Instruction Leaflet
41-971.3M

Type HCB-1 Pilot-wire Relay System

Effective: December 1999
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(|) Denotes Change Since Previous Issue

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.

1.0 APPLICATION

The type HCB-1 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 20 milliseconds 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 series resistance are required.

The HCB-1 and HCB relays are not compatible, since the filter response is not the same.

2.0 CONSTRUCTION

The relay consists of a combination positive, negative, and zero phase sequence filter, a saturating auxiliary transformer, two full wave rectifier units, a polar unit, a Zener clipper, and an indicating contactor switch (ICS), all mounted in a single case. The external equipment normally supplied with the relay consists of an insulating transformer, a millimeter and test switch.

2.1. SEQUENCE FILTER

The sequence filter consists of a three-legged iron core reactor and a set of resistors designated R_1 and R_0. The reactor has three windings; two primary and a tapped secondary winding, wound on the center leg of a “F” type of lamination. The secondary taps are wired to the A, B and C tap connections in front of the relay. R_0 consists of three tube resistors with taps wired to the F, G and H tap connections in the front of the relay.

2.2. SATURATING TRANSFORMER

The output of the sequence filter connects to the primary of a two-winding saturating transformer. The primary winding is tapped and wired to a tap block T in the front of the relay. The secondary winding is connected to the Zener clipper circuit and from a fixed tap to the relay coil circuits.

2.3. POLAR UNIT

This unit consists of a rectangular-shape magnetic frame, an electromagnet, a permanent magnet, and an armature with either one or two contacts. The poles of the crescent-shaped permanent magnet bridge the magnetic frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These non-magnetic joints

All possible contingencies which may arise during installation, operation or maintenance, and all details and variations of this equipment do not purport to be covered by these instructions. If further information is desired by purchaser regarding this particular installation, operation or maintenance of this equipment, the local ABB representative should be contacted.

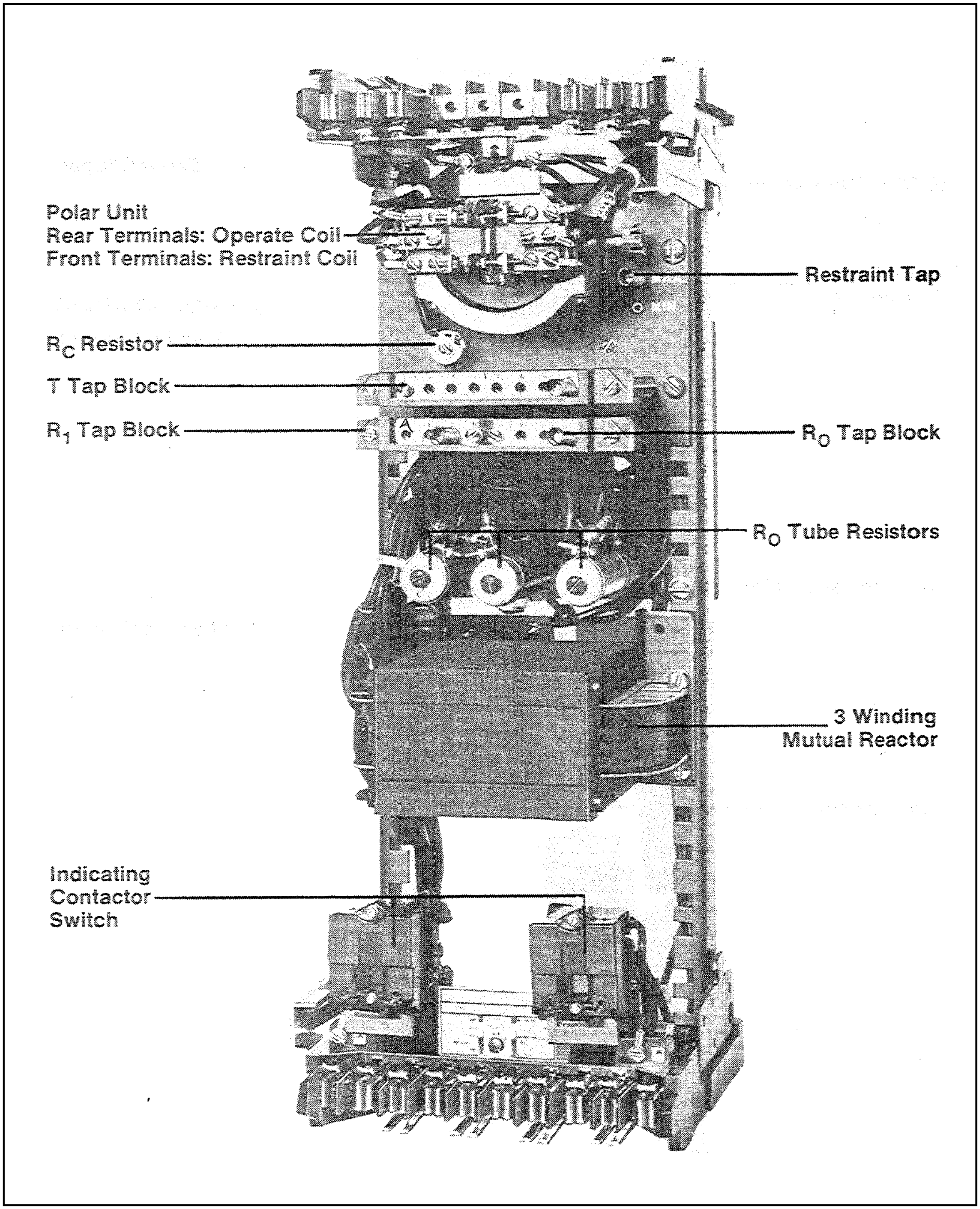


Figure 1: *Type HCB -1 Relay Without Case (Front View)*

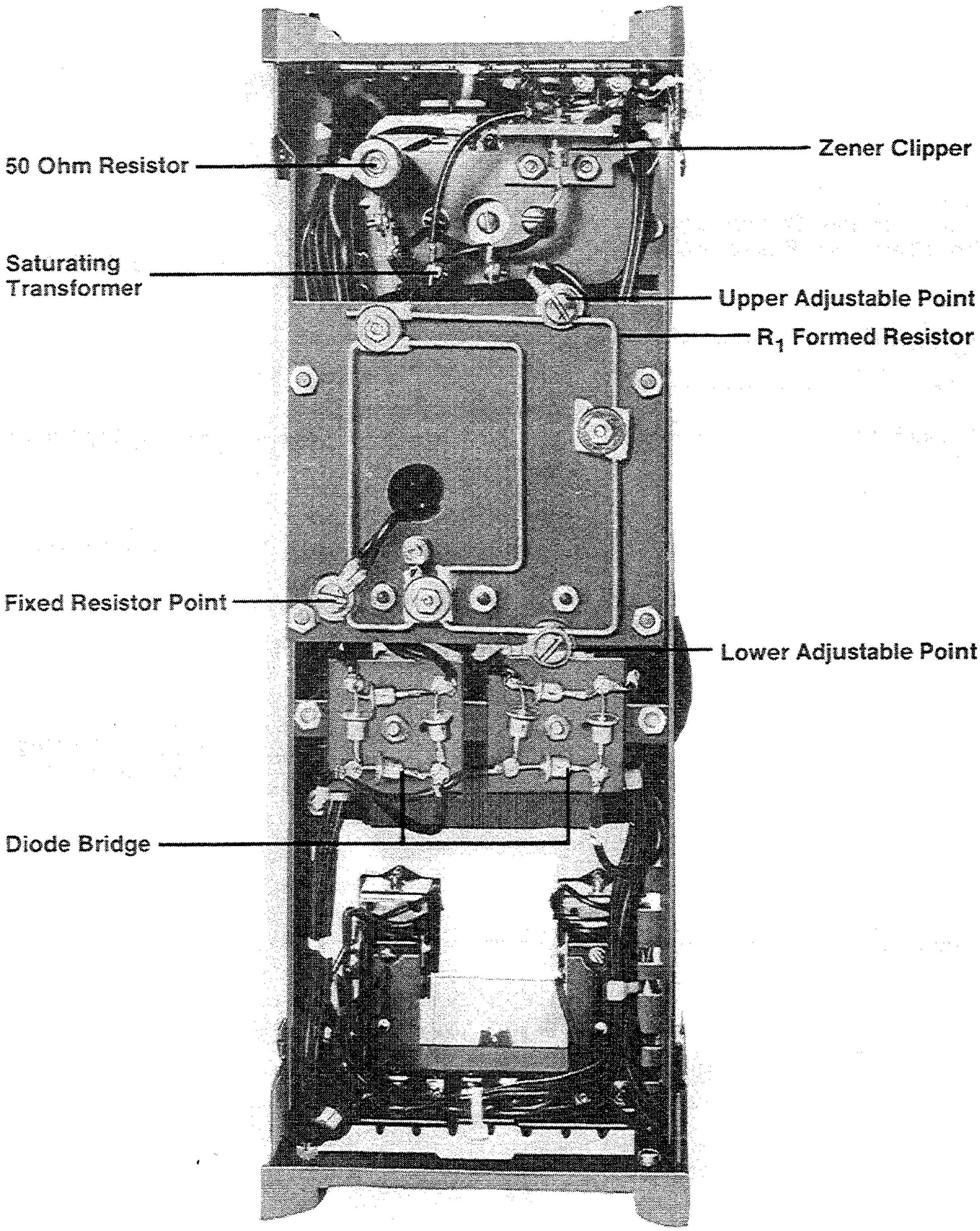


Figure 2: *Type HCB-1 Relay Without Case (Rear View)*

represent air gaps which are bridged by two adjustable magnetic shunts. The operating and restraint windings are concentrically wound around a magnetic core. The armature is fastened to this core at one end and floats in the front air gap at the other end. The moving contact is connected to the free end of a leaf spring.

2.4. Restraint Taps

A set of restraint taps are located on the front of the relay near the polar unit. These taps are the maximum and minimum restraint taps of the relay.

2.5. INDICATING CONTACTOR SWITCH UNIT (ICS)

The dc indicating contactor switch is a small clapper-type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, bypassing the main relay contacts. Also during this operation, two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push-rod located on the bottom of the cover.

The front spring, in addition to holding the target, provides restraint for the armature, and thus controls the pickup value of the switch.

3.0 OPERATION

The connection of the HCB-1 system of relays to the protected transmission line is shown in Figure 10. In such a connection, the relays operate for faults within the line terminals but not for faults external to the protected transmission line. This is accomplished by comparing the relative polarities of voltages at opposite ends of the transmission line by means of a metallic pilot-wire.

As shown in Figure 4, the composite sequence filter of each HCB-1 relay receives three-phase current from the current transformers of the transmission line. The composite sequence filter of the HCB-1 converts the three-phase current input into a single-phase voltage output, V_F, of a magnitude which is a function of the positive, negative and zero sequence components of fault current. This voltage V_F, is impressed on the primary wiring of the saturating transformer. The saturating transformer output voltage, V_S, is impressed on the primary wiring of the saturating transformer. The saturating transformer output voltage, V_S, is impressed on the primary wiring of the saturating transformer. The saturating transformer output voltage, V_S, is applied to the relay coils and to the pilot-wire through an insulating transformer. The saturating transformer and a zener clipper across its secondary winding serve to limit the energy input to the pilot-wire.

During an external fault, assuming matched relays, the magnitude of V_S at both stations will be the same. The relative polarities of the V_S voltages will be shown in Figure 4. Since the voltages add, most of the current will circulate through the restraint coils and the pilot-wire, with a minimum of operating coil current. The relative effects of the operating and restraint coil currents are such that the relay is restrained.

During an internal fault, the relative V_S voltages reverse. Since the V_S voltages now oppose each other, most of the current flowing in the restraint coils is also forced through the operating coils with a minimum of current in the pilot-wire. This increase in operating current overcomes the restraining effect and both the relays operate.

Within limits, as defined in Figure 7 and under “Characteristics,” all the relays will operate for an internal fault regardless of the fault current distribution at the various stations. The nominal pickup (total internal fault current) of the relaying system is equal to the minimum trip of a single relay multiplied by the number of relays. For example, if the pickup of each relay, with the pilot-wire open, is 6 amperes, a two terminal line system has a nominal pickup of 2 X 6 = 12 amperes.

3.1. PILOT-WIRE EFFECTS

In Figure 4 it can be seen that a short-circuited pilot-wire will short circuit the relay operating coils. Depending on the location of the short, at least one of the relays will fail to trip during an internal fault. If the pilot-wire is open circuited, almost all the restraint coil current will flow through the operating coil, and the relay operates as an overcurrent relay on fault currents.

Excessive pilot-wire series impedance will approach an open-circuited condition and the relays will operate during external faults. Excessive pilot-wire shunt capacitance will approach a short-circuited condition and the relays will not operate. The pilot-wire requirements are given in Table 4.

3.2. POLAR UNIT THEORY

The polar unit flux paths are shown in Figure 5. With balanced air gaps, the permanent magnet produces flux flowing in two path, one through the front gaps and one through the rear gaps. This flux produces north and south poles, as shown. By turning the left shunt in, some of the flux is forced through the armature, making it a north pole. Thus, reducing the left-hand rear gap will produce a force tending to pull the armature to the right. Similarly, reducing the right-hand gap will produce a force tending to pull the armature to the left.

Electrical flux produced by current flowing in the operating and restraint windings of the polar unit either adds to or subtracts from the magnetic flux. In the case of restraint current, the flux adds to the magnetic flux to keep the armature to the right. On the other hand, the operating current subtracts from the magnetic flux to move the armature to the left. On an ampere turn basis, the polar unit operates when the operating ampere turns are greater than the restraint ampere turns plus the magnetic restraint or bias expressed in ampere turns.

4.0 CHARACTERISTICS

The voltage, V_F impressed by the filter upon the saturating transformer varies with the tap setting (A, B, C) of the relay.

The sequence network in the relay is arranged for several possible combinations of sequence components. For tap C the output of the network will contain the positive, negative and zero sequence components of the line current. In this case, the taps on the upper tap plate indicate the balanced three-phase amperes (positive sequence amperes) which will pick up the relay with the pilot-wire open.

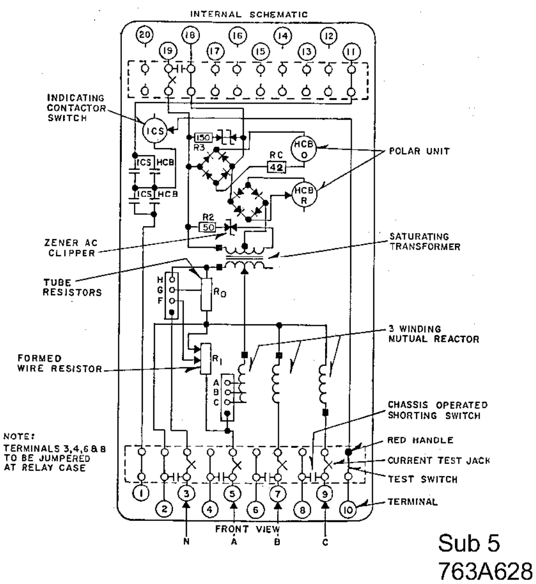


Figure 3: *Internal Schematic of the Type HCB-1 Relay in FT-42 Case (Double Trip Circuit). For the Single Trip Relay, the Circuits Associated with Terminal II are omitted.*

For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the relay to pick up at 86% of the tap setting. For BC faults, the relay will pick up at approximately 53% of the tap setting. This difference in pickup current for different phase-to-phase faults is fundamental; and occurs because of the angles at which the positive and negative sequence components of current add together.

In some applications, the maximum load current and minimum fault current are too close together to set the relay to pick up under minimum fault current, and not operate under load with the pilot-wire accidently open. For these cases, tap B is available which cuts the three-phase sensitivity in half, while the phase-to-phase setting is substantially unchanged. The relay then trips at 90% of tap value for AB and CA faults, and at twice tap value for three-phase faults. The setting for BC faults is 65 percent of tap value.

It is possible to eliminate response to positive sequence current entirely, and operate the relay on negative-plus-zero sequence current. Tap A is available to operate in this manner. The relay picks up at about tap value for all phase-to-phase faults, but is unaffected by balanced load current or three-phase faults.

For ground faults, separate taps G and H are available for adjustment of the ground fault sensitivity to about 1/4 or 1/8 of the upper tap plate setting. For example, if the upper tap plate is set at tap 4, the relay pick-up current for ground faults can be either 1 or 1/2 ampere. It is possible to eliminate response to zero sequence current. Tap F provides such an operation.

The response of the relay to various types of faults are summarized in the following tables.

Table 1
Phase Faults

Sequence Components in Sequence Filter Output	Taps	Pickup – Multiples of T		
		3Ø	AB CA	BC
Pos., Neg., Zero	C	1	.86	.53
Pos., Neg., Zero	B	2	.9	.66
Neg., Zero	A	—	1.00	1.00

Table 2
Ground Faults

Comb.	Lower Left Tap	Ground Fault Pickup Multiples of T Tap	
		Tap G	Tap H
1	C	.25	.12
2	B	.20	.10
3	A	.20	.10

The voltage, V_F impressed by the filter upon the saturating transformer is:

$$V_F = C_1 I_{A1} + C_2 I_{A2} + C_0 I_0 \qquad \text{Equ. (1)}$$

Table 3 shows the values of the C-constants in Eq. (1).

For tap settings of C and H, the voltage, V_F impressed by the filter upon the saturating transformer is:

Table 3
Constants For Equation (1)

Tap	C_1	C_2	C_0
A	0	0.26	—
B	-0.08	0.34	—
C	-0.20	0.46	—
F	—	—	0
G	—	—	2.5
H	—	—	4.9

$$V_F = -.2I_{A1} + .46I_{A2} + 4.9I_{A0} \text{ Volts} \qquad \text{Equ. (2)}$$

4.1. SINGLE RELAY PICKUP (Pilot-wire Open) I_S

Single relay pickup, I_S, is defined as the phase current required to operate one relay with the pilot-wire side of the insulating transformer open circuited (H1-H4). The single relay pickup point in terms of filter voltage is:

$$V_F = 0.2T(Tap\ C) V_F = 0.15T(Tap\ A)$$

$$V_F = 0.16\text{T (Tap B)} \qquad \text{Equ. (3)}$$

where T is the saturating transformer tap value. Single relay pickup is defined by equating (2) and (3):

$$0.2T = -0.2I_{A1} + .46I_{A2} + 4.9\ I_{A0} \qquad \text{Equ. (4)}$$

Current I_S varies with the type of fault. For example, for a 3 phase fault, $I_S = I_{A1}$, since only positive sequence current is present. Substituting $I_S = I_{A1}$ in Equ. (4) and rearranging, the 3 phase fault pickup is:

$$I_S = I_{A1} + \frac{0.2T}{.2} = T \quad \text{(3 phase fault)} \qquad \text{Equ. (5)}$$

For 4 Tap:

$$I_S = T = 4 \text{ amp} \qquad \text{(3 phase fault)}$$

For a phase A to ground fault, if $I_{A1} = I_{A2} = I_{A0}$ (I_{A2} is the phase A negative sequence current):

$$0.2T = -.2I_{A1} + .46I_{A2} + 4.9\,I_{A0}$$

$$I_{A1} = \frac{0.2T}{5.2} = I_{A2} = I_{A0}$$

But: $$I_S = I_{A1} = I_{A2} + I_{A0}$$

$$= 3I_{A1}$$

$$(0.2T)(3)$$

So:

$$I_S = 3I_{A1} = \frac{(0.2T \times 3)}{5.2} = 0.12T \text{ (A-G Fault)} \quad \text{Equ. (6)}$$

For T = 4

$I_S = 0.5$

4.2. NOMINAL PICKUP (All Relays)

The nominal pickup, I_{nom}, is defined as

$$I_{nom} = KI_S \quad \text{Equ. (7)}$$

Where I_{nom} = total internal fault current

K = number of relays (2 or 3)

I_S = single-relay pickup with pilot wire disconnected (see above)

For example, in the previous example or a phase-A-ground fault, the single-relay pickup was determined as I_S = 0.5 ampere for 4CH taps with the pilot-wire open. For a two-terminal line, the nominal pickup for a phase-A-to-ground fault (4CH taps) is:

$$I_{nom}(A\ to\ G) = 0.5 = 0.5 \times 2 = 1.0\ ampere$$

4.3. MINIMUM TRIP (All Relays)

With equal inputs to all relays and zero pilot-wire shunt capacitance, the relays will operate at their nominal pickup point. The minimum trip points will vary somewhat from nominal value, depending on the pilot-wire constants and the magnitude and phase angle of the various relay input currents. For example, Figure 6 shows the relay operating points for a two-terminal line, assuming input current one relay only.

An example of the characteristics with various current distributions shown in Figure 6. The filter output voltage, V_F, of each relay, as defined by equation (1) must be in phase or 180 degrees out-of-phase, in order for Figure 7 to apply.

4.4. INSULATING TRANSFORMER

Unless otherwise noted, all characteristics presented include an insulating transformer with each relay. Two ratios are available: 4/1 and 6/1. The high voltage side (H1-H4 Terminals) is connected to the pilot-wires.

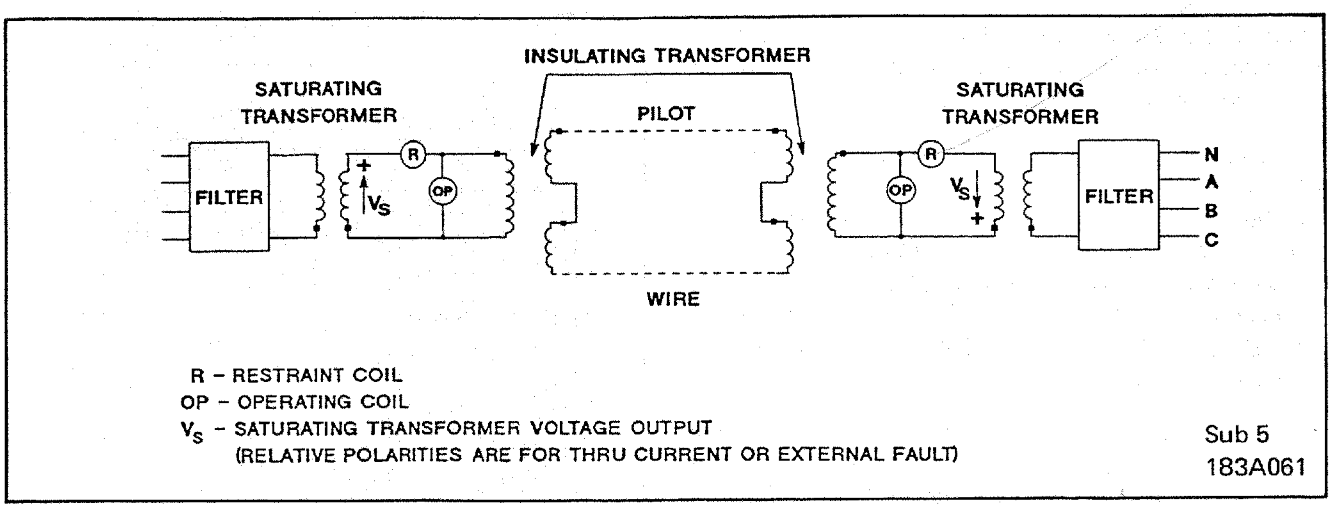


Fig. 4. Simplified External Schematic of the HCB - 1 Relay System

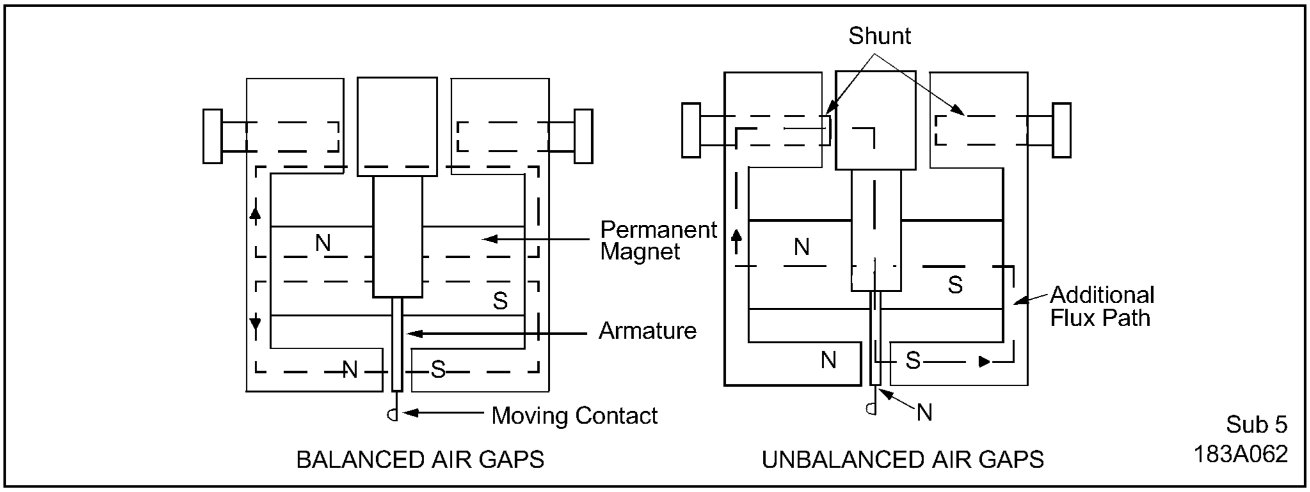


Figure 5: *Polar Unit Permanent Magnet Flux Paths*

4.5. PILOT-WIRE REQUIREMENTS

The relays should not be applied with pilot-wire series resistance or shunt capacitance exceeding the following values:

Table 4
Insulating Transformer Rate

No. of Relays	4/1		6/1	
	R_L	C_S	R_L	C_S
2	2000	1.5	4500	0.33
3	500/LEG	1.8	1000/LEG	0.75

R_L = series loop resistance in ohms.

C_S = total shunt capacitance in microfarads. (Total wire to wire capacitance)

Where the shunt capacitance exceeds the above amount, it may be feasible in some cases to provide shunt reactors to compensate for the excessive capacitance. The amount of capacitance which can be compensated is limited and varies depending upon the magnitude of the pilot-wire distributed effect.

A shielded, twisted pilot-wire pair, preferably of #19 AWG or larger, is recommended; however, open wires may be used if they are frequently transposed in areas of exposure to power circuit induction. The voltage impressed across either insulating transformer (H1-H4 Terminals) as a result of induction or a rise in station ground potential, should be less than 7.5 volts to prevent undesired relay operation.

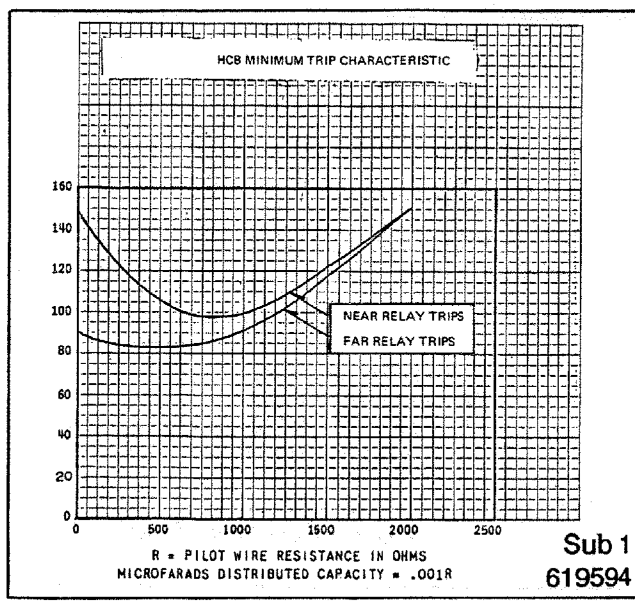


Figure 6: *Typical Curves Showing the Effect of the Pilot-wire on Minimum Trip Current, Two-Terminal Line (Maximum Resistant Tap). Insulating Transformer 4/1 ratio made by connecting the lead located in front of the tap block to the desired setting by means of the connecting screw*

For three-terminal applications, the loop resistance of all legs of the pilot-wire must be balanced within 5 percent, with variable resistors. The pilot-wire resistance to be balanced is divided by 16 and 36 for the 4 to 1 and 6 to 1 ratio insulating transformers respectively, since the balancing resistors are located on the relay side of the insulating transformers.

Induced voltages and rises in station-ground potential may be handled by the following means:

a) Neutralizing reactors may be connected in series with the pilot to hold pilot-wire potential close to the remote ground potential in the presence of a rise in station-ground potential. They do not limit pilot-wire voltages to safe values in the presence of a longitudinal induced voltage. When using the neutralizing reactor, the pilot-wire sheath should be insulated from station ground to minimize sheath-to-pair potential. All other parts in the cable which are connected to station ground should also be protected with neutralizing reactors to minimize pair-to-pair voltages.

b) Drainage reactors may be connected across the pilot-wire to ground through a KX642 protector tube. The drainage reactor is particularly effective in limiting pair-to-ground voltage in the presence of an induced voltage. When the tube flashes, both wires are connected to ground through the drainage reactor windings which offer a low impedance to ground but maintain a high impedance to an ac voltage across the wires. Thus, the HCB-1 system will operate normally even though the protector tube has flashed over. The drainage reactor is not intended to handle a rise in ground potential.

c) The neutralizing and drainage reactors may be utilized together. If the neutralizing reactor is to be of any value, the drainage reactor through the protector tube must be connected to remote ground.

For more information with reference to the insulation and protection equipment, refer to I.L. 41-971.4.

4.6. TRIP CIRCUIT

The main contacts will safely close 30 amperes at 250 volts dc, and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pick-up setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

5.0 SETTINGS

There are four settings in the relay. The correct tap setting should be determined as outlined under section 5.2, “Setting Calculations”.

1) Restraint taps – maximum or minimum

   To change taps, connect the lead in front of the relay to the correct tap.

2) T tap – 4, 5, 6, 7, 8, 10, and 12

3) R_1 tap – A, B, C

4) R_0 tap – R, G and H

5.1. INDICATING CONTACTOR SWITCH (ICS)

The only setting required on the ICS is the selection of the 0.2 or 2.0 ampere tap setting. This selection is made by connecting the lead located in front of the tap block to the desired setting by means of the connecting screw.

5.2. SETTING CALCULATIONS

The HCB-1 relay has four sets of taps: R_1, T, R_0, and restraint taps. 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 fault current that flows into the protected line from all terminals.

<u>TERMS</u>

A, B, C, D, F, G, H — Relay Taps

I_{3P} – total minimum internal 3-phase secondary fault current fed from all terminals, divided by the number of terminals (2 or 3)

I_L – maximum secondary load current flowing through the protected line

I_g – total minimum secondary ground fault current fed into the protected line from all terminals, divided by the number of terminals

I_{nom} (P-P) – nominal internal phase-to-phase fault sensitivity.

I_{nom} (P-G) – nominal internal line-to-ground fault sensitivity.

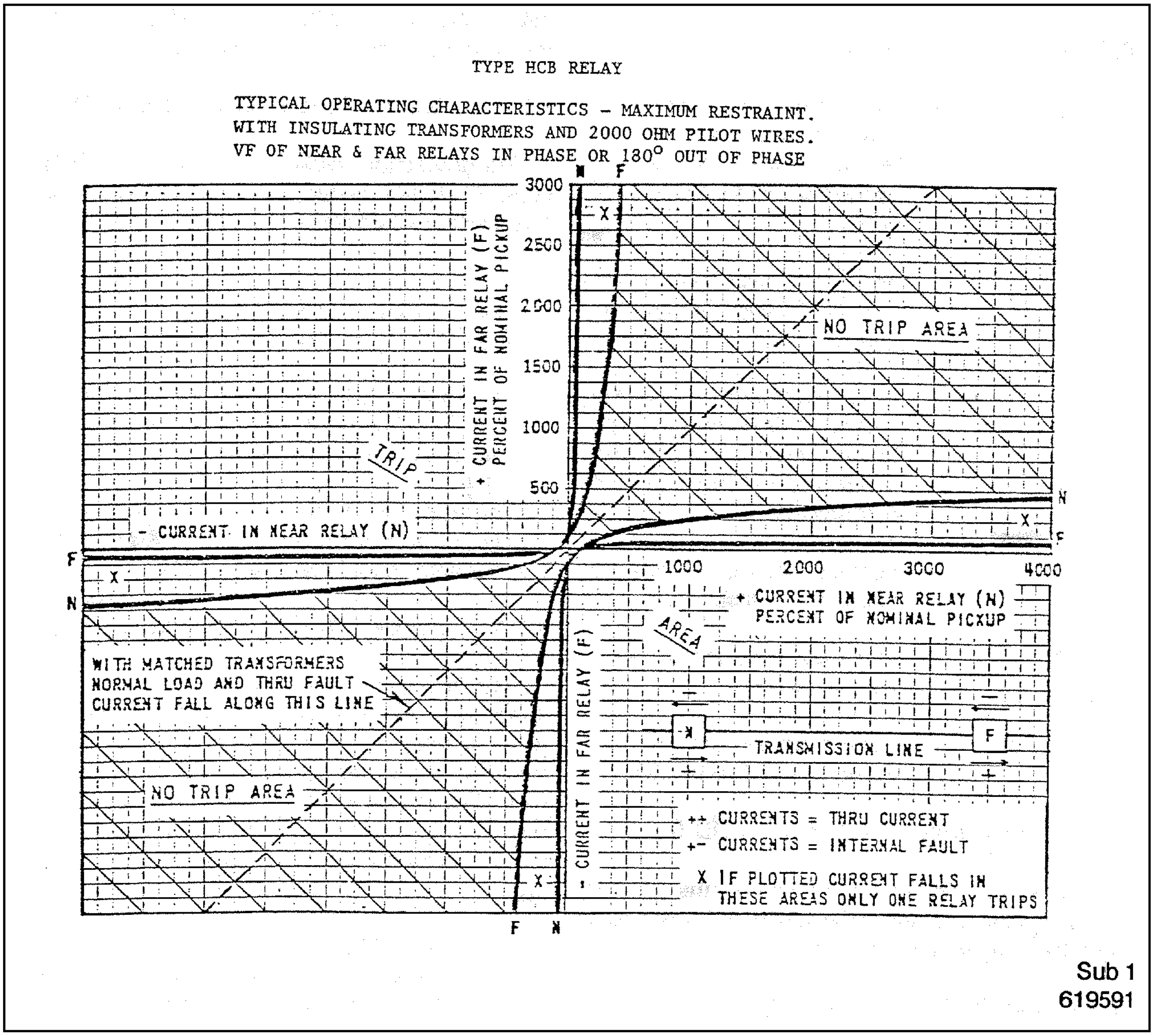


Figure 7: *Typical Operating Characteristics of the HCB-1 Relay System — Maximum Restraint Tap, with 4/1 Insulating Transformers and 2000-Ohm Pilot-wire. VF of Near and Far Relays in Phase or 180° Out-of-Phase.*

R_{NC} (I), R_{NC} (II) – current transformer ratio at Station I and II respectively.

5.2.1. Phase Fault Sensitivity (R1 and Taps)

The phase fault pickup is determined by the B, C and T taps. In order to operate on the minimum 3-phase fault current, the T tap should be set for not more than:

$$T = I_L(tap\ C);\ T = 0.5\ I_{3P}(tap\ B) \qquad \text{Equ. (8)}$$

In order to prevent operation on load current if the pilot-wires become open circuited, the T tap should be set for not less than:

$$T = I_L(tap\ C);\ T = \frac{I_L}{2}(tap\ B) \qquad \text{Equ. (9)}$$

The available taps are:

T: 4, 5, 6, 7, 8, 10, 12

Where sufficient fault current is available, it is recommended that the relays be set as follows:

$$T = 1.25\ I_L(tap\ C); T = 0.62\ I_L(tap\ B) \qquad \text{Equ. (10)}$$

The taps must be set the same at all stations. Where the ct ratios are not identical use auxiliary ct's to match the currents within 5% of each other.

5.2.2. Ground Fault Sensitivity (R_0 TAP)

The ground-fault pickup is determined by G, H and T taps. (T should be determined by the phase setting.) The minimum fault current I_g should exceed the following:

Tap A or B:	I_g = .20T (Tap G);	I_g = .10T (Tap H)
Tap C:	I_g = .25T (Tap G);	I_g = .12T (Tap H)

For cable circuits, where the line charging current exceeds 5% of nominal positive sequence pickup current, set tap G; otherwise set tap H.

The taps must be set identically at all stations. Use auxiliary ct's where the main ct's have a different ratio. The currents should match within 5%.

5.2.3. Restraint Tap (Max. and Min. Taps)

Set in maximum restraint tap for all two-terminal lines. Set in minimum restraint tap for all three terminal lines. The use of maximum restraint on two terminal applications allows the relay to be used for all pilot-wires as indicated in Table 4. The use of minimum restraint on three-terminal applications compensates for the desensitizing effect of a third terminal.

NOTE: The relay pick-up calibration will change slightly (within 5%) between minimum restraint tap and maximum restraint. In most applications, it is not necessary to recalibrate the relay when changing to the minimum restraint tap.

5.2.4. Tapped Loads

Where one transformer bank is tapped to a line protected with two HCB-1 relays, the critical point is to set above the fault current flow for a fault on the other side of the bank. Set the T for not less than:

$$T = 1.91\ I_{PL}(tap\ C);\ T = 1.52\ I_{PL}(tap\ B) \qquad \text{Equ. (11)}$$

where I_{PL} = total secondary fault current feed from all terminals to a phase-to-phase fault on the low side of the bank, divided by the number of terminals (2 or 3).

NOTE: The tapped bank must not act as a ground source for high-side faults. Ordinarily this means that the R_0 tap settings (G, H) need not be changed since no zero-sequence current flows in the line when the low side is grounded.

5.3. SETTING EXAMPLE

Assume:

Two-terminal line.

ct ratio = 600/5

Full-load current = IL = 400A

Minimum 3-phase internal fault current:

Through Station I = 1500A

Through Station II = 2500A

Minimum internal line-to-ground fault current:

Through Station I = 400A

Through Station II = 285A

5.3.1. Phase Fault Pickup

$$I_{(max)} = I_{3P} = \frac{1500 + 2500}{2} x \frac{5}{600} = 16.7(tap\ \text{C})$$

$$I_{(max)} = 0.5 I_{3P} = 8.3(tap\ \text{B})$$

$$I_{(min)} = I_L \frac{400}{120} = 3.3(tap\ \text{C})$$

$$I_{(min)} = \frac{I_L}{2} = 1.7(tap\ \text{B})$$

The phase fault current is sufficient to allow the relay to be set to prevent tripping on an open circuited pilot-wire. Therefore, the desired taps would be:

$$T = 1.25\ I_L = 4.1(tap\ \text{C})$$

$$T = 0.62\ I_L = 2.0(tap\ \text{B})$$

Set both relays for T = 4, R1 = C

The nominal 3-phase fault pick-up current from equation 7 is:

$$I_{nom} = 2T = 8 \text{ amperes}$$

5.3.2. Ground Fault Pickup

Set R_0 = H

For line to ground fault:

$$I_g = \frac{400 + 285}{2} \times \frac{5}{600} = 2.85A$$

$$I_{nom} = 2 \times 0.12 \times 4 = 0.96A$$

5.3.3. Restraint Tap

Use maximum restraint tap.

6.0 INSTALLATION

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

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

7.0 ACCEPTANCE TESTS

The following tests are recommended when the relay is received from the factory.

HCB-1 current pickup values will be within 5% tolerance of the I.L. specification, only for those taps at which the relay is calibrated. For other tap settings, the tolerance may be higher than 5% of nominal, unless recalibration of the relay is performed.

The HCB-1 is factory calibrated at the following taps:

R_1: "C" Tap
R_0: "H" Tap
T "4" Amps

If other tap settings are used, the HCB-1 relay must be recalibrated at the applied settings to obtain pickup current within 5% of the I.L. specifications.

7.1. MAIN UNIT

Connect the relay to the insulating transformer as shown in Figure 8, and set C, H, 4 and maximum restraint tap. With the insulating transformer terminals H1 and H4 open circuited, measure the minimum pick-up current I79 (min.), with current applied through terminals 7 and 9. This value should not be greater than 2.25 amperes.

NOTE: The relay may operate at values of current lower than 2.25 amperes depending upon the insulating transformer used and the prior history of the polar unit. The pickup should not be lower than 1.4 amperes. To increase pickup, short H1-H4 of insulating transformer, apply 40 amperes momentarily to terminals 3 and 5 of relay and check pickup of relay. It should be 2.12 + 5% amperes. If not, the polar unit should be recalibrated per "Polar Unit Calibration."

Now, connect a resistance, R_{PW}, across H1 and H4 of the insulating transformer, with a 10-mfd capacitor connected between H2 and H3. Connect a capacitor. CPW in parallel with R_{PW}. With R_{PW} and C_{PW} set as specified in Table 5 suddenly apply I35 = 30 amperes (through terminals 3 and 5).

Table 5

RPW TEST - Maximum Restraint Tap R1 = C, R0 = H, T-4			
Insulating Transformer Ratio	R_{PW} * In Ohms		C_{PW} in Microfarads
4 to 1	1200	1900	0.75
6 to 1	2700	4300	0.33

* *The relay should not operate at the lower value of RPW, but should operate at the higher value.*

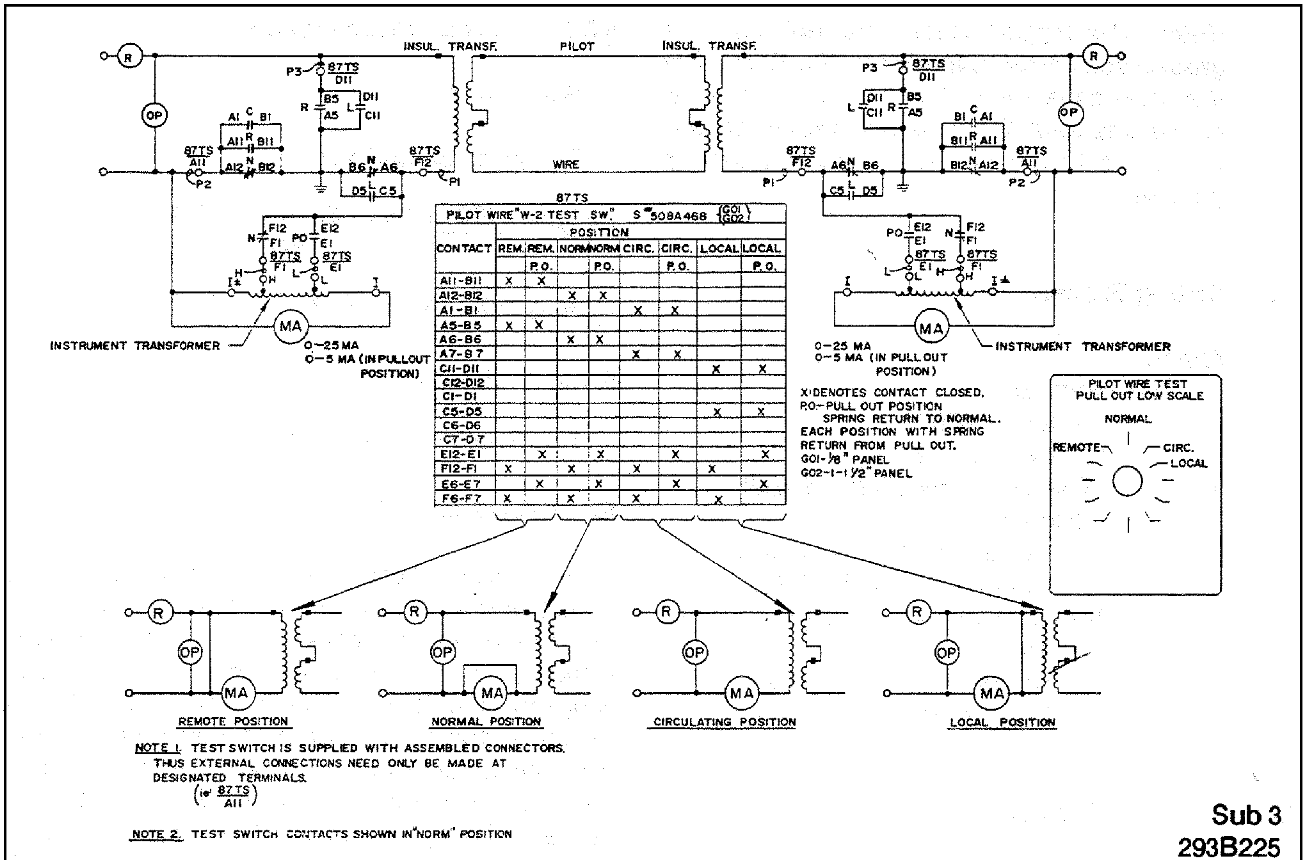


Figure 8: HCB-1 Relay Test Circuits with S#508A468601 - G02 Type W-2 Switch and S#291B318A09 Milliammeter 0 - 5 -25 ma

Additional tests for the sequence filter and the operating unit are described under "Calibration Check." These latter tests are not required unless the relay fails to meet the acceptance tests.

7.1.1. Indicating Contactor Switch (ICS)

Close the main relay contacts and pass sufficient direct current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

7.2. CALIBRATION CHECK

The following tests are recommended whenever a check on the relay calibration is desired.

7.2.1. Over-All Relay Check

Over-all calibration can be checked by the procedure described under "Acceptance Tests." If the relay has been recalibrated in the minimum restraint tap (factory calibration is made in the maximum restraint tap) the R_{PW} test should be made in accordance with

Table 6

R_{PW} TEST - MIN. RESTRAINT TAP R_1 = C, R_0 = H, T = 4		
INSULATING TRANSFORMER RATIO	R_{PW}* IN OHMS	C_{PW} IN MICROFARADS
4 to 1	800 - 1400	0.75
6 to 1	1800 - 3100	0.33

* *The relay should not operate at the lower value of RPW, but should operate at the higher value.*

7.2.2. Sequence Filter

Remove tap screw from upper tap plate and connect a high-resistance voltmeter across the common of the upper tap plate and Terminal 2. Energize the relay with 1_{79} = 2.05 amperes (terminals 7 and 9). The measured open-circuit voltage, V_F, should be:

V_F = .8 ±5% volts with tap settings C and H. Repeat this voltage measurement with I_{59} = 3.44 amperes.

7.2.3. Operating Unit

The following test will check the polar unit calibration and the performance of the rectifiers. Connect a variable non-inductive resistor across the high-voltage terminals of the insulating transformer (H1 to H4), and connect dc millimeters in series with the operating and restraining coils of the polar unit by opening these circuits. (The restraint can be opened at the tap circuit for max. and min. restraint. The operating circuit has to be opened at the polar unit. The operating coil terminals are the rear terminals of the polar unit.) These millimeters 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 C, H, and 4, energize the relay with I35 = 10 amperes (terminals 3 and 5) and increase the variable resistance across the insulating transformer high-voltage terminals until the relay just trips. The values obtained should conform to the following equations:

For minimum restraint: $I_O = 0.12I_R + 7$

For maximum restraint: $I_O = 0.16I_R + 7$

where I_O and I_R are operating and restraining coil currents, respectively, in milliamperes. The results are subject to variations between individual relays, due to different exciting impedances of the insulating transformers. However, the value should never be lower than:

For minimum restraint: $I_O = 0.12I_R + 74$

For maximum restraint: $I_O = 0.16I_R + 4$

7.3. CALIBRATION PROCEDURE

If the factory calibration has been disturbed, the following procedure should be followed to recalibrate the relay.

7.3.1. Filter Calibration

This adjustment is performed by means of the taps on the formed wire resistor (see Figure 2 for location).

1. Remove tap screw from upper tap plate and set lower tap screws in A and H.
2. Connect voltmeter (low-reading, high resistance rectox) across tap A and the common of the upper tap block.
3. Pass 10 amperes ac into terminal 7 and out terminal 5 of the relay and record voltage (voltage should be .70 to .80).
4. Remove voltmeter leads and connect them to non-adjustable point of formed resistor in rear of relay and the front of left-hand tube resistor. (F.V.)
5. Adjust upper adjustable point of formed resistor until voltmeter reads 1.73 times voltage of step 3.
6. Check calibration
   a) Set taps on C and H. (T tap removed) pass 10 amps. into terminal 7 and out terminal 9. Measure the voltage across terminal 5 and common of upper tap block. (Should be between 3.8 and 4.0 volts.)
   b) Pass 10 amperes into terminal 5 and out terminal 7. Measure voltage across non-adjustable point of formed resistor in rear of relay and the front screw of left-hand tube resistor (F.V.). Voltage should be equal to 1/3 of voltage of step 6a.
7. Connect voltmeter to middle adjustable point and upper adjustable point of formed resistor.
8. Pass 10 amperes into terminal 5 and out terminal 7.
9. Adjust middle adjustable point until voltage equals 1/3 of that of step 4.

7.3.2. R_0 Taps

No adjustments can be made on the R_0 resistors. Value of resistance can be checked by passing 5 amperes ac through terminal 3 and out terminal 5. T tap must be disconnected. Following voltages should be measured across terminal 2 and the specified tap of R_0.

R_0 Tap Setting	Volts ac
G	3.8 to 4.2
H	7.6 to 8.4

7.3.3. Polar Unit Contact Adjustment

Place a .088 to .095 inch feeler gage between the right-hand pole face on the armature. This gap should be measured near the front of the right-hand pole face. Bring up the backstop screw until it just makes with the moving contact. Place .045 to .050

gage between moving contact and the stationary contact on the left-hand side of the polar unit. Bring up the stationary contact until it just makes with the gage and lock in place. For relays with double contacts make sure that both upper and lower contacts make at the same time.

7.3.4. Polar Unit Calibration

Connect the restraint tap link in the position in which it will be used. Connect terminals X1 and X2 of the insulating transformer across the pilot-wire terminals of the relay. Connect the relay taps on 4, C, and H.

The sensitivity of the polar unit is adjusted by means of two magnetic, screw-type shunts at the rear of the unit. Looking at the relay front view, turning out the right-hand shunt decreases the amount of current required to close to the right-hand stop. Conversely, drawing out the left-hand shunt decreases the amount required to trip the relay. In general, the father out the shunt screws are turned, the greater the toggles action will be and as a result, the dropout current will be lower. In adjusting the polar units, be sure that a definite toggle action is obtained, rather than a gradual movement of the armature.

Start with both shunts out 4 to 5 turns. Short out the pilot-wire on the high side of the insulating transformer. Momentarily apply 40 amperes from terminals 5 to 3. Now remove the short from H1 to H4 and apply current to terminals 7 and 9. Adjust the shunts at the rear of the polar unit such that the unit operates at 2.10 to 2.15 amperes and resets at 1.0 amperes or higher.

NOTE: Right-hand shunt controls pickup while left-hand shunt controls dropout.

After this adjustment is complete, short out pilot-wire and apply 40 amperes momentarily from terminals 5 to 3. Now remove the short from H1 to H4 and check pickup for I_{79}. If value has changed from before, it will be necessary to re-adjust the right-hand shunt. Several trials may be necessary before the relay will pickup at 2.10 amperes and dropout at 1.0 amperes or higher. In each case, 40 amperes should be applied to terminal 5 and 3 with the H1 and H4 terminals shorted before any additional adjustments are performed on the shunt.

After the shunts have been adjusted, apply 40 amperes momentarily to terminals 3 and 5 of the relay with the pilot-wire open. Pickup will be approximately 1.4 amperes with current applied to terminals 7 and 9. This change in pickup is due to a change in the residual magnetism in the polar unit of the relay. In the de-energized state, the permanent magnet of this unit produces a flux or magnetic bias to keep the contacts open. When the unit is energized, a second flux (electrical) is produced which either adds to or subtracts from the magnetic flux. When the electrical flux is removed, the magnetic structure of the polar unit is changed. Hence, the flux produced by an excess of restraint current, adds to the magnetic bias, and the flux produced by an excess of operating current subtracts from the magnetic bias. This characteristic is inherent in the polar unit and has no effect on the overall performance of the relay.

After the shunt adjustment has been made, change the input current connections to terminals 3 and 5. Apply 40 amperes momentarily with H1 and H4 terminals shorted. Remove short and measure pickup with current applied to terminals 3 and 5. The relay should trip with I_{35} = 0.45 to 0.55 amperes.

8.0 ROUTINE MAINTENANCE

8.1. CONTACTS

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

8.2. ICS UNIT

Close the main relay contacts and pass sufficient direct current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap setting being used. The indicator target should drop freely.

8.3. OPERATING UNIT

Check the relay minimum pick-up with the pilot-wires disconnected from terminals H1 and H4 of the insulating transformer, by energizing with I_{79} current (terminals 7 and 9). Pick-up current should be:

I_{79} (MIN) = .53 T ±5% amperes

Additional tests are recommended with the pilot-wire connected as described under "Complete System Test".

9.0 COMPLETE SYSTEM TEST

At the time of the initial installation and at subsequent maintenance periods, it is recommended that the following relay system checks be made, with the pilot-wire connected.

9.1. MINIMUM PICKUP

CAUTION

In making this test with the relay in place on the switchboard, it is necessary to connect the load box in the circuit between the relay and the "HOT" side of the supply circuit. If this precaution is not observed, it is possible to cause a short circuit between the grounded station service supply circuit and the ground of the current transformer circuit.

The minimum pickup of each relay should be checked before starting the system tests. With taps 4CH, as specified in Figure 9, and the pilot-wire circuit open on the high side of the insulating transformer, each relay should trip with I_{AN} = 0.45 to 0.55 amp or with I_{BC} = 2.10 to 2.15 amp.

With the pilot-wire connected, energize one relay with I_{AN} and determine the minimum pick-up of all relays. Repeat this test by energizing the other relay or relays. Record these values for future reference.

9.2. VERIFICATION CIRCUIT TESTS (Ref. Figure 9)

In performing these tests, the following procedure should be used.

1. Standard testing equipment is recommended for permanent installation with the relays as shown in Figure 8. If this equipment is not available, a similar portable test should be set up using a low-resistance ac milliammeter.
2. Red handle flexitest case switch should be open to interrupt the breaker trip circuit.
3. A test crew is necessary at each substation with a means of communication between them.
4. When the test calls for delivering only specified currents to the relay, it is necessary to use a thin piece of insulating material in the ammeter test jack. For example, test #5 of Figure 9 relay "N". To apply phase A to N current to the near relay only, the switches associated with terminals 6, 7, 8, 9 of Figure 3 must be open. Opening switches 6 and 8 short circuits the current transformers for phases B and C. ***However, it is also necessary to insert the insulating material in the ammeter test jacks associated with terminals 7 and 9 in order to break up the connection between the filter in the relay chassis and the grounded input circuits from current transformer circuits from current transformers in phases B and C.***
5. To facilitate making test #2 of Figure 9 two ammeter test plugs wired together with a foot or two of flexible wire should be used. With these two test plugs suitably wired together, one of them may be shoved in the ammeter test jack associated with terminal 9, Figure 3. *(This should not be done until the switches for terminals 6 and 8 have been open, thus short circuiting the current transformers involved)*. It is desirable to wire the test plugs together such that when one is shoved in the one ammeter test jack with the red side up, and the other is shoved in the other ammeter test jack with the black side up, it is then known that the B and C phase currents to the relay have been reserved at the input to the chassis in line with test #2, Figure 9. After these test plugs are properly inserted, it is then appropriate to close the switches associates with the terminals 6 and 8, Figure 3, in order to remove the short circuit from the current transformer secondaries.

Perform the tests as indicated in Figure 9 recording the milliammeter readings and the relay input current at the same instant, for future reference. The headings "Circulating" and "Remote" in the table of Figure 9 refer to the test switch positions, "CIRC" and "REM." For tests 3 to 6 of Figure 9, the input current should be increased to about 1.5 amperes by an auxiliary current transformer, if the secondary load current is below this value. Also record the input and output readings with the test switch in the "Local" position. Typical values for the "Local" position readings are shown in Figure 13.

9.3. THREE TERMINAL LINES

A similar procedure to Figure 9 should be followed for three-terminal line applications. In this case open the line circuit breaker at one terminal, and disconnect the leads from the pilot-wire terminals to the insulating transformer (open H1 and H4) at the that terminal. This leaves the remaining position of the line operating as a two terminal line. Now perform the normal tests as outlined for the two terminal line system test. When these tests have been satisfactorily completed, return the third terminal relay to normal and close the breaker at that station. Repeat the above procedure with a different breaker open and relay disconnected. This will complete the check of the three terminal line.

9.4. ENERGY REQUIREMENTS

The volt-ampere burden of the type HCB-1 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:

Relay Taps	Phase A VA	Phase A Angle	Phase B VA	Phase B Angle	Phase C VA	Phase C Angle
A-F- 4	2.4	5°	0.6	0°	2.5	50°
A-H- 10	3.25	0°	0.8	100°	1.28	55°
B-F- 4	2.3	0°	0.63	0°	2.45	55°
B-G- 4	3.98	0°	1.28	92°	.88	42°
B-H- 10	4.95	0°	2.35	90°	0.3	60°
C-F- 4	2.32	0°	0.78	0°	2.36	50°
C-H- 10	6.35	342°	3.83	80°	1.98	185°

Relay Taps	Phase A VA	Phase A Angle	Phase B VA	Phase B Angle	Phase C VA	Phase C Angle
A-F- 4	2.47	0°	2.110°		1.97	20°
A-H- 10	7.36	0°	12.553°		6.7	26°
B-F- 4	2.45	0°	2.0915°		2.07	10°
B-G- 4	16.82	9.90°	16.7913.5°		15.10	4.0°
B-H- 10	16.8	55°	22.050°		12.3	38°
C-F- 4	2.49	0°	1.9915°		2.11	15°
C-H- 10	31.2	41°	36.038°		23.6	35°

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

The continuous rating of the relay is 10 amperes.

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

9.5. PILOT-WIRE ENERGY

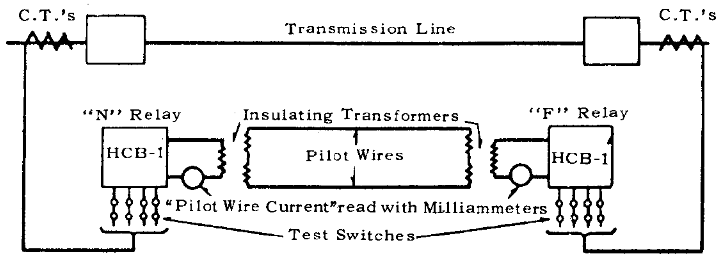
The current and voltage impressed on the pilot-wire do not exceed 100 milliamperes and 60 volts. The wave form and magnitude of the pilot-wire current are such that telephone interference is within the limits allowed by the local operating telephone company. This permits the use of leased telephone lines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

10.0 RENEWAL PARTS

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

APPROXIMATE RESISTANCE VALUES OF COMPONENTS IN HCB-1 RELAY		
Transformer	Secondary Winding	Start to Tap 20 to 30 ohms Start to Finish 110 to 140 Ohms
Polar Unit	Operating Coil	290-320
Polar Unit	Restraining Coil	Maximum 12 - 16 ohms Minimum 9 - 12 ohms
Resistor	R_C	41 - 44 ohms
Tube Resistor	R_0	Total of 1.6 ohms
Formed Resistor	R_1	0.131 ohms
Rectifiers		IN91 Germanium Diodes
Indicating Contactor Switch		0.2 amp. Tap 6.5 ohms 2.0 amp. Tap o.15 ohms

THIS SPACE RESERVED FOR NOTES



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 performing these tests, the verification tests of page 15 should be followed.

1. Test #1 of #2: The relay at both ends of the line should be set on R_1 = C, R_0 = F, and T = 4. This setting will permit tests, 1 & 2 to be performed without the influence of any zero sequence current unbalance which may exist.
2. Test #3, 4, 5, and 6: The relay at both ends of the line should be set on R_1 = C, R_0 = H, and T = 4.

RELAY "N"							RELAY "F"						
Test No.	Test Switch NABC	Relay Current	Relay Trip	"Pilot Wire Current" Remote	Circ.	Local	Test No.	Test Switch NABC	Relay Current	Relay Trip	"Pilot Wire Current" Remote	Circ.	Local
1		A,B,C,N	No	(1)	(1)	(1)	1		A,B,C,N	No	(1)	(1)	(1)
2		A,C,B,N	No	(2)	(2)	(2)	2		A,C,B,N	No	(2)	(2)	(2)
3		A,N	Yes	None (4)	(3)	(3) (4)	3		O	Yes	(3) (4)	(3)	None (4)
4		O	Yes	(3) (4)	(3)	None (4)	4		A,N	Yes	None (4)	(3)	(3) (4)
5		A,N	No	(3)	(3)	(3)	5		A,N	No	(3)	(3)	(3)
6		A,N	Yes	(3) (4)	(6)	(3) (4)	6		B,C,N	Yes	(3) (4)	(6)	(3) (4)

R E M A R K S

Tests 1 and 2 are to check normal positive sequence rotation of phases.
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.

LEGEND OF TEST SWITCH SYMBOLS: To Relay — N A B C — **Normal Connection. All Currents to Relay.** — N A B C — To C.T.'s

EXAMPLE — **Phase A current from C. T.'s to Relay. Phase B and C. T.'s shorted to neutral.**

(1) The "pilot wire current" will vary depending upon the magnitude of the through load current and the characteristics of the pilot wire. See Figures 11, 12 and 13.
(2) Since the relay is temporarily connected for negative sequence, these currents should be approximately 2.3 times the values of test 1.
(3) These readings may be "off scale" depending upon the magnitude of the load current.
(4) The relay at this station should reset because the relay operating coil will be receiving no current from either the pilot wire or the current transformers.
(5) 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.

Figure 9: HCB-1 Relay System Verification Tests

(6) 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.

INTERPRETATION OF TESTS

1. Tests #1 and #2 are designed to indicate that the relays have been wired with the correct phase rotation.

a. If either relay has inadvertently been connected for the wrong phase rotation, then the fact will be apparent when reading local current. Local current should be interpreted from Figure 13, with the amount of load current which is present. Although Figure 13 shows positive sequence amperes input for the abscissa, it can still be used to interpret test #2 in line with note (2) because, with the relay on tap $R_1 = C$ as specified, and with the temporary reversal of phases B and C, the relay has an increased output as noted in note (2).

b. In the event the pilot wire is open-circuited, the apparent circulating current will be quite low, being limited to the magnetizing current of the insulating transformer. Also, it will not be possible to read current from the remote end.

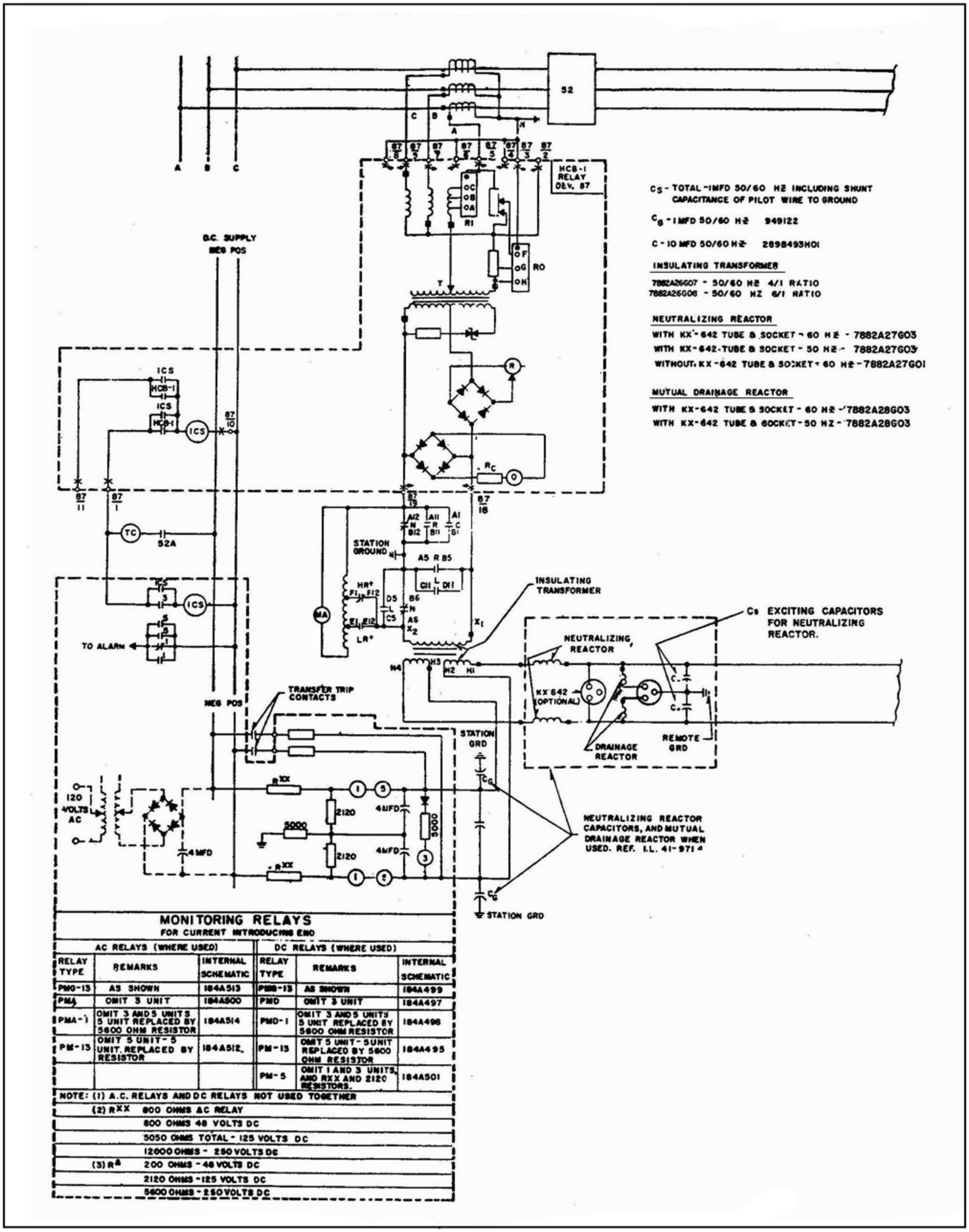
c. If the pilot wire is short-circuited, then the circulating current will be near normal, but it will not be possible to read current from the remote end.

2. If the pilot wire is reversed, (a) the circulating current will be low on test #1, but it will be possible to read pilot-wire current from the remote relay. (b) Both relays will trip on test #5. If the monitoring relays also suffer from this error in connection, then the error should be corrected at one relay location by reversing the connections to the H_1-H_4 terminals of the insulating transformer. However, if the monitoring relays do not suffer from this error, then the polarity of the pilot wires insofar as the HCB-1 relay installation is concerned may be suitably corrected by making a reversal of connections either at the X_1-X_2 terminals of one insulating transformer, or at the output terminals of the relay, #18 and #19, Figure 3.

3. If the phases are rolled at one end of the line, then this will be picked up by test #5. On test #5, neither relay should trip when phase-A-to-neutral current is delivered to each of the two relays with the switching arrangement as shown and discussed. However, if one or both relays trip, then try checking the near relay, phase-A-to-neutral current, against phase-B-to-neutral current at the far relay. Also, check phase-A-to-neutral current at the near relay against phase-C-to-neutral current at the far relay. If, for example, neither relay trips when phase-A-to-neutral current is used for the near relay and phase-B-to-neutral current is used at the far relay, then it is an indication that what had been thought to be phase B current at the far location really identifies with phase A current at the near location. This identifies a rolled-phase condition, and also indicates the correction which must be made in the connections of the current transformer input to the relay.

4. One combination of errors which is somewhat tricky to pick up is the combination of pilot wires reversed plus a rolled-phase condition at one end. Let it be assumed that the pilot wire is reversed at the far end, making an error of 180 degrees. Then let it be assumed that the phases are also rolled by 120 degrees, thereby adding another error of 120 degrees. Adding these two together brings the total up to 300 degrees, which is within 60 degrees of what would be normal. Because of this, the only symptom which will appear in the first four tests is that the circulating current is likely to be lower than one would expect when read at one end or the other on test #1. However, test #5 may be used to identify this combination of errors. When the condition exists as described, when test #5 is extended to check phase A current at the near end against each of the three currents at the far end in turn, it will be found that at least one of the two relays will always trip. If this condition is found, reverse the pilot-wire connection, check out the rolled-phase condition and correct it, and then proceed with all six tests.

5. Test #6 is a final verification test.

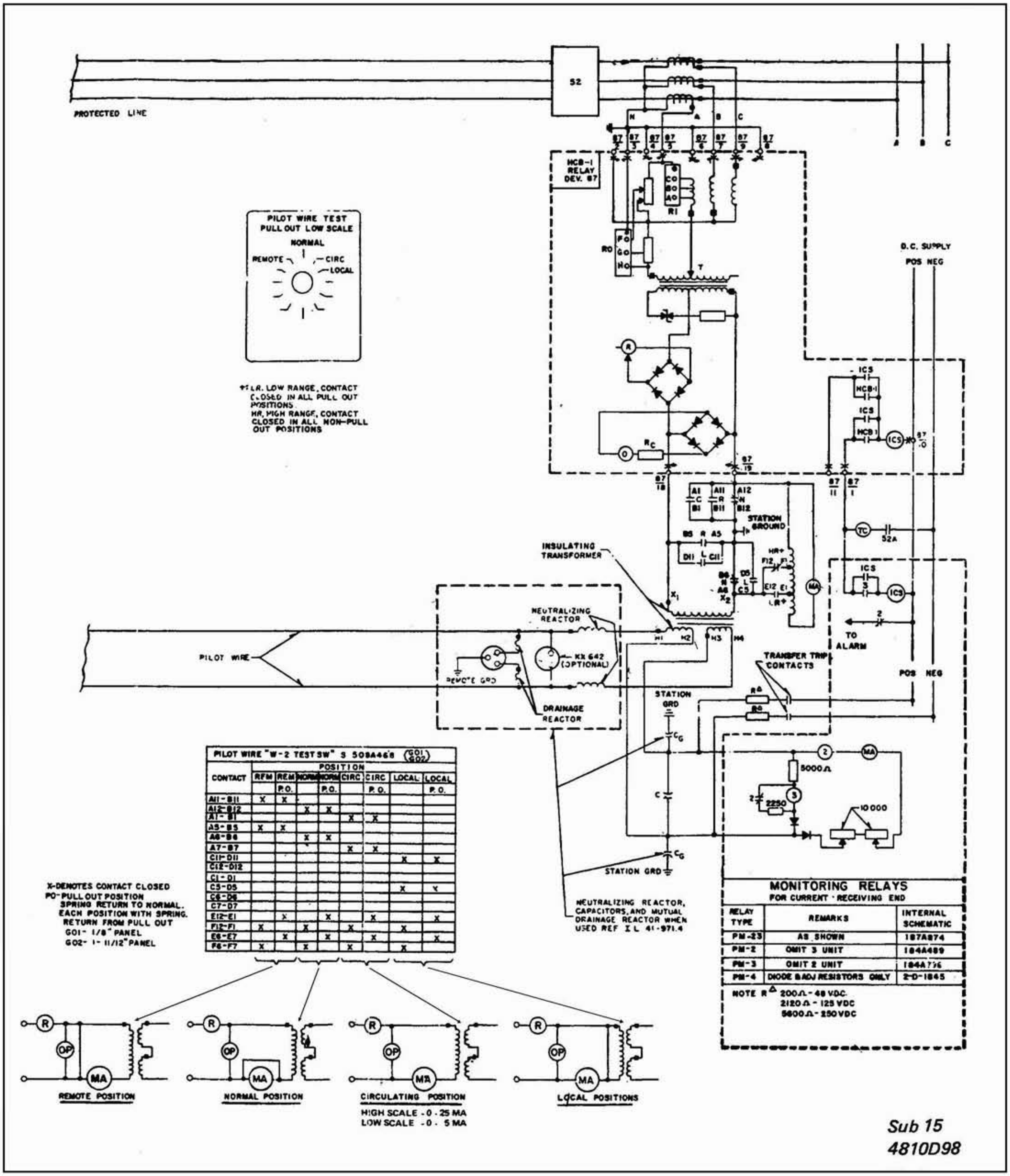


MONITORING RELAYS
FOR CURRENT INTRODUCING END

AC RELAYS (WHERE USED)			DC RELAYS (WHERE USED)		
RELAY TYPE	REMARKS	INTERNAL SCHEMATIC	RELAY TYPE	REMARKS	INTERNAL SCHEMATIC
PMG-13	AS SHOWN	184A513	PMG-13	AS SHOWN	184A499
PMA	OMIT 3 UNIT	184A500	PMD	OMIT 3 UNIT	184A497
PMA-1	OMIT 3 AND 5 UNITS 5 UNIT REPLACED BY 5600 OHM RESISTOR	184A514	PMD-1	OMIT 3 AND 5 UNITS 5 UNIT REPLACED BY 5600 OHM RESISTOR	184A498
PM-13	OMIT 5 UNIT- 5 UNIT. REPLACED BY RESISTOR	184A512	PM-13	OMIT 5 UNIT - 5 UNIT REPLACED BY 5600 OHM RESISTOR	184A495
			PM-5	OMIT 1 AND 3 UNITS, AND RXX AND 2120 RESISTORS.	184A501

NOTE: (1) A.C. RELAYS AND DC RELAYS NOT USED TOGETHER
(2) R^{XX} 800 OHMS AC RELAY
800 OHMS 48 VOLTS DC
5050 OHMS TOTAL - 125 VOLTS DC
12000 OHMS - 250 VOLTS DC
(3) R^{Δ} 200 OHMS - 48 VOLTS DC
2120 OHMS - 125 VOLTS DC
5600 OHMS - 250 VOLTS DC

Fig.10a Typical HCB-1 Relay System



PILOT WIRE "W-2 TEST SW" S 508A468 (G01/G02)

CONTACT	RFM	REM P.O.	NORM	NORM P.O.	CIRC	CIRC P.O.	LOCAL	LOCAL P.O.
A11-B11	X	X						
A12-B12			X	X				
A1-B1					X	X		
A5-B5	X	X						
A6-B6			X	X				
A7-B7					X	X		
C11-D11							X	X
C12-D12								
C1-D1								
C5-D5							X	X
C6-D6								
C7-D7								
E12-E1		X		X		X		X
F12-F1	X		X		X		X	
E6-E7		X		X		X		X
F6-F7	X		X		X		X	

MONITORING RELAYS FOR CURRENT - RECEIVING END

RELAY TYPE	REMARKS	INTERNAL SCHEMATIC
PM-23	AS SHOWN	187A874
PM-2	OMIT 3 UNIT	184A489
PM-3	OMIT 2 UNIT	184A736
PM-4	DIODE & ADJ RESISTORS ONLY	2-D-1845

NOTE R△ 200Ω - 48 VDC.
2120Ω - 125 VDC
5600Ω - 250 VDC

Fig.10b Typical HCB-1 Relay System

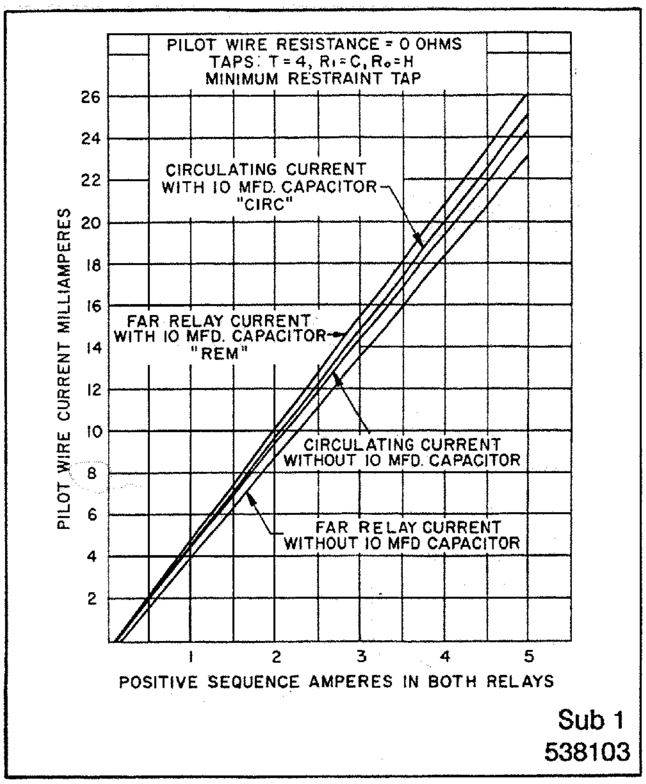


Fig. 11. Typical Test Output vs. Input Relay Current in a Two - Terminal Line with Zero Pilot - Wire Resistance

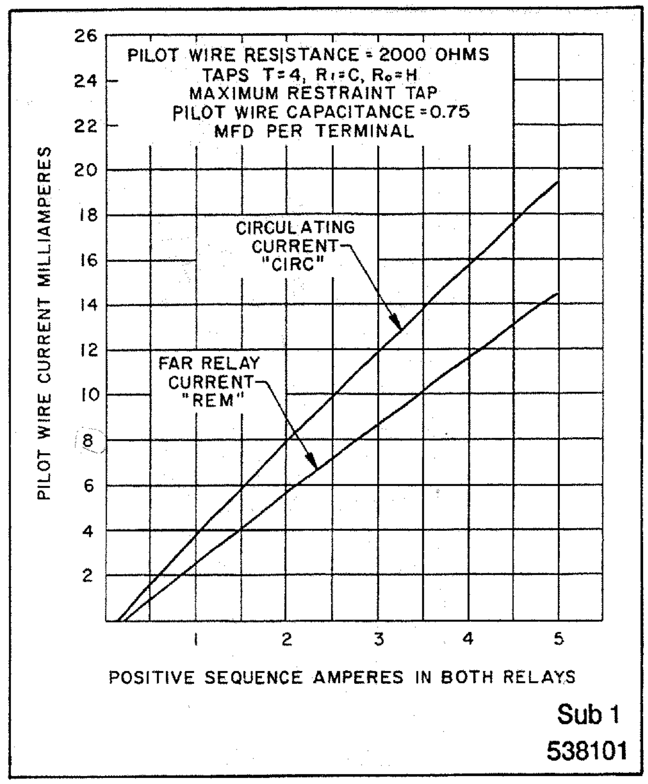


Fig. 12. Typical Test Output vs. Relay Current in a Two - Termianl Line with 2000 - Ohm Pilot - Wire Resistance With or Without 10 - mfd Capacitor

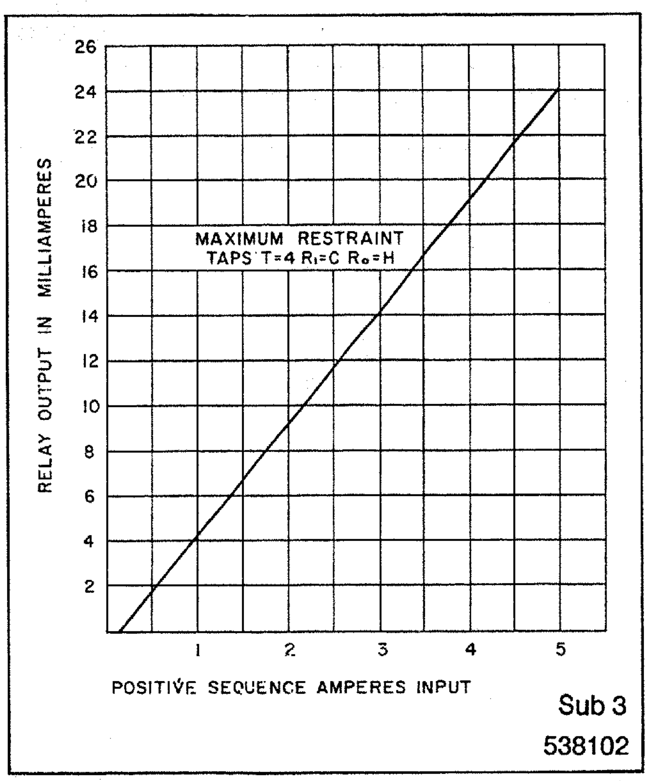


Fig. 13. Typical Curve of Relay Output vs. Positive Sequence Input - Test Switch in Local Position

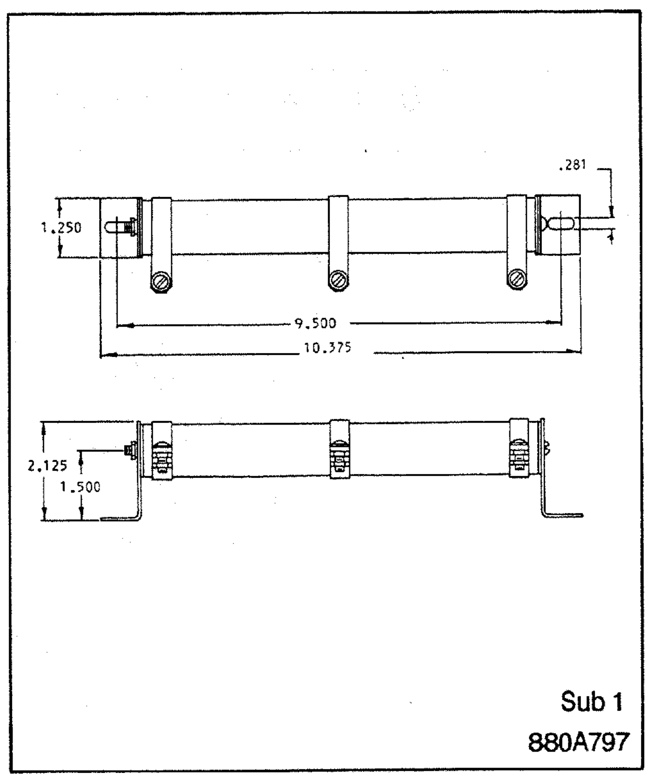


Fig. 14. Outline and Drilling Plan of S#290B664G65 Balancing Resistor for Thre - Terminal Line Applications

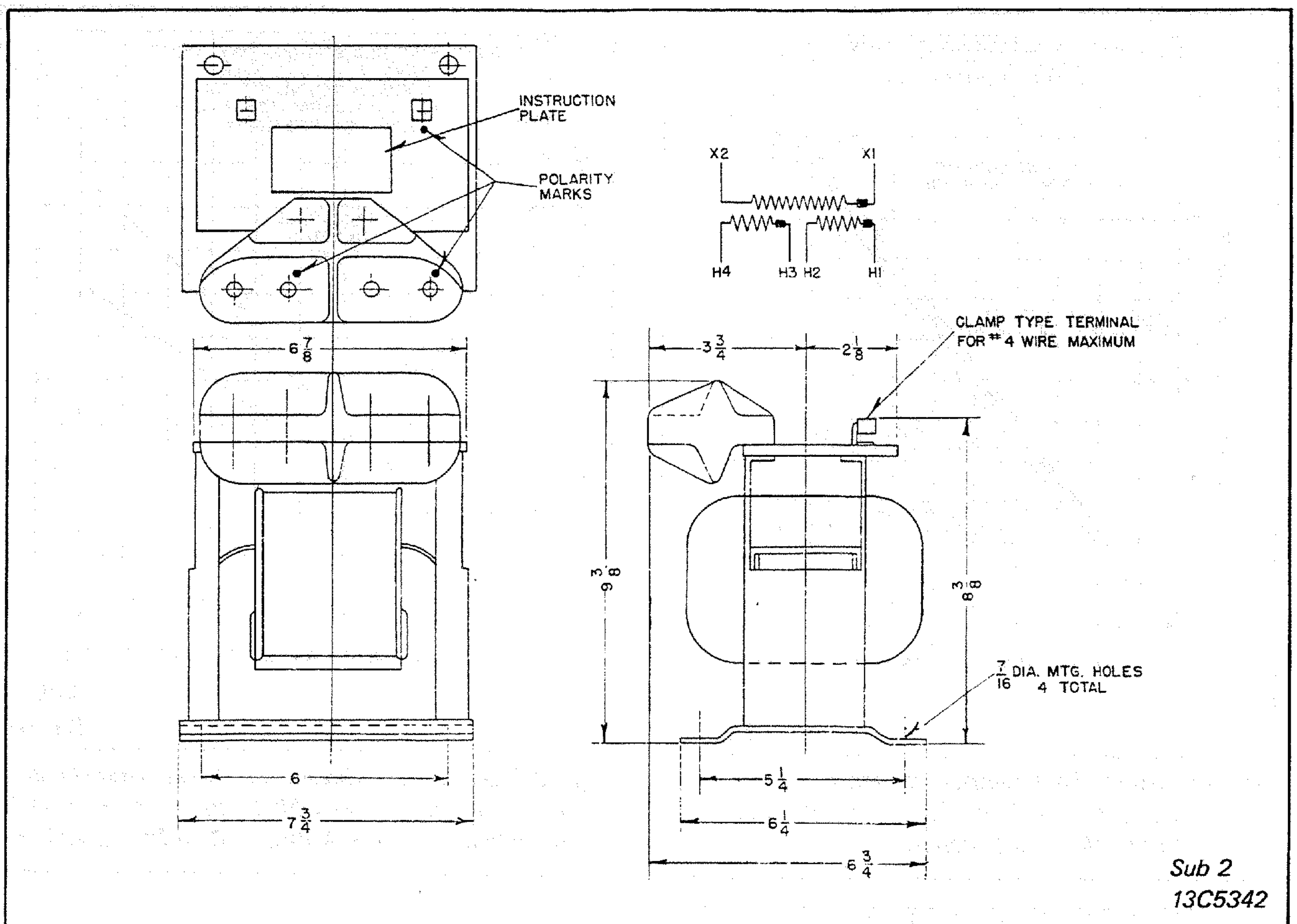


Fig. 15. Outline and Drilling Plan of HCB - 1 Relay Insulating Transformer

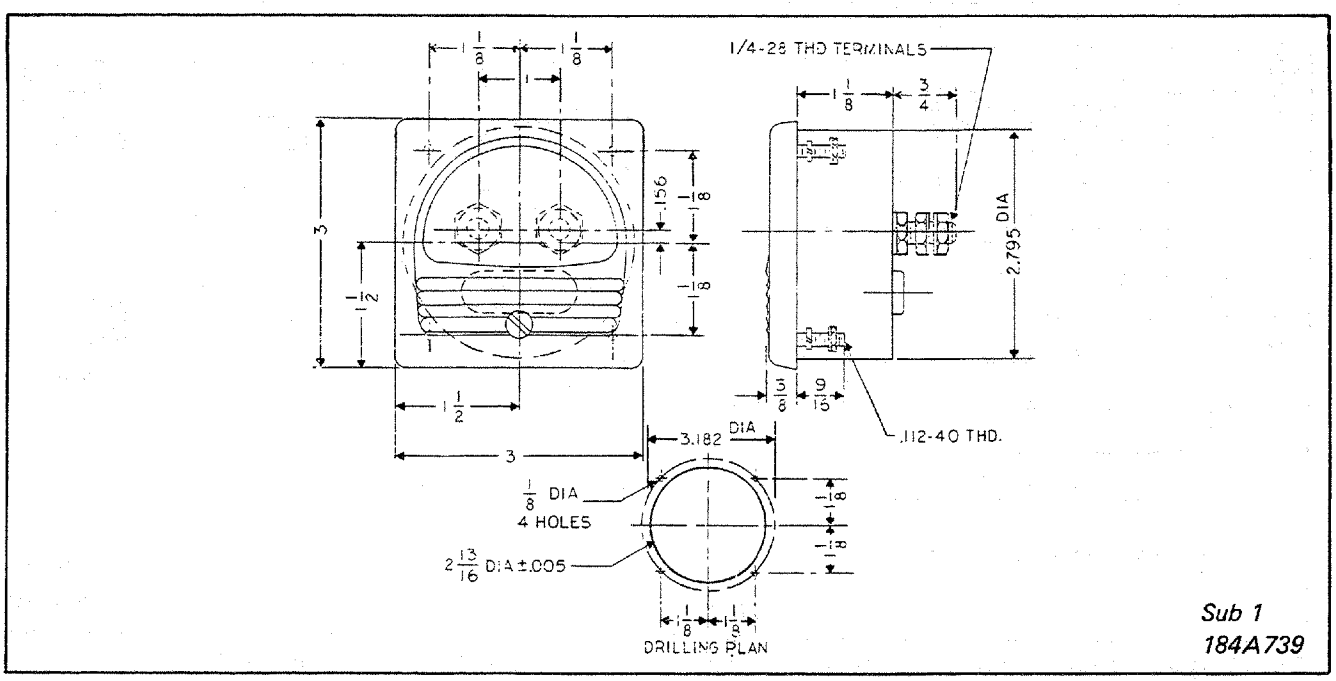


Fig. 16. Outline and Drilling Plan of the Semi - Fluxh - Type Test Milliammeter

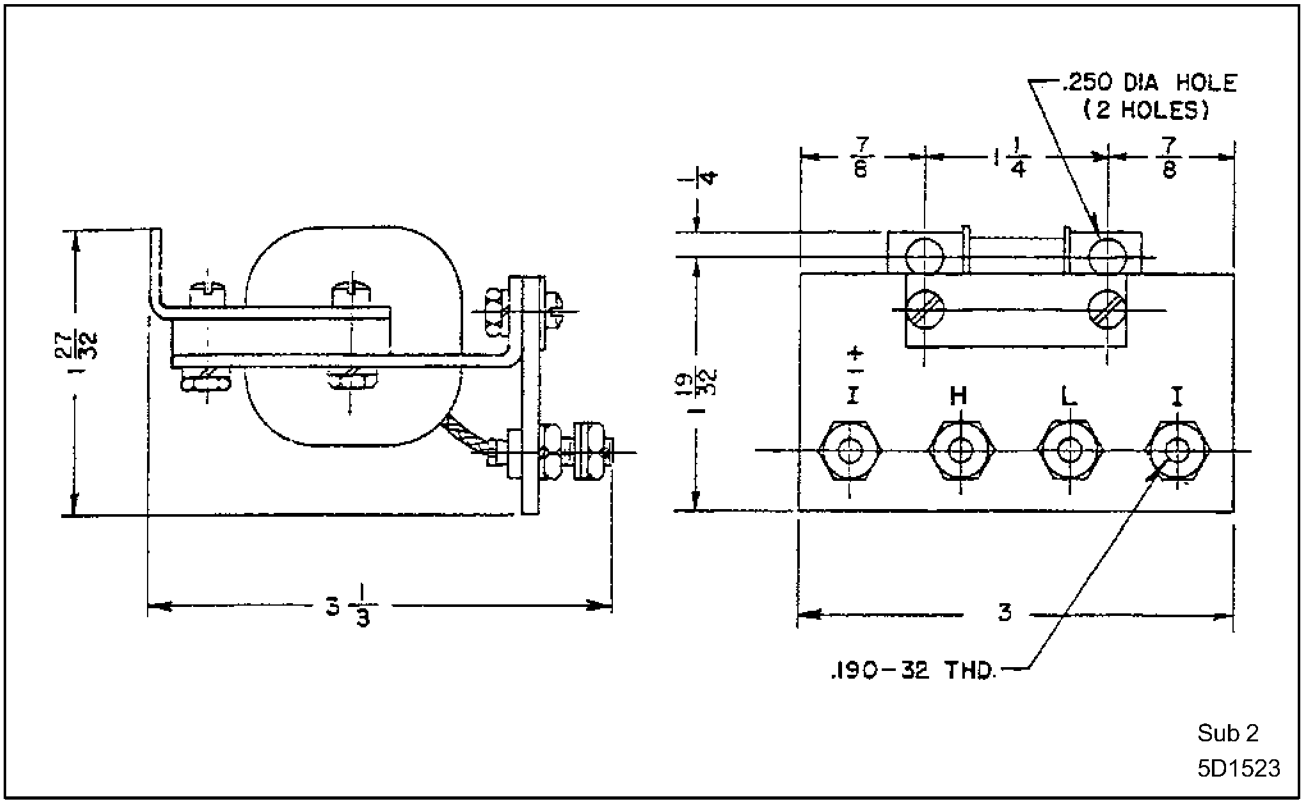
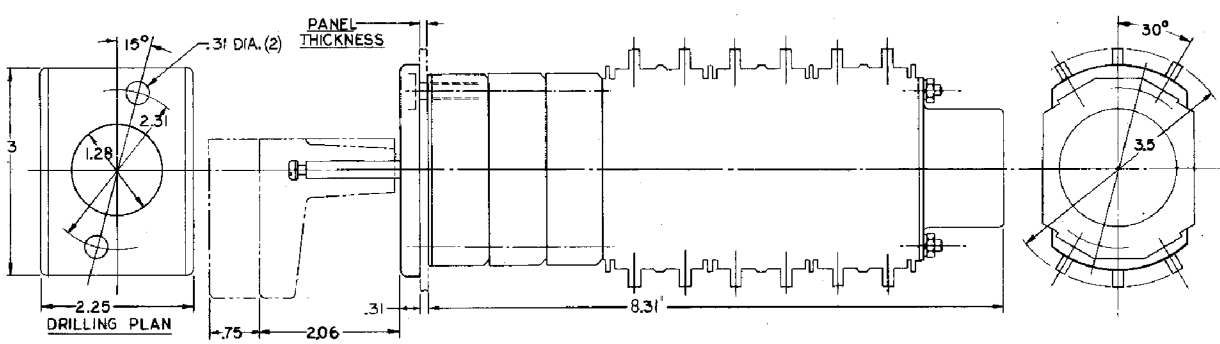
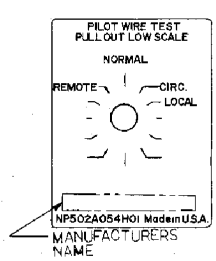


Figure 17: *Outline of the Test Milliammeter Auxiliary Transformer.*





PILOT WIRE W-2 TEST SW. S#508A468 {G01-G02}

CONTACT	POSITION							
	REM	REM P.O.	NORM	NORM P.O.	CIRC	CIRC P.O.	LOCAL	LOCAL P.O.
A11-B11	X	X						
A12-B12			X	X				
A1-B1					X	X		
A5-B5	X	X						
A6-B6			X	X				
A7-B7					X	X		
C11-D11							X	X
C12-D12								
C1-D1								
C5-D5							X	X
C6-D6								
C7-D7								
E12-E1		X		X		X		X
F12-F1	X		X		X		X	
E6-E7		X		X		X		X
F6-F7	X		X		X		X	

X: DENOTES CONTACT CLOSED
P.O. PULL-OUT POSITION SPRING RETURN TO NORMAL
EACH POSITION WITH SPRING RETURN FROM PULL-OUT
G01 1/8" PANEL
G02 1-1/2" PANEL

Sub 1
293B226

Figure 18: *Outline and Drilling Plan of the Type W-2 Test Switch.*

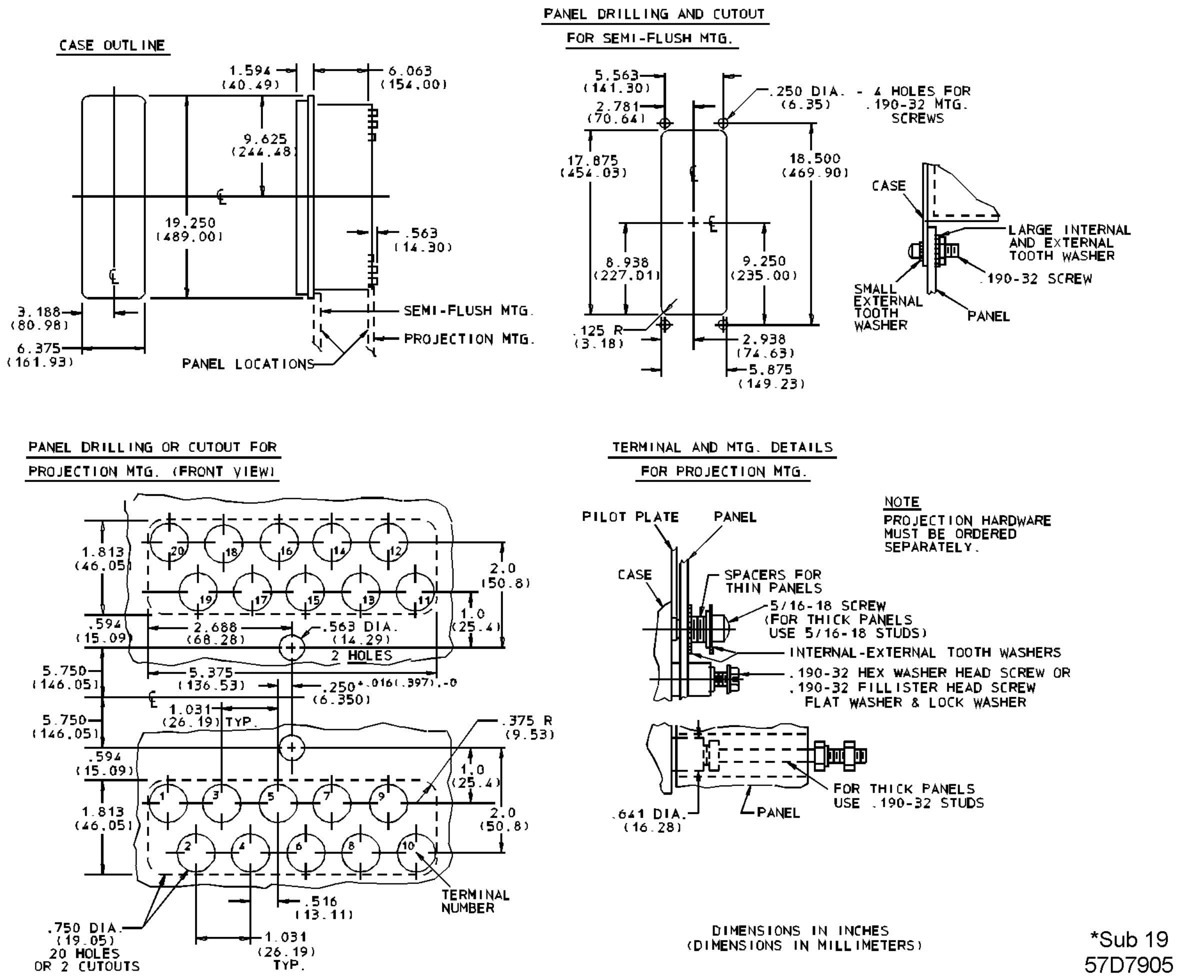


Figure 19: *Outline and Drilling Plan for t he Type HCB-1 Relay in the Type FT-42 Case.*

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