



INSTALLATION • OPERATION • MAINTENANCE INSTRUCTIONS

TYPE HCB PILOT WIRE 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 HCB relay is a high speed pilot wire relay designed for the complete phase and ground protection of two and three terminal transmission lines. Simultaneous tripping of the relay at each terminal is obtained in about 1/60 of a second for all faults. A complete installation for a two terminal line consists of two relays, two insulating transformers, and an interconnecting pilot wire circuit. For a three terminal line, three relays, three insulating transformers, and a wye-connected pilot wire circuit with branches of equal impedances are required.

CONSTRUCTION

The relay consists of a combination positive and zero phase sequence filter, a saturating auxiliary transformer, two rectox units, a polar type relay unit, and a neon lamp all mounted in a single case. The external equipment normally supplied with the relay consists of an insulating transformer, a milliammeter and test switch. The construction of these components is as follows:

Sequence Filter

The currents from the current transformer secondaries are passed thru a filter consisting of a three winding iron core reactor and two resistors. The secondary of the three

winding reactor and the resistors are tapped to obtain settings for various fault conditions. The output of this filter provides a voltage across the primary of the saturating transformer proportional to the positive sequence current plus a constant times the zero sequence current. This combination is selected as the discriminating function because it can be adjusted to have definite values lying in a comparatively small range for all types of phase and ground faults. Thus, a single operating element can be used for all types of faults. The two lower tap dials provide the adjustment of the relative amounts of positive and zero sequence currents that are combined to produce the required discriminating voltage. The right-hand lower tap dial (front view) adjusts the sensitivity to ground fault currents. The left-hand lower tap dial adjusts the positive phase sequence sensitivity when the ratio of the current transformers at the terminals of the line are not equal.

Saturating Auxiliary Transformer

The voltage from the filter is fed into the tapped primary (upper tap plate) of a small saturating transformer. This transformer is used to limit the voltage impressed on the pilot wire, and to provide a small range of voltage for a large variation of maximum to minimum fault currents. Thus, high operating energy is obtained for very light faults and limited operating energy for heavy faults. The relay operating characteristic changes from percentage differential at low current values to approximately directional characteristics at high current values.

The upper tap plate changes the out-put of the saturating transformer, and is marked in amperes required to operate the relay when the

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* Denotes change from superseded Issue

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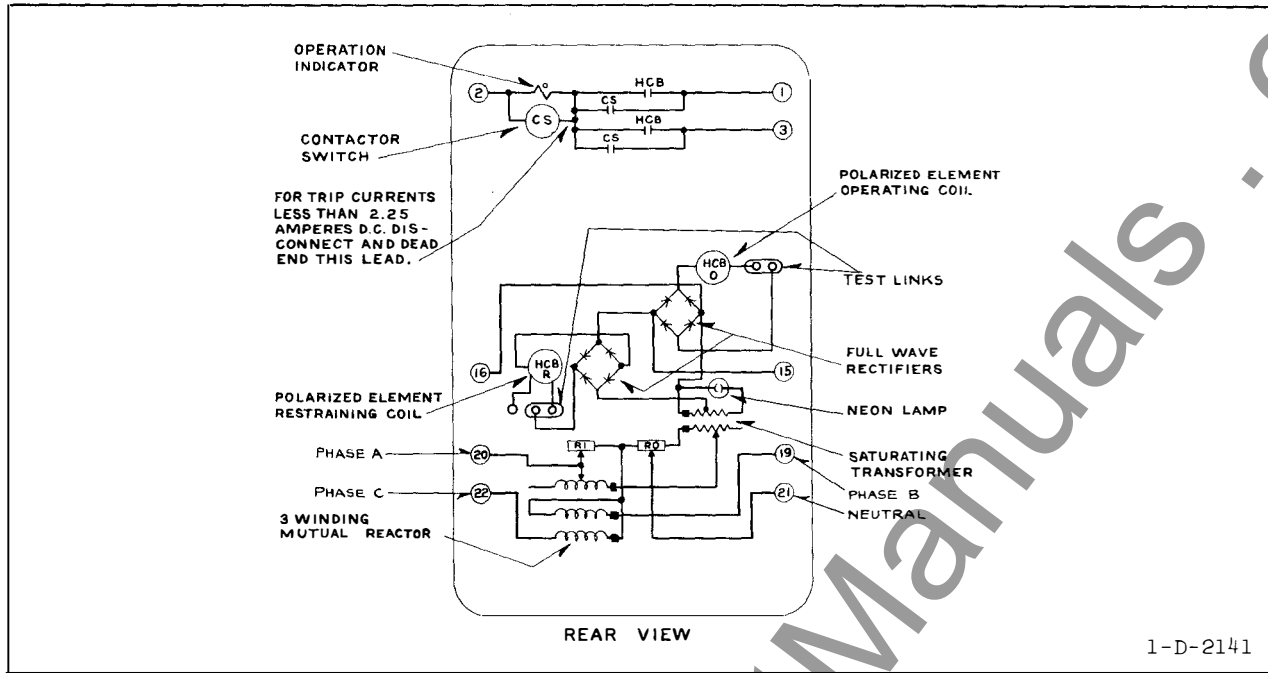


Fig. 1—Internal Schematic of the Type HCB Relay in the Standard Case.

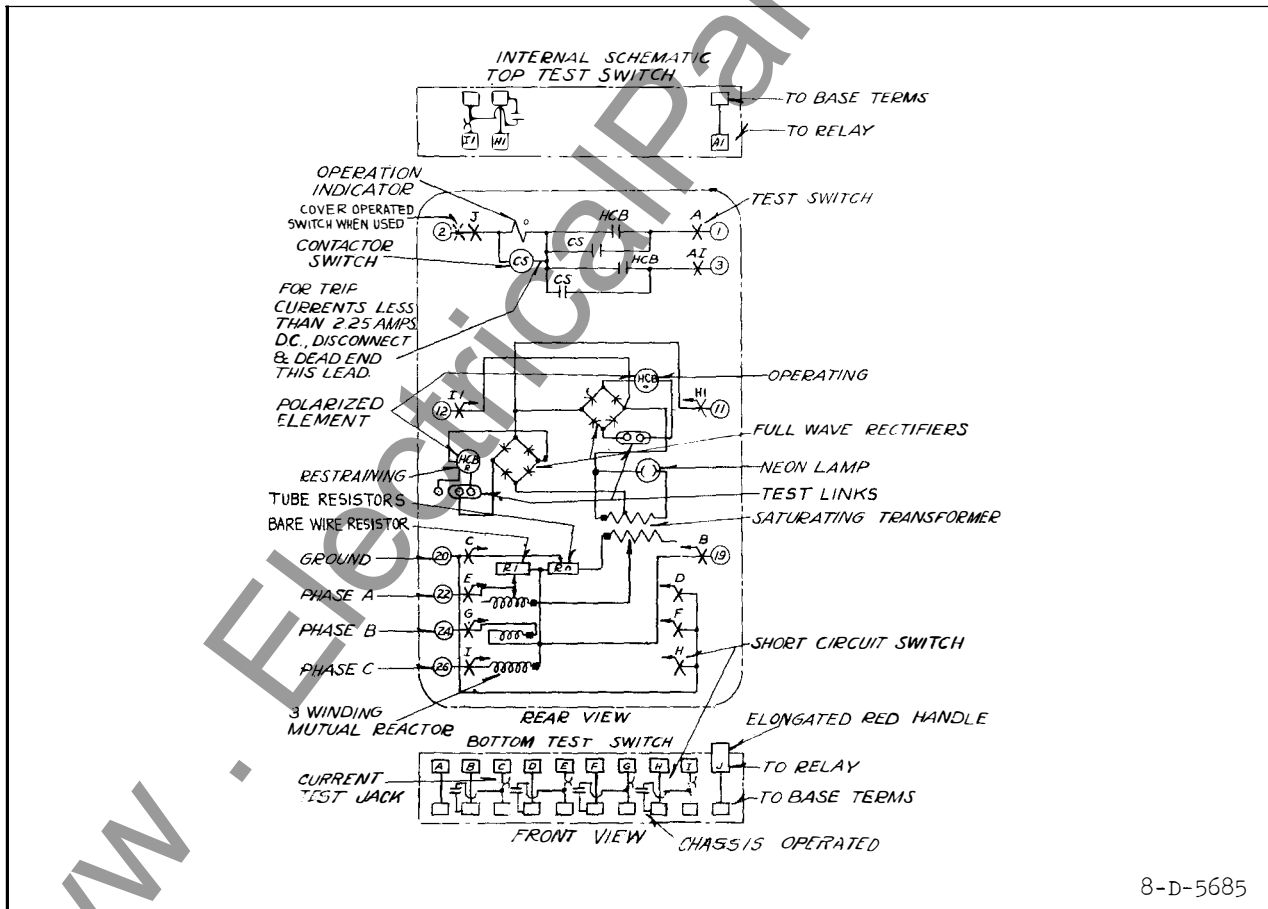


Fig. 2—Internal Schematic of the Type HCB Relay in the Type FT Case.

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pilot wire is open or when equal amounts of currents are fed to an internal fault thru the line terminals. For further discussion, see section entitled, "Settings".

Rectox Units

The secondary of the saturating transformer feeds the two rectox units, the insulating transformer, and the pilot wire, as shown schematically in Fig. 8. The rectox units are used to convert the a-c output of the saturating transformer to d-c for use on the d-c polar-type relay element. The use of a sensitive polar-type relay, requiring a small amount of energy, keeps the volt-ampere burden on the current transformers very low.

Polar-Type Relay

This element consists of a rectangular shaped magnetic frame, an electromagnet, a permanent magnet, and an armature with a double set of contacts. The poles of the permanent magnet clamp directly to each side of the magnetic frame. Flux from the permanent magnet divides into two paths, one path across the air gap at the front of the element in which the armature is located, the other across two gaps at the base of the frame. Two adjustable shunts are located across the rear air gaps. These change the reluctance of the magnetic path so as to force some of the flux thru the moving armature which is fastened to the leaf spring and attached to the frame midway between the two rear air gaps. Flux in the armature polarizes it and creates a magnetic bias causing it to move towards one or the other of the poles, depending upon the adjustment of the magnetic shunts. Two concentric coils are placed around the armature and within the magnetic frame. The coils are connected in opposition with one used as a restraining winding and the other as an operating winding. The restraining winding sets up a magnetic field, which, in conjunction with the field from the permanent magnet holds the contact in the normal open position. The operating winding produces a magnetic field which acts to move the armature in the contact closing direction. The restraining winding is tapped and the leads are brought out to taps at the upper left of the relay. The left hand position of the test link is the minimum restraint connection, and the right

hand position is the maximum restraint connection.

The moving contacts are fastened on the free end of the leaf spring. Two stationary contact screws are mounted to the left (front view) of the moving contact assembly and are adjusted for normally open contacts.

Insulating Transformer

The insulating transformer is connected as shown in Fig. 8 and serves to isolate the terminal equipment from the pilot wire. This avoids interconnection of station grounds that may have large differences of potentials between them. The mid-taps of the parallel-wound secondary windings are brought out separately to provide a means of connecting supervisory relays symmetrically within the pilot wire circuit. When auxiliary supervisory relays are not used, these mid-taps are to be connected together and may be grounded to drain the voltages induced along the length of the pilot wires when these voltages approach the voltage limit of the cable. This is discussed further under Pilot Wire below.

The transformers have a 4/1 ratio and are insulated for 5000 volts.

Pilot Wire

One pair of pilot wires connecting the secondaries of the insulating transformers is required to provide a continuous circuit between the relays. For the pilot wires a lead-covered twisted pair of No. 19 wire or larger is recommended, however, open wires may be used. The following points should be considered in selecting pilot wire circuits.

1. The total circuit resistance (including neutralizing reactors when used) between terminals of the Type HCB relays exclusive of the insulating transformers and expressed in terms of the pilot wire voltage must not exceed 2000 ohms for two terminal lines (500 ohms per wye branch for three terminal lines).

2. The shunt capacity between pilot wires should not exceed 0.75 microfarad per pilot wire terminal for two terminal lines (0.60 mfd. per leg. for three terminal lines). In cases where this value is exceeded, compensating reactors will be required to reduce the

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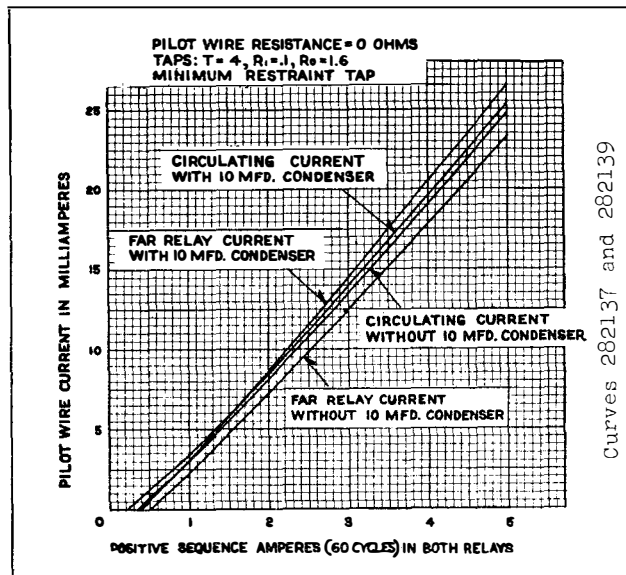


Fig. 3—Typical Test Output Vs. Input Relay Current in A Two Terminal Line With Zero Pilot Wire Resistance.

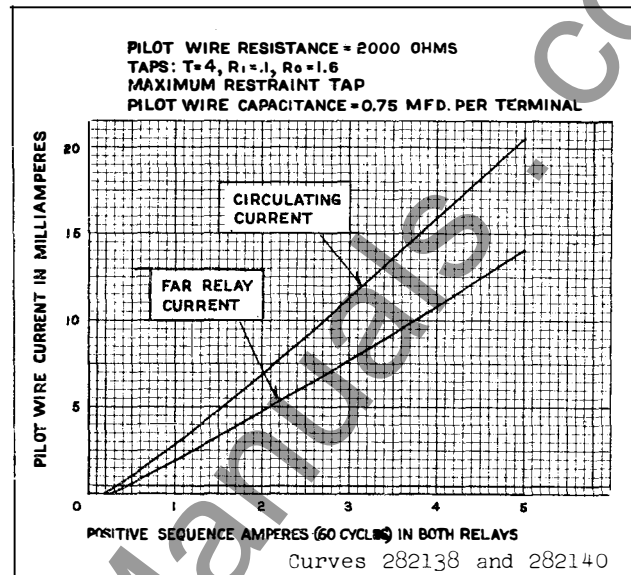


Fig. 4—Typical Test Output Vs. Input Relay Current In A Two Terminal Line With 2000 Ohm Pilot Wire Resistance With or Without the 10 MFD. Condenser.

shunt currents which tend to desensitize the relay.

3. The difference in the longitudinal induced voltage which appears between wires should not exceed 15 volts total (7.5 volts per relay).

4. The induced voltage to ground which occurs on the pilot wires during maximum fault conditions should not exceed the rating of the pilot wires or insulating transformers. The transformers are insulated for 5000 volts. In general, the pilot wires will be insulated for a much lower voltage.

Induced voltages and differences between station ground potentials which appear along the pilot wire may be reduced to safe limits by the following means:

- a. Excessive voltages can be reduced by grounding the mid-taps of the insulating transformers and allowing current to circulate over the pilot wires to ground. The voltage between pilot wires must not exceed 15 volts.
- b. For more serious induction two winding neutralizing reactors can be used to

limit the voltages. In cases where the sheath current may be sufficient to cause damage the sheath must be insulated from ground and three winding neutralizing reactors should be used. Reactors are available for 1000 and 2000 volt neutralization.

- c. Another method consists of connecting a suitable two winding drainage reactor and a protector tube, such as the type KX642, to the pilot wires at suitable points. The arrangement is such that when the tube flashes because of high extraneous voltages, both wires are connected to ground, through the reactor and the tube. The impedance to ground is low, but the impedance between wires is kept high to avoid interfering with the operation of the HCB relays.

OPERATION

The HCB pilot wire relay operates as a percentage differential device when the fault currents are small, and has essentially directional characteristics, comparing the direction of current flow at the terminals of the protected section when the fault currents are large.

The voltage appearing across the secondary of the saturating transformer is balanced against a similar voltage at the opposite end of the protected line section, thru the restraint winding of each relay, the insulating transformers and the pilot wires, as shown in Fig. 8. On external faults, a flow of fault power thru the protected line section, produces voltages across the secondaries of the saturating transformers which are essentially equal and in series. These voltages act to circulate current thru the restraining coil of each relay which is connected in series with pilot wire. Under this condition the operating coils connected across the pilot wires do not receive sufficient current to overcome the restraint and so tripping does not occur.

For internal faults with equal feed-in from the terminals, the voltages across the saturating transformers are in opposition. This results in all of the current flowing thru the restraining and operating coils in series and none thru the pilot wires. The relays at the ends of the section operate under this condition to give simultaneous tripping of the breakers at the terminals of the protected section.

The impedance of the filter and the operating coil can be adjusted so that the sum of the minimum trip currents from all terminals, when fed in from only one terminal, is sufficient to trip the relays simultaneously. This is affected somewhat by very low or very high pilot wire impedance, since in this case energy to trip any terminal not supplying current to the fault, must be carried over the pilot wire. Consequently, settings are based on total fault current fed in from all terminals disregarding the current distribution from the terminals.

If the pilot wire becomes open circuited, all of the current in the restraining coil will also flow thru the operating coil. While this condition exists the relay operates as an overcurrent device and will trip on all faults and also on heavy loads greater than the relay setting. A short circuit on the pilot wires will prevent tripping, since it short circuits the operating winding of the relay.

However, if the short circuit on the pilot wire is so placed that it is 1000 or more pilot wire ohms from one of the two relays, then that relay will not be blocked.

The current and voltage impressed on the pilot wire do not exceed 100 milliamperes and 60 volts. The wave form and magnitude of the pilot wire current is such that telephone interference is within the limits allowed by the Bell Telephone Company. This permits the use of leased telephone lines as a pilot wire channel.

SUPERVISION

A faulted pilot wire mentioned above may be detected by the milliammeter and test switch (supplied with the relay) or by continuously-operated supervisory relays supplied as extra equipment.

The condition of the pilot wire under normal load conditions may be determined by reading the pilot wire current by means of the test switch and milliammeter.

A comparison of the readings obtained with the typical values of Figs. 3 and 4 will indicate the condition of the pilot wire. It should be noted that, when the far relay current is being read, the near relay is short circuited, and the far relay is shunted by the resistance of the pilot wires plus the impedance of the near relay insulating transformers.

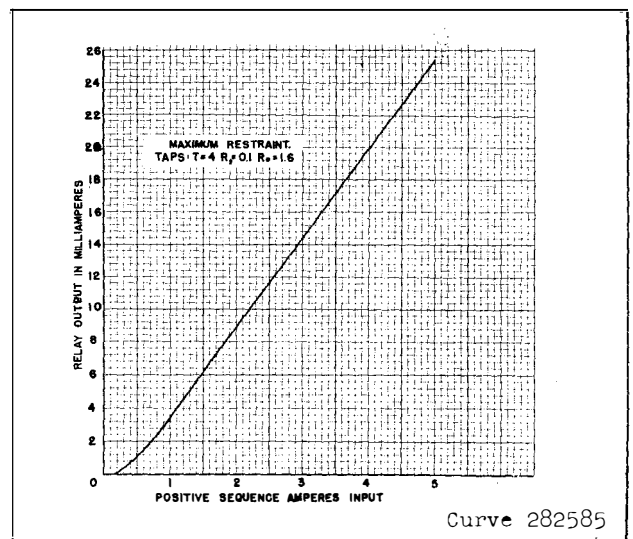


Fig. 5—Typical Curve of Relay Output vs. Positive Sequence Amperes Input.

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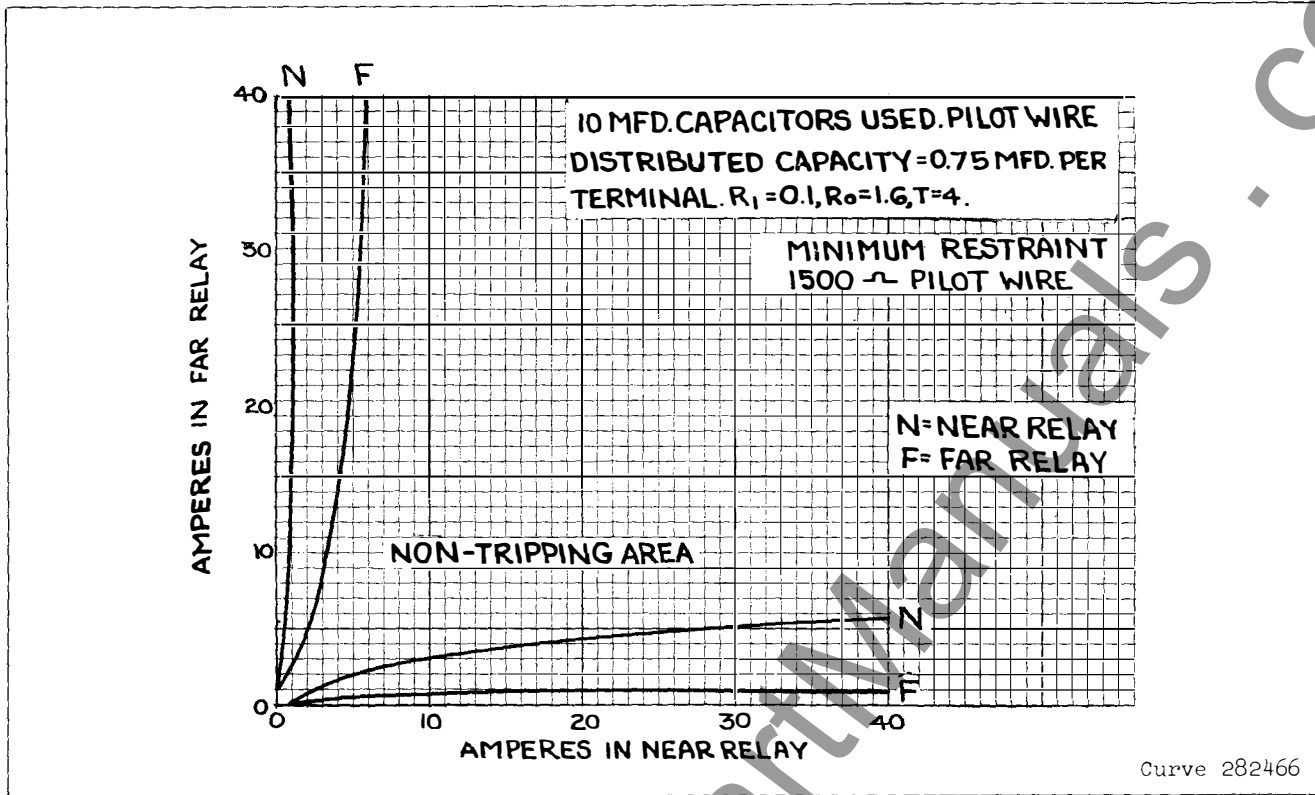


Fig. 6- Typical Operating Characteristics On Phase A to Ground Faults With Currents In Phase and 1500 Ohm Pilot Wire.

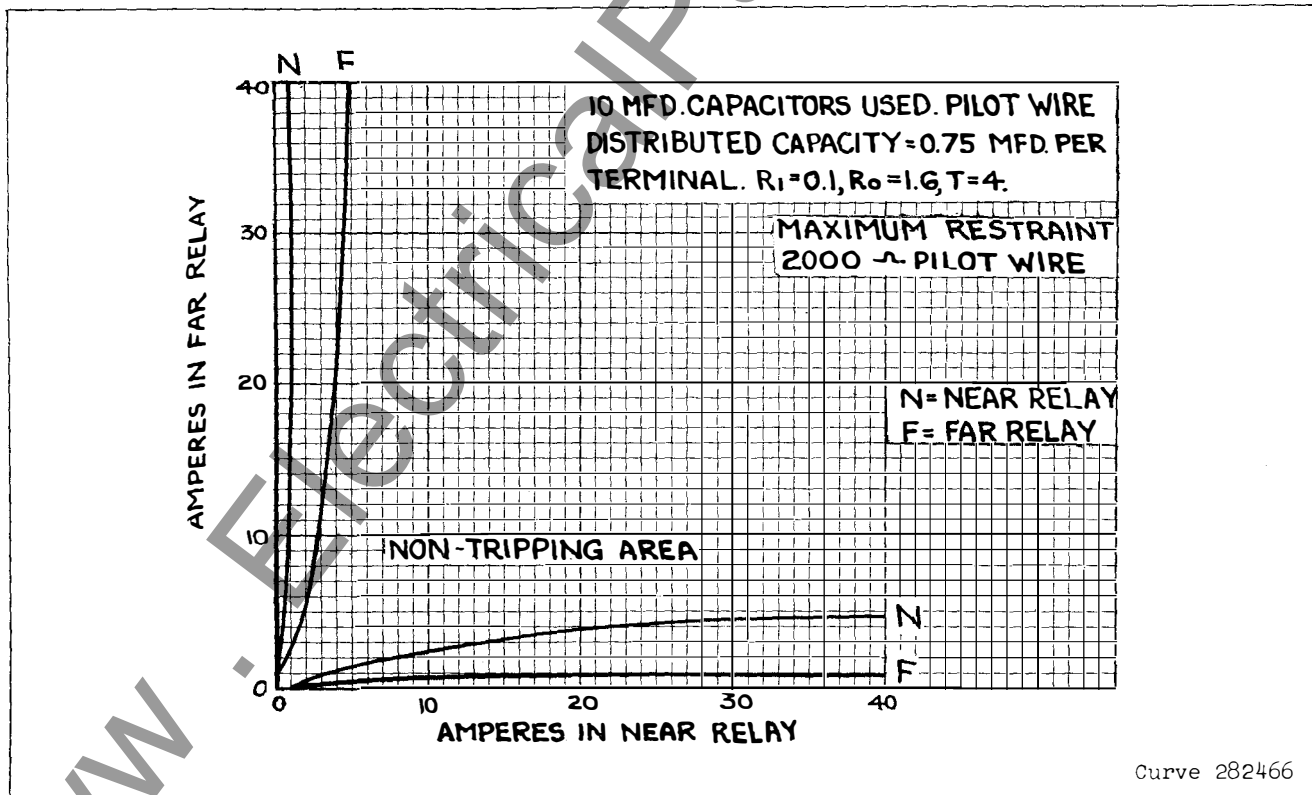


Fig. 7- Typical Operating Characteristics On Phase A to Ground Faults With Currents in Phase and 2000 Ohm Pilot Wire.

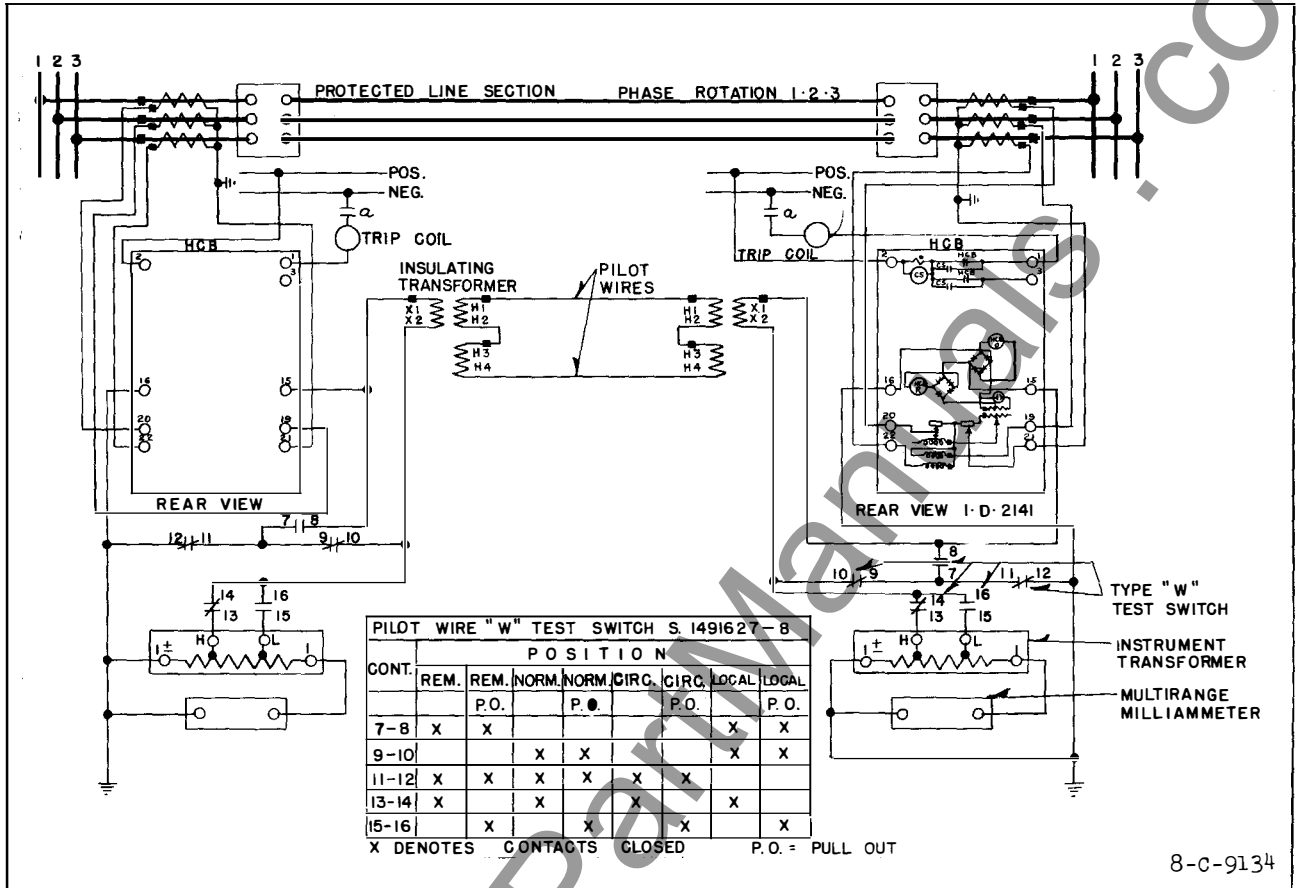


Fig. 8—External Connections of the Type HCB Relay in the Standard Case For Phase and Ground Protection of A Two Terminal Line.

Fig. 5 shows typical values for relay output current vs. positive sequence input current. For this test, the insulating transformer is short circuited on the low voltage side so that the milliammeter is connected directly across the relay output terminals.

CHARACTERISTICS

Typical overall operating characteristics of the relay are illustrated in Figs. 6 and 7. The general shape of these curves is similar for other types of faults, relay settings, and pilot wire lengths. The ampere abscissa and ordinate scales may be interpolated to show the operating characteristics for other conditions and tap settings by the use of the following equation:

$$I_{an} = \frac{2.35}{T} \left\{ 2I_{a1}^{\circ} R_1 + I_{a0}^{\circ} (R_1 + 3R_0) \right\} \quad (1)$$

where I_{an} is the value to read on the curve (Figures 7 and 8).

For example, assume relay tap settings of $T = 6$, $R_1 = .1$, $R_0 = .68$, and also assume that a phase b to ground fault occurs, for which the "near" relay components are as follows:

$$I_{a1}^{\circ} = 10 + j0 \quad (2)$$

$$I_{a0}^{\circ} = .9a^2 (I_{a1}^{\circ}) \quad (3)$$

In equation (3), the factor .9 was arbitrarily used as a reminder that the distribution factors for positive and zero sequence components are not necessarily equal for any given system. Also, the operator a^2 signifies that I_{a0} is 240° leading I_{a1} for a phase b to ground fault, neglecting dissimilarities in the sequence networks. First substituting the particular condition of equation (3) in equation (1) gives

$$I_{an} = \frac{2.35}{T} I_{a1} \left\{ 2R_1 + .9a^2 (R_1 + 3R_0) \right\} \quad (4)$$

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Substituting values for the several taps in (4) gives

$$I_{an} = \frac{2.35}{6} I_{a1} \left\{ \begin{array}{l} 2 \times .1 + .9 (-.5-j.866) \\ (.1 + 3 \times .68) \end{array} \right\} \quad (5)$$

$$I_{an} = .392 I_{a1} \{-.763-j1.67\} \quad (6)$$

$$I_{an} = I_{a1}^{\circ} .718 \underline{245.4^{\circ}} \quad (7)$$

Substituting the numerical value for I_{a1} given by equation (2) results in a numerical value for I_{an} of

$$I_{an} = .718 \times 10 = 7.18 \text{ amperes.}$$

This is the value to read on the curve for the typical values chosen for the taps R_1 , R_0 , and T at the particular phase b to ground fault values indicated by equations (2) and (3). It should be noted that the total phase b current to the "near" relay is $I_b = I_{b1} + I_{b2} + I_{b0} = 29$ amperes, assuming $I_{b2} = I_{b1}$.

For a phase to phase fault, there is no zero sequence current, and the phase current, I_{LL} , is equal in magnitude to $\sqrt{3} I_{a1}$. Hence, for phase to phase faults, equation (1) reduces to:

$$I_{an} = \frac{2.35}{T} \left\{ 2 \frac{I_{LL}}{\sqrt{3}} R_1 \right\} \quad (8)$$

SETTINGS

The HCB relay has three different taps which are provided to obtain flexibility for a wide range of application. The taps to provide correct operation for any given application are easily selected and have a wide latitude. That is, correct operation can be obtained for different combinations of tap values. The following discussion establishes limits for the various tap settings under different operating conditions. It should be kept in mind that settings to obtain operation on minimum internal fault conditions are based on the total current that flows into the section from all terminals.

Positive Sequence Filter Tap

The lower left tap (R_1) has three available taps .075, .10, and .15 (the .075 tap is actually marked .07 because of space limitations). These taps permit compensation for current transformers of different ratios at the various terminals. Where the current transformers have the same ratios, the values of R_1 should be the same on all relays. A value of $R_1 = .10$ is usually recommended except where a more sensitive setting of "T" (described below) is desired than is obtainable with $R_1 = .10$. Where the current transformers are different at the different terminals, select the value of R_1 which is proportional to the current transformer ratios. For example, assume a ratio of 300/5 at one terminal and 600/5 at another terminal. Set $R_1 = .075$ at the 300/5 terminal and $R_1 = .15$ at the 600/5 terminal. The ratios obtainable are 1/1, 2/1, 3/2, and 4/3. In the event that the ratio of the R_1 taps is not 1/1 it will be necessary to compensate for the unbalance by increasing the minimum trip calibration 25% above its normal value or by neutralizing the distributed capacitance of the pilot wire. The same procedure applies to three terminal lines.

Positive Sequence Current Tap

The upper tap (T) has values of 4, 5, 6, 8, 10, 12 and 15. This tap should be selected to assure operation on minimum internal line-to-line faults, and where possible, to prevent tripping on load current if the pilot wire becomes accidentally open circuited. The highest setting of "T" that will cause operation on internal line-to-line faults is given by the equation :

$$T = 5.7 I_{LL} R_1 \quad (9)$$

where I_{LL} is the total minimum internal line-to-line secondary fault current fed from all terminals, divided by the number of terminals.

The factor "5.7" is used as the operation of the positive sequence filter is such that the relay requires 1.73 times as much current for operation on a line-to-line fault as on a three phase fault. This means that the three-phase trip setting should be 57% of the desired line-to-line current setting. Also, the

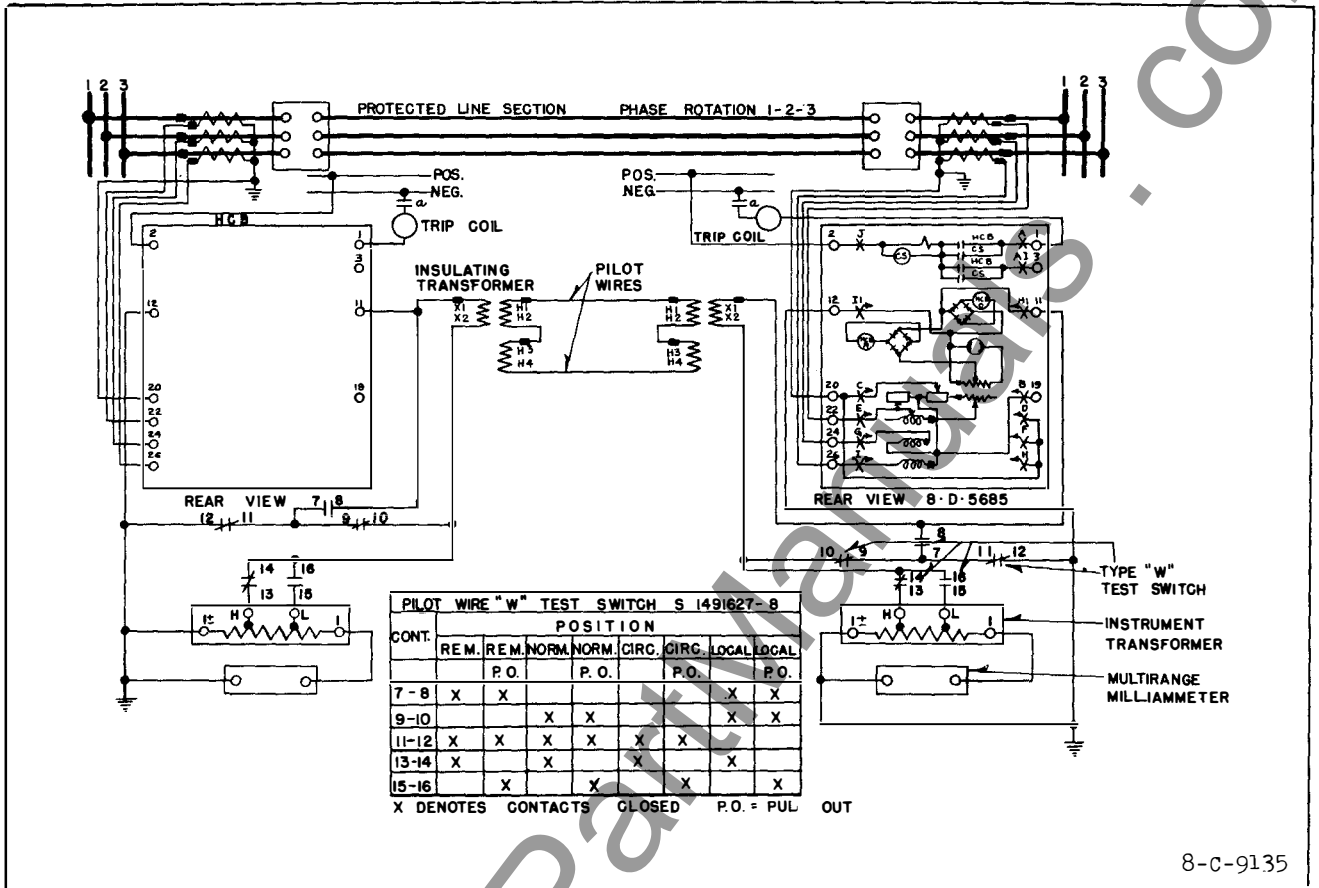
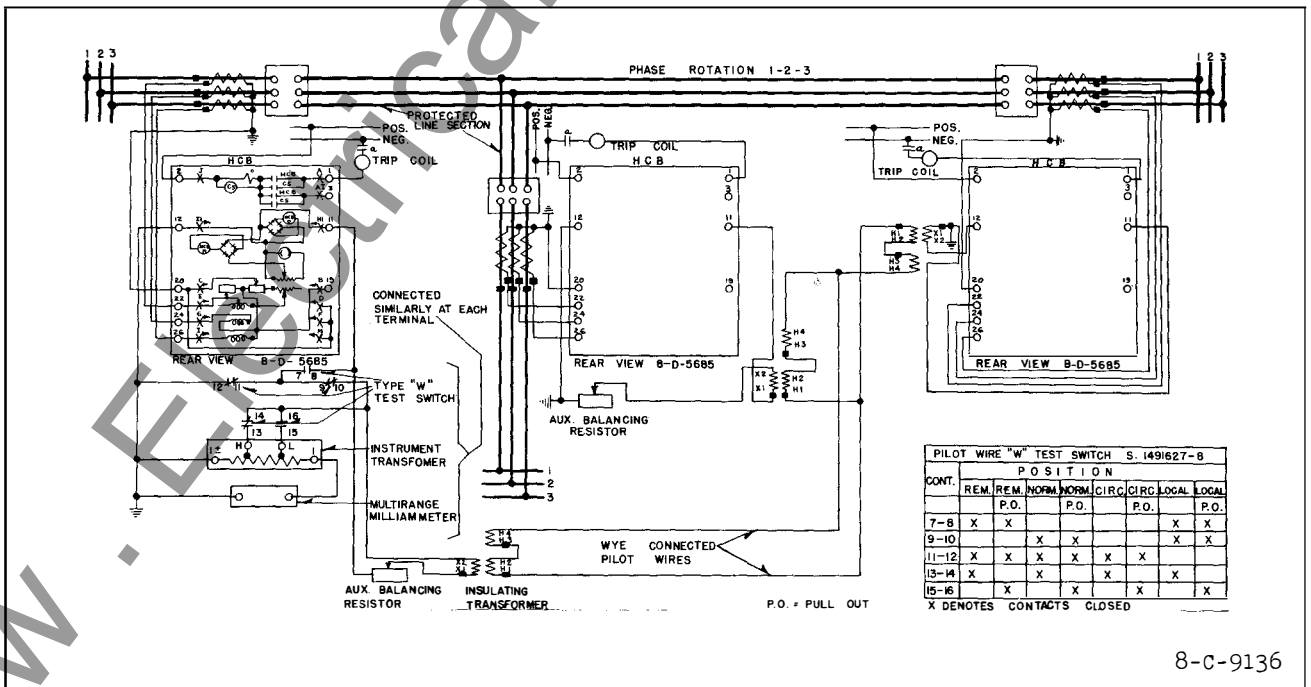


Fig. 9- External Connections of the Type HCB Relay in the Type FT Case For Phase and Ground Protection of a Two Terminal Line.



* Fig. 10- External Connections of the Type HCB Relay in the Type FT Case For Phase and Ground Protection of A Three Terminal Line.

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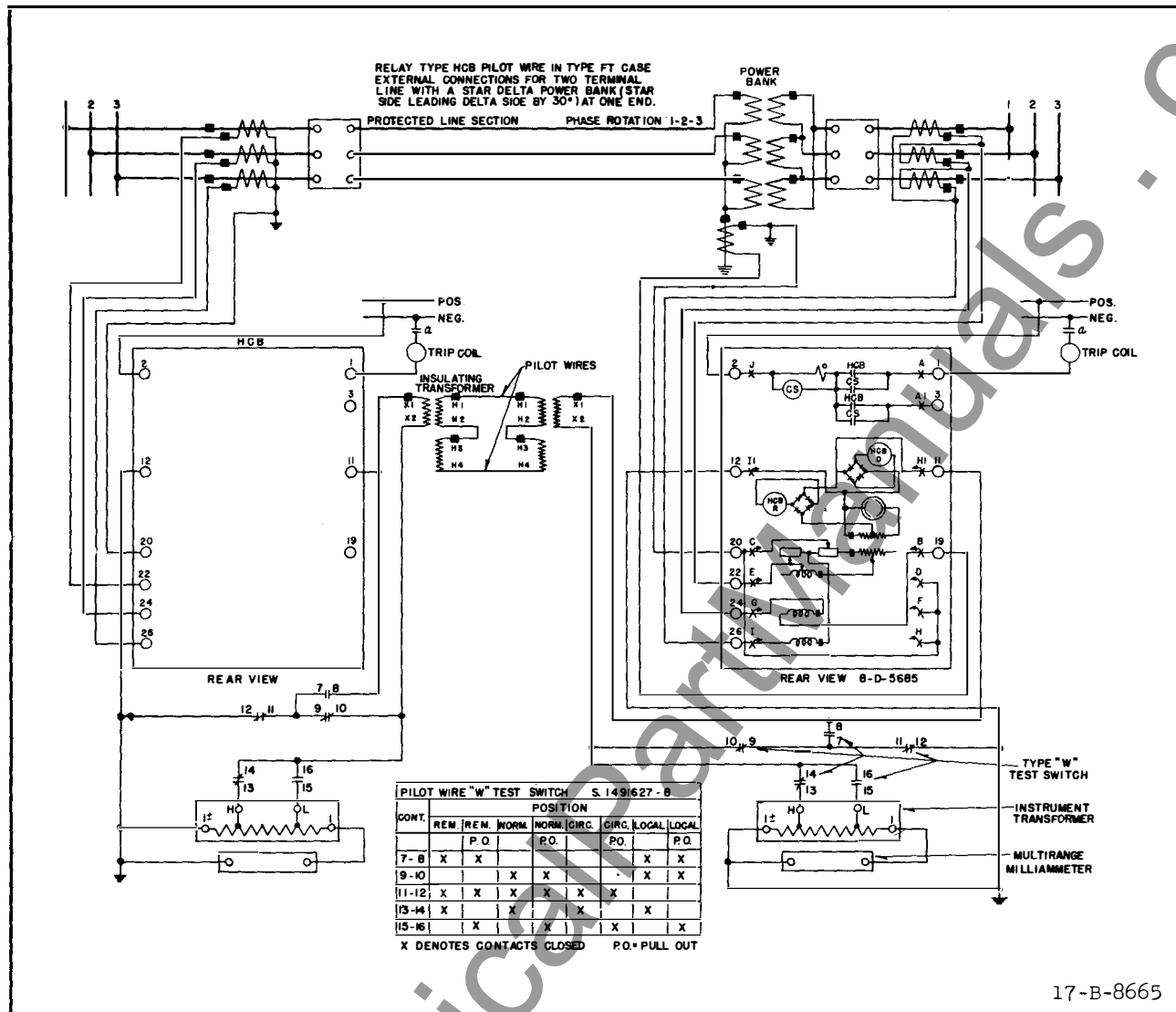


Fig. 11- External Connections of the Type HCB Relay in the Type FT Case For Phase and Ground Protection of a Two Terminal Line With a Transformer Bank.

numerical values of T are the positive sequence currents required to operate the relay when R_1 is set on .10. Therefore, to compensate for the value of R_1 used in the formula, T, must be divided by 0.1 thereby obtaining the factor "5.7".

Where line-to-line currents are not known, an alternate equation can be used.

The alternate equation is:

$$T = (5.7) (.86) (I_{3\phi}) R_1 \quad (10)$$

where $I_{3\phi}$ is the total minimum internal three

phase secondary fault current fed from all terminals divided by the number of terminals. The factor ".86" is used as line-to-line fault current is 86% of the three phase fault current when the negative sequence impedance of the system equals the positive sequence impedance of the system.

Equation (9) and (10) give the upper limit of "T" which must not be exceeded to obtain operation on the line-to-line faults. The actual setting should always be below the values obtained from equation (9) or (10). The minimum limits for this setting are discussed below.

The setting of "T" which will cause operation on load current if the pilot wires become accidentally open circuited is given by the equation:

$$T = 10 R_1 I_{\text{Load}} \quad (11)$$

where " I_{Load} " is the maximum secondary full load balanced current flowing through the terminal.

It is generally desirable to select a value of "T" which will not cause operation if the pilot wires are accidentally open circuited. A safety factor of at least 25% is generally recommended to prevent such operations. That is, "T", should be set 25% above the value obtained from equation (11) if the relay is not to operate on load current with the pilot wires open circuited.

This consideration may be neglected if it is realized that relay operation will be obtained if pilot wires are opened during heavy load currents,

Note: "T" must be set the same at all terminals (even where different transformer ratios are used.)

Zero Sequence Tap

The lower tap (R_0) has taps .025, .033, .05, .39, .51, .68, .90, 1.2 and 1.6. (The first two taps are actually marked .02 and .03 because of space limitations). The three lowest taps are not used in applications where high sensitivity to ground faults is required. They are used on special applications where response to positive sequence current only is required. Where such response is required, R_0 is set to equal to $1/3 R_1$

Maximum sensitivity to ground faults is ob-

tained with $R_0 = 1.6$. This setting is generally recommended where current transformers with the same ratio are installed at all terminals. Where current transformers of different ratios are installed at the various terminals, values of R_0 should be selected which are most nearly proportional to the transformer ratios. When the ratio of the R_0 taps can not be made to exactly match the ratio of the R_1 taps, pick the ratio to match as closely as possible, and use maximum restraint tap.

The minimum tap to obtain operation on minimum ground faults is expressed by the equation:

$$R_0 = \frac{0.2T}{I_g} \quad (12)$$

where I_g is the total minimum secondary ground fault current fed into the section from all terminals (taking into account possible ground fault resistance), divided by the number of terminals, and where "T" is the actual tap selected (not the value calculated from equation (9) or (10).

It is recommended that " R_0 " be set as high above the value obtained from equation (12) as possible keeping the value of R_0 approximately proportional to the current transformer ratios.

Restraint Tap

The restraint coil has a tap which permits the entire coil or part of it to be used. The relay is normally shipped with the restraint tap link connected in the maximum restraint position. This link is in the upper left hand corner of the panel carrying the polar element. The link is connected to the left for minimum restraint, and to the right for maximum restraint. Maximum restraint should be used with pilot wires of 1500 to 2000 ohms.

Example of Relay Settings

Assume a two terminal line with current transformers rated 400/5 at station 1 and 300/5 at station 2. Also assume that full load current is 300 amperes, and on minimum

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internal phase-to-phase faults 2000 amperes feed into the fault from station 1 and 1000 amperes from station 2. Further assume that on minimum internal ground faults, 400 amperes feed into the fault from station 1 and none from station 2.

Positive Sequence Filter Tap

Set R_1 proportional to the transformer ratio. R_1 at station 1 = 0.10, R_2 at station 2 = 0.075.

Positive Sequence Current Tap

From equation (9)

$$T = \frac{5.7 \times 3000 \times 5 \times .1}{400 \times 2} = 10.7$$

or

$$T = \frac{5.7 \times 3000 \times 5 \times .075}{300 \times 2} = 10.7$$

This represents the highest permissible setting. The setting which will cause tripping on load current if the pilot wire becomes accidentally open circuited is given by equation (11).

$$T = \frac{10 \times .1 \times 300 \times 5}{400} = 3.75$$

or

$$T = \frac{10 \times 0.075 \times 300 \times 5}{300} = 3.75$$

Select T at both stations = 6.

Zero Sequence Tap

The minimum tap which will cause tripping to minimum internal ground faults is given by equation (12).

$$R_0 = \frac{0.2 \times 6 \times 400}{200 \times 5} = .48 \text{ at station 1}$$

$$R_0 = \frac{0.2 \times 6 \times 300}{200 \times 5} = .36 \text{ at station 2}$$

Select R_0 at station 1 = 1.6

And R_0 at station 2 = 1.2

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 relay is shipped with the operation indicator and the contactor switch connected in parallel. This circuit has a resistance of approximately 0.25 ohm 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 short lead to the coil on the front stationary contact of the contactor switch. 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.

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 recom-

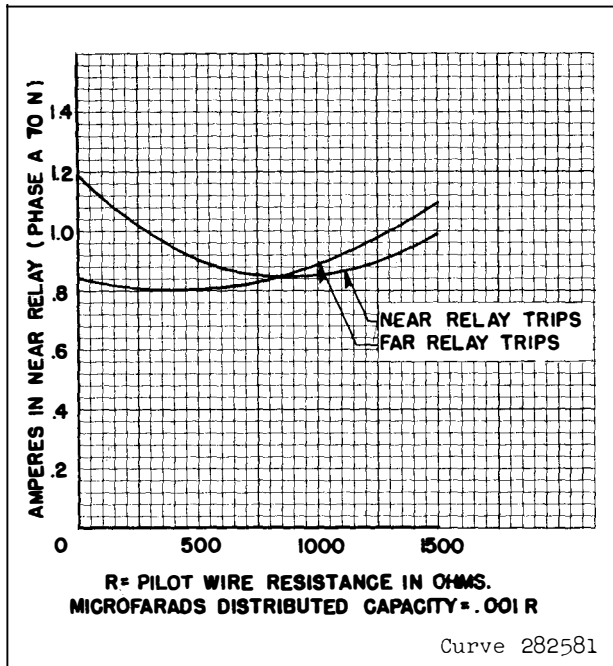


Fig. 12—Typical Curves Showing the Effect of Pilot Wire Resistance and Capacitance on Minimum Trip Current With Minimum Restraint.

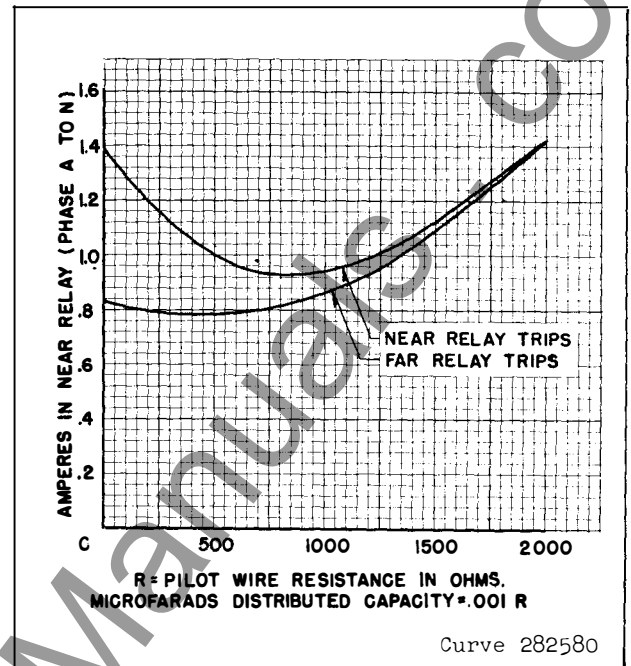


Fig. 13—Typical Curves Showing the Effect of Pilot Wire Resistance and Capacitance on Minimum Trip Current With Maximum Restraint.

mended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

CAUTION 1. Make sure that the neon lamp is in place, whenever relay operation is being checked. This is required to limit distortion in pilot wire voltage wave.

2. When changing taps under load the spare tap screw should be inserted before removing the other tap screw.

Sequence Filter

There are no adjustments to be made in the zero sequence resistor. The taps on the R_1 resistor are adjustable, however, but this is a factory calibration which should not ordinarily be disturbed. To check the positive sequence current filter, pass a current $I = 6.94$ amperes through a pair of phase terminals, for example, in at phase B, out of phase C (see Figure 2) and measure the open circuit filter voltage with a high resistance voltmeter. This may be done by removing the positive sequence current tap screw, T, and connecting the voltmeter across the open circuit thus formed. The voltage should be

$8R_1$ plus or minus 5% for each of the three phase-to-phase combinations, AB, BC, or CA. For example, at $I = 6.94$ amperes and $R_1 = .1$, the voltage should be 0.8 volts.

Polar-Type Element

Contact Adjustment: Adjust the left-hand (front view) contacts until they just make a light circuit, when the armature rivet touches the left-hand pole face. Give both the left-hand contact screws four to five additional turns, and lock in position with the lock nuts provided. This moves the armature rivet away from the left-hand pole face and provides contact follow. Now adjust the right-hand backstop screws until they just touch the moving contacts when the moving contacts are in the contact closing position as above. Back off each backstop screw two turns and lock in position.

Calibration: Connect the restraint tap link in the position in which it will be used. Connect the low voltage terminals of the insulating transformer across the pilot wire terminals of the relay. Connect the relay taps on $T = 4$, $R_1 = .1$, $R_0 = 1.6$.

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Adjust the right-hand magnetic shunt in or out as required, until the relay just closes contacts at 6.9 to 7.0 amperes phase B to phase C current. When this adjustment has been made, change the input current connections to phase A to neutral. The relay should trip for phase A to neutral current between .45 and .55 amperes.

The above is given as a laboratory calibration on an individual relay with its insulating transformer. This does not take into consideration the characteristics of the pilot wire circuit between the relays.

Figs. 12 and 13 show typical variations of minimum trip current for various lengths of pilot wire circuits up to the limiting values of 1500 ohms for relays operating on minimum restraint (Fig. 12) and 2000 ohms for relays operating on maximum restraint (Fig. 13).

For these curves, both relays are set on taps $T = 4$, $R_1 = 0.1$, $R_0 = 1.6$. Each relay is originally calibrated to trip on a current of .47 amperes, phase A to neutral, with the high side of the insulating transformer open-circuited. This value of current is equivalent in the relay filter to 4 amperes positive sequence only, with the taps as specified above.

Restraining Coil: The effectiveness of the restraining coil of the relay element, and the performance of the Rectox units, may be checked as follows, if desired. Connect a variable non-inductive resistor across the high voltage terminals of the insulating transformer, and connect d-c milliammeters in series with the operating and restraining coils of the element, by opening these circuits at the test links provided for this purpose. These milliammeters should have low resistance, and should be capable of reading in the order of 20 to 25 ma. in the operating coil and 100 to 150 ma. in the restraining circuit. Using $T = 4$, $R_1 = .1$, $R_0 = 1.6$, pass 10 amperes 60 cycles from phase A to Neutral in the relay, and increase the variable resistance across the insulating transformer high voltage terminals until the relay just

trips. This should be in the order of 1400 to 2000 ohms when maximum restraint is used. Read the d-c current (milliamperes) in the operating and restraining coils at this point. The values obtained should conform substantially to the following equations.

For Minimum Restraint

$$I_O = .12 I_R + 8$$

For Maximum Restraint

$$I_O = .16 I_R + 8$$

where I_O and I_R are operating and restraining coil currents, respectively, in milliamperes. The results are subject to slight variations between individual relays.

The polarity of the connections to the pilot wires, and the correct "Phasing out" of A, B, C phases at the two stations may be checked by the six tests outlined on Page 17.

Pilot Wire Current

The pilot wire current which should flow under normal load conditions is given in Figs. 3 and 4. If the relay taps in use differ from those indicated in these figures, suitable conversion factors must be used as given in the text. The pilot wire current will vary inversely with T and directly with R_1 .

Contactor 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 d-c have been passed through the coil.

Operation Indicator

Adjust the indicator to operate at 0.2 ampere d-c gradually applied 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 by new springs, they should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 2.8 ohms.

ENERGY REQUIREMENTS

The volt-ampere burden of the type HCB relay is practically independent of the pilot

wire resistance and of the current tap used. The following burdens were measured at a balanced three - phase current of 5 amperes:

For tap 4 $R_1 = .075$ and $R_0 = .39$

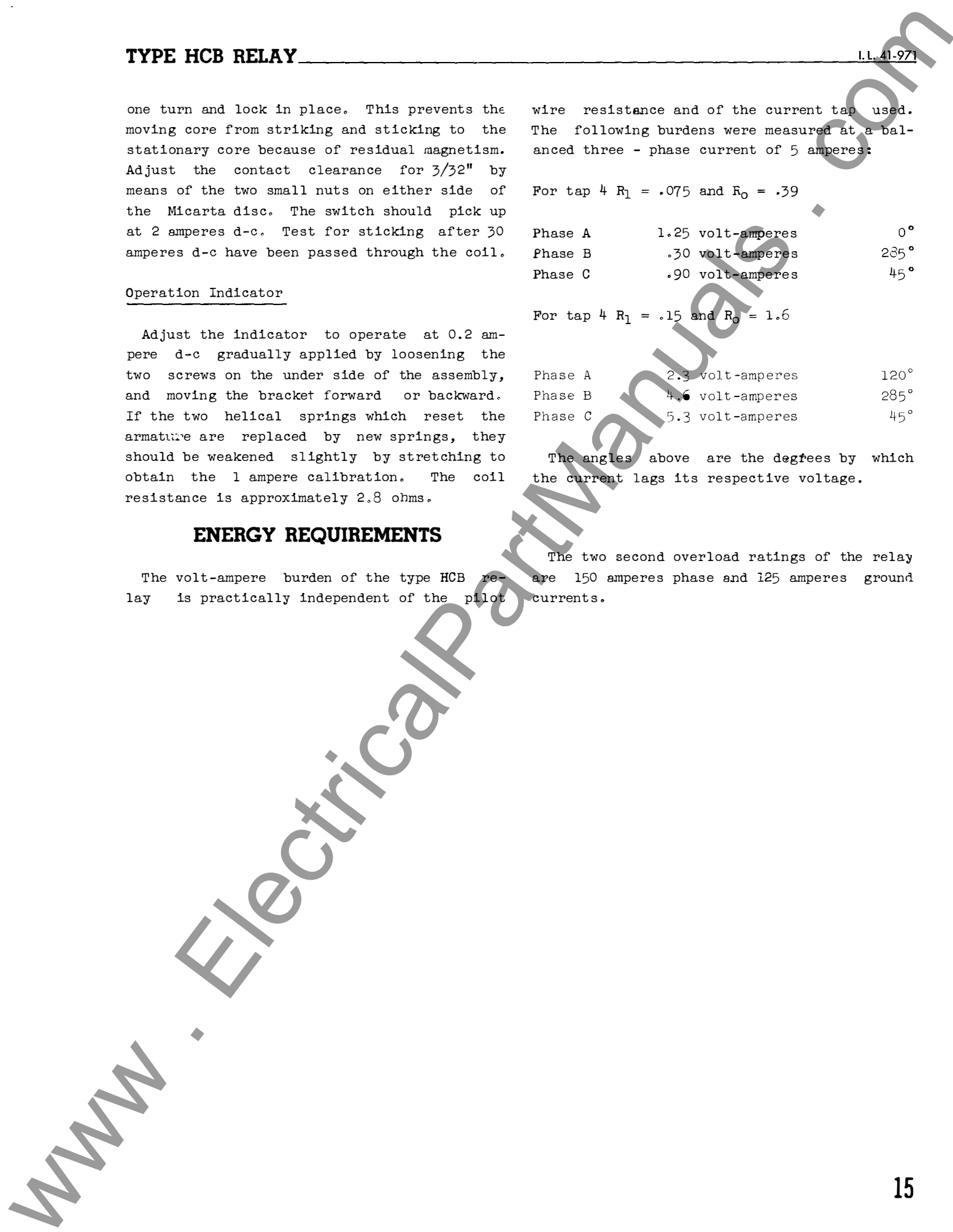
Phase A	1.25 volt-amperes	0°
Phase B	.30 volt-amperes	285°
Phase C	.90 volt-amperes	45°

For tap 4 $R_1 = .15$ and $R_0 = 1.6$

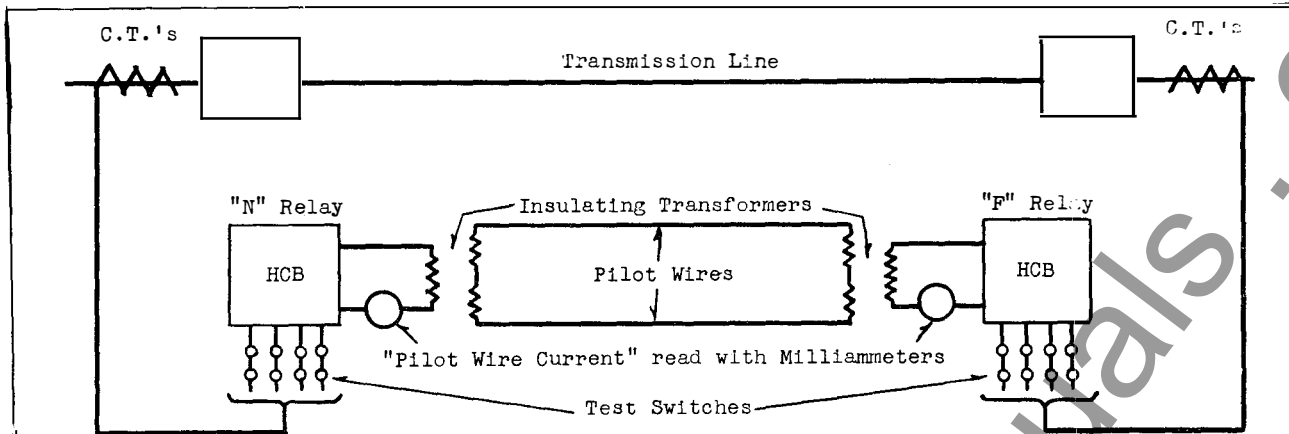
Phase A	2.3 volt-amperes	120°
Phase B	4.6 volt-amperes	285°
Phase C	5.3 volt-amperes	45°

The angles above are the degrees by which the current lags its respective voltage.

The two second overload ratings of the relay are 150 amperes phase and 125 amperes ground currents.



TYPE HCB RELAY

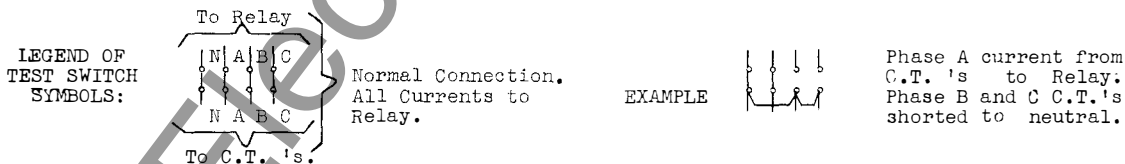


Note: The line should be carrying through load current amounting to at least 1.5 amperes as measured in the secondary of the Current Transformers. This test is based on the ratio of the C.T.'s being the same at each end of the line, in which case set the taps of both relays to $R_1 = .1$; $R_0 = 1.6$; $T = 4$ for this test.

RELAY "N"						RELAY "F"				
Test No.	Test Switch	Relay Current	Relay Trip	"Pilot Wire Current"		Test Switch	Relay Current	Relay Trip	"Pilot Wire Current"	
				Circulating	Relay F				Circulating	Relay N
1		A,B,C,N	No	(1)	(1)		A,B,C,N	No	(1)	(1)
2		A,C,B,N	No	(2)	(2)		A,C,B,N	No	(2)	(2)
3		A, N	Yes	(3)	(0)		0	Yes	(3)	(3) (4)
4		0	Yes	(3)	(3) (4)		A, N	Yes	(3)	(0)
5		A, N	No	(3)	(3)		A, N	No	(3)	(3)
6		A, N	Yes	(6)			B,C,N	Yes	(6)	

REMARKS

Tests 1 and 2 are to check normal positive sequence rotation of phases. The test switch connections of test #2 may be made readily with relays in the Flexitest case by using clip leads and insulating barriers in the ammeter test jacks. However, care should be used to avoid accidentally open-circuiting the current transformer circuits.
 Tests 3 and 4 simulate internal Phase A to Ground fault with single end feed.
 Test 5 simulates an external Phase A to Ground fault. (5)
 Test 6 simulates an internal Phase A to Ground fault, with equal feed from the two ends, since $I_B + I_C = -I_A$, with balanced load.



- The "pilot wire current" will vary depending upon the magnitude of the through load current and the characteristics of the pilot wire. See Figures 4 and 5.
- Since the relay is temporarily connected for negative sequence, it should have practically zero output in this test.
- These readings may be "off scale" depending upon the magnitude of the load current.
- The relay at this station should reset when the "far" current is being read because the local relay will be receiving no current from either the pilot wire or the current transformers.
- Test 4 and 5 can be repeated using phase B to neutral current, and again with phase C to neutral current, but this is not strictly necessary on the basis that, having proved the phase sequence with tests 1 and 2, and having proved the correspondence of phase A at the two ends of the line with test 5, then phases B and C must be correct.
- Some pilot wire current will be read, depending upon the magnitude of the distributed capacity of the pilot wire in combination with the magnetizing impedance of the insulating transformer.

TYPE HCB RELAY

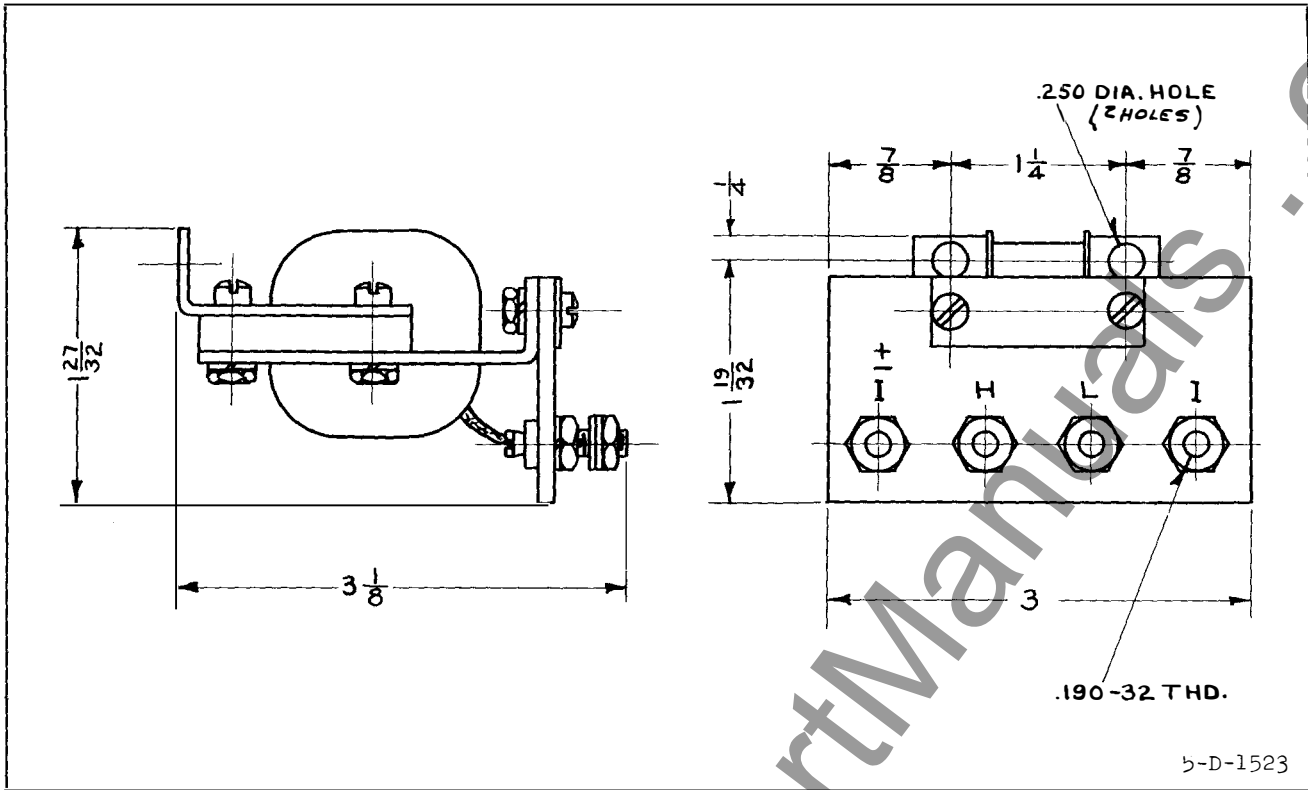


Fig. 17—Outline of the Test Milliammeter Auxiliary Transformer. For Reference Only.

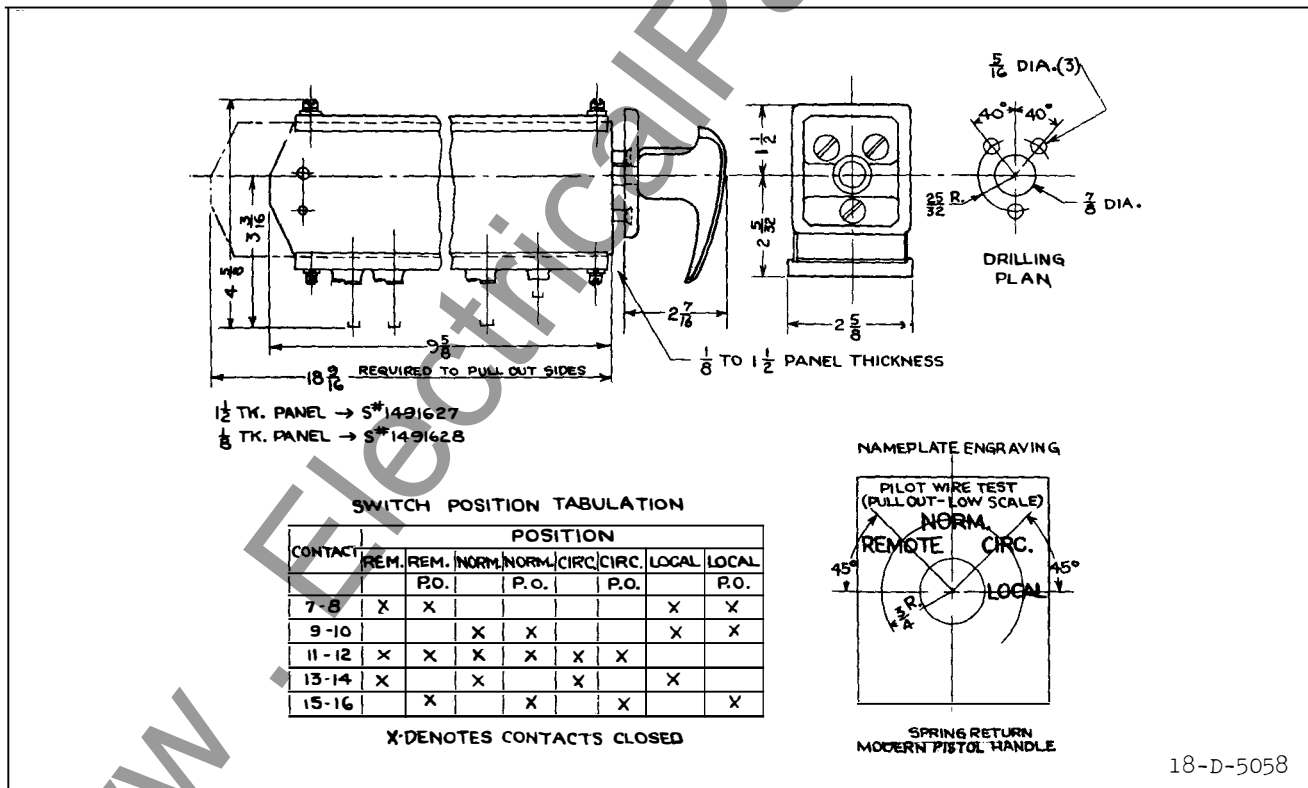


Fig. 18—Outline and Drilling Plan of the Type W Test Switch. For Reference Only.

SWITCH POSITION TABULATION

CONTACT	POSITION						
	REM. P.O.	REM. P.O.	NORM. P.O.	NORM. P.O.	CIRC. P.O.	CIRC. P.O.	LOCAL P.O.
7-8	X	X					X
9-10			X	X			X
11-12	X	X	X	X	X	X	
13-14	X		X		X		X
15-16		X		X		X	X

X DENOTES CONTACTS CLOSED



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