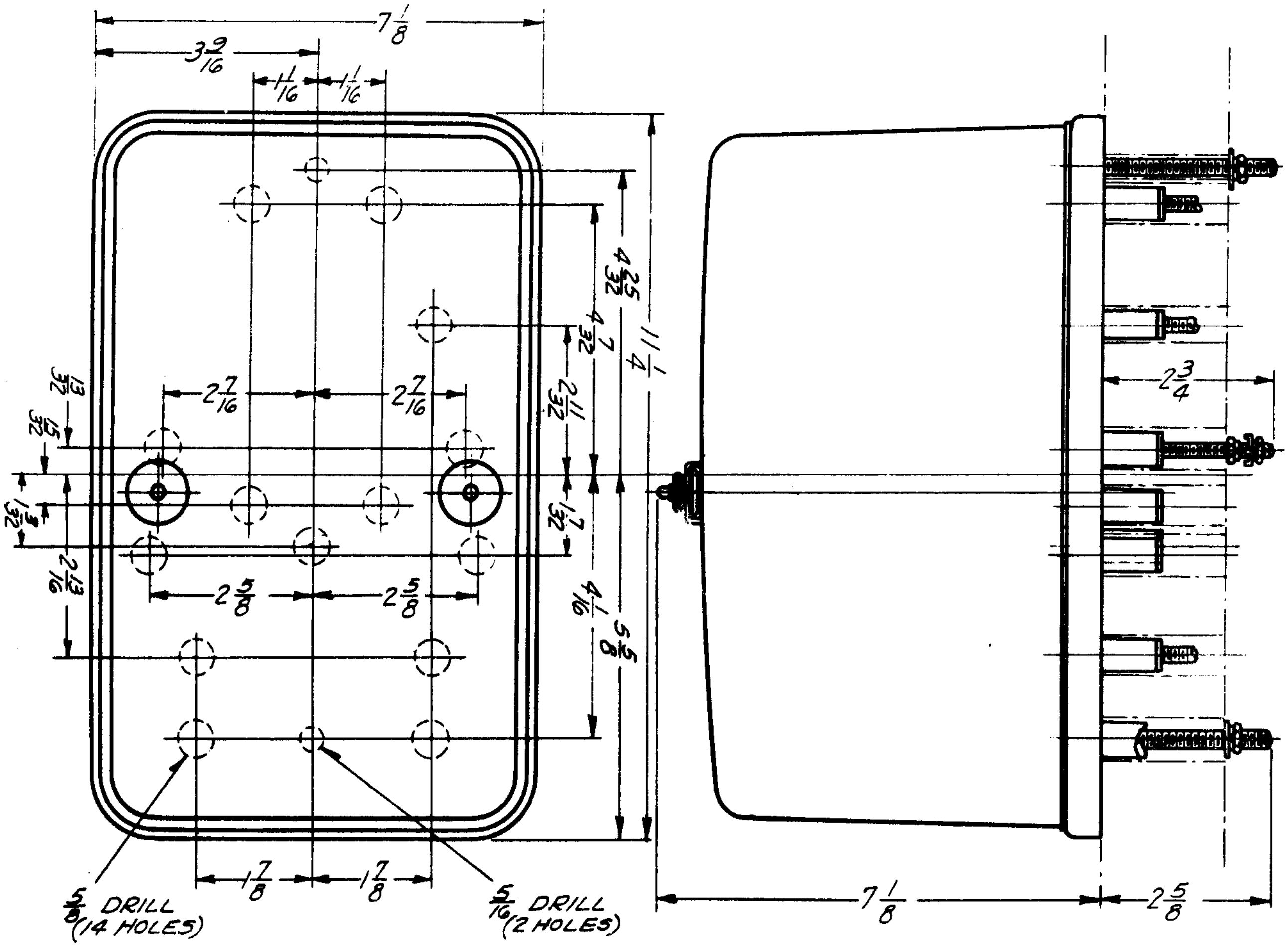

Fig. 8 - Relay-Type HCZ 14 Terminals - Outline and Drilling Plan

back stop screws should be accurately adjusted to give between .002" and .005" follow to the right-hand or tripping contacts. The follow on the left-hand contacts should be not greater than .003" in order to minimize the rebound.

It is necessary that the directional element cooperate with the instantaneous element in preventing improper tripping during certain line faults. The most serious case is where the directional element is closed due to the normal power flow and a short circuit then occurs on another nearby line. It is necessary that the directional contacts should open before the impedance contacts can close. Any excessive follow on the contact springs will materially delay the time of opening the circuit. In many installations the requirements are so severe that the follow on the right-hand contacts should be cut down to the minimum of .002" which is so small that it is just perceptible.

Behind the current coils are a pair of stop screws which limit the travel of the loop. Adjust these stops so that they touch the loop at the same time that the contacts strike their back stops.

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" end play.

Apply 110 volts, 5 amperes, in phase, and make sure that the contacts will close properly in both directions. The element should operate on at least 16 watts; two volts and 8 amperes is a suggested test.

Adjustment of Auxiliaries

Adjust the contact gap of the auxiliary contactor so that the latter will operate at a minimum of 90 volts D-C. This gap should be approximately 3/64". Energize the directional element at 4 volts and 5 amperes unity power factor, and see that the auxiliary contactor picks up when the right-hand contacts are made. See that the contactor remains sealed-in with the movable directional contacts in the middle position (not touching either stationary contacts) and that it resets when the left-hand contacts are made.

Contactor Switch. The contactor switch should have a travel of approximately 1/16" and should operate at 1.0 ampere D-C. There should not be sticking or freezing of the plunger at 30 amperes D-C.

Operation Indicator. Adjust the operation indicator to operate 1 ampere D-C. gradually rising current. Also, make sure that the iron vane will not stick magnetically when operated momentarily at approximately 15 amperes D-C.

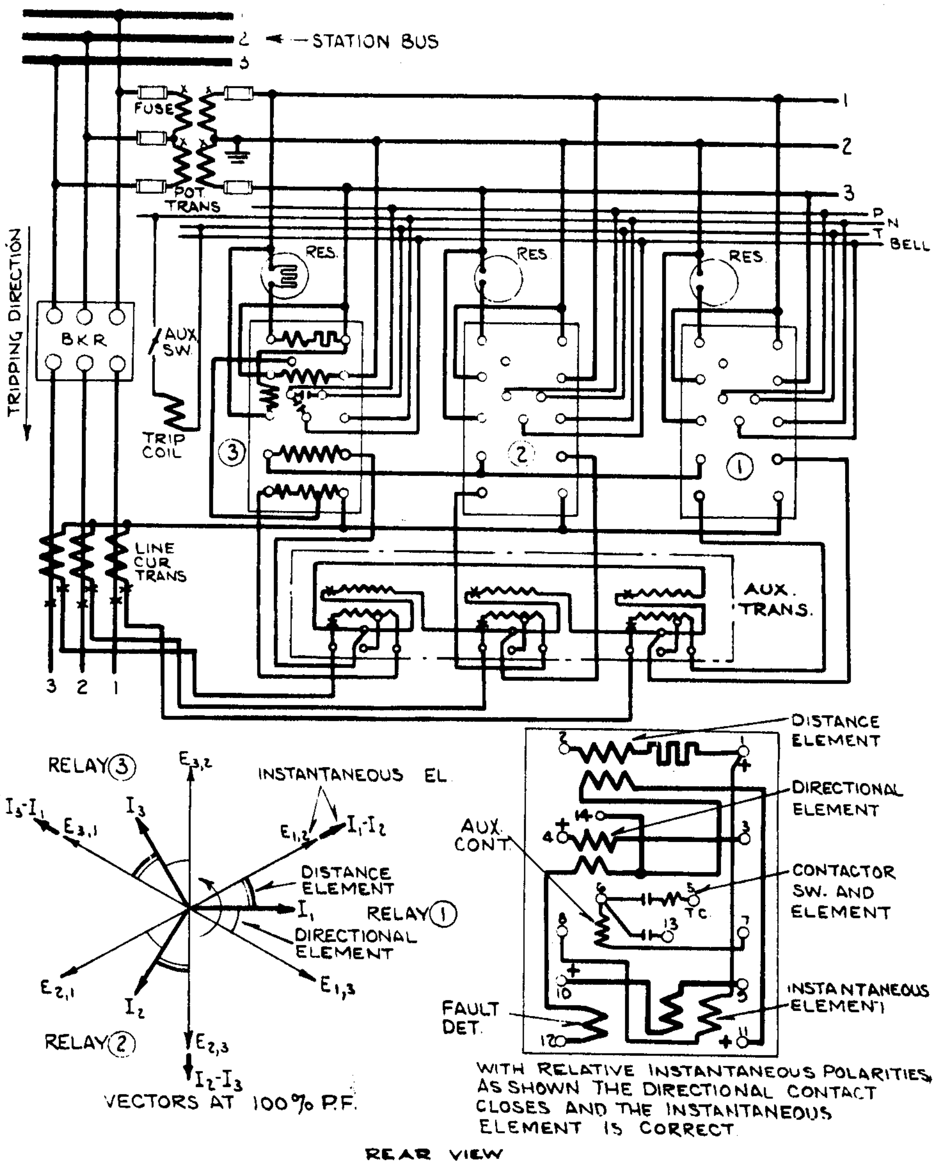

Fig. 9-External Connections HCZ 14 Terminal Relay Star Current Connection of Directional and Distance Elements-Delta Connection of Instantaneous Element using Auxiliary 5/5 Current Transformers

Fault Detector. This should pick up at 8 amperes and drop out before the current has been decreased to 5 amperes.

MAINTENANCE

It is necessary to give this relay regular attention, and an inspection every six months is recommended. Examine both the instantaneous and distance element stops on the voltage coil to make sure that they have not stuck. It is desirable to clean both stops with benzine (petroleum ether) on every inspection.

All the contacts should be kept clean and in good alignment. A small file, rather than sandpaper, should be used for cleaning the contacts because it is not likely to leave foreign matter imbedded in the silver.

The mechanical condition of all operating parts should be given careful inspection. Where convenient, operating current and voltage should be applied for the purpose of operating all the parts.

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