TYPE HCB PILOT WIRE RELAY SYSTEM

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 series resistance are required.

CONSTRUCTION

The relay consists of a combination positive and zero phase sequence filter, a saturating auxiliary transformer, two full wave rectifier units, a polar type relay unit, a neon lamp, 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 milliammeter and test switch. The construction of these components is as follows:

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, located near the bottom of the relay, has two primary and one tapped secondary windings wound on the center leg. The secondary taps are wired to the circularly arranged R_1 tap connections in the front of the relay. The R_1 tap links also connect to the R_1 resistor (looped resistance wire). R_0 consists of three tube resistors located above the reactor. The taps on these resistors are wired to the circularly arranged R_0 tap connections in the front of the relay. The 0.02, 0.03, and 0.05 R_0 taps are on the R_1 resistance wire rather than on the tube resistors.

SATURATING TRANSFORMER

The output of the sequence filter connects to a two-winding saturating transformer in the top rear of the relay. The primary (bottom) winding is tapped and wired to a tap plate, T, located in the front, above the R_1 and R_0 connections. The secondary (top) winding is connected to the neon lamp and from a fixed tap to the relay coil circuits.

RECTIFIER UNITS

The left-hand (rear view) full-wave rectifier supplies a d-c output for the operating coil. The right-hand rectifier supplies the restraint coil.

POLAR RELAY UNIT

This unit consists of a rectangular-shaped magnetic frame, an electromagnet, a permanent magnet, and an armature with one contact. 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 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.

TEST LINKS AND RESTRAINT TAP

Two test links are located at the top front of the relay. The left-hand (front view) link provides a tap connection to the restraint coil. The link, when in the left-hand position, is connected to the restraint coil tap for minimum restraint. With this link in the right-hand position, maximum restraint is provided. The right-hand (front view) link is connected in the operating coil circuit.

INDICATING CONTACTOR SWITCH UNIT (ICS)

The d-c 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
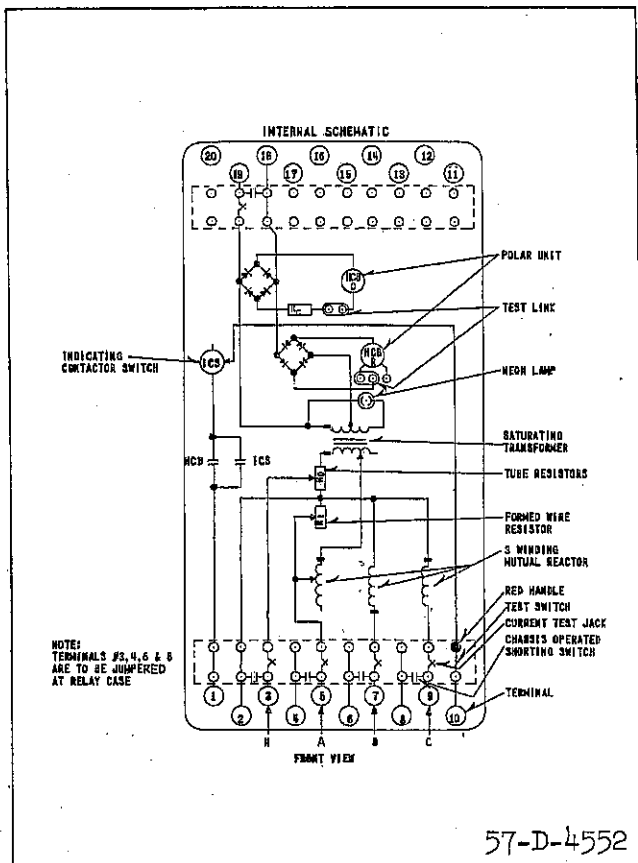
Fig. 1 Internal Schematic of Type HCB Relay in FT-42 Case.

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 at the bottom of the cover.

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

OPERATION

The composite sequence filter converts the three-phase current input into a single-phase voltage output of a magnitude which is an adjustable function of the phase 1 positive and zero sequence current. This voltage is impressed on a saturating transformer. This transformer and a neon tube across its secondary serve to limit the energy input to the pilot wire. The saturating transformer output voltage, V_S, (in Figure 2), is connected to the relay coils and to the pilot wire through the insulating transformer.

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 as shown in Figure 2. 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 polarities 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 5 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.

PILOT WIRE EFFECTS

In Figure 2, 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 over-current device.

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.

OPERATING UNIT THEORY

The polar unit flux paths are shown in Figure 3. With balanced air gaps, the permanent magnet produces flux flowing in two paths, 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.

CHARACTERISTICS

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

$$V_F = 2I_{11}R_1 + I_{10}(R_1 + 3R_0) \text{ volts} \qquad (1)$$

where R_1 and R_0 are the positive and zero sequence tap values, respectively;

I_{11} and I_{10} are the positive and zero sequence phase 1 current inputs, respectively, in amperes. *These are vector quantities.*

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
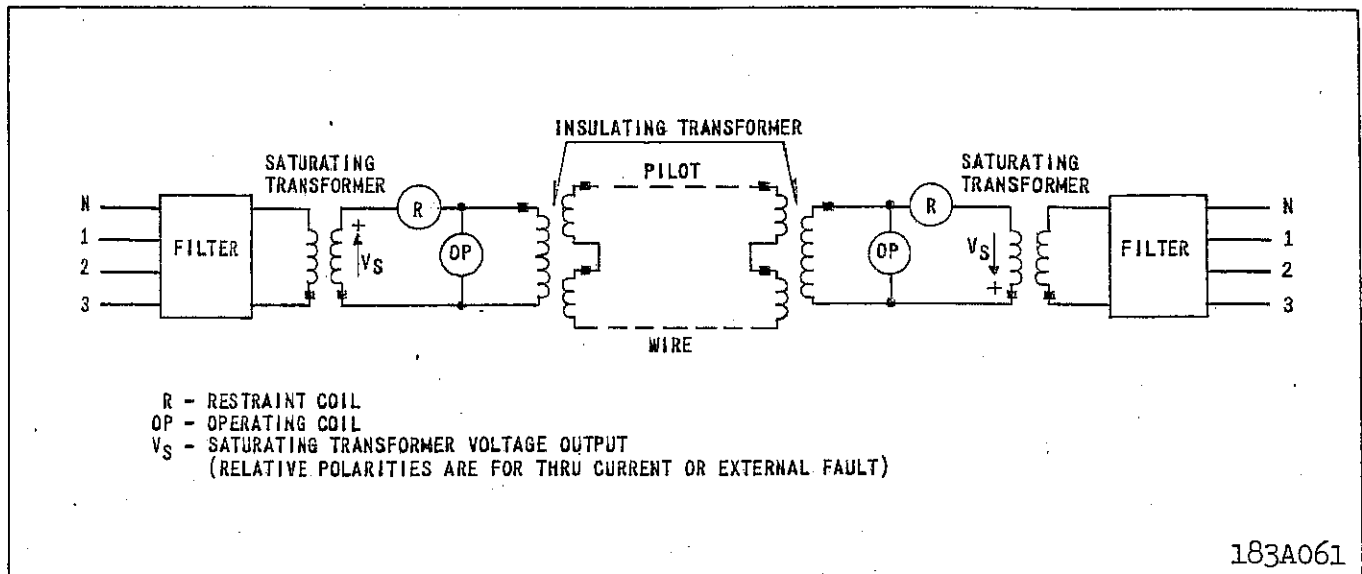
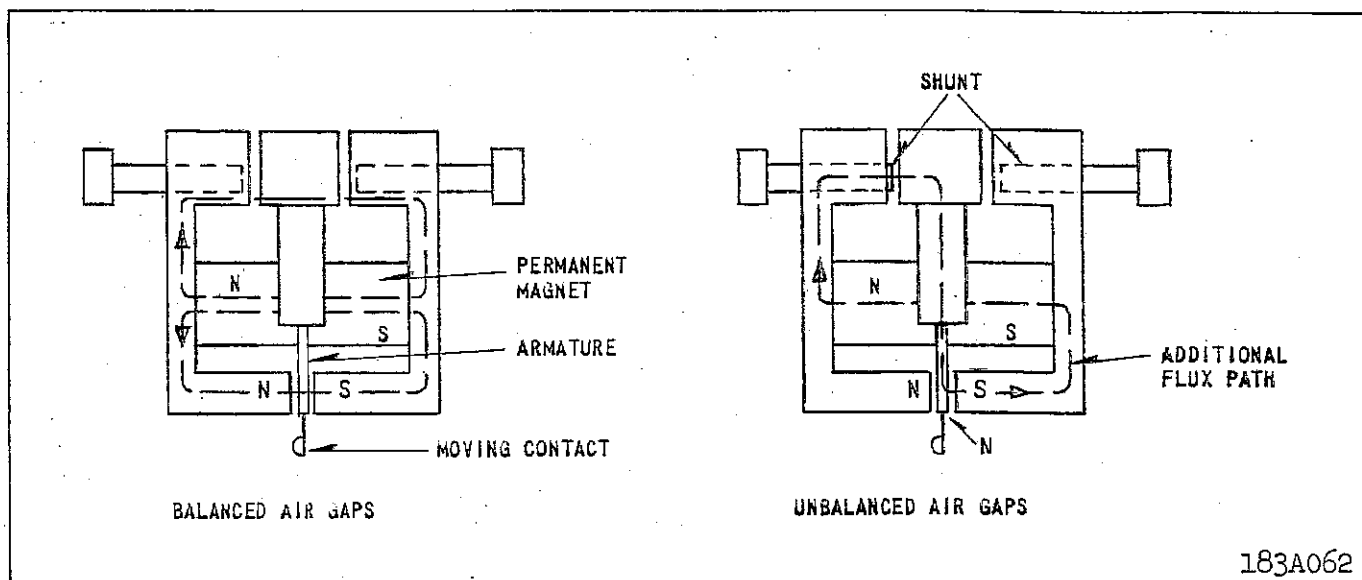Fig. 2 Simplified External Schematic of the HCB Relay System.

Fig. 3 Polar Unit Permanent Magnet Flux Paths.

wire side of the insulating transformer open circuited (H1-H4). The single relay pickup point in terms of filter voltage is:

$$V_F = 0.2T \qquad (2)$$

where T is the saturating transformer tap value. Single relay pickup is defined by equating (1) & (2):

$$0.2T = 2 I_{11} R_1 + I_{10} (R_1 + 3R_0) \qquad (3)$$

Current I_s varies with the type of fault. For example, for a 3 phase fault, $I_s = I_{11}$, since only positive sequence current is present.[11] Substituting $I_s = I_{11}$ in Eq. (3) & rearranging, the 3 phase fault pickup is:

$$I_s = I_{11} = \frac{0.2T}{2 R_1} = \frac{T}{10R_1} \quad \text{(3 phase fault)} \qquad (4)$$

If $R_1 = 0.1$, $R_0 = 1.6$ & $T = 4$:

$$I_s = \frac{T}{10R_1} = \frac{4}{10 \times 0.1} = 4 \text{ amp. (3 phase fault)}$$
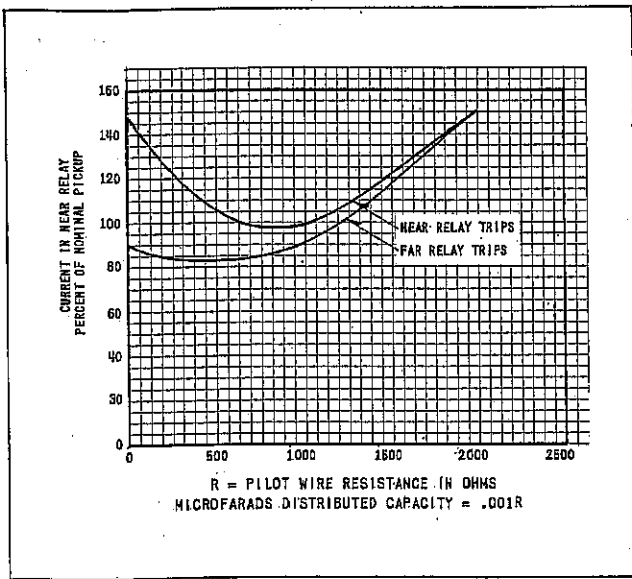
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Fig. 4 *Typical Curves Showing the Effect of the Pilot Wire on Minimum Trip Current, Two-Terminal Line (Maximum Restraint Tap).*

For a phase 1 to ground fault, if $I_{11} = I_{12} = I_{10}$ (I_{12} is the phase 1 negative sequence current):

$$0.2T = 2I_{11} R_1 + I_{11} (R_1 + 3R_0)$$

$$I_{11} = \frac{0.2T}{3(R_1 + R_0)} = I_{10}$$

But: $I_S = I_{11} + I_{12} + I_{10}$

$$= 3I_{11}$$

So: $I_S = 3I_{11} = \frac{0.2T}{R_1 + R_0}$ (1-G fault)   (5)

If $R_1 = 0.1$, $R_0 = 1.6$ & $T = 4$:

$$I_S = \frac{0.2T}{R_1 + R_0} = \frac{0.2 \times 4}{0.1 + 1.6}$$

$$= \frac{0.8}{1.7} = 0.471 \text{ amp. (1-G fault)}$$

NOMINAL PICKUP (ALL RELAYS)

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

$$I_{nom} = K I_S \qquad (6)$$

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, for a phase-1-to-ground fault, & $I_{11} = I_{10}$ with the pilot wire open circuited, the single-relay pickup was previously determined as $I_{1G} = 0.471$ ampere. For a two-terminal line, the nominal pickup for a phase-1-to-ground fault ($R_1 = 0.1$; $R_0 = 1.6$; $T = 4$) is:

$$I_{nom} \text{ (1 to G)} = 0.471K = 0.471 \times 2 = 0.942 \text{ ampere.}$$

MINIMUM TRIP (ALL RELAYS)

With equal inputs to all relays and zero pilot-wire shunt capacitance, the relays will operate at their nominal pick-up 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 4 shows the relay operating points for a two-terminal line, assuming input current to the near relay, only.

An example of the characteristics with various current distributions is shown in Figure 5. 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 5 to apply.

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 is connected to the pilot-wires.

PILOT-WIRE REQUIREMENTS

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

TABLE I

No. of Relays	Insulating Transformer Ratio			
	4/1		6/1	
	R_L	C_S	R_L	C_S
2	2000	1.5	—	—
3	500/LEG	1.8	1000/LEG	0.75

R_L = series loop resistance in ohms.
C_S = total shunt capacitance in microfarads.

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 (H-1 to H-4) as a result of induction or a rise in station ground potential, should be less than 7.5 volts to prevent undesired relay operation.

For three-terminal applications, the loop resistance of all legs of the pilot wire must be balanced within 5 percent, with variable resistors as shown in Figure 6. 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.

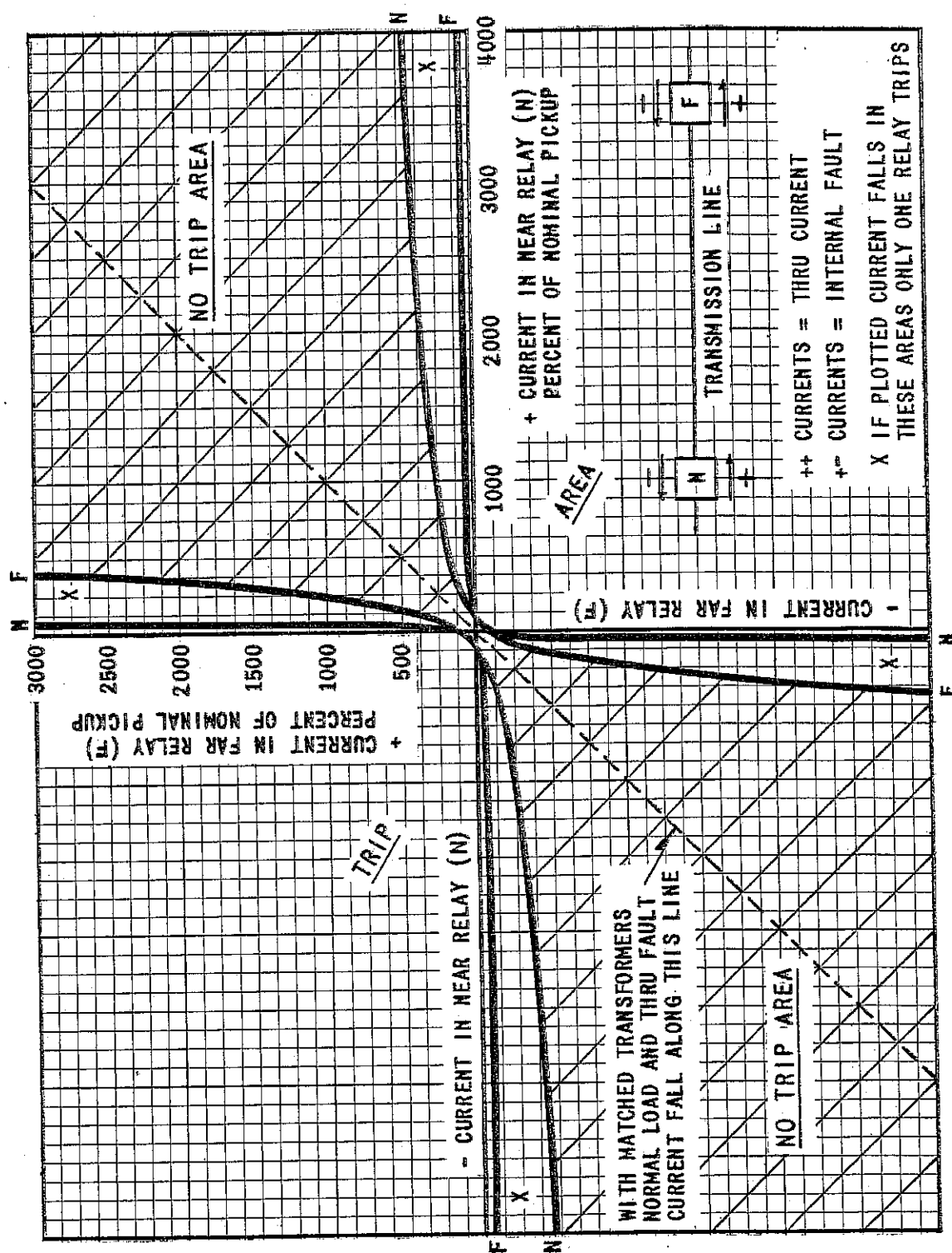Induced voltages and rises in station-ground po-

Fig. 5 *Typical Operating Characteristics of the HCB Relay System — Maximum Restraint Tap, with Insulating Transformers and 2000-Ohm Pilot Wire. V$_F$ of Near and Far Relays in Phase or 180° Out of Phase.*
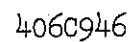
Fig. 6 *External Schematic of the Type HCB Relay in FT-42 Case — Two- or Three-Terminal Line.*

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tential may be handled by the following means:

a) Neutralizing reactors may be connected in series with the pilot wire to hold the terminal equipment at the local ground potential. The neutralizing reactor will also hold the pilot wire close to the remote ground potential, unless the wires are raised above remote ground potential by an induced voltage. The neutralizing reactor is effective in protecting terminal equipment in the presence of a rise in station-ground potential, but may not limit pilot-wire voltages to safe values in the presence of induced voltages. When using the neutralizing reactor, the pilot-wire sheath should be insulated from station ground to minimize sheath-to-pair potential in the presence of a rise in station-ground potential. All other pairs 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 and 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 a-c voltage across the wires. Thus, the HCB system will operate normally even though the protector tube has flashed over. The drainage reactor will maintain the terminal equipment at the station-ground potential, but may not limit potentials near the center of the pilot-wire circuit to safe values in the presence of a station-ground potential rise.

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 KX642 protector tube must be connected to remote ground.

TRIP CIRCUIT

The main contacts will safely close 30 amperes at 250 volts d.c., 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.

TRIP CIRCUIT CONSTANT

Indicating Contactor Switch (ICS)

0.2 ampere tap; 6.5 ohms d-c resistance
2.0 ampere tap; 0.15 ohms d-c resistance

BURDEN DATA

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, $R_1 = 0.075$ and $R_0 = 0.39$

Phase A	1.25 volt-amperes	0°
Phase B	0.30 volt-amperes	285°
Phase C	0.90 volt-amperes	45°

For tap 4, $R_1 = 0.15$ 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.

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 Bell Telephone Company. This permits the use of leased telephone lines as a pilot-wire channel.

TAPS

There are four setting taps in the relay:

1) Restraint tap — maximum or minimum
   Connections are made by links in the top front of the relay.

2) Upper tap, T — 4, 5, 6, 8, 10, 12, and 15
   Connections are made to a tap plate in the front of the relay.

3) R_1 tap — 0.075, 0.10, 0.15
   Connections are made to circularly arranged taps in the front of the relay. (The 0.075 tap is actually marked 0.07).

4) R_0 tap — 0.025, 0.033, 0.05, 0.39, 0.51, 0.68, 0.90, 1.2, and 1.6.
   Connections are made to circularly arranged taps in the front of the relay. (The 0.025 and 0.033 taps are actually marked 0.02 and 0.03, respectively.)

SETTING CALCULATIONS

The HCB 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.

TERMS

R_1, T, R_0 — 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.

$R_c(I), R_c(II)$ — current transformer ratio at Station I and II respectively.

PHASE FAULT SENSITIVITY

The phase fault pickup is determined by the R_1 and T taps. In order to operate on the minimum line-to-line fault current, the R_1 and T taps should be set for not more than:

$$\frac{T}{R_1} = 5I_{3P} \qquad (7)$$

In order to prevent operation on load current if the pilot wires become open circuited, the R_1 and T taps should be set for not less than:

$$\frac{T}{R_1} = 10I_L \qquad (8)$$

The available taps are:

R_1: 0.075, 0.10, and 0.15

T : 4, 5, 6, 8, 10, 12, and 15

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

$$\frac{T}{R_1} = 1.25 \times 10I_L = 12.5I_L \qquad (9)$$

The required T/R_1 ratio may be obtained by any combination of T and R_1. However, the T tap must be set the same at all stations. The R_1 taps may be utilized to compensate for different CT ratios with two-terminal lines if the pilot-wire loop resistance is 1000 ohms or less. Auxiliary CT's and identical R_1 tap settings must be used with different main CT ratios on all three-terminal lines and on two-terminal lines with more than 1000 ohms loop resistance in the pilot wire.

GROUND FAULT SENSITIVITY

The ground fault pickup is determined by R_0 and T taps. (T should be determined by the phase setting.) In order to operate on the minimum line-to-ground fault current, the R_0 tap setting should be not less than:

$$R_0 = \frac{0.2T}{I_g} \qquad (10)$$

The available R_0 taps are: 0.39, 0.51, 0.68, 0.90, 1.2, and 1.6.

The R_0 taps, 0.025, 0.033, and 0.05, are utilized to set $R_0 = 1/3 R_1$, where no zero sequence sensitivity

is desired. Equation (10) does not apply for these three taps.

For overhead lines, it is recommended that the 1.6 R_0 tap be used to obtain maximum sensitivity.

For cable circuits, where the line charging current exceeds 5% of nominal pickup current, set R_0 for about:

$$R_0 = \frac{T}{7.5}$$

The R_0 taps need not be identical as required with the R_1 taps for three terminal lines and two terminal lines over 1000 ohms pilot wire resistance, where the zero sequence relay currents at the line terminals are not identical for an external fault. However, for a conventional line section the R_0 taps are set in the same proportion as are the R_1 taps.

RESTRAINT TAP

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 I. The use of minimum restraint on three terminal applications compensates for the desensitizing effect of a third terminal.

Note: The relay pick-up calibration must be changed if set in the minimum restraint tap. See "Adjustments and Maintenance."

SETTING EXAMPLE

CASE I

Assume:

Two-terminal line.
CT ratio = 600/5
Full-load current = I_L = 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 = 0

Phase fault pickup:

$$\frac{T}{R_1} \text{(maximum)} = 5I_{3P} = 5 \times \frac{1500 + 2500}{2} \times \frac{5}{600} = 83.3$$

$$\frac{T}{R_1} \text{(maximum)} = 10I_L = 10 \times 400 \times \frac{5}{600} = 33.3$$

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

$$\frac{T}{R_1} = 12.5I_L = 41.7.$$

Set both relays for: T = 4, R_1 = 0.1.

The nominal pick-up current from equation 3 for a phase-to-phase fault is:

TABLE II — R_{PW} TEST — MAXIMUM RESTRAINT TAP

$R_1 = 0.10$, $R_0 = 1.6$,   T = 4

Insulating Transformer Ratio	Relay Should Not Operate	R_{PW} in Ohms	Relay Should Operate	C_{PW} in Microfarads
4 to 1	1200		1900	0.75
6 to 1	2700		4300	0.33

$$I_{nom}(P\text{-}P) = \frac{T}{2.89R_1} = \frac{4}{0.289} = 13.8 \text{ amperes,}$$

$$\left[I_{nom}(P\text{-}P) = \frac{T}{1.92R_1} \text{ for three-terminal lines}\right]$$

Ground fault pickup:

* $$R_0(\text{minimum}) = \frac{0.2T}{I_g} = \frac{0.2 \times 4}{400/2} \times \frac{600}{5} = 0.48$$

An R_0 tap exceeding 0.48 will provide tripping. As recommended for overhead lines:

Set $R_0 = 1.6$.

The ground fault nominal pickup is:

$$I_{nom}(P\text{-}G) = \frac{0.4T}{R_0} = \frac{1.6}{1.6} = 1.0 \text{ ampere,}$$

$$\left[I_{nom}(P\text{-}G) = \frac{0.6T}{R_0} = \text{ for three-terminal lines}\right]$$

Restraint tap:

Use maximum restraint tap.

CASE II (DIFFERENT CT RATIOS)

Assume 400/5 CT's at Station II and 600/5 CT's at Station I, with less than 1000 ohms pilot wire loop resistance.

At Station I, set $R_0 = 1.6$ as in Case I. However, set $R_1 = 0.15$ to obtain R_1 settings proportional to the CT ratio. From equation 6:

$$T = 12.5R_1I_L = 12.5 \times 0.15 \times 400 = 7.5$$

Set T = 8

Station II settings are:

$$R_1 = 0.15\frac{R_C \text{ (II)}}{R_C \text{ (I)}} = 0.15 \times \frac{400}{600} = 0.10$$

T = 8 (Same as Station I)

$$R_0 = 1.6 \times \frac{400}{600} = 1.07 \text{ (Set 1.2)}$$

SETTING THE RELAY

Set taps T_1, R_1, R_0, and the restraint tap. If the maximum restraint tap is used, no adjustments are necessary. If the minimum restraint tap is used, recalibrate the relay pickup as described in "Adjustments and Maintenance — Calibration."

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 studs 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.

ADJUSTMENTS AND MAINTENANCE

CAUTION   *1. Make sure that the neon lamp is in place whenever relay operation is being checked.*
   2. When changing taps under load, the spare tap screw should be inserted before removing the other tap screw.

ACCEPTANCE TESTS

The following tests are recommended when the relay is received from the factory. If the relay does not perform as specified below, the relay either is not calibrated or it contains a defect.

Main Unit

Connect the relay to the insulating transformer, as shown in Figure 6, and set $R_1 = 0.10$, $R_0 = 1.6$, T = 4, and maximum restraint tap. With the insulating transformer terminals H1 and H4 open circuited, measure the minimum pick-up current, I_{79} (min.), with current applied through terminals 7 and 9. This value should be:

$$I_{79} \text{ (min.)} = 6.94 \pm 5\% \text{ amperes.}$$

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, C_{PW}, in parallel with R_{PW}. With R_{PW} and
* C_{PW} set as specified in Table II suddenly apply $I_{35} = 30$ amperes (through terminals 3 and 5).

* TABLE III — R_{PW} TEST — MINIMUM RESTRAINT TAP

$R_1 = 0.10,$ $R_0 = 1.6,$ $T = 4$

Insulating Transformer Ratio	R_{PW} in Ohms		C_{PW} in Microfarads
	Relay Should Not Operate	Relay Should Operate	
4 to 1	800	1400	0.75
6 to 1	1800	3100	0.33

The relay should not operate at the lower value of R_{PW}, but should operate at the higher value (e.g., 1200 and 1900 ohms for 4-to-1 ratio insulating transformer).

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.

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.

CALIBRATION CHECK

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

Over-all Relay Check

Over-all calibration can be checked by the procedure described under "Acceptance Tests." If the relay has been calibrated in the minimum restraint tap (factory calibration is made in the maximum restraint tap), the R_{PW} test should be made in accord-
* ance with Table III instead of Table II.

Sequence Filter:
Remove tap screw T and connect a high-resistance voltmeter across this open-circuited point by connecting to the tap plate and to one of the saturating transformer taps at the rear of the tap block. Energize the relay with $I_{79} = 6.94$ amperes (terminals 7 and 9). The measured open-circuit voltage, V_F, should be:

$$V_F = 8R_1 \pm 5\% \text{ volts.}$$

(e.g., if $R_1 = 0.1$, $V_F = 8 \times 0.1 = 0.8$ volt.)

Repeat this voltage measurement with $I_{59} = 6.94$ amperes.

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 d-c milliammeters in series with the operating and restraining coils of the polar unit 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 $T = 4$, $R_1 = 0.1$, $R_0 = 1.6$, energize the relay with $I_{35} = 10$ 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 substantially to the following equations:

For minimum restraint

$$I_O = 0.12 \, I_R + 8$$
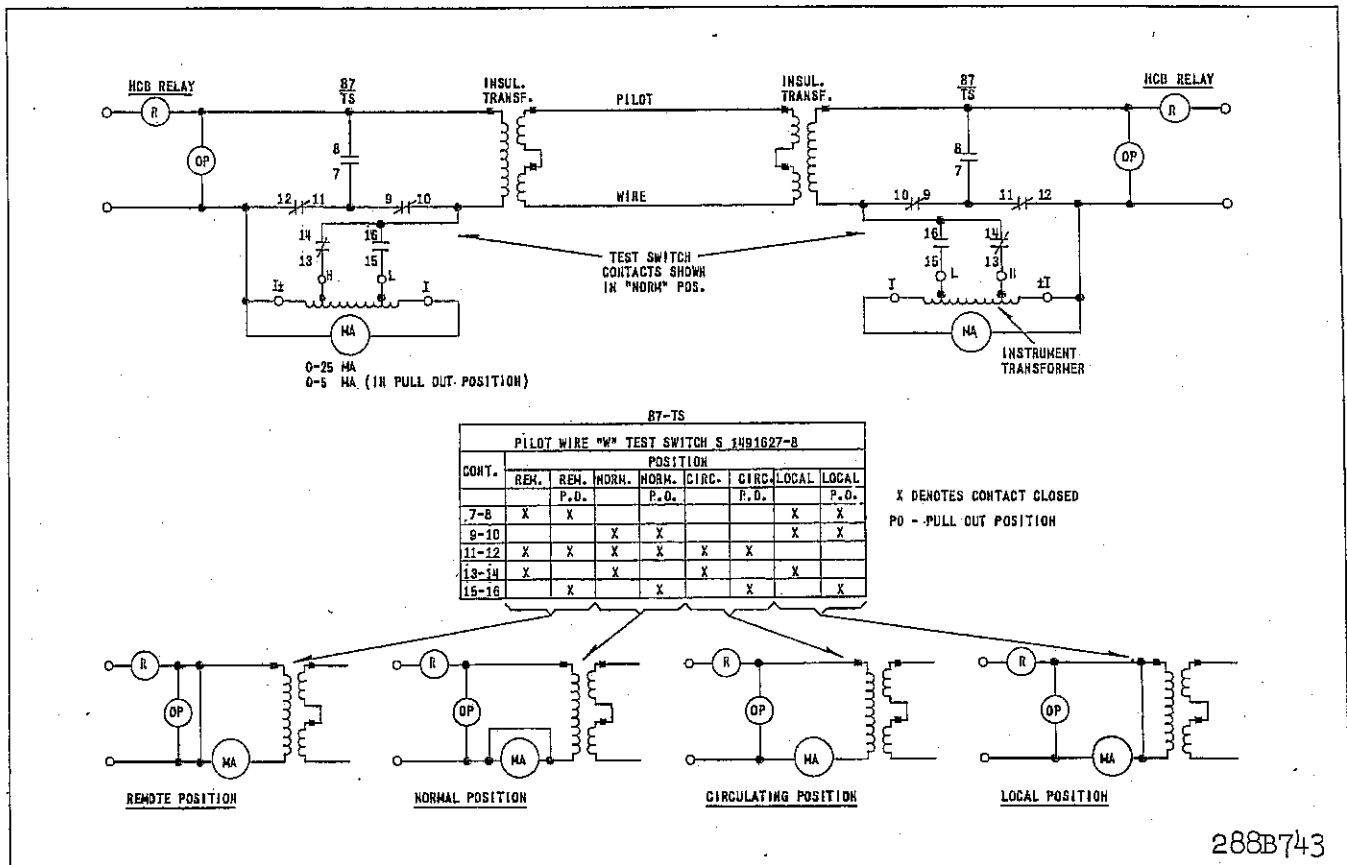
For maximum restraint

$$I_O = 0.16 \, I_R + 8$$

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.

CALIBRATION PROCEDURE

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

Polar Unit:
The sensitivity of the polar unit is adjusted by means of two magnetic, screw type shunts at the rear of the element. These shunt screws are held in proper adjustment by a flat strip spring across the back of the element frame, so no locking screws are required. 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. Conversly, drawing out the left hand shunt decreases the amount of current required to trip the relay. In general the farther out the shunt screw are turned, the greater the toggle action will be and as a result, the dropout current will be lower. In adjusting the polar elements, be sure that a definite toggle action is obtained, rather than a gradual movement of the armature.

Polar Unit Contact Adjustment:
Adjust the right hand stationary stop screw until the large armature

CONT.	PILOT WIRE "W" TEST SWITCH S 1491627-8							
	POSITION							
	REM.	REM. P.O.	NORM.	NORM. P.O.	CIRC.	CIRC. P.O.	LOCAL	LOCAL P.O.
7-8	X	X					X	X
9-10			X	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 CONTACT CLOSED
PO - PULL OUT POSITION

REMOTE POSITION   NORMAL POSITION   CIRCULATING POSITION   LOCAL POSITION

288B743

* *Fig. 7 HCB Relay Test Circuits with S#1491627 Type W Switch and S#1162968 or S# 291B318A09 Milliammeter, 0-5-25 ma.*

rivet clears the right hand pole face by a few thousandths of an inch. Next adjust the left hand stationary contact so that there is approximately .025 of an inch between it and the moving contact.

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 T = 4, R_1 = 0.1, R_0 = 1.6.

With the left hand shunt out 4 to 5 turns adjust the right hand magnetic shunt in or out as required, until the relay closes contacts with a positive snappy toggle action at I_{79} = 6.9 to 7.0 amperes. When this adjustment has been made, change the input current connections to terminals 3 and 5. The relay should trip for I_{35} = 0.45 to 0.55 amperes. For relays with double contacts make sure that both upper and lower contacts meet at the same values of pick up current.

ROUTINE MAINTENANCE

Contacts: All contacts should be cleaned periodically. A contact burnisher, S#182A836H01, is recommended for this purpose. The use of abrasive

material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

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.

Operating Unit: Check the relay minimum pickup, 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:

$$I_{79}(min) = \frac{T}{5.77\ R_1} \pm 5\% \text{ amperes}$$

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

COMPLETE SYSTEM TEST

At the time of the initial installation and at subsequent maintenance periods, it is recommended that

11

the following relay system checks be made, with the pilot wire connected.

MINIMUM PICKUP

Energize one relay with I_{35} current and determine the minimum pick-up point of all relays. Repeat this test by energizing the other relay or relays. Record these values for future reference. If the neon lamp is lit during these tests; the pilot circuit is presenting too high a shunting effect on the relays.

LOADED CIRCUIT TEST

Standard testing equipment is recommended for permanent installation with the relays, as shown in Figure 7. If this equipment is not available, a similar portable test should be set up, using a low-resistance a-c milliammeter. Perform the tests as indicated in Figure 8, 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 8 refer to the test switch positions, "CIRC" and "REM." For tests 3 to 6 of Figure 8, 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 11.

A similar procedure to Figure 8 should be followed for three-terminal line applications. In this case open the line circuit breaker at one terminal, and disconnect the loads from the pilot wire terminals of the HCB relay at that terminal. This leaves the remaining portion 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.

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.
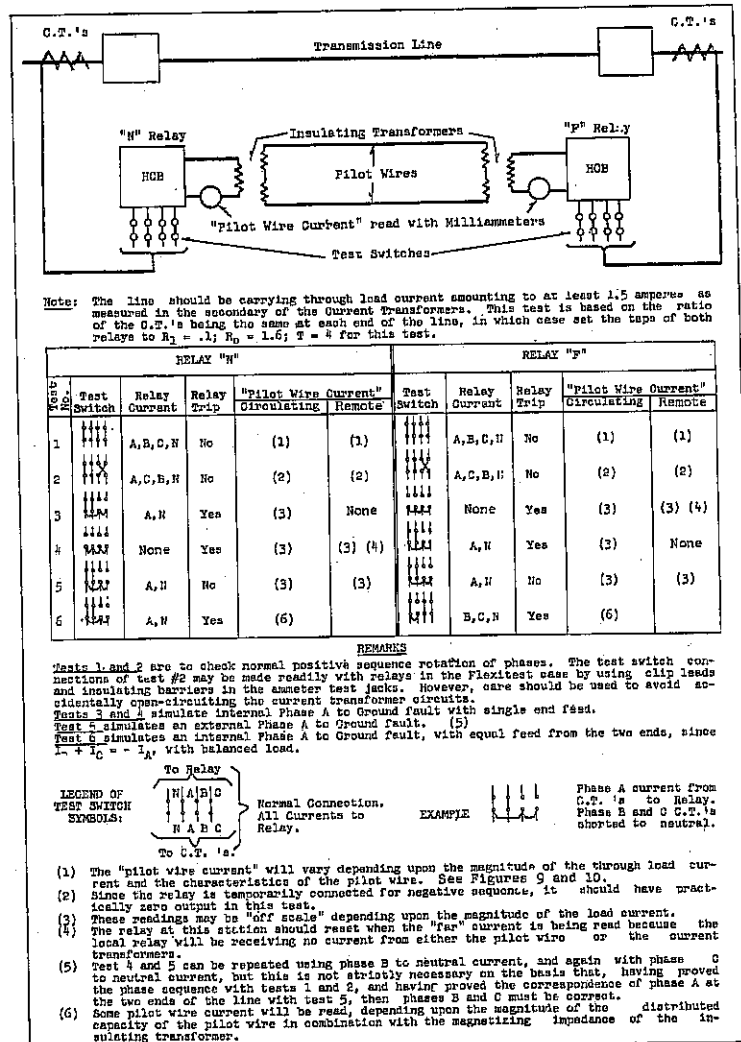

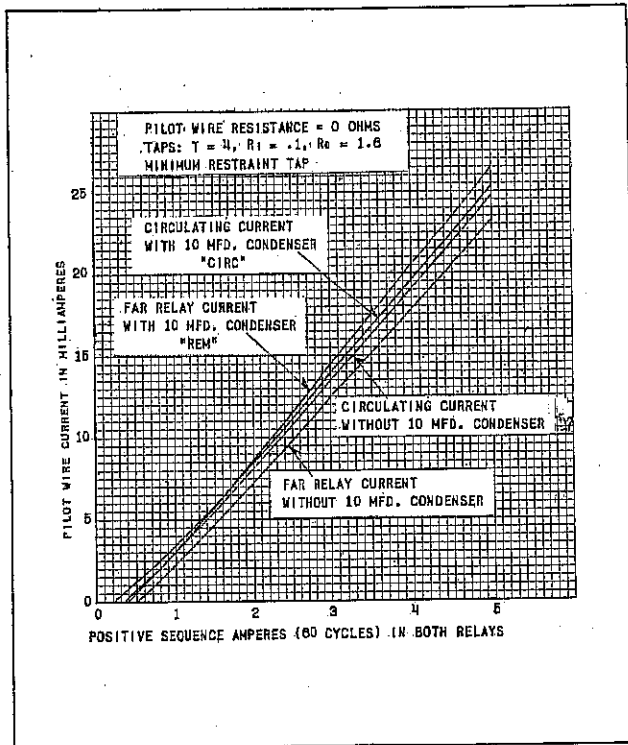*Fig. 8 HCB Relay System Testing Procedure*

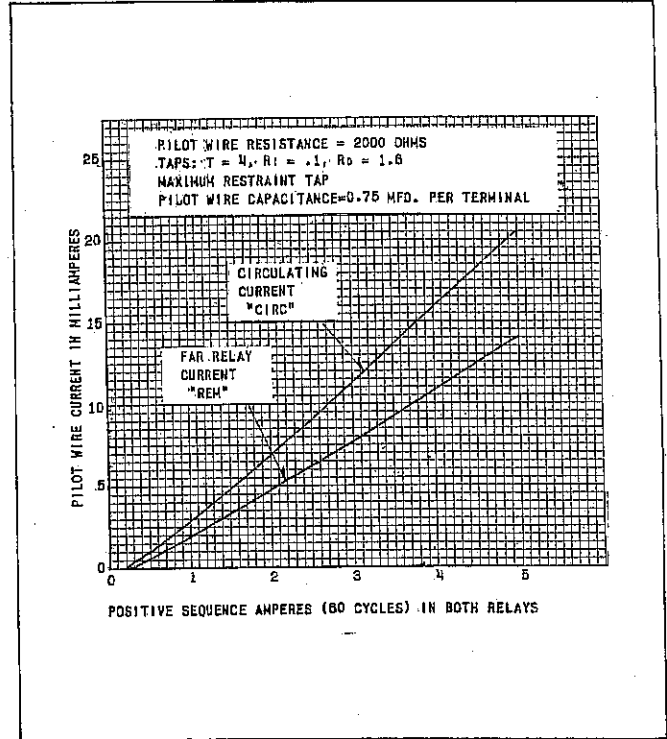Fig. 9 Typical Test Output vs. Input Relay Current in a Two-Terminal Line with Zero Pilot-Wire Resistance.

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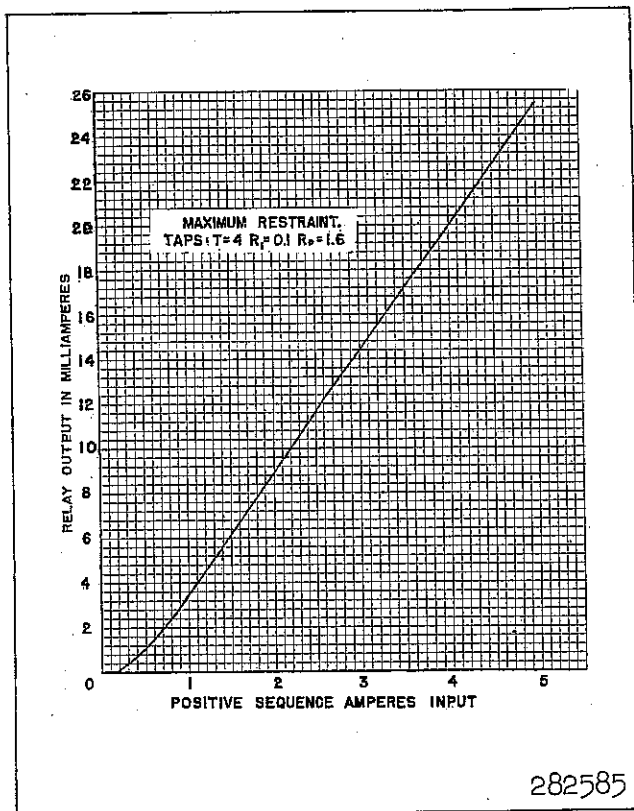

282585

Fig. 11 Typical Curve of Relay Output vs. Positive-Sequence Input — Test Switch in Local Position.
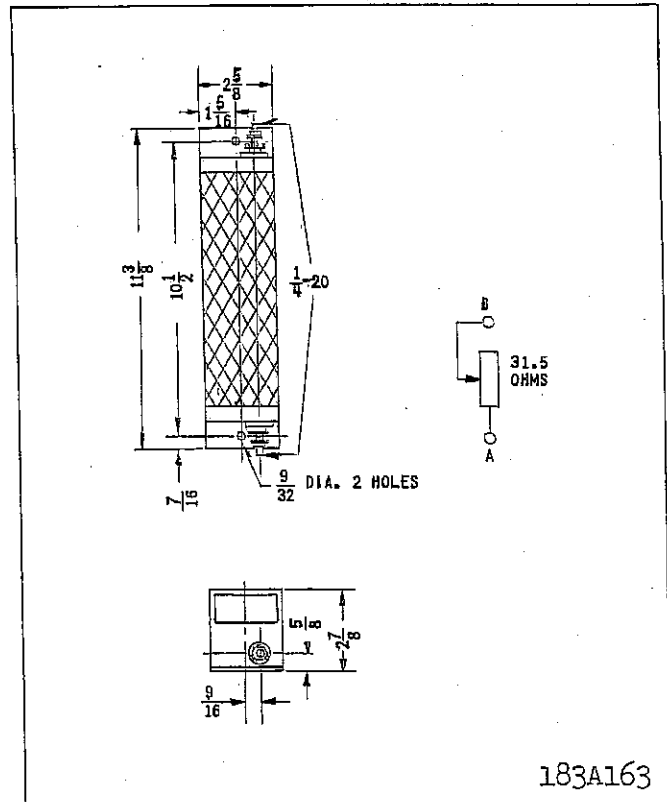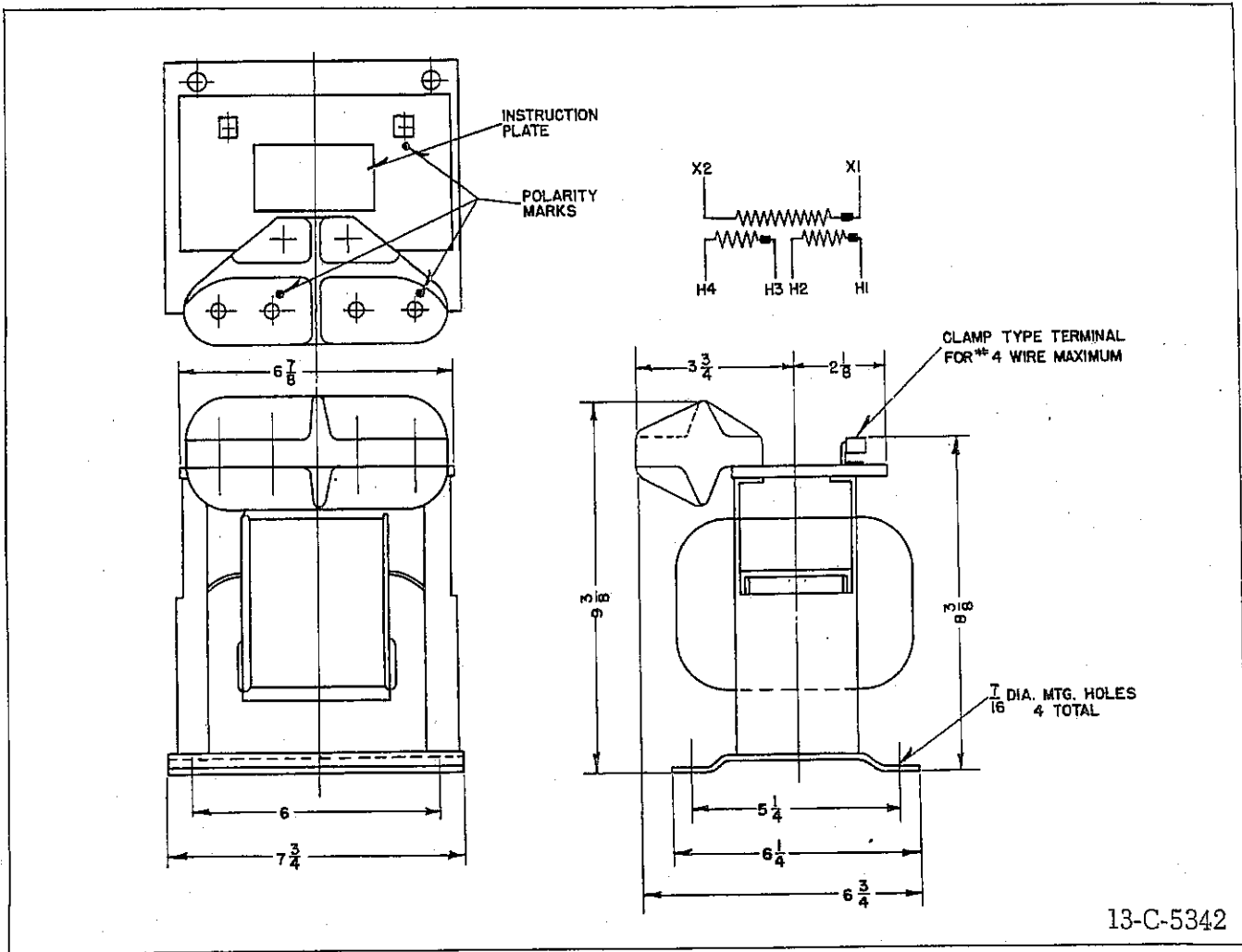

183A163

Fig. 12 Outline and Drilling Plan of S#1209991 Balancing Resistor for Three-Terminal Line Applications.

13

13-C-5342

✳ *Fig. 13 Outline and Drilling Plan of HCB Relay Insulating Transformer.*
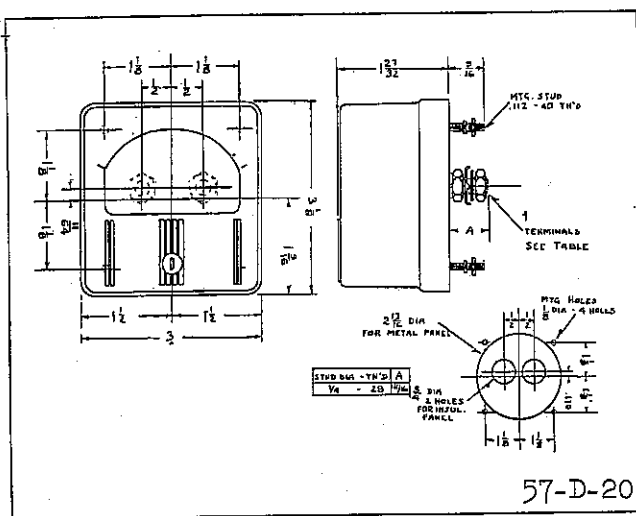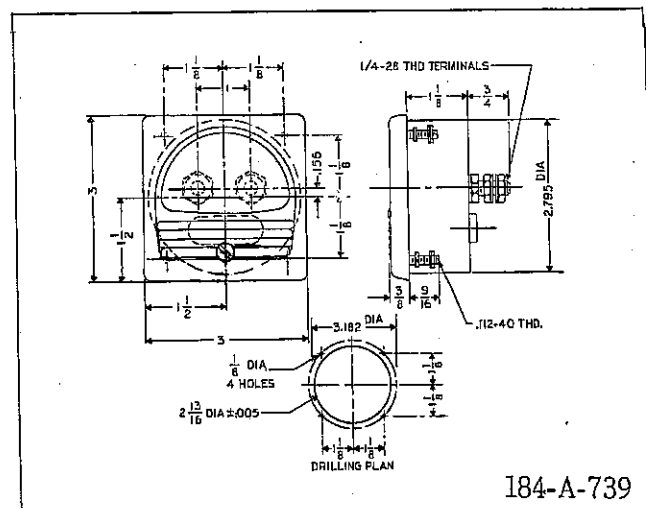

57-D-20

Fig. 14 Outline and Drilling Plan of the Projection-Type Test Milliammeter.

184-A-739

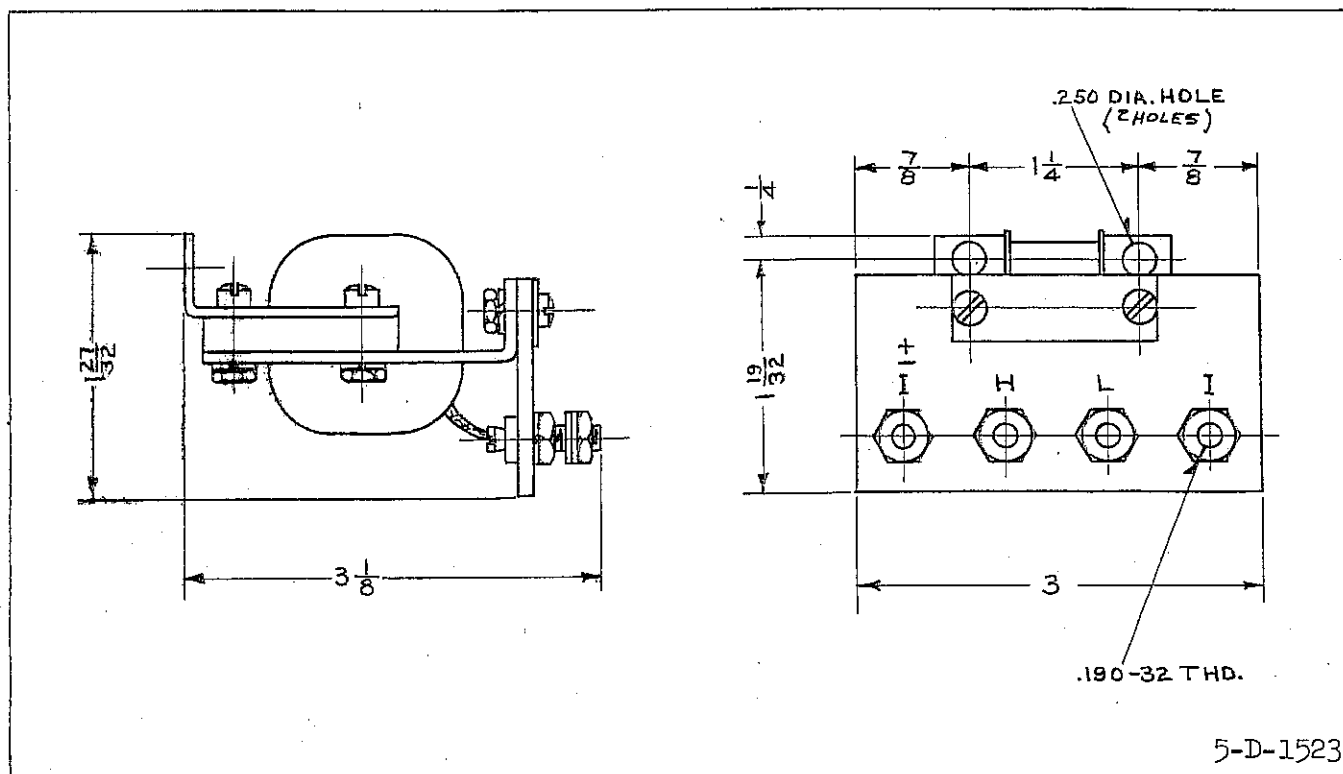✳ *Fig. 15 Outline and Drilling Plan of the Semi-Flush-Type Test Milliammeter.*

.250 DIA. HOLE
(2 HOLES)

.190-32 THD.

5-D-1523

Fig. 16 Outline of the Test Milliammeter Auxiliary Transformer.

1½ TK. PANEL → S#1491627
⅛ TK. PANEL → S#1491628

DRILLING PLAN

NAMEPLATE ENGRAVING

PILOT WIRE TEST
(PULL-OUT-LOW SCALE)

REMOTE · NORM. · CIRC. · LOCAL

SPRING RETURN
MODERN PISTOL HANDLE

17-D-3593

SWITCH POSITION TABULATION

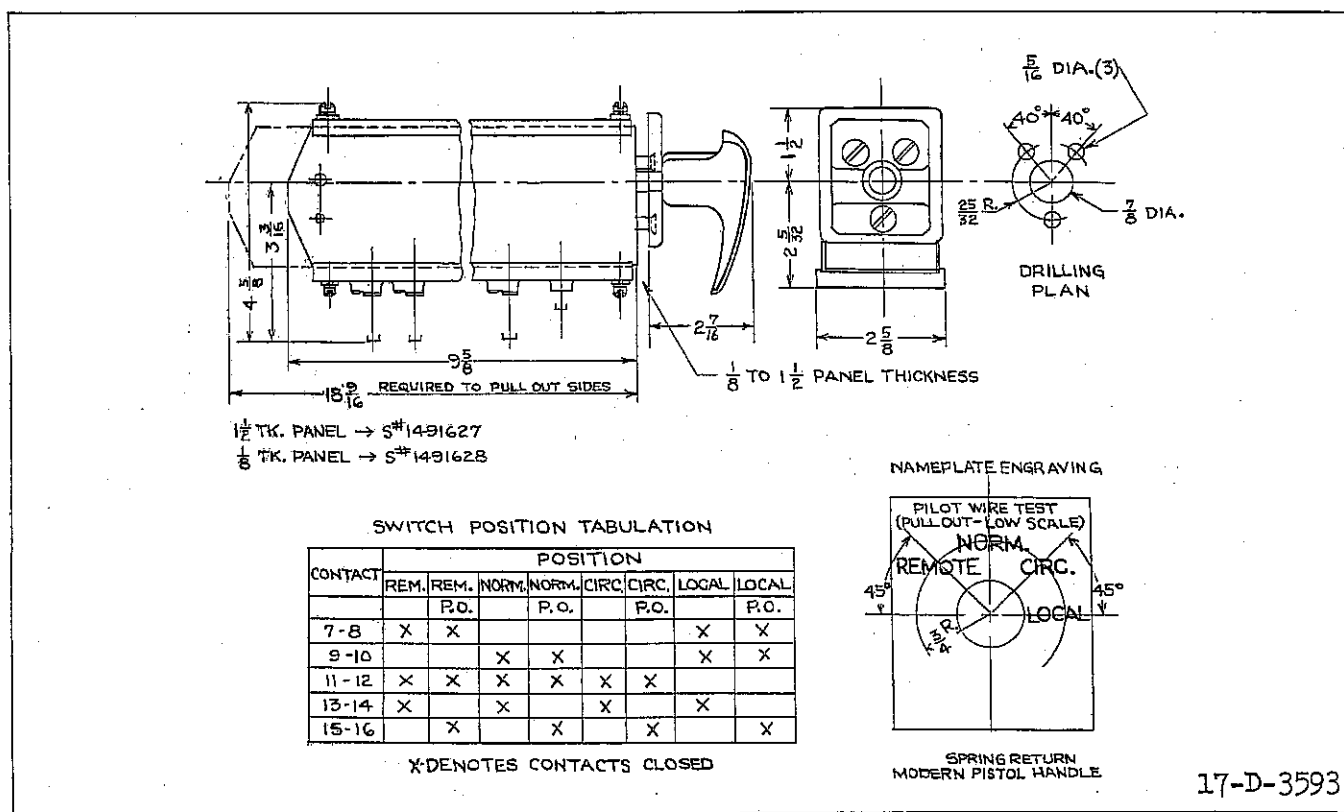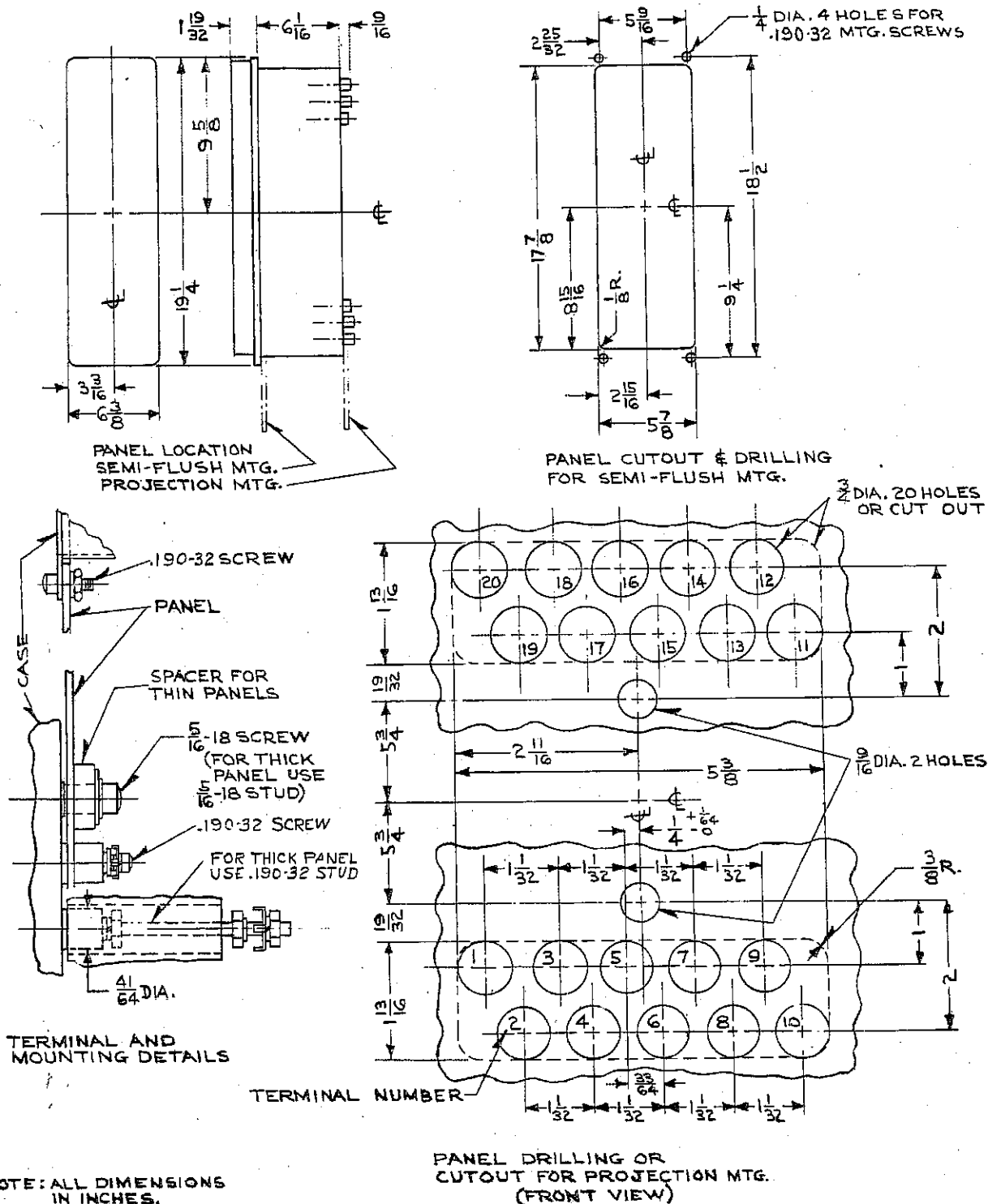| CONTACT	POSITION							
	REM.	REM. P.O.	NORM.	NORM. P.O.	CIRC.	CIRC. P.O.	LOCAL	LOCAL P.O.
7-8	X	X					X	X
9-10			X	X			X	X
11-12	X	X	X	X	X	X		
13-14	X		X		X		X	
15-16		X		X		X		X

X-DENOTES CONTACTS CLOSED

Fig. 17 Outline and Drilling Plan of the Type W Test Switch.

* Fig. 18 Outline and Drilling Plan for the Type HCB Relay in the Type FT-42 Case.

57-D-7905

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