



# INSTALLATION • OPERATION • MAINTENANCE I N S T R U C T I O N S

## TYPE HKB RELAY AND TEST EQUIPMENT FOR TYPE FD CARRIER

**CAUTION** Before putting 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 HKB relay is a high speed carrier relay used in conjunction with power line carrier equipment to provide complete phase and ground fault protection of a transmission line section. Simultaneous tripping of the relays at each line terminal is obtained in three cycles or less for all internal faults within the limits of the relay settings. The relay operates on line current only, and no source of a - c line potential is required. Consequently, the relays will not trip during a system swing or out-of-step conditions. The carrier equipment operates directly from the station battery.

### PART I—TYPE HKB RELAY

#### CONSTRUCTION

The relay consists of a combination positive, negative and zero sequence network, a saturating auxiliary transformer, two Rectox units, two polar relay units, a telephone-type relay, a neon lamp, contactor switch and operation indicator all mounted in a Type M-20 Flexitest Case.

When the standard projection case is supplied, the sequence network, tap plates, and saturating auxiliary transformer are mounted

in a box which can be located on the rear of the switchboard panel in any convenient position. The remainder of the relay elements are mounted in the relay case proper. The taps and terminal numbers of the relay in the standard case and the external box correspond to those in the type FT case. (See Figures 1, 2, and 3). Terminals 18, 19 and 20 of the external box are to be connected to the corresponding terminals of the relay in the standard case. Otherwise, all external connections for the relay in the standard projection case or in the type FT case are made to the same terminals.

#### Sequence Network

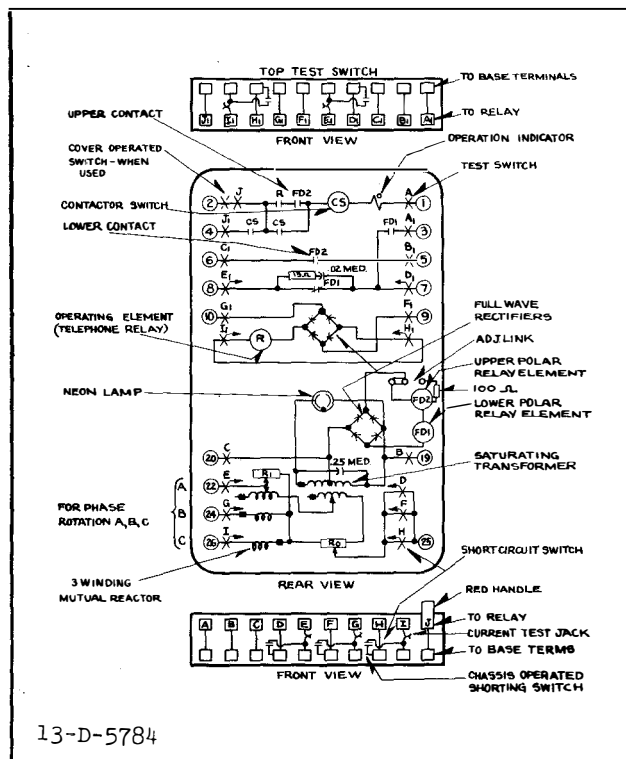
The currents from the current transformer secondaries are passed thru a network consisting of a three-winding iron-core reactor and two resistors. The zero-sequence resistor,  $R_0$ , consists of three resistor tubes tapped to obtain settings for various ground fault conditions. The other resistor  $R_1$  is a formed single wire mounted on the rear of the relay sub-base. The output of this network provides a voltage across the primary of the saturating transformer.

The lower tap block provides for adjustment of the relative amounts of the positive, negative and zero sequence components of current in the network output. Thus, a single relay element energized from the network can be used as a fault detector for all types of faults.

#### Saturating Auxiliary Transformer

The voltage from the network is fed into the tapped primary (upper tap plate) of a small saturating transformer. This transformer and

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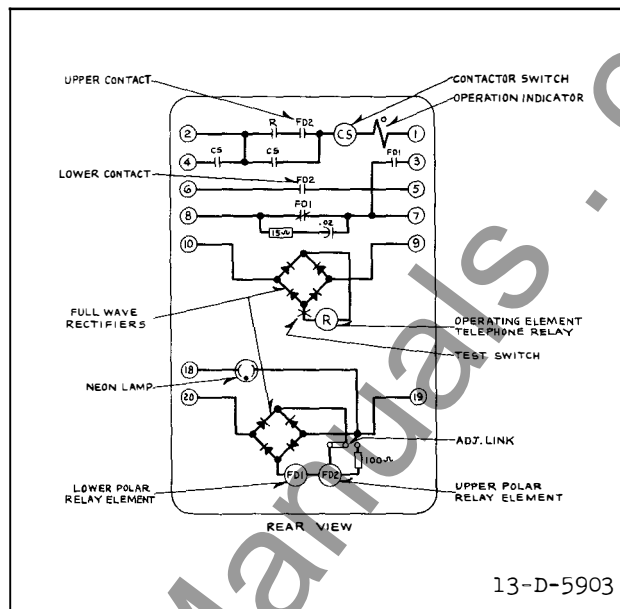
**Fig. 1—Internal Schematic of the Type HKB Carrier Relay in the Type FT Case.**

a neon lamp connected across its secondary are used to limit the voltage impressed on the fault detectors (polar relay elements) and the carrier Control Unit, thus providing a small range of voltage for a large variation of maximum to minimum fault currents. This provides high operating energy for light faults, and limits the operating energy for heavy faults to a reasonable value.

The upper tap plate changes the output of the saturating transformer, and is marked in amperes required to pick up the lower fault detector element. For further discussion, see section entitled, "Setting".

Rectox Units

The secondary of the saturating transformer feeds a bridge-connected Rectox Unit, the output of which energizes the polar fault detector elements. A second Rectox, energized from the output of the Control Unit, supplies a d-c voltage to the telephone relay element which operates only for an internal fault. The use



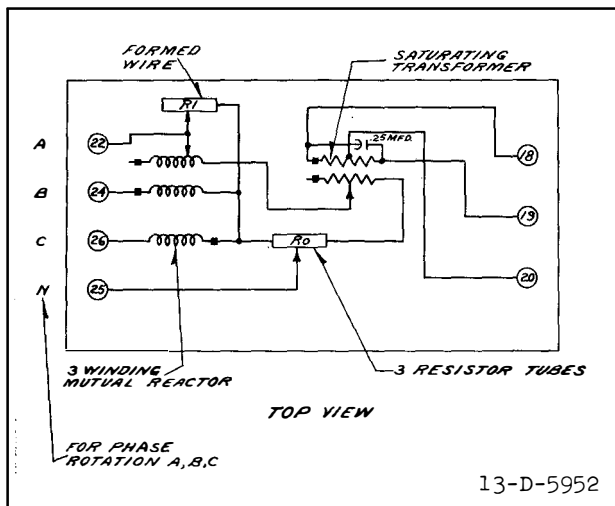
**Fig. 2—Internal Schematic of the Type HKB Carrier Relay in the Standard Projection Case.**

of sensitive polar relay keeps down the energy required from the current transformers.

## Polar-Type Relays

These elements consist of a rectangular shaped magnetic frame, an electromagnet, a permanent magnet, and an armature with a set of contacts. The poles of the permanent magnet clamp directly to each side of the magnetic frame. Flux from the permanent magnet divides into two paths, one path across the air gap at the front of the element in which the armature is located, the other across two gaps at the base of the frame. Two adjustable screw type shunts which require no locking screws are located across the rear air gaps. These change the reluctance of the magnetic path so as to force some of the flux thru the moving armature which is fastened to the leaf spring and attached to the frame midway between the two rear air gaps. Flux in the armature polarizes it and creates a magnetic bias causing it to move toward one or the other of the poles, depending upon the adjustment of the magnetic shunt screws.

A coil is placed around the armature and within the magnetic frame. The current which



**Fig. 3—Internal Schematic of the Sequence Network Used with the Type HKB Relay in the Standard Projection Case.**

flows in the coil produces a magnetic field which opposes the permanent magnet field and acts to move the armature in the contact-closing direction.

#### Contactor Switch

The d-c contactor switch in the relay is a small solenoid type switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward, the disc bridges three silver stationary contacts. The coil is in series with the main contacts of the relay and with the trip coil of the breaker. When the relay contacts close, the coil becomes energized and closes the switch contacts. This shunts the main relay contacts thereby relieving them of the duty of carrying tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker. The contactor switch is equipped with a third point which is connected to a terminal on the relay to operate a bell alarm.

#### Operation Indicator

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

gravity to indicate completion of the trip circuit. The indicator is reset from outside of the case by a push rod.

### OPERATION

The HKB carrier relaying system compares the phase positions of the currents at the ends of a line-section over a carrier channel to determine whether an internal or external fault exists. The three-phase line currents energize a sequence network which gives a single-phase output voltage proportional to a combination of sequence components of the line current. During a fault, this single-phase voltage controls an electronic circuit which allows the transmission of carrier on alternate half-cycles of the power-frequency current. Carrier is transmitted from both line terminals in this manner, and is received at the opposite ends where it is compared with the phase position of the local sequence network output. This comparison takes place in a vacuum tube. The polarities of the voltages to be compared are such that for an internal fault, plate current flows on alternate power-frequency half-cycles. A relay connected in the plate circuit of the vacuum tube operates under this condition to complete the trip circuit. During an external fault, the change in direction of current flow causes the plate current to be continuously blocked, and the plate circuit relay does not operate.

Since this relaying system operates only during a fault, the carrier channel is available at all other times for the transmission of other functions.

### CHARACTERISTICS

The sequence network in the relay is arranged for several possible combinations of sequence components. For most applications, 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 which will pick up the lower or carrier start fault detector (FD1). The upper polar element (FD2), which supervises

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operation of the telephone-type relay, is adjusted to pick up at a current 25 percent above tap value. The taps available are 3, 4, 5, 6, 7, 8, and 10. These taps are on the primary of the saturating transformer. For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the fault detector FDI to pick up at 86% of the tap setting. For BC faults, the fault detector will pick up at approximately 50% of the tap setting. This difference in pick-up 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.

With the sequence network arranged for positive, negative and zero sequence output, there are some applications where the maximum load current and minimum fault current are too close together to set the relay to pick up under minimum fault current, yet not operate under load. For these cases, a tap 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. In some cases, it may be desirable to eliminate response to positive sequence current entirely, and operate the relay on negative-plus-zero sequence current. A tap is available to operate in this manner. The fault detector picks up at 95% of tap value for all phase-to-phase faults, but is unaffected by balanced load current or three-phase faults.

For ground faults, separate taps are available for adjustment of the ground fault sensitivity to about 1/4 or 1/8 of the upper tap plate setting. See Table II. For example, if the upper tap plate is set at tap 4, the fault detector (FDI) pick-up current for ground faults can be either 1 or 1/2 ampere. In special applications, it may be desirable to eliminate response to zero sequence current. The relay is provided with a tap to allow such operation.

## SETTINGS

The HKB relay has separate tap plates for adjustment of the phase and ground fault sensitivities and the sequence components included in the network output. The range of the available taps is sufficient to cover a wide range of application. The method of determining the correct taps for a given installation is discussed in the following paragraph.

In all cases, the similar fault detectors on the relays at both terminals of a line section must be set to pick up at the same value of line current. This is necessary for correct blocking during faults external to the protected line section.

### Sequence Combination Taps

The two halves of the lower tap plate are for connecting the sequence network to provide any of the combinations described in the previous section. The left half of the tap plate changes the tap on the third winding of the mutual reactor and thus changes the relative amounts of positive and negative sequence sensitivity. Operation of the relay with the various taps is given in the table below.

TABLE I

Comb.	Sequence Components in Network Output	Taps on Lower Tap Block	Fault Detector FDI Pick Up $\Delta$	
			3 $\phi$ Fault	$\phi$ - $\phi$ Fault
		Left Half    Right Half		
1	Pos., Neg., Zero	C    G or H*	Tap Value	86% Tap Value (53% on BC Fault)
2	Pos., Neg., Zero	B    G or H	2x Tap Value	90% Tap Value (65% on BC Fault)
3	Neg., Zero	A    G or H	--	95% Tap Value

\* Taps F, G and H are zero-sequence taps for adjusting ground fault sensitivity. See section on zero-sequence current tap.

$\Delta$  Fault detector FD2 is set to pick up at 125% of FDI for a two-terminal line, or 250% of FDI for a three-terminal line.

### Positive-Sequence Current Tap and FD2 Tap

The upper tap plate has values of 3,4,5,6,7, 8, and 10. As mentioned before, these numbers represent the three-phase, fault detector FDI pickup currents, when the relay is connected for positive, negative and zero sequence out-

put. The fault detector FD2 closes its contact to allow tripping at current value 25 percent above the fault detector FD1 setting. This 25 percent difference is necessary to insure that the carrier start fault detectors (FD1) at both ends of a transmission line section pick up to start carrier on an external fault before operating energy is applied through FD2.

For a three-terminal line, the tap link on FD1 panel is connected to the right hand tap which allows FD2 to pick up at 250% of FD1 setting. This is necessary to allow proper blocking on three-terminal lines when approximately equal currents are fed in two terminals, and their sum flows out the third terminal of the line. For two-terminal lines, the link is connected to the left hand tap, and operation is as described in the previous paragraph.

The taps on the upper and lower tap plates should be selected to assure operation on minimum internal line-to-line faults, and yet not operate on normal load current, particularly if the carrier channel is to be used for auxiliary functions. The dropout current of the fault detector is 75 percent of the pick-up current, and this factor must also be considered in selecting the positive-sequence current tap and sequence component combination. The margin between load current and fault detector pick up should be sufficient to allow the fault detector to drop out after an external fault, when load current continues to flow.

## Zero-Sequence Current Tap

The right half of the lower tap plate is for adjusting the ground fault response of the relay. Taps G and H give ground fault sensitivities as listed in Table II. Tap F is used in applications where increased sensitivity to ground faults is not required. When this tap is used, the voltage output of the network due to zero-sequence current is eliminated.

TABLE II

Comb.	Lower Left Tap	Ground Fault Pickup Percent of Upper Tap Setting	
		Tap G	Tap H
1	C	25%	12%
2	B	20	10
3	A	20	10

## Examples of Relay Settings

### CASE I

Assume a two-terminal line with current transformers rated 400/5 at both terminals. Also assume that full load current is 300 amperes, and that on minimum internal phase-to-phase faults 2000 amperes is fed in from one end and 600 amperes from the other end. Further assume that on minimum internal ground faults, 400 amperes is fed in from one end, and 100 amperes from the other end.

### Positive Sequence Current Tap

Secondary Values:

$$\text{Load Current} = 300 \times \frac{5}{400} = 3.75 \text{ amperes} \quad (1)$$

Minimum Phase-To-Phase Fault Currents:

$$600 \times \frac{5}{400} = 7.5 \text{ amperes} \quad (2)$$

Fault detector FD1 setting (three phase) must be at least:

$$\frac{3.75}{0.75} = 5 \text{ amperes (0.75 is dropout ratio of fault detector)} \quad (3)$$

so that the fault detector will reset on load current.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector FD1 setting (three-phase) must be not more than:

$$7.5 \times \frac{1}{0.866} \times \frac{1}{1.25} = 6.98 \text{ amperes} \quad (4)$$

$$\left( 1.25 = \frac{\text{FD2 pick up}}{\text{FD1 pick up}} \right)$$

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### Sequence Combination Tap

From a comparison of (3) and (4) above, it is evident that the fault detector can be set to trip under minimum phase fault condition yet not operate under maximum load. In this case, tap C on the lower left tap block would be used (see Table I, Comb 1) as there is sufficient difference between maximum load and minimum fault to use the full three-phase sensitivity. Current tap 6 would be used.

### Zero Sequence Tap

Secondary Value:

$$100 \times \frac{5}{400} = 1.25 \text{ amperes minimum ground fault current.}$$

With the upper tap 6 and sequence tap C in use, the fault detector FDI pickup currents for ground faults are as follows:

$$\begin{aligned} \text{Lower right tap G-1/4} \times 6 &= 1.5 \text{ amp.} \\ \text{Minimum trip} &= 1.25 \times 1.5 = 1.88 \text{ amp.} \\ \text{Lower right tap H-1/8} \times 6 &= 0.75 \text{ amp.} \\ \text{Minimum trip} &= 1.25 \times 0.75 = 0.94 \text{ amp.} \end{aligned}$$

From the above, tap H would be used to trip the minimum ground fault of 1.25 amperes.

### Case II

Assume the same fault currents as in Case I, but a maximum load current of 500 amperes. In this example, with the same sequence combination as in Case I, the fault detectors cannot be set to trip on the minimum internal three-phase fault, yet remain inoperative on load current. (Compare (5) and (6) below). However, by connecting the network per Combination 2 on Table I, the relay can be set to trip on minimum phase-to-phase fault, although it will have only half the sensitivity to three-phase faults. This will allow operation at maximum load without picking up the fault detector, and provide high speed relaying of all except light three-phase faults.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault

detector tap must now be not more than:

$$7.5 \times \frac{1}{1.25} \times \frac{1}{0.9} = 6.6 \quad (5)$$

To be sure the fault detector FDI will reset after a fault, the minimum tap setting is determined as follows:

$$\text{Load Current} = 500 \times \frac{5}{400} = 6.25 \text{ amps} \quad (6)$$

$$\frac{6.25}{0.75} = 8.33 \quad (7)$$

Since the fault detector pickup current for three-phase faults is twice tap value, half the above value (Eq. 7) should be used in determining the minimum three-phase tap.

$$\frac{8.33}{2} = 4.17 \quad (8)$$

From a comparison of (5) and (8) above, tap 5 or 6 could be used.

With the three-phase tap 5 in use, the fault detector pickup current for ground faults will be as follows:

$$\begin{aligned} \text{Tap G-1/5} \times 5 &= 1.0 \text{ a.} \\ \text{Minimum trip} &= 1.0 \times 1.25 \text{ a.} = 1.25 \text{ amp.} \end{aligned}$$

$$\begin{aligned} \text{Tap H-1/10} \times 5 &= 0.5 \text{ a.} \\ \text{Minimum trip} &= 1.25 \times 0.5 \text{ a.} = 0.63 \text{ amp.} \end{aligned}$$

Therefore, tap H would be used to trip the minimum ground fault of 1.25 ampere with a margin of safety.

## INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the two mounting studs for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made

direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

## ADJUSTMENTS AND MAINTENANCE

### CAUTION

1. Make sure that the neon lamp is in place whenever relay operation is being checked. This is necessary to limit the voltage peaks in the filter output at high currents so as to prevent damage to the Rectox Units.
2. When changing taps under load, the spare tap screw should be inserted before removing the other tap screw.
- \* 3. All contacts should be periodically cleaned. A contact burnisher S#182A836H01 is recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.
4. The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

### Sequence Network

There are no adjustments to make in the network.

The following mechanical adjustments are given as a guide, and some deviation from them may be necessary to obtain proper electrical calibration.

### FAULT DETECTORS-GENERAL

The sensitivity of the polar elements is ad-

justed 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 the right-hand contact. Conversely, drawing out the left-hand shunt increases the amount of current required to trip the relay. In general, the farther out the shunt screws are turned, the greater the toggle action will be, and as a result, the drop out 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 from the back (left-hand, front view) to the front (right-hand, front view) contact as the current is increased.

- \* Set the relay taps on 5, C, and H. Connect the panel link to the left-hand terminal. **Note:** When different relay taps are used in service than for calibration, the actual pickup current will vary slightly from the calculated value per Table I. This occurs because fractional turns cannot be used on the saturating transformer primary winding.

A. Lower Polar Element (FD-1) - Adjust the contact screws to obtain an .050" contact gap such that the armature motion between the left and right hand contacts is in the central part of the air gap between the pole faces. Tighten the contact locking nuts. Approximate adjustments of the two magnetic shunt screws are as follows:

Screw both shunt screws all the way in. Then back out both screws six turns. Pass 4.33 amperes, 60 cycles, in phase A and out phase B. Screw in the left hand shunt until the armature moves to the right. If the armature moves to the right at less than 4.33 amperes, screw out the left-hand shunt until proper armature action is obtained.

Reduce the current until the armature resets to the left. This should happen at not less than 75% of the pickup value, or 3.25 amperes. If the armature resets at less than this

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value, it will be necessary to advance the right hand shunt to obtain a dropout of 75% or greater. This in turn will require a slight readjustment of the left hand shunt. Recheck the pickup and dropout points several times, and make any minor "trimming" adjustments of the shunt screws that may be necessary to obtain correct calibration. If the above procedure does not give a sufficiently high dropout, a small amount of further adjustment can be obtained by advancing the right-hand contact screw a fraction of a turn. As finally adjusted, the contact gap should be at least .030", and the action of the armature should be snappy at the pickup and dropout points.

B. Upper Polar Element (FD-2) - Adjust the contact screws to obtain an .050" contact gap such that the armature motion between contacts is in the central portion of the air gap between the pole faces. Tighten the locking nuts.

Follow the same adjustment procedure as for FD1, except for a pickup current of 5.41 amperes, and a dropout current of at least 75% of pickup, or 4.06 amperes. Just above the pickup current, there will be a slight amount of contact vibration. Make a final adjustment of the two right-hand contact screws to obtain equal vibration of both contacts as indicated by a neon lamp connected in the contact circuit.

### Operating Element (Telephone Type Relay)

Adjust the contact gap to 0.045". This is done by bending down the armature contact-lever stop on the relay frame. Now with the armature in the operated position, adjust the armature residual gap to 0.010" by means of the adjustable set screw. This gap should be measured just below the armature set screw. For those relays with a fixed residual spacer, the gap is about 0.008". Check to see that there is a contact follow of a few thousandths of an inch after the contact closes.

Connect a d-c milliammeter (0-25 ma.) across test switchjaws H1 and I1 (relay out of case). Connect a source of variable a-c voltage (0 to 10 volts, 60 cycles) across switchjaws F1 and G1. The relay should pick up at 10 to 12 ma.

direct current in the coil circuit with sine wave voltage applied to the a-c side of the bridge rectifier. The dropout current will be 4 to 7 ma. The contact spring tension can be changed, if necessary, to obtain these values.

For the relay in the standard case, apply a-c voltage across terminals 9 and 10 and insert a test plug connected to a d-c milliammeter in the single test switch jack of the relay. If clip leads are used, it will be necessary to slip a strip of insulating material such as fiber into the test switch jack after opening the switch blade to obtain a reading.

### Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core when the switch is picked up. This can be most conveniently done by turning the relay upside-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 2 amperes d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 0.25 ohm.

### Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced by new springs, they should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 0.16 ohms.



## RENEWAL PARTS

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

## ENERGY REQUIREMENTS

Burdens measured at a balanced three-phase current of five amperes.

Relay Taps	Phase A		Phase B		Phase C	
	VA	Angle	VA	Angle	VA	Angle
A-F-3	2.4	5°	0.6	0°	2.5	50°
A-H-10	3.25	0°	0.8	100°	1.28	55°
B-F-3	2.3	0°	0.63	0°	2.45	55°
B-H-10	4.95	0°	2.35	90°	0.3	60°
C-F-3	2.32	0°	0.78	0°	2.36	50°
C-H-10	6.35	342°	3.83	80°	1.98	185°

Burdens measured at a single-phase to neutral current of five amperes.

Relay Taps	Phase A		Phase B		Phase C	
	VA	Angle	VA	Angle	VA	Angle
A-F-3	2.47	0°	2.1	10°	1.97	20°
A-H-10	7.3	60°	12.5	53°	6.7	26°
B-F-3	2.45	0°	2.09	15°	2.07	10°
B-H-10	16.8	55°	22.0	50°	12.3	38°
C-F-3	2.49	0°	1.99	15°	2.11	15°
C-H-10	31.2	41°	36.0	38°	23.6	35°

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

## PART II — HKB CONTROL UNIT (FD CARRIER)

The construction, operation, and adjustment of the Control Unit used with the HKB relay are covered in a separate instruction book identified as I.B. 84-891-1. The Control Unit is a part of the Type FD carrier assembly.

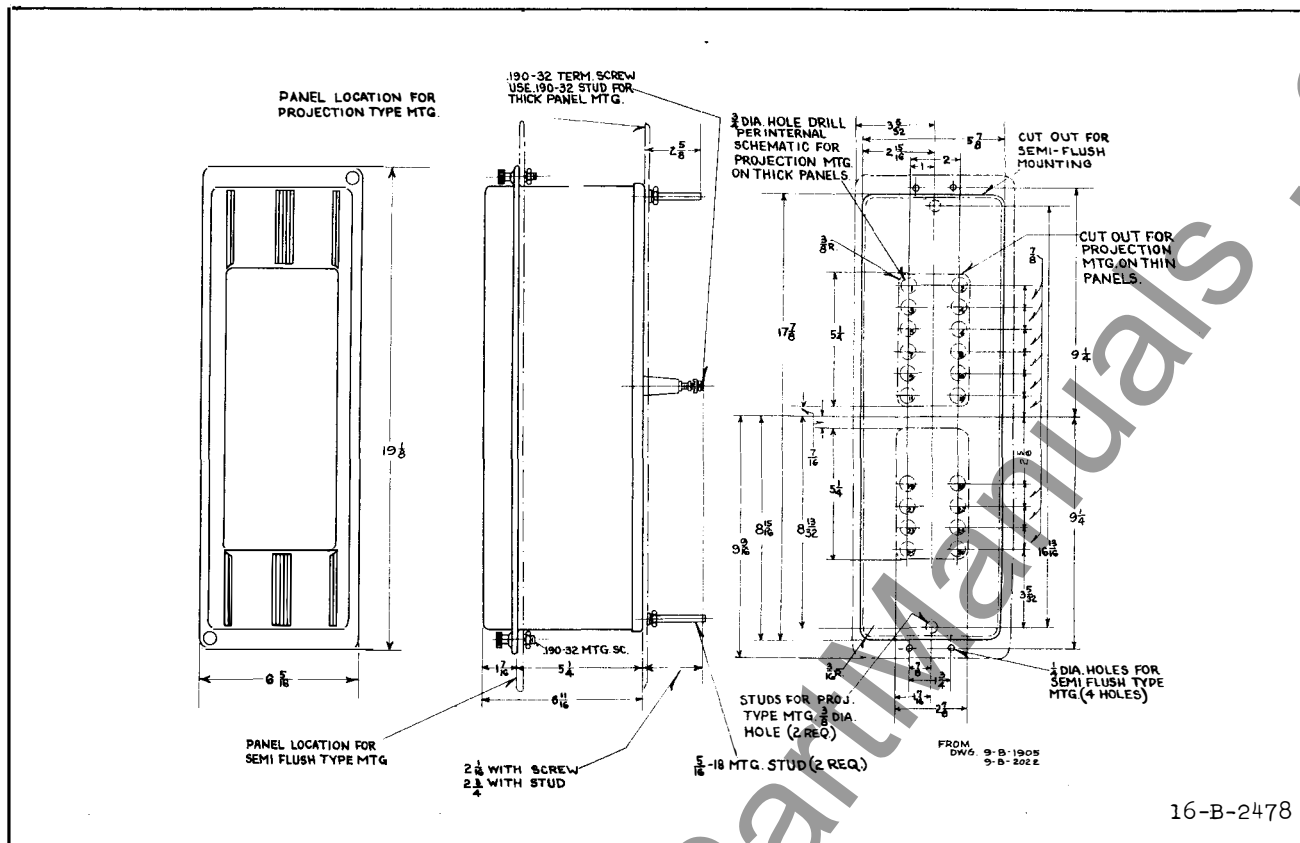
## OVERALL TEST OF COMPLETE INSTALLATION

After the complete equipment has been installed and adjusted, the following tests can be made which will provide an overall check on the relay and carrier equipment. The phase

rotation of the three-phase currents can be checked by measuring the a-c voltage across relay terminals 19 and 20 or test switches B and C with a high resistance a-c voltmeter of at least 1000 ohms per volt. The reading obtained should be approximately 0.9 volts per ampere of balanced three-phase load current (secondary value) with relay taps 4, C and H.

The following test requires that a balanced three-phase load current of at least 1.0 ampere (secondary) be flowing through the line-section protected by the HKB relays. At both terminals of the protected line-section, remove the HKB relay cover and open the trip circuit by pulling the test switch blade with the long red handle. Put the tap screw on the upper tap plate in the 4 tap, and on the lower one in the C and H taps. Be sure to insert the spare tap screw before removing the connected one. Now open test switches D and E on the relay at one end of the line section (station A) and insert a current test plug or strip of insulating material into the test jack on switch E to open the circuit through that switch. The above operation shorts the phase A to neutral circuit ahead of the sequence filter and disconnects the phase A lead from the filter. This causes the phase B and C currents to return to the current transformers through the zero-sequence resistor in the filter, thus simulating a phase A-to-ground fault fed from one end of the line only. As a result, both the fault detectors and operating element at Station A should close their contacts. Completion of the trip circuit can be checked by connecting a small lamp (not over 10 watts) across the terminals of test switch J.

Now perform the above operations at the opposite end of the line-section (station B) without resetting the switches at Station A. This simulates a phase-to ground fault external to the protected line-section. The fault detectors, but not the operation element at B should pick up, and the operating element at A should reset. Restore test switches D and E at Station A to normal (closed). The line conditions now represent a phase-to-ground fault fed from Station B only. The



\* Fig. 4—Outline and Drilling Plan for the M-20 Projection or Semi-Flush Type FT Flexitest Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.

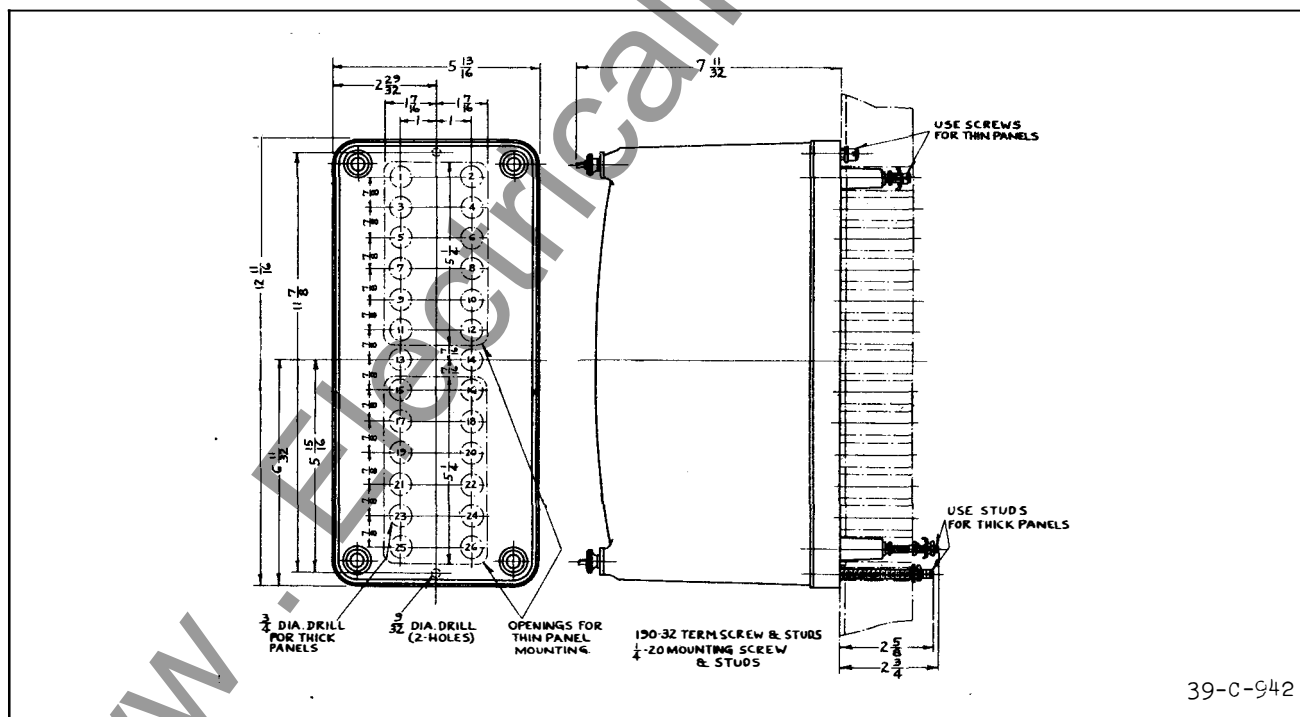


Fig. 5—Outline and Drilling Plan for the Standard Projection Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.

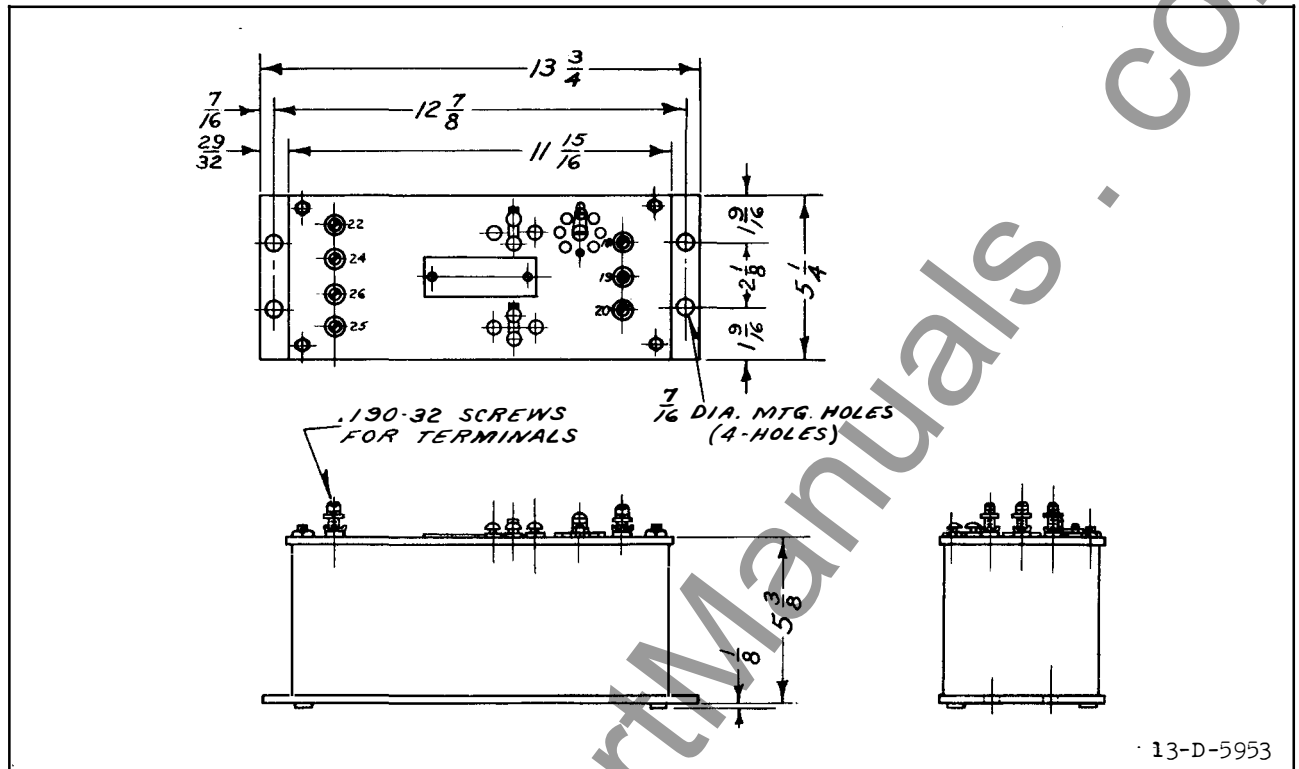


Fig. 6—Outline and Drilling Plan for the Sequence Filter Used with the Type HKB Relay in the Standard Case. For Reference Only.

fault detectors at A should reset and the operating element at B should pick up. Restore test switches D and E at Station B to normal, and all elements of the relay at Station B should reset. For the relay in the standard case, the above test can be performed using suitable external test switches.

The above tests have checked phase rotation, the polarity of the sequence filter output, the interconnections between the relay and the carrier set and the Phase A current connections to the relay at both stations. Phase B and C can be similarly checked by opening test switches F and G for phase B, and switches H and I for phase C. The same procedure described for Phase A is then followed.

If all the tests have been completed with satisfactory results, the test switches at both line terminals should be closed (close the trip circuit test switch last) and the relay cover replaced. The equipment is now ready to protect the line-section to which it is connected.

### PART III — TYPE HKB TEST FACILITIES

#### APPLICATION

The type HKB test facilities provide a simple manually operated test procedure that will check the combined relay and carrier equipment. The test can be performed without the aid of instruments. The results given assurance that all equipment is in normal operating condition without resorting to more elaborate test procedures.

#### CONSTRUCTION

##### Test Switch

The type W test switch is provided with eight pairs of contacts, two pairs of which are closed in the "carrier on" position. The contact arrangement is shown in Fig. 7, and the outline and drilling plan in Fig. 10. These contacts are used to complete the HKB trip circuit and the alarm circuit is indicated in Fig. 7 by contacts 1, 2, and 7, 8. In the "carrier off" position the HKB trip

## TYPE HKB RELAY

circuit is opened through contacts 1 and 2, but the alarm circuit remains closed. Two test positions to the right of the "carrier off" positions are provided. When the switch is moved to either of these positions, the relay trip and alarm circuits are interrupted and a red alarm light is turned on by switch contact 3 and 4. Moving the switch to the **TEST 1** position will connect the output of the auxiliary test transformer directly to the HKB terminals number 25 and 26, through the type W contacts number 9 and 10, 11 and 12. Moving the switch to the **TEST 2** position will connect the test transformer with a reversed polarity to the HKB relay through switch contacts 13, 14 and 15, 16.

### Auxiliary Test Transformer

The auxiliary test transformer is designed to operate from a 115 volt, 60 cycle power source. Four secondary taps numbered 1, 2, 3, and 4 are provided to vary the magnitude of the test current, as follows:

Trans. Tap	Relay Tap	
	G	H
1	3 amp.	2 amp.
2	5	4
3	7.5	5.5
4	9.5	7

The outline and drilling plan of the transformer is shown in Fig. 8.

### Indicating Lamps

The red and blue indicating lamps are standard rectangular Minalites. Outline and drilling dimensions are given in Fig. 10.

## ADJUSTMENT

Choose a transformer tap that will provide approximately two times the phase-to-ground current setting of the FD-2 fault detector as previously determined.

## OPERATION

A multi-contact switch is provided at each line terminal which serves the dual functions of a carrier on-off switch and a test switch.

This switch is arranged to apply a single phase current to the HKB relay to simulated internal and through fault conditions. Relay operation is noted by observing a blue indicating lamp connected in the HKB relay trip circuit. During the test the HKB trip circuit to the line breaker is opened and a red warning light is energized through auxiliary contacts on the test switch.

Use of the auxiliary test equipment is to be limited to provide a simplified test after the initial installation tests have been performed as described in part II of this instruction leaflet.

The test apparatus is to be connected as shown in Fig. 7 with the auxiliary test transformers energized from 115 volt, 60 cycle power sources at each line terminal that are in phase with each other. The following operation procedure assumes that the same polarity is used in connecting the test transformer at each line terminal.

1. Turn the carrier test switch at both line terminals to CARRIER OFF.
2. Turn the carrier test switch to TEST 1 at line terminal #1. The local relay should operate to transmit half cycle impulses of carrier, and trip. Tripping will be indicated by the blue light.

3. Turn the HKB test switch at the remote line terminal #2 to TEST 1. This will simulate an internal fault fed from both line terminals. The relay at line terminal #2 will trip, and the relay at line terminal #1 will remain tripped. Tripping will be indicated by the blue lights at each line terminal. Carrier will be transmitted in half cycle impulses simultaneously from each end of the line.

4. Reset the HKB test switch at line terminal #1. The relay at terminal #1 will reset and turn off the blue light. The relay at terminal #2 will hold its trip contact closed, lighting the blue light.

5. Turn the HKB test switch at line terminal #1 to TEST 2. This condition will simu-

late an external fault. The trip contacts of both relay, will be held open and the blue light will be extinguished.

This completes the test procedure.

## Component Style Numbers

6. Reset the test switches at both line terminals to CARRIER OFF before returning to CARRIER ON for normal service. Push in handle to turn in ON position.

Test Transformer S #1338284  
Type W Test Switch S #1584284 for 1/8" panel mounting.  
Type W Test Switch S #1584285 for 1-1/2" panel mounting.

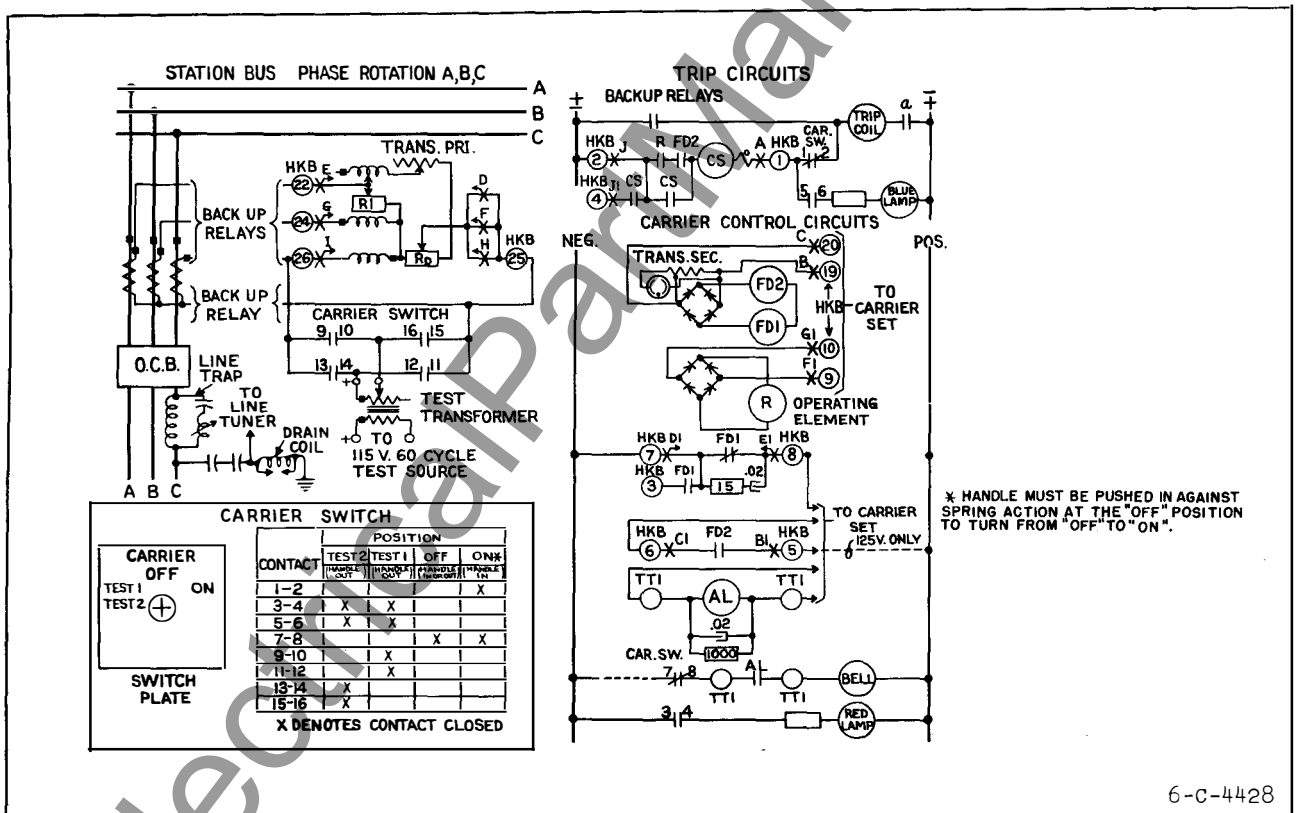


Fig. 7 - Schematic Connections of Type HKB Relay and Test Facilities.

# TYPE HKB RELAY

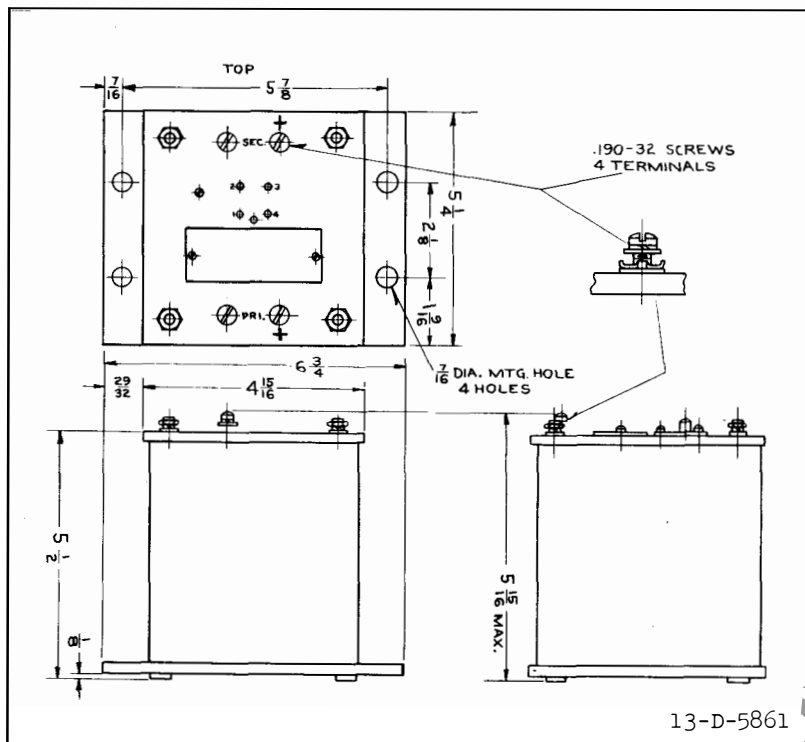


Fig. 8—Outline and Drilling Plan of the Type HKB Test Transformer. For Reference Only.

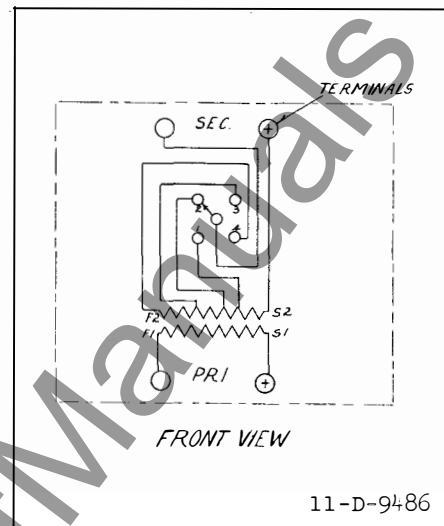


Fig. 9—Internal Schematic of the Type HKB Test Transformer.

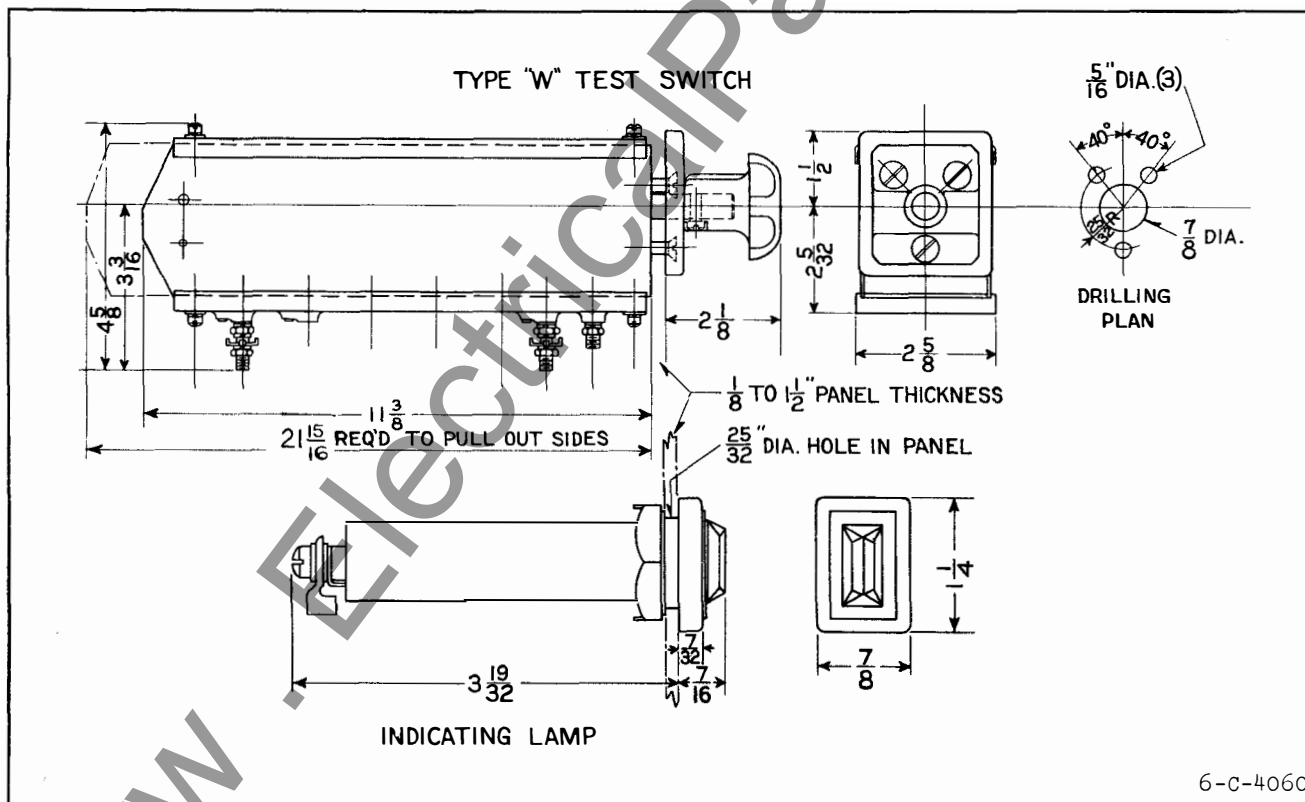


Fig. 10—Outline and Drilling Plan of the Type W Test Switch and Indicating Lamps which are Part of the Type HKB Test Facilities. For Reference Only.

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# INSTALLATION • OPERATION • MAINTENANCE INSTRUCTIONS

## TYPE HKB RELAY AND TEST EQUIPMENT FOR TYPE FD CARRIER

**CAUTION** Before putting 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 HKB relay is a high speed carrier relay used in conjunction with power line carrier equipment to provide complete phase and ground fault protection of a transmission line section. Simultaneous tripping of the relays at each line terminal is obtained in three cycles or less for all internal faults within the limits of the relay settings. The relay operates on line current only, and no source of a - c line potential is required. Consequently, the relays will not trip during a system swing or out-of-step conditions. The carrier equipment operates directly from the station battery.

### PART I—TYPE HKB RELAY

#### CONSTRUCTION

The relay consists of a combination positive, negative and zero sequence network, a saturating auxiliary transformer, two Rectox units, two polar relay units, a telephone-type relay, a neon lamp, contactor switch and operation indicator all mounted in a Type M-20 Flexitest Case.

When the standard projection case is supplied, the sequence network, tap plates, and saturating auxiliary transformer are mounted

in a box which can be located on the rear of the switchboard panel in any convenient position. The remainder of the relay elements are mounted in the relay case proper. The taps and terminal numbers of the relay in the standard case and the external box correspond to those in the type FT case. (See Figures 1, 2, and 3). Terminals 18, 19 and 20 of the external box are to be connected to the corresponding terminals of the relay in the standard case. Otherwise, all external connections for the relay in the standard projection case or in the type FT case are made to the same terminals.

#### Sequence Network

The currents from the current transformer secondaries are passed thru a network consisting of a three-winding iron-core reactor and two resistors. The zero-sequence resistor,  $R_0$ , consists of three resistor tubes tapped to obtain settings for various ground fault conditions. The other resistor  $R_1$  is a formed single wire mounted on the rear of the relay sub-base. The output of this network provides a voltage across the primary of the saturating transformer.

The lower tap block provides for adjustment of the relative amounts of the positive, negative and zero sequence components of current in the network output. Thus, a single relay element energized from the network can be used as a fault detector for all types of faults.

#### Saturating Auxiliary Transformer

The voltage from the network is fed into the tapped primary (upper tap plate) of a small saturating transformer. This transformer and

**SUPERSEDES I. L. 41-650. 5**

\*Denotes change from superseded Issue

**EFFECTIVE AUGUST 1955**

## TYPE HKB RELAY

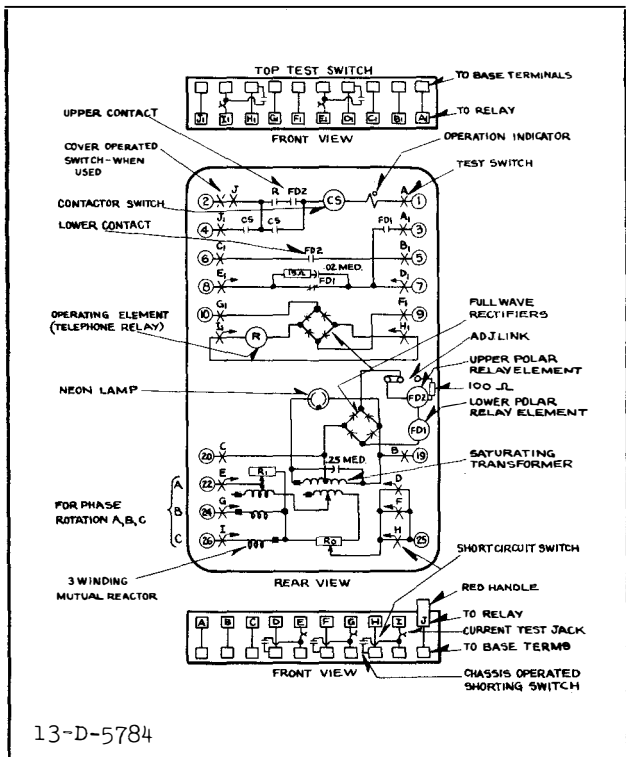


Fig. 1—Internal Schematic of the Type HKB Carrier Relay in the Type FT Case.

a neon lamp connected across its secondary are used to limit the voltage impressed on the fault detectors (polar relay elements) and the carrier Control Unit, thus providing a small range of voltage for a large variation of maximum to minimum fault currents. This provides high operating energy for light faults, and limits the operating energy for heavy faults to a reasonable value.

The upper tap plate changes the output of the saturating transformer, and is marked in amperes required to pick up the lower fault detector element. For further discussion, see section entitled, "Setting".

### Rectox Units

The secondary of the saturating transformer feeds a bridge-connected Rectox Unit, the output of which energizes the polar fault detector elements. A second Rectox, energized from the output of the Control Unit, supplies a d-c voltage to the telephone relay element which operates only for an internal fault. The use

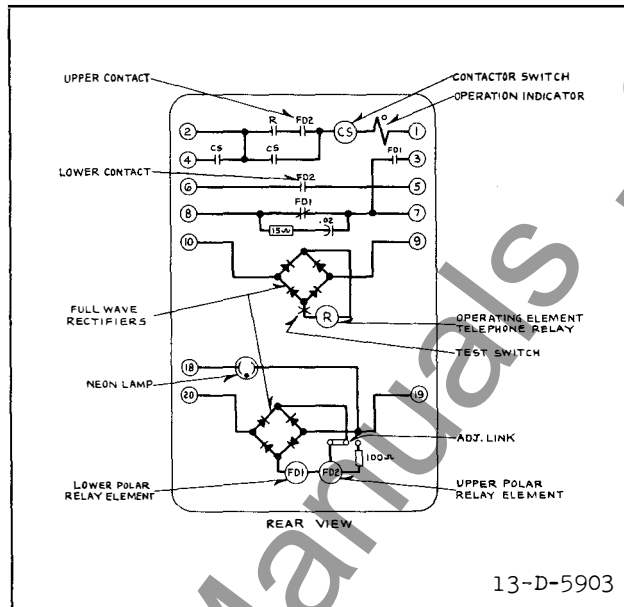


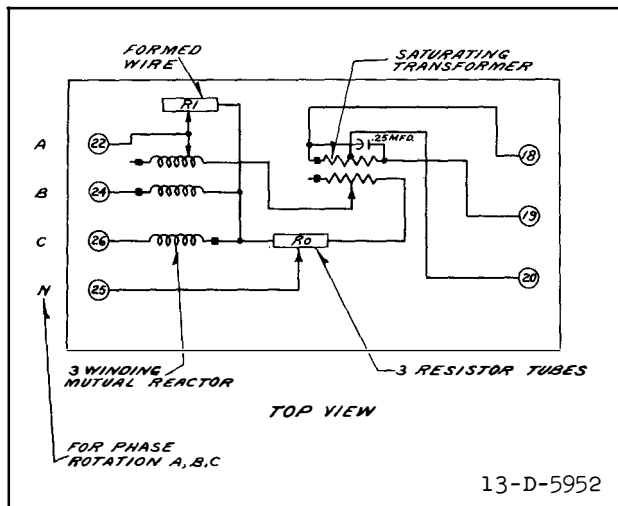
Fig. 2—Internal Schematic of the Type HKB Carrier Relay in the Standard Projection Case.

of sensitive polar relay keeps down the energy required from the current transformers.

### Polar-Type Relays

These elements consist of a rectangular shaped magnetic frame, an electromagnet, a permanent magnet, and an armature with a set of contacts. The poles of the permanent magnet clamp directly to each side of the magnetic frame. Flux from the permanent magnet divides into two paths, one path across the air gap at the front of the element in which the armature is located, the other across two gaps at the base of the frame. Two adjustable screw type shunts which require no locking screws are located across the rear air gaps. These change the reluctance of the magnetic path so as to force some of the flux thru the moving armature which is fastened to the leaf spring and attached to the frame midway between the two rear air gaps. Flux in the armature polarizes it and creates a magnetic bias causing it to move toward one or the other of the poles, depending upon the adjustment of the magnetic shunt screws.

A coil is placed around the armature and within the magnetic frame. The current which



**Fig. 3—Internal Schematic of the Sequence Network Used with the Type HKB Relay in the Standard Protection Case.**

flows in the coil produces a magnetic field which opposes the permanent magnet field and acts to move the armature in the contact-closing direction.

#### Contactor Switch

The d-c contactor switch in the relay is a small solenoid type switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward, the disc bridges three silver stationary contacts. The coil is in series with the main contacts of the relay and with the trip coil of the breaker. When the relay contacts close, the coil becomes energized and closes the switch contacts. This shunts the main relay contacts thereby relieving them of the duty of carrying tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker. The contactor switch is equipped with a third point which is connected to a terminal on the relay to operate a bell alarm.

#### Operation Indicator

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

gravity to indicate completion of the trip circuit. The indicator is reset from outside of the case by a push rod.

### OPERATION

The HKB carrier relaying system compares the phase positions of the currents at the ends of a line-section over a carrier channel to determine whether an internal or external fault exists. The three-phase line currents energize a sequence network which gives a single-phase output voltage proportional to a combination of sequence components of the line current. During a fault, this single-phase voltage controls an electronic circuit which allows the transmission of carrier on alternate half-cycles of the power-frequency current. Carrier is transmitted from both line terminals in this manner, and is received at the opposite ends where it is compared with the phase position of the local sequence network output. This comparison takes place in a vacuum tube. The polarities of the voltages to be compared are such that for an internal fault, plate current flows on alternate power-frequency half-cycles. A relay connected in the plate circuit of the vacuum tube operates under this condition to complete the trip circuit. During an external fault, the change in direction of current flow causes the plate current to be continuously blocked, and the plate circuit relay does not operate.

Since this relaying system operates only during a fault, the carrier channel is available at all other times for the transmission of other functions.

### CHARACTERISTICS

The sequence network in the relay is arranged for several possible combinations of sequence components. For most applications, 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 which will pick up the lower or carrier start fault detector (FD1). The upper polar element (FD2), which supervises

## TYPE HKB RELAY

operation of the telephone-type relay, is adjusted to pick up at a current 25 percent above tap value. The taps available are 3, 4, 5, 6, 7, 8, and 10. These taps are on the primary of the saturating transformer. For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the fault detector FD1 to pick up at 86% of the tap setting. For BC faults, the fault detector will pick up at approximately 50% of the tap setting. This difference in pick-up 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.

With the sequence network arranged for positive, negative and zero sequence output, there are some applications where the maximum load current and minimum fault current are too close together to set the relay to pick up under minimum fault current, yet not operate under load. For these cases, a tap 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. In some cases, it may be desirable to eliminate response to positive sequence current entirely, and operate the relay on negative-plus-zero sequence current. A tap is available to operate in this manner. The fault detector picks up at 95% of tap value for all phase-to-phase faults, but is unaffected by balanced load current or three-phase faults.

For ground faults, separate taps are available for adjustment of the ground fault sensitivity to about 1/4 or 1/8 of the upper tap plate setting. See Table II. For example, if the upper tap plate is set at tap 4, the fault detector (FD1) pick-up current for ground faults can be either 1 or 1/2 ampere. In special applications, it may be desirable to eliminate response to zero sequence current. The relay is provided with a tap to allow such operation.

## SETTINGS

The HKB relay has separate tap plates for adjustment of the phase and ground fault sensitivities and the sequence components included in the network output. The range of the available taps is sufficient to cover a wide range of application. The method of determining the correct taps for a given installation is discussed in the following paragraph.

In all cases, the similar fault detectors on the relays at both terminals of a line section must be set to pick up at the same value of line current. This is necessary for correct blocking during faults external to the protected line section.

### Sequence Combination Taps

The two halves of the lower tap plate are for connecting the sequence network to provide any of the combinations described in the previous section. The left half of the tap plate changes the tap on the third winding of the mutual reactor and thus changes the relative amounts of positive and negative sequence sensitivity. Operation of the relay with the various taps is given in the table below.

TABLE I

Comb.	Sequence Components in Network Output	Taps on Lower Tap Block	Fault Detector FD1 Pick Up $\Delta$	
			3 $\phi$ Fault	$\phi$ - $\phi$ Fault
		Left Half   Right Half		
1	Pos., Neg., Zero	C   G or H*	Tap Value	86% Tap Value (53% on BC Fault)
2	Pos., Neg., Zero	B   G or H	2x Tap Value	90% Tap Value (65% on BC Fault)
3	Neg., Zero	A   G or H	--	Tap Value

\* Taps F, G and H are zero-sequence taps for adjusting ground fault sensitivity. See section on zero-sequence current tap.

$\Delta$  Fault detector FD2 is set to pick up at 125% of FD1 for a two-terminal line, or 250% of FD1 for a three-terminal line.

### Positive-Sequence Current Tap and FD2 Tap

The upper tap plate has values of 3, 4, 5, 6, 7, 8, and 10. As mentioned before, these numbers represent the three-phase, fault detector FD1 pickup currents, when the relay is connected for positive, negative and zero sequence out-

put. The fault detector FD2 closes its contact to allow tripping at current value 25 percent above the fault detector FDI setting. This 25 percent difference is necessary to insure that the carrier start fault detectors (FDI) at both ends of a transmission line section pick up to start carrier on an external fault before operating energy is applied through FD2.

For a three-terminal line, the tap link on FDI panel is connected to the right hand tap which allows FD2 to pick up at 250% of FDI setting. This is necessary to allow proper blocking on three-terminal lines when approximately equal currents are fed in two terminals, and their sum flows out the third terminal of the line. For two-terminal lines, the link is connected to the left hand tap, and operation is as described in the previous paragraph.

The taps on the upper and lower tap plates should be selected to assure operation on minimum internal line-to-line faults, and yet not operate on normal load current, particularly if the carrier channel is to be used for auxiliary functions. The dropout current of the fault detector is 75 percent of the pick-up current, and this factor must also be considered in selecting the positive-sequence current tap and sequence component combination. The margin between load current and fault detector pick up should be sufficient to allow the fault detector to drop out after an external fault, when load current continues to flow.

#### Zero-Sequence Current Tap

The right half of the lower tap plate is for adjusting the ground fault response of the relay. Taps G and H give ground fault sensitivities as listed in Table II. Tap F is used in applications where increased sensitivity to ground faults is not required. When this tap is used, the voltage output of the network due to zero-sequence current is eliminated.

TABLE II

Comb.	Lower Left Tap	Ground Fault Pickup Percent of Upper Tap Setting	
		Tap G	Tap H
1	C	25%	12%
2	B	20	10
3	A	20	10

#### Examples of Relay Settings

##### CASE I

Assume a two-terminal line with current transformers rated 400/5 at both terminals. Also assume that full load current is 300 amperes, and that on minimum internal phase-to-phase faults 2000 amperes is fed in from one end and 600 amperes from the other end. Further assume that on minimum internal ground faults, 400 amperes is fed in from one end, and 100 amperes from the other end.

#### Positive Sequence Current Tap

Secondary Values:

$$\text{Load Current} = 300 \times \frac{5}{400} = 3.75 \text{ amperes} \quad (1)$$

Minimum Phase-To-Phase Fault Currents:

$$600 \times \frac{5}{400} = 7.5 \text{ amperes} \quad (2)$$

Fault detector FDI setting (three phase) must be at least:

$$\frac{3.75}{0.75} = 5 \text{ amperes (0.75 is dropout ratio of fault detector)} \quad (3)$$

so that the fault detector will reset on load current.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector FDI setting (three-phase) must be not more than:

$$7.5 \times \frac{1}{0.866} \times \frac{1}{1.25} = 6.98 \text{ amperes} \quad (4)$$

$$\left( 1.25 = \frac{\text{FD2 pick up}}{\text{FD1 pick up}} \right)$$

## TYPE HKB RELAY

### Sequence Combination Tap

From a comparison of (3) and (4) above, it is evident that the fault detector can be set to trip under minimum phase fault condition yet not operate under maximum load. In this case, tap C on the lower left tap block would be used (see Table 1, Comb 1) as there is sufficient difference between maximum load and minimum fault to use the full three-phase sensitivity. Current tap 6 would be used.

### Zero Sequence Tap

Secondary Value:

$$100 \times \frac{5}{400} = 1.25 \text{ amperes minimum ground fault current.}$$

With the upper tap 6 and sequence tap C in use, the fault detector FDI pickup currents for ground faults are as follows:

$$\begin{aligned}\text{Lower right tap G-1/4} \times 6 &= 1.5 \text{ amp.} \\ \text{Minimum trip} &= 1.25 \times 1.5 = 1.88 \text{ amp.} \\ \text{Lower right tap H-1/8} \times 6 &= 0.75 \text{ amp.} \\ \text{Minimum trip} &= 1.25 \times 0.75 = 0.94 \text{ amp.}\end{aligned}$$

From the above, tap H would be used to trip the minimum ground fault of 1.25 amperes.

### Case II

Assume the same fault currents as in Case I, but a maximum load current of 500 amperes. In this example, with the same sequence combination as in Case I, the fault detectors cannot be set to trip on the minimum internal three-phase fault, yet remain inoperative on load current. (Compare (5) and (6) below). However, by connecting the network per Combination 2 on Table I, the relay can be set to trip on minimum phase-to-phase fault, although it will have only half the sensitivity to three-phase faults. This will allow operation at maximum load without picking up the fault detector, and provide high speed relaying of all except light three-phase faults.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault

detector tap must now be not more than:

$$7.5 \times \frac{1}{1.25} \times \frac{1}{0.9} = 6.6 \quad (5)$$

To be sure the fault detector FDI will reset after a fault, the minimum tap setting is determined as follows:

$$\text{Load Current} = 500 \times \frac{5}{400} = 6.25 \text{ amps} \quad (6)$$

$$\frac{6.25}{0.75} = 8.33 \quad (7)$$

Since the fault detector pickup current for three-phase faults is twice tap value, half the above value (Eq. 7) should be used in determining the minimum three-phase tap.

$$\frac{8.33}{2} = 4.17 \quad (8)$$

From a comparison of (5) and (8) above, tap 5 or 6 could be used.

With the three-phase tap 5 in use, the fault detector pickup current for ground faults will be as follows:

$$\begin{aligned}\text{Tap G-1/5} \times 5 &= 1.0 \text{ a.} \\ \text{Minimum trip} &= 1.0 \times 1.25 \text{ a.} = 1.25 \text{ amp.}\end{aligned}$$

$$\begin{aligned}\text{Tap H-1/10} \times 5 &= 0.5 \text{ a.} \\ \text{Minimum trip} &= 1.25 \times 0.5 \text{ a.} = 0.63 \text{ amp.}\end{aligned}$$

Therefore, tap H would be used to trip the minimum ground fault of 1.25 ampere with a margin of safety.

## INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the two mounting studs for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made

direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

## ADJUSTMENTS AND MAINTENANCE

### CAUTION

1. Make sure that the neon lamp is in place whenever relay operation is being checked. This is necessary to limit the voltage peaks in the filter output at high currents so as to prevent damage to the Rectox Units.

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

3. All contacts should be periodically cleaned with a fine file. S #1002110 file is recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

4. The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

### Sequence Network

There are no adjustments to make in the network.

The following mechanical adjustments are given as a guide, and some deviation from them may be necessary to obtain proper electrical calibration.

### FAULT DETECTORS - GENERAL

The sensitivity of the polar elements is ad-

justed 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 from front view, turning out the right-hand shunt decreases the amount of current required to close the right-hand contact. Conversely, drawing out the left-hand shunt increases the amount of current required to trip the relay. In general, the farther out the shunt screws are turned, the greater the toggle action will be, and as a result, the drop out 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 from the back (left-hand, front view) to the front (right-hand, front view) contact as the current is increased.

During calibration, connect a 10,000 ohm resistor across terminals 19 and 20 or switch jaws B and C. (For the special relay wired per 18-D-5121, use terminals 3 and 22 or switchjaws A1 and E.) Connect the panel link to the left-hand terminal. Set the relay taps on 5, C, and H.

A. Lower Polar Element (FD-1) - Adjust the contact screws to obtain an .050" contact gap such that the armature motion between the left and right hand contacts is in the central part of the air gap between the pole faces. Tighten the contact locking nuts. Approximate adjustments of the two magnetic shunt screws are as follows:

Screw both shunt screws all the way in. Then back out both screws six turns. Pass 4.33 amperes, 60 cycles, in phase A and out phase B. Screw in the left hand shunt until the armature moves to the right. If the armature moves to the right at less than 4.33 amperes, screw out the left-hand shunt until proper armature action is obtained.

Reduce the current until the armature resets to the left. This should happen at not less than 75% of the pickup value, or 3.25 amperes. If the armature resets at less than this

## TYPE HKB RELAY

value, it will be necessary to advance the right hand shunt to obtain a dropout of 75% or greater. This in turn will require a slight readjustment of the left hand shunt. Recheck the pickup and dropout points several times, and make any minor "trimming" adjustments of the shunt screws that may be necessary to obtain correct calibration. If the above procedure does not give a sufficiently high dropout, a small amount of further adjustment can be obtained by advancing the right-hand contact screw a fraction of a turn. As finally adjusted, the contact gap should be at least .030", and the action of the armature should be snappy at the pickup and dropout points.

B. Upper Polar Element (FD-2) - Adjust the contact screws to obtain an .050" contact gap such that the armature motion between contacts is in the central portion of the air gap between the pole faces. Tighten the locking nuts.

Follow the same adjustment procedure as for FD1, except for a pickup current of 5.41 amperes, and a dropout current of at least 75% of pickup, or 4.06 amperes. Just above the pickup current, there will be a slight amount of contact vibration. Make a final adjustment of the two right-hand contact screws to obtain equal vibration of both contacts as indicated by a neon lamp connected in the contact circuit.

### Operating Element (Telephone Type Relay)

Adjust the contact gap to 0.045". This is done by bending down the armature contact-lever stop on the relay frame. Now with the armature in the operated position, adjust the armature residual gap to 0.010" by means of the adjustable set screw. This gap should be measured just below the armature set screw. For those relays with a fixed residual spacer, the gap is about 0.008". Check to see that there is a contact follow of a few thousandths of an inch after the contact closes.

Connect a d-c milliammeter (0-25 ma.) across test switchjacks H1 and H2 (relay end of frame). Connect a source of variable a-c voltage (0-10 volts, 60 cycles) across switchjacks W1 and G1. The relay should pick up at 1.0 ampere a-c.

direct current in the coil circuit with sine wave voltage applied to the a-c side of the bridge rectifier. The dropout current will be 4 to 7 ma. The contact spring tension can be changed, if necessary, to obtain these values.

For the relay in the standard case, apply a-c voltage across terminals 9 and 10 and insert a test plug connected to a d-c milliammeter in the single test switch jack of the relay. If clip leads are used, it will be necessary to slip a strip of insulating material such as fiber into the test switch jack after opening the switch blade to obtain a reading.

### Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core when the switch is picked up. This can be most conveniently done by turning the relay upside-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 2 amperes d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 0.25 ohm.

### Operation Indicator

Adjust the indicator to operate at 1.0 ampere a-c gradually applied by loosening the two screws on the under side of the assembly, and swing the bracket forward or backward. If the helical springs which reset the armature are replaced by new springs, they should be stretched slightly by stretching to about 1/2 inch beyond their rest position. The coil resistance is approximately 0.25 ohm.



## RENEWAL PARTS

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

## ENERGY REQUIREMENTS

Burdens measured at a balanced three-phase current of five amperes.

Relay Taps	Phase A		Phase B		Phase C	
	VA	Angle	VA	Angle	VA	Angle
A-F-3	2.4	5°	0.6	0°	2.5	50°
A-H-10	3.25	0°	0.8	100°	1.28	55°
B-F-3	2.3	0°	0.63	0°	2.45	55°
B-H-10	4.95	0°	2.35	90°	0.3	60°
C-F-3	2.32	0°	0.78	0°	2.36	50°
C-H-10	6.35	342°	3.83	80°	1.98	185°

Burdens measured at a single-phase to neutral current of five amperes.

Relay Taps	Phase A		Phase B		Phase C	
	VA	Angle	VA	Angle	VA	Angle
A-F-3	2.47	0°	2.1	10°	1.97	20°
A-H-10	7.3	60°	12.5	53°	6.7	26°
B-F-3	2.45	0°	2.09	15°	2.07	10°
B-H-10	16.8	55°	22.0	50°	12.3	38°
C-F-3	2.49	0°	1.99	15°	2.11	15°
C-H-10	31.2	41°	36.0	38°	23.6	35°

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

## PART II — HKB CONTROL UNIT (FD CARRIER)

The construction, operation, and adjustment of the Control Unit used with the HKB relay are covered in a separate instruction book identified as I.B. 84-891-1. The Control Unit is a part of the Type FD carrier assembly.

## OVERALL TEST OF COMPLETE INSTALLATION

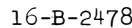
After the complete equipment has been installed and adjusted, the following tests can be made which will provide an overall check on the relay and carrier assembly. The phase

rotation of the three-phase currents can be checked by measuring the a-c voltage across relay terminals 19 and 20 or test switches B and C with a high resistance a-c voltmeter of at least 1000 ohms per volt. The reading obtained should be approximately 0.9 volts per ampere of balanced three-phase load current (secondary value) with relay taps 4, C and H.

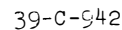
The following test requires that a balanced three-phase load current of at least 1.0 ampere (secondary) be flowing through the line-section protected by the HKB relays. At both terminals of the protected line-section, remove the HKB relay cover and open the trip circuit by pulling the test switch blade with the long red handle. Put the tap screw on the upper tap plate in the 4 tap, and on the lower one in the C and H taps. Be sure to insert the spare tap screw before removing the connected one. Now open test switches D and E on the relay at one end of the line section (station A) and insert a current test plug or strip of insulating material into the test jack on switch E to open the circuit through that switch. The above operation shorts the phase A to neutral circuit ahead of the sequence filter and disconnects the phase A lead from the filter. This causes the phase B and C currents to return to the current transformers through the zero-sequence resistor in the filter, thus simulating a phase A-to-ground fault fed from one end of the line only. As a result, both the fault detectors and operating element at Station A should close their contacts. Completion of the trip circuit can be checked by connecting a small lamp (not over 10 watts) across the terminals of test switch J.

Now perform the above operations at the opposite end of the line-section (station B) without resetting the switches at Station A. This simulates a phase-to ground fault external to the protected line-section. The fault detectors, but not the operation element at B should pick up, and the operating element at A should reset. Restore test switches D and E at Station A to normal (closed). The line conditions now represent a phase-to-ground fault fed from Station B only. The

**TYPE HKB RELAY** \_\_\_\_\_



\* Fig. 4—Outline and Drilling Plan for the M-20 Projection or Semi-Flush Type FT Flexitest Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.



**Fig. 5—Outline and Drilling Plan for the Standard Projection Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.**

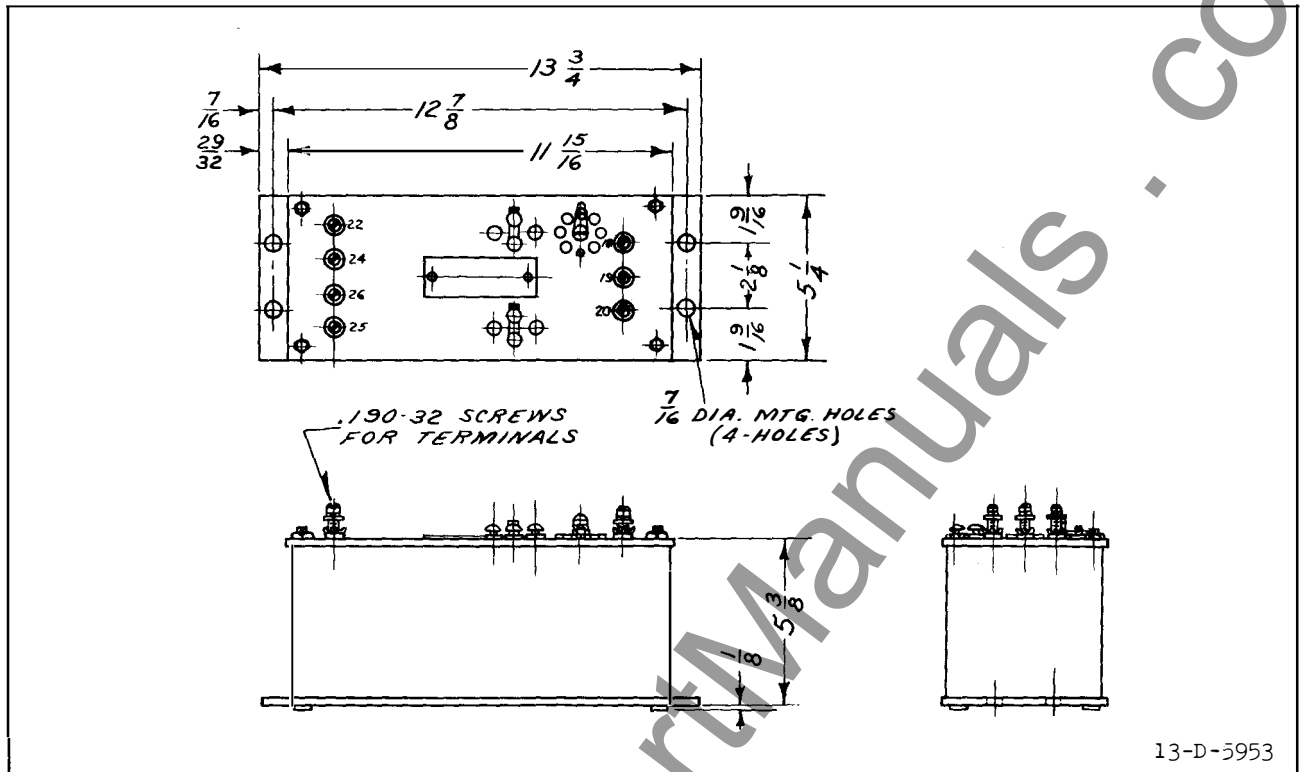


Fig. 6—Outline and Drilling Plan for the Sequence Filter Used with the Type HKB Relay in the Standard Case. For Reference Only.

fault detectors at A should reset and the operating element at B should pick up. Restore test switches D and E at Station B to normal, and all elements of the relay at Station B should reset. For the relay in the standard case, the above test can be performed using suitable external test switches.

The above tests have checked phase rotation, the polarity of the sequence filter output, the interconnections between the relay and the carrier set and the Phase A current connections to the relay at both stations. Phase B and C can be similarly checked by opening test switches F and G for phase B, and switches H and I for phase C. The same procedure described for Phase A is then followed.

If all the tests have been completed with satisfactory results, the test switches at both line terminals should be closed (close the trip circuit test switch last) and the relay cover replaced. The equipment is now ready to protect the line-section to which it is connected.

## PART III — TYPE HKB TEST FACILITIES

### APPLICATION

The type HKB test facilities provide a simple manually operated test procedure that will check the combined relay and carrier equipment. The test can be performed without the aid of instruments. The results given assurance that all equipment is in normal operating condition without resorting to more elaborate test procedures.

### CONSTRUCTION

#### Test Switch

The type W test switch is provided with eight pairs of contacts, two pairs of which are closed in the "carrier on" position. The contact arrangement is shown in Fig. 7, and the outline and drilling plan in Fig. 10. These contacts are used to complete the HKB trip circuit and the alarm circuit is indicated in Fig. 7 by contacts 1, 2, and 7, 8. In the "carrier off" position the HKB trip

## TYPE HKB RELAY

circuit is opened through contacts 1 and 2, but the alarm circuit remains closed. Two test positions to the right of the "carrier off" positions are provided. When the switch is moved to either of these positions, the relay trip and alarm circuits are interrupted and a red alarm light is turned on by switch contact 3 and 4. Moving the switch to the TEST 1 position will connect the output of the auxiliary test transformer directly to the HKB terminals number 25 and 26, through the type W contacts number 9 and 10, 11 and 12. Moving the switch to the TEST 2 position will connect the test transformer with a reversed polarity to the HKB relay through switch contacts 13, 14 and 15, 16.

### Auxiliary Test Transformer

The auxiliary test transformer is designed to operate from a 115 volt, 60 cycle power source. Four secondary taps numbered 1, 2, 3, and 4 are provided to vary the magnitude of the test current, as follows:

Trans. Tap	Relay Tap	
	G	H
1	3 amp.	2 amp.
2	5	4
3	7.5	5.5
4	9.5	7

The outline and drilling plan of the transformer is shown in Fig. 8.

### Indicating Lamps

The red and blue indicating lamps are standard rectangular Minalites. Outline and drilling dimensions are given in Fig. 10.

## ADJUSTMENT

Choose a transformer tap that will provide approximately two times the phase-to-ground current setting of the FD-2 fault detector as previously determined.

## OPERATION

A multi-contact switch is provided at each line terminal which serves the dual functions of a carrier on-off switch and a test switch.

This switch is arranged to apply a single phase current to the HKB relay to simulated internal and through fault conditions. Relay operation is noted by observing a blue indicating lamp connected in the HKB relay trip circuit. During the test the HKB trip circuit to the line breaker is opened and a red warning light is energized through auxiliary contacts on the test switch.

Use of the auxiliary test equipment is to be limited to provide a simplified test after the initial installation tests have been performed as described in part II of this instruction leaflet.

The test apparatus is to be connected as shown in Fig. 7 with the auxiliary test transformers energized from 115 volt, 60 cycle power sources at each line terminal that are in phase with each other. The following operation procedure assumes that the same polarity is used in connecting the test transformer at each line terminal.

1. Turn the carrier test switch at both line terminals to CARRIER OFF.

2. Turn the carrier test switch to TEST 1 at line terminal #1. The local relay should operate to transmit half cycle impulses of carrier, and trip. Tripping will be indicated by the blue light.

3. Turn the HKB test switch at the remote line terminal #2 to TEST 1. This will simulate an internal fault fed from both line terminals. The relay at line terminal #2 will trip, and the relay at line terminal #1 will remain tripped. Tripping will be indicated by the blue lights at each line terminal. Carrier will be transmitted in half cycle impulses simultaneously from each end of the line.

4. Reset the HKB test switch at line terminal #1. The relay at terminal #1 will reset and turn off the blue light. The relay at terminal #2 will hold its trip contact closed, lighting the blue light.

5. Turn the HKB test switch at line terminal #1 to TEST 2. This condition will simu-

late an external fault. The trip contacts of both relay, will be held open and the blue light will be extinguished.

This completes the test procedure.

## Component Style Numbers

6. Reset the test switches at both line terminals to CARRIER OFF before returning to CARRIER ON for normal service. Push in handle to turn in ON position.

Test Transformer S #1338284  
Type W Test Switch S #1584284 for 1/8" panel mounting.  
Type W Test Switch S #1584285 for 1-1/2" panel mounting.

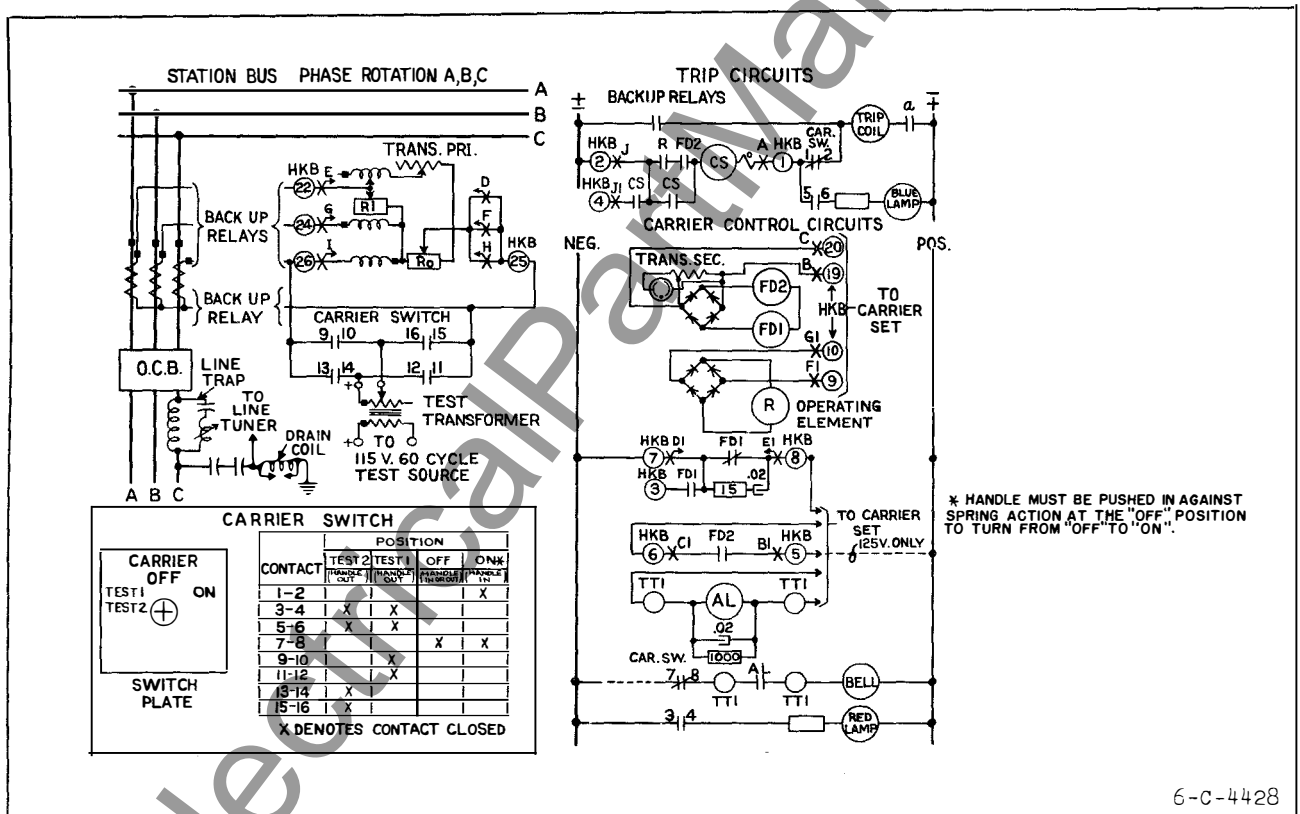


Fig. 7- Schematic Connections of Type HKB Relay and Test Facilities.

# TYPE HKB RELAY

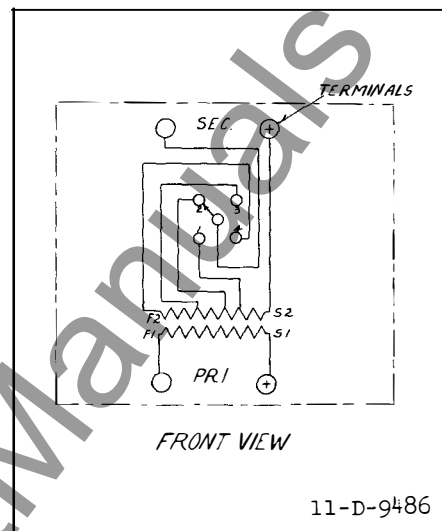
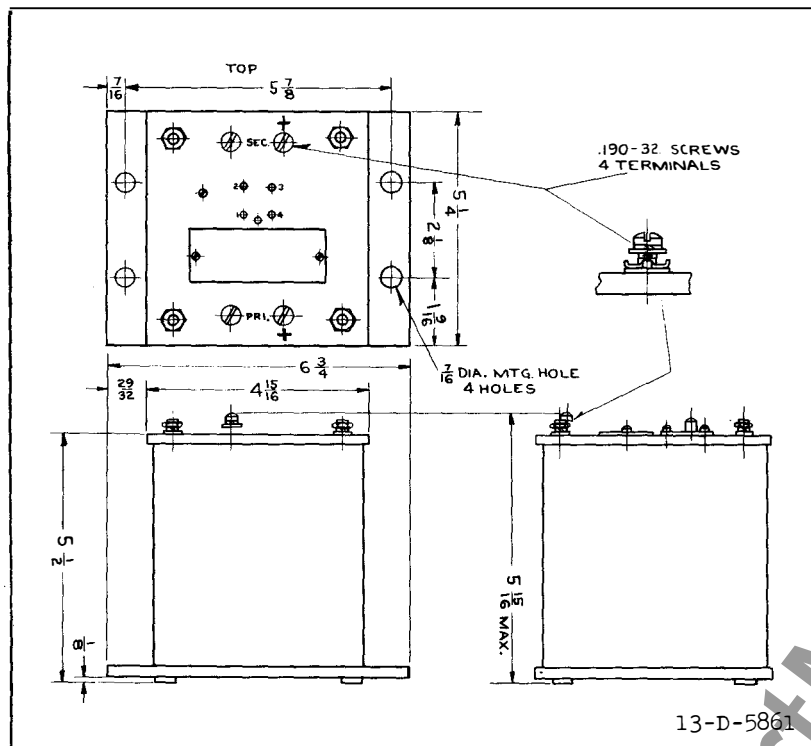


Fig. 8—Outline and Drilling Plan of the Type HKB Test Transformer. For Reference Only.

Fig. 9—Internal Schematic of the Type HKB Test Transformer.

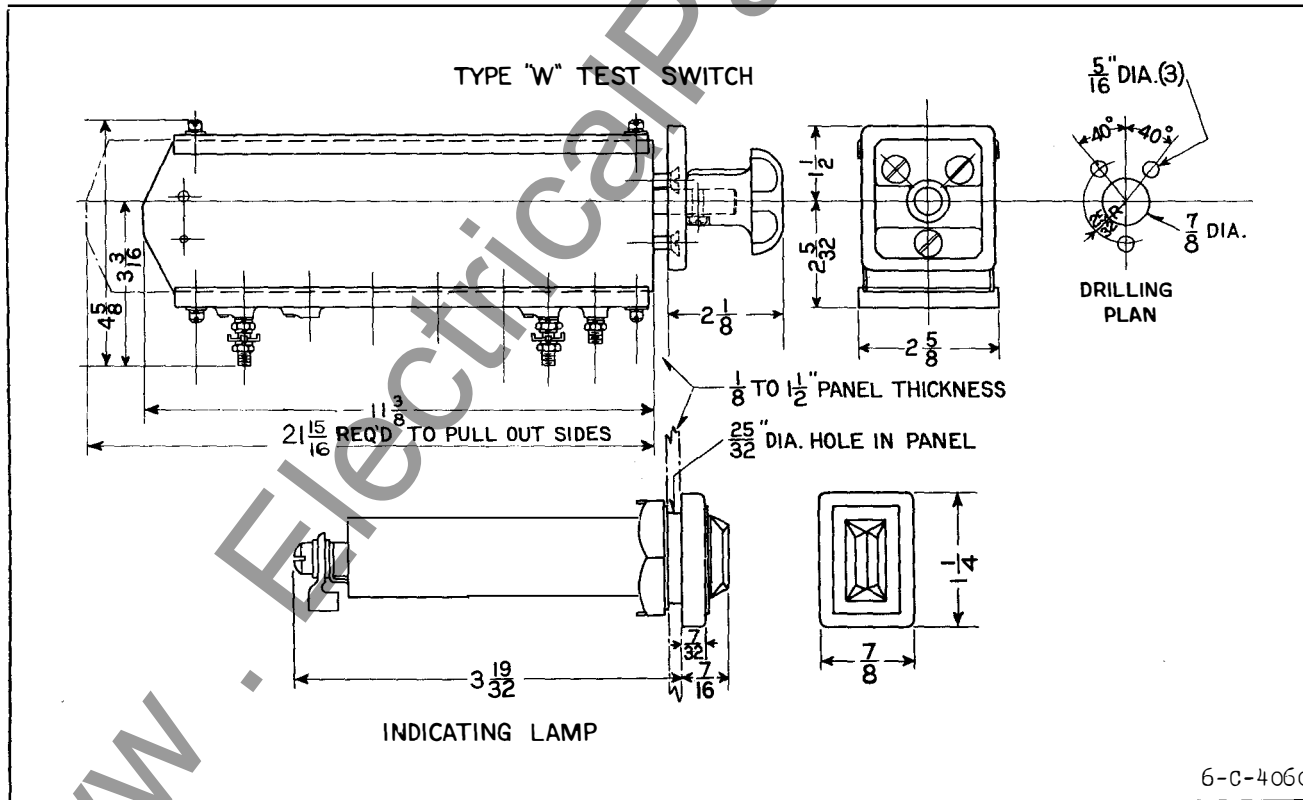


Fig. 10—Outline and Drilling Plan of the Type W Test Switch and Indicating Lamps which are Part of the Type HKB Test Facilities. For Reference Only.

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**METER DIVISION**

**NEWARK, N.J.**

Printed in U. S. A.





# INSTALLATION • OPERATION • MAINTENANCE INSTRUCTIONS

## TYPE HKB RELAY AND TEST EQUIPMENT FOR TYPE FD CARRIER

**CAUTION** Before putting 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 HKB relay is a high speed carrier relay used in conjunction with power line carrier equipment to provide complete phase and ground fault protection of a transmission line section. Simultaneous tripping of the relays at each line terminal is obtained in three cycles or less for all internal faults within the limits of the relay settings. The relay operates on line current only, and no source of a - c line potential is required. Consequently, the relays will not trip during a system swing or out-of-step conditions. The carrier equipment operates directly from the station battery.

### PART I—TYPE HKB RELAY

#### CONSTRUCTION

The relay consists of a combination positive, negative and zero sequence network, a saturating auxiliary transformer, two Rectox units, two polar relay units, a telephone-type relay, a neon lamp, contactor switch and operation indicator all mounted in a Type M-20 Flexitest Case.

When the standard projection case is supplied, the sequence network, tap plates, and saturating auxiliary transformer are mounted

in a box which can be located on the rear of the switchboard panel in any convenient position. The remainder of the relay elements are mounted in the relay case proper. The taps and terminal numbers of the relay in the standard case and the external box correspond to those in the type FT case. (See Figures 1, 2, and 3). Terminals 18, 19 and 20 of the external box are to be connected to the corresponding terminals of the relay in the standard case. Otherwise, all external connections for the relay in the standard projection case or in the type FT case are made to the same terminals.

#### Sequence Network

The currents from the current transformer secondaries are passed thru a network consisting of a three-winding iron-core reactor and two resistors. The zero-sequence resistor,  $R_0$ , consists of three resistor tubes tapped to obtain settings for various ground fault conditions. The other resistor  $R_1$  is a formed single wire mounted on the rear of the relay sub-base. The output of this network provides a voltage across the primary of the saturating transformer.

The lower tap block provides for adjustment of the relative amounts of the positive, negative and zero sequence components of current in the network output. Thus, a single relay element energized from the network can be used as a fault detector for all types of faults.

#### Saturating Auxiliary Transformer

The voltage from the network is fed into the tapped primary (upper tap plate) of a small saturating transformer. This transformer and

## TYPE HKB RELAY

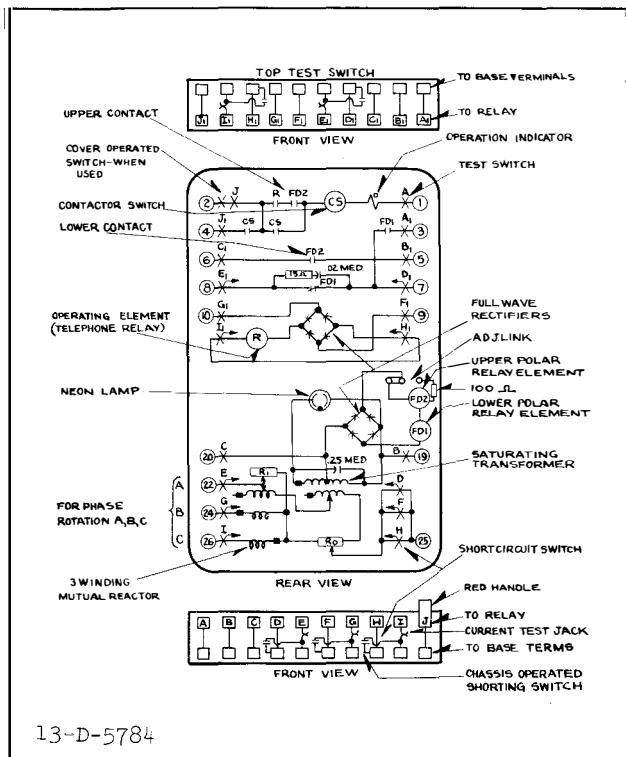


Fig. 1— Internal Schematic of the Type HKB Carrier Relay in the Type FT Case.

a neon lamp connected across its secondary are used to limit the voltage impressed on the fault detectors (polar relay elements) and the carrier Control Unit, thus providing a small range of voltage for a large variation of maximum to minimum fault currents. This provides high operating energy for light faults, and limits the operating energy for heavy faults to a reasonable value.

The upper tap plate changes the output of the saturating transformer, and is marked in amperes required to pick up the lower fault detector element. For further discussion, see section entitled, "Setting".

### Rectox Units

The secondary of the saturating transformer feeds a bridge-connected Rectox Unit, the output of which energizes the polar fault detector elements. A second Rectox, energized from the output of the Control Unit, supplies a d-c voltage to the telephone relay element which operates only for an internal fault. The use

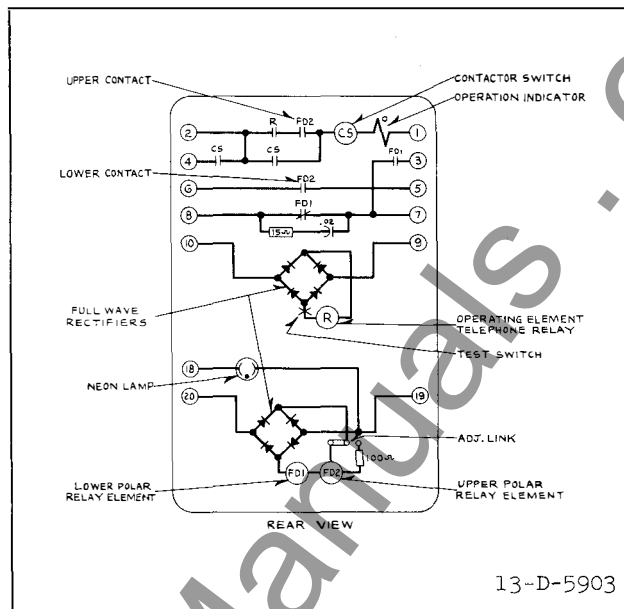


Fig. 2— Internal Schematic of the Type HKB Carrier Relay in the Standard Projection Case.

of sensitive polar relay keeps down the energy required from the current transformers.

### Polar-Type Relays

These elements consist of a rectangular shaped magnetic frame, an electromagnet, a permanent magnet, and an armature with a set of contacts. The poles of the permanent magnet clamp directly to each side of the magnetic frame. Flux from the permanent magnet divides into two paths, one path across the air gap at the front of the element in which the armature is located, the other across two gaps at the base of the frame. Two adjustable screw type shunts which require no locking screws are located across the rear air gaps. These change the reluctance of the magnetic path so as to force some of the flux thru the moving armature which is fastened to the leaf spring and attached to the frame midway between the two rear air gaps. Flux in the armature polarizes it and creates a magnetic bias causing it to move toward one or the other of the poles, depending upon the adjustment of the magnetic shunt screws.

A coil is placed around the armature and within the magnetic frame. The current which

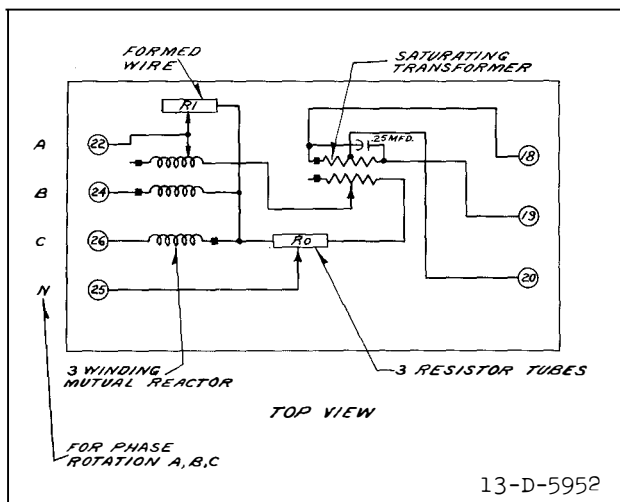


Fig. 3—Internal Schematic of the Sequence Network Used with the Type HKB Relay in the Standard Projection Case.

flows in the coil produces a magnetic field which opposes the permanent magnet field and acts to move the armature in the contact-closing direction.

#### Contactor Switch

The d-c contactor switch in the relay is a small solenoid type switch. A cylindrical plunger with a silver disc mounted on its lower end moves in the core of the solenoid. As the plunger travels upward, the disc bridges three silver stationary contacts. The coil is in series with the main contacts of the relay and with the trip coil of the breaker. When the relay contacts close, the coil becomes energized and closes the switch contacts. This shunts the main relay contacts thereby relieving them of the duty of carrying tripping current. These contacts remain closed until the trip circuit is opened by the auxiliary switch on the breaker. The contactor switch is equipped with a third point which is connected to a terminal on the relay to operate a bell alarm.

#### Operation Indicator

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

gravity to indicate completion of the trip circuit. The indicator is reset from outside of the case by a push rod.

### OPERATION

The HKB carrier relaying system compares the phase positions of the currents at the ends of a line-section over a carrier channel to determine whether an internal or external fault exists. The three-phase line currents energize a sequence network which gives a single-phase output voltage proportional to a combination of sequence components of the line current. During a fault, this single-phase voltage controls an electronic circuit which allows the transmission of carrier on alternate half-cycles of the power-frequency current. Carrier is transmitted from both line terminals in this manner, and is received at the opposite ends where it is compared with the phase position of the local sequence network output. This comparison takes place in a vacuum tube. The polarities of the voltages to be compared are such that for an internal fault, plate current flows on alternate power-frequency half-cycles. A relay connected in the plate circuit of the vacuum tube operates under this condition to complete the trip circuit. During an external fault, the change in direction of current flow causes the plate current to be continuously blocked, and the plate circuit relay does not operate.

Since this relaying system operates only during a fault, the carrier channel is available at all other times for the transmission of other functions.

### CHARACTERISTICS

The sequence network in the relay is arranged for several possible combinations of sequence components. For most applications, 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 which will pick up the lower or carrier start fault detector (FD1). The upper polar element (FD2), which supervises

## TYPE HKB RELAY

operation of the telephone-type relay, is adjusted to pick up at a current 25 percent above tap value. The taps available are 3, 4, 5, 6, 7, 8, and 10. These taps are on the primary of the saturating transformer. For phase-to-phase faults AB and CA, enough negative sequence current has been introduced to allow the fault detector FD1 to pick up at 86% of the tap setting. For BC faults, the fault detector will pick up at approximately 50% of the tap setting. This difference in pick-up 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.

With the sequence network arranged for positive, negative and zero sequence output, there are some applications where the maximum load current and minimum fault current are too close together to set the relay to pick up under minimum fault current, yet not operate under load. For these cases, a tap 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. In some cases, it may be desirable to eliminate response to positive sequence current entirely, and operate the relay on negative-plus-zero sequence current. A tap is available to operate in this manner. The fault detector picks up at 95% of tap value for all phase-to-phase faults, but is unaffected by balanced load current or three-phase faults.

For ground faults, separate taps are available for adjustment of the ground fault sensitivity to about 1/4 or 1/8 of the upper tap plate setting. See Table II. For example, if the upper tap plate is set at tap 4, the fault detector (FD1) pick-up current for ground faults can be either 1 or 1/2 ampere. In special applications, it may be desirable to eliminate response to zero sequence current. The relay is provided with a tap to allow such operation.

## SETTINGS

The HKB relay has separate tap plates for adjustment of the phase and ground fault sensitivities and the sequence components included in the network output. The range of the available taps is sufficient to cover a wide range of application. The method of determining the correct taps for a given installation is discussed in the following paragraph.

In all cases, the similar fault detectors on the relays at both terminals of a line section must be set to pick up at the same value of line current. This is necessary for correct blocking during faults external to the protected line section.

### Sequence Combination Taps

The two halves of the lower tap plate are for connecting the sequence network to provide any of the combinations described in the previous section. The left half of the tap plate changes the tap on the third winding of the mutual reactor and thus changes the relative amounts of positive and negative sequence sensitivity. Operation of the relay with the various taps is given in the table below.

TABLE I

Comb.	Sequence Components in Network Output	Taps on Lower Tap Block		Fault Detector FD1 Pick Up $\Delta$	
				3 $\phi$ Fault	$\phi$ - $\phi$ Fault
		Left Half	Right Half		
1	Pos., Neg., Zero	C	G or H*	Tap Value	86% Tap Value (53% on BC Fault)
2	Pos., Neg., Zero	B	G or H	2x Tap Value	90% Tap Value (65% on BC Fault)
3	Neg., Zero	A	G or H	--	Tap Value

\* Taps F, G and H are zero-sequence taps for adjusting ground fault sensitivity. See section on zero-sequence current tap.

$\Delta$  Fault detector FD2 is set to pick up at 125% of FD1 for a two-terminal line, or 250% of FD1 for a three-terminal line.

### Positive-Sequence Current Tap and FD2 Tap

The upper tap plate has values of 3, 4, 5, 6, 7, 8, and 10. As mentioned before, these numbers represent the three-phase, fault detector FD1 pickup currents, when the relay is connected for positive, negative and zero sequence out-

put. The fault detector FD2 closes its contact to allow tripping at current value 25 percent above the fault detector FD1 setting. This 25 percent difference is necessary to insure that the carrier start fault detectors (FD1) at both ends of a transmission line section pick up to start carrier on an external fault before operating energy is applied through FD2.

For a three-terminal line, the tap link on FD1 panel is connected to the right hand tap which allows FD2 to pick up at 250% of FD1 setting. This is necessary to allow proper blocking on three-terminal lines when approximately equal currents are fed in two terminals, and their sum flows out the third terminal of the line. For two-terminal lines, the link is connected to the left hand tap, and operation is as described in the previous paragraph.

The taps on the upper and lower tap plates should be selected to assure operation on minimum internal line-to-line faults, and yet not operate on normal load current, particularly if the carrier channel is to be used for auxiliary functions. The dropout current of the fault detector is 75 percent of the pick-up current, and this factor must also be considered in selecting the positive-sequence current tap and sequence component combination. The margin between load current and fault detector pick up should be sufficient to allow the fault detector to dropout after an external fault, when load current continues to flow.

#### Zero-Sequence Current Tap

The right half of the lower tap plate is for adjusting the ground fault response of the relay. Taps G and H give ground fault sensitivities as listed in Table II. Tap F is used in applications where increased sensitivity to ground faults is not required. When this tap is used, the voltage output of the network due to zero-sequence current is eliminated.

TABLE II

Comb.	Lower Left Tap	Ground Fault Pickup Percent of Upper Tap Setting	
		Tap G	Tap H
1	C	25%	12%
2	B	20	10
3	A	20	10

#### Examples of Relay Settings

##### CASE I

Assume a two-terminal line with current transformers rated 400/5 at both terminals. Also assume that full load current is 300 amperes, and that on minimum internal phase-to-phase faults 2000 amperes is fed in from one end and 600 amperes from the other end. Further assume that on minimum internal ground faults, 400 amperes is fed in from one end, and 100 amperes from the other end.

#### Positive Sequence Current Tap

Secondary Values:

$$\text{Load Current} = 300 \times \frac{5}{400} = 3.75 \text{ amperes} \quad (1)$$

Minimum Phase-To-Phase Fault Currents:

$$600 \times \frac{5}{400} = 7.5 \text{ amperes} \quad (2)$$

Fault detector FD1 setting (three phase) must be at least:

$$\frac{3.75}{0.75} = 5 \text{ amperes (0.75 is dropout ratio of fault detector)} \quad (3)$$

so that the fault detector will reset on load current.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault detector FD1 setting (three-phase) must be not more than:

$$7.5 \times \frac{1}{0.866} \times \frac{1}{1.25} = 6.98 \text{ amperes} \quad (4)$$

$$\left( 1.25 = \frac{\text{FD2 pick up}}{\text{FD1 pick up}} \right)$$

## TYPE HKB RELAY

### Sequence Combination Tap

From a comparison of (3) and (4) above, it is evident that the fault detector can be set to trip under minimum phase fault condition yet not operate under maximum load. In this case, tap C on the lower left tap block would be used (see Table I, Comb 1) as there is sufficient difference between maximum load and minimum fault to use the full three-phase sensitivity. Current tap 6 would be used.

### Zero Sequence Tap

Secondary Value:

$$100 \times \frac{5}{400} = 1.25 \text{ amperes minimum ground fault current.}$$

With the upper tap 6 and sequence tap C in use, the fault detector FDI pickup currents for ground faults are as follows:

$$\begin{aligned} \text{Lower right tap G-1/4} \times 6 &= 1.5 \text{ amp.} \\ \text{Minimum trip} &= 1.25 \times 1.5 = 1.88 \text{ amp.} \\ \text{Lower right tap H-1/8} \times 6 &= 0.75 \text{ amp.} \\ \text{Minimum trip} &= 1.25 \times 0.75 = 0.94 \text{ amp.} \end{aligned}$$

From the above, tap H would be used to trip the minimum ground fault of 1.25 amperes.

### Case II

Assume the same fault currents as in Case I, but a maximum load current of 500 amperes. In this example, with the same sequence combination as in Case I, the fault detectors cannot be set to trip on the minimum internal three-phase fault, yet remain inoperative on load current. (Compare (5) and (6) below). However, by connecting the network per Combination 2 on Table I, the relay can be set to trip on minimum phase-to-phase fault, although it will have only half the sensitivity to three-phase faults. This will allow operation at maximum load without picking up the fault detector, and provide high speed relaying of all except light three-phase faults.

In order to complete the trip circuit on a 7.5 ampere phase-to-phase fault, the fault

detector tap must now be not more than:

$$7.5 \times \frac{1}{1.25} \times \frac{1}{0.9} = 6.6 \quad (5)$$

To be sure the fault detector FDI will reset after a fault, the minimum tap setting is determined as follows:

$$\text{Load Current} = 500 \times \frac{5}{400} = 6.25 \text{ amps} \quad (6)$$

$$\frac{6.25}{0.75} = 8.33 \quad (7)$$

Since the fault detector pickup current for three-phase faults is twice tap value, half the above value (Eq. 7) should be used in determining the minimum three-phase tap.

$$\frac{8.33}{2} = 4.17 \quad (8)$$

From a comparison of (5) and (8) above, tap 5 or 6 could be used.

With the three-phase tap 5 in use, the fault detector pickup current for ground faults will be as follows:

$$\begin{aligned} \text{Tap G-1/5} \times 5 &= 1.0 \text{ a.} \\ \text{Minimum trip} &= 1.0 \times 1.25 \text{ a.} = 1.25 \text{ amp.} \end{aligned}$$

$$\begin{aligned} \text{Tap H-1/10} \times 5 &= 0.5 \text{ a.} \\ \text{Minimum trip} &= 1.25 \times 0.5 \text{ a.} = 0.63 \text{ amp.} \end{aligned}$$

Therefore, tap H would be used to trip the minimum ground fault of 1.25 ampere with a margin of safety.

## INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the two mounting studs for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The electrical connections may be made

direct to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for ebony-asbestos or slate panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

## RELAYS IN TYPE FT CASE

The type FT cases are dust-proof enclosures combining relay elements and knife-blade test switches in the same case. This combination provides a compact flexible assembly easy to maintain, inspect, test and adjust. There are six case sizes, designated as S10, S20, M10, M20, L10, L20. S refers to the small; M the medium; and L, the large size chassis frame. The numbers refer to the possible number of test switch positions 10 or 20.

To remove the chassis, first remove the cover which exposes the relay elements and test switches for inspection and testing. Next open the elongated red handle switches. These should always be opened first before any of the black handle switches or the cam action latches. This opens the trip circuit to prevent accidental trip out. Then open all the remaining switches. With all the switches fully opened, grasp the two cam action latch arms and pull outward. Using the latch arms as handles, pull the chassis out of the case. The chassis can be set on a test bench in a normal upright position as well as on its top, back or sides for easy inspection, maintenance and test.

After removing the chassis a duplicate chassis may be inserted in the case or the blade portion of the switches can be closed and the cover put in place without the chassis. The chassis operated shorting switch located behind the current test switch prevents open circuiting the current transformers when the current type test switches are closed.

When the chassis is to be put back in the case, the above procedure is to be followed in the reversed order. The elongated red handle switch should not be closed until after the

chassis has been latched in place and all of the black handle switches closed.

The electrical circuits are as follows: Each terminal in the base connects thru a test switch to the relay elements in the chassis as shown on the internal schematic diagrams. The relay terminal is identified by numbers marked on both the inside and outside of the base. The test switch positions are identified by letters marked on the top and bottom surface of the moulded blocks. These letters can be seen when the chassis is removed from the case.

The potential and control circuits thru the relay are disconnected from the external circuit by opening the associated test switches. Opening the current test switch short-circuits the current transformer secondary and disconnects one side of the relay coil but leaves the other side of the coil connected to the external circuit thru the current test jack jaws. This circuit can be isolated by inserting the current test plug (without external connections), by inserting the ten circuit test plug, or by inserting a piece of insulating material approximately 1/32" thick into the current test jack jaws. Both switches of the current test switch pair must be open when using the current test plug or insulating material in this manner to short-circuit the current transformer secondary.

A cover operated switch can be supplied with its contacts wired in series with the trip circuit. This switch opens the trip circuit when the cover is removed. This switch can be added to the existing type FT cases at any time.

The relays can be tested in service, in the case but with the external circuits isolated or out of the case as follows:

For testing in service the ammeter test plug connected to suitable instruments, can be inserted in the current test jaws after opening the knife-blade switch to check the current thru the relay.

## TYPE HKB RELAY

Voltages between the potential circuits can be measured conveniently by clamping #2 clip leads on the projecting clip lead lug on the contact jaw.

For testing in the case the ten circuit test plug can be inserted in the contact jaws, with all blades in the full open position. This connects the relay elements to a set of binding posts and completely isolates the relay circuits from the external connections by means of an insulating barrier on the plug. The plug is inserted in the bottom test jaws with the binding posts up and in the top test switch jaws with the binding posts down.

The external test circuits may be made to the relay elements by #2 test clip leads instead of the test plug. When connecting an external test circuit to the current elements using clip leads, care should be taken to see that the current test jack jaws are open so that the relay is completely isolated from the external circuits. Suggested means for isolating this circuit are outlined above.

For testing out of the case relay elements may be tested by using the ten circuit test plug or by #2 test clip leads as described above. The factory calibration is made with the chassis in the case and removing the chassis from the case will change the calibration values of some relays by a small percentage. It is recommended that the relay be checked in position as a final check on calibration.

## ADJUSTMENTS AND MAINTENANCE

### CAUTION

1. Make sure that the neon lamp is in place whenever relay operation is being checked. This is necessary to limit the voltage peaks in the filter output at high currents so as to prevent damage to the Rectox Units.

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

3. All contacts should be periodically cleaned with a fine file. S #1002110 file is recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

4. The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer. If the adjustments have been changed, the relay taken apart for repairs, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

### Sequence Network

There are no adjustments to make in the network.

The following mechanical adjustments are given as a guide, and some deviation from them may be necessary to obtain proper electrical calibration.

### FAULT DETECTORS-GENERAL

The sensitivity of the polar elements 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 the right-hand contact. Conversely, drawing out the left-hand shunt increases the amount of current required to trip the relay. In general, the farther out the shunt screws are turned, the greater the toggle action will be, and as a result, the drop out 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 from the back (left-hand, front view) to the front (right-hand, front view) contact as the current is increased.

During calibration, connect a 10,000 ohm resistor across terminals 19 and 20 or switch



jaws B and C. (For the special relay wired per 18-D-5121, use terminals 3 and 22 or switchjaws A1 and E.) Connect the panel link to the left-hand terminal. Set the relay taps on 5, C, and H.

A. Lower Polar Element (FD-1) - Adjust the contact screws to obtain an .050" contact gap such that the armature motion between the left and right hand contacts is in the central part of the air gap between the pole faces. Tighten the contact locking nuts. Approximate adjustments of the two magnetic shunt screws are as follows:

Screw both shunt screws all the way in. Then back out both screws six turns. Pass 4.33 amperes, 60 cycles, in phase A and out phase B. Screw in the left hand shunt until the armature moves to the right. If the armature moves to the right at less than 4.33 amperes, screw out the left-hand shunt until proper armature action is obtained.

Reduce the current until the armature resets to the left. This should happen at not less than 75% of the pickup value, or 3.25 amperes. If the armature resets at less than this value, it will be necessary to advance the right hand shunt to obtain a dropout of 75% or greater. This in turn will require a slight readjustment of the left hand shunt. Recheck the pickup and dropout points several times, and make any minor "trimming" adjustments of the shunt screws that may be necessary to obtain correct calibration. If the above procedure does not give a sufficiently high dropout, a small amount of further adjustment can be obtained by advancing the right-hand contact screw a fraction of a turn. As finally adjusted, the contact gap should be at least .030", and the action of the armature should be snappy at the pickup and dropout points.

B. Upper Polar Element (FD-2) - Adjust the contact screws to obtain an .050" contact gap such that the armature motion between contacts is in the central portion of the air gap between the pole faces. Tighten the locking nuts.

Follow the same adjustment procedure as for FD1, except for a pickup current of 5.41 amperes, and a dropout current of at least 75% of pickup, or 4.06 amperes. Just above the pickup current, there will be a slight amount of contact vibration. Make a final adjustment of the two right-hand contact screws to obtain equal vibration of both contacts as indicated by a neon lamp connected in the contact circuit.

#### Operating Element (Telephone Type Relay)

Adjust the contact gap to 0.045". This is done by bending down the armature contact-lever stop on the relay frame. Now with the armature in the operated position, adjust the armature residual gap to 0.010" by means of the adjustable set screw. This gap should be measured just below the armature set screw. For those relays with a fixed residual spacer, the gap is about 0.008". Check to see that there is a contact follow of a few thousandths of an inch after the contact closes.

Connect a d-c milliammeter (0-25 ma.) across test switchjaws H1 and I1 (relay out of case). Connect a source of variable a-c voltage (0 to 10 volts, 60 cycles) across switchjaws F1 and G1. The relay should pick up at 10 to 12 ma. direct current in the coil circuit with sine wave voltage applied to the a-c side of the bridge rectifier. The dropout current will be 4 to 7 ma. The contact spring tension can be changed, if necessary, to obtain these values.

For the relay in the standard case, apply a-c voltage across terminals 9 and 10 and insert a test plug connected to a d-c milliammeter in the single test switch jack of the relay. If clip leads are used, it will be necessary to slip a strip of insulating material such as fiber into the test switch jack after opening the switch blade to obtain a reading.

#### Contact Switch

Adjust the stationary core of the switch for a clearance between the stationary core when the switch is picked up. This can be most

## TYPE HKB RELAY

conveniently done by turning the relay up-side-down. Screw up the core screw until the moving core starts rotating. Now, back off the core screw until the moving core stops rotating. This indicates the point where the play in the moving contact assembly is taken up, and where the moving core just separates from the stationary core screw. Back off the stationary core screw one turn beyond this point and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 2 amperes d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 0.25 ohm.

### Operation Indicator

Adjust the indicator to operate at 1.0 ampere d-c gradually applied by loosening the two screws on the under side of the assembly, and moving the bracket forward or backward. If the two helical springs which reset the armature are replaced by new springs, they should be weakened slightly by stretching to obtain the 1 ampere calibration. The coil resistance is approximately 0.16 ohms.

## RENEWAL PARTS

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

## ENERGY REQUIREMENTS

Burdens measured at a balanced three-phase current of five amperes.

Relay Taps	Phase A VA	Angle	Phase B VA	Angle	Phase C VA	Angle
A-F-3	2.4	5°	0.6	0°	2.5	50°
A-H-10	3.25	0°	0.8	100°	1.28	55°
B-F-3	2.3	0°	0.63	0°	2.45	55°
B-H-10	4.95	0°	2.35	90°	0.3	60°
C-F-3	2.32	0°	0.78	0°	2.36	50°
C-H-10	6.35	342°	3.83	80°	1.98	185°

Burdens measured at a single-phase to neutral current of five amperes.

Relay Taps	Phase A VA	Angle	Phase B VA	Angle	Phase C VA	Angle
A-F-3	2.47	0°	2.1	10°	1.97	20°
A-H-10	7.3	60°	12.5	53°	6.7	26°
B-F-3	2.45	0°	2.09	15°	2.07	10°
B-H-10	16.8	55°	22.0	50°	12.3	38°
C-F-3	2.49	0°	1.99	15°	2.11	15°
C-H-10	31.2	41°	36.0	38°	23.6	35°

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

## PART II — HKB CONTROL UNIT (FD CARRIER)

The construction, operation, and adjustment of the Control Unit used with the HKB relay are covered in a separate instruction book identified as I.B. 84-891-1. The Control Unit is a part of the Type FD carrier assembly.

## OVERALL TEST OF COMPLETE INSTALLATION

After the complete equipment has been installed and adjusted, the following tests can be made which will provide an overall check on the relay and carrier equipment. The phase rotation of the three-phase currents can be checked by measuring the a-c voltage across relay terminals 19 and 20 or test switches B and C with a high resistance a-c voltmeter of at least 1000 ohms per volt. The reading obtained should be approximately 0.9 volts per ampere of balanced three-phase load current (secondary value) with relay taps 4, C and H.

The following test requires that a balanced three-phase load current of at least 1.0 ampere (secondary) be flowing through the line-section protected by the HKB relays. At both terminals of the protected line-section, remove the HKB relay cover and open the trip circuit by pulling the test switch blade with the long red handle. Put the tap screw on the upper tap plate in the 4 tap, and on the lower one in the C and H taps. Be sure to insert the spare tap screw before removing the con-

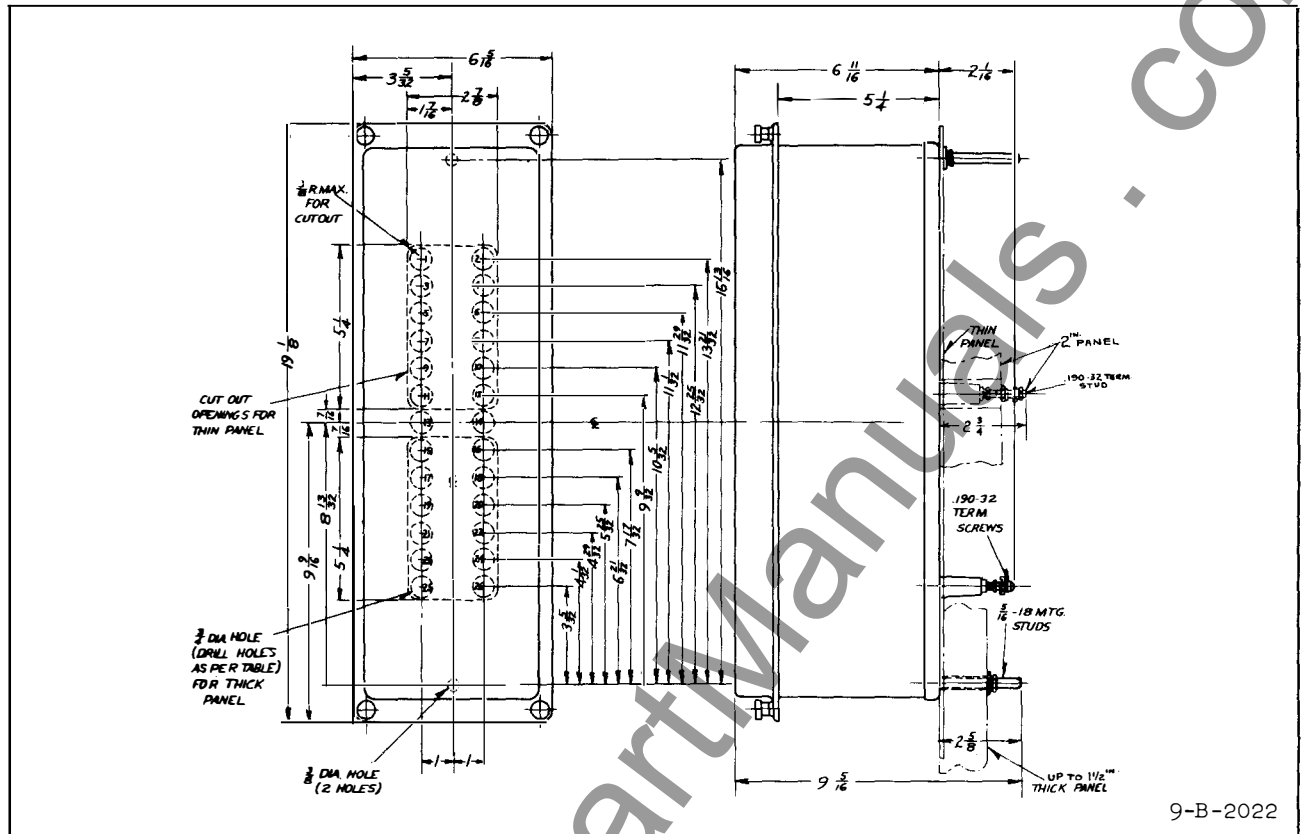


Fig. 4—Outline and Drilling Plan for the M-20 Projection Type FT Flexitest Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.

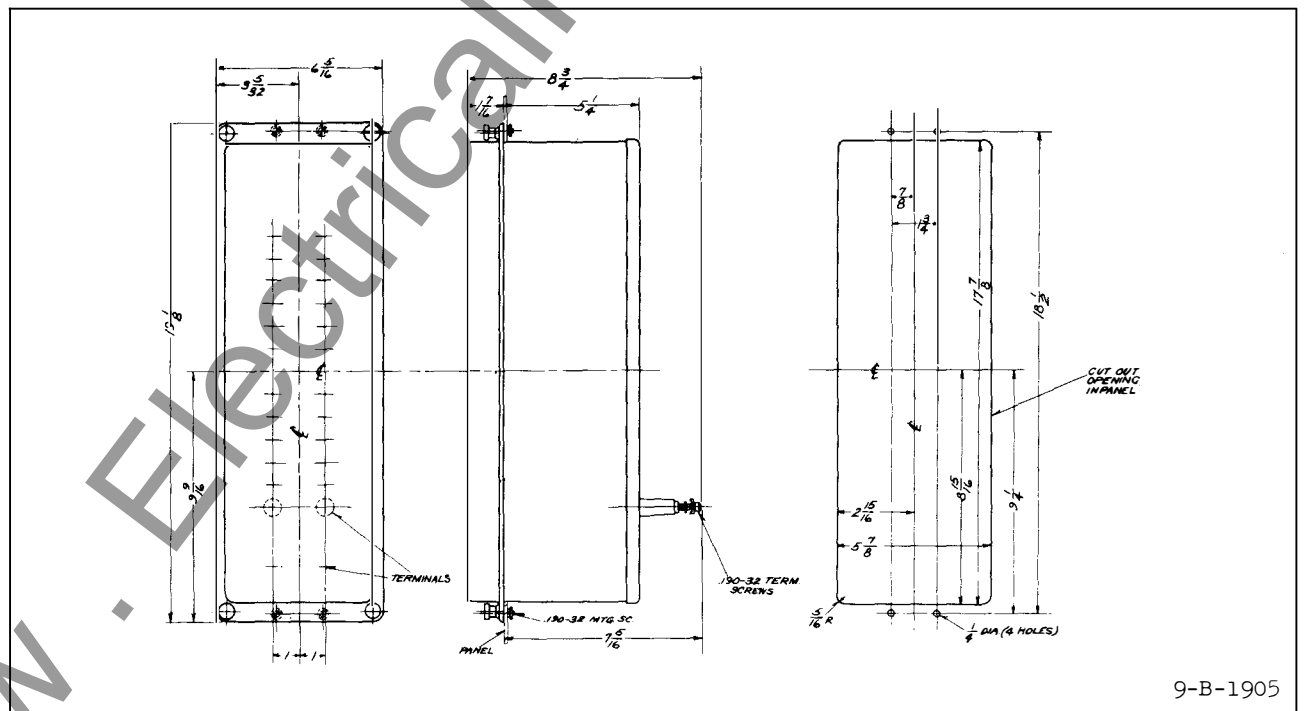


Fig. 5—Outline and Drilling Plan for the M-20 Semi-Flush Type FT Flexitest Case. For Reference Only.

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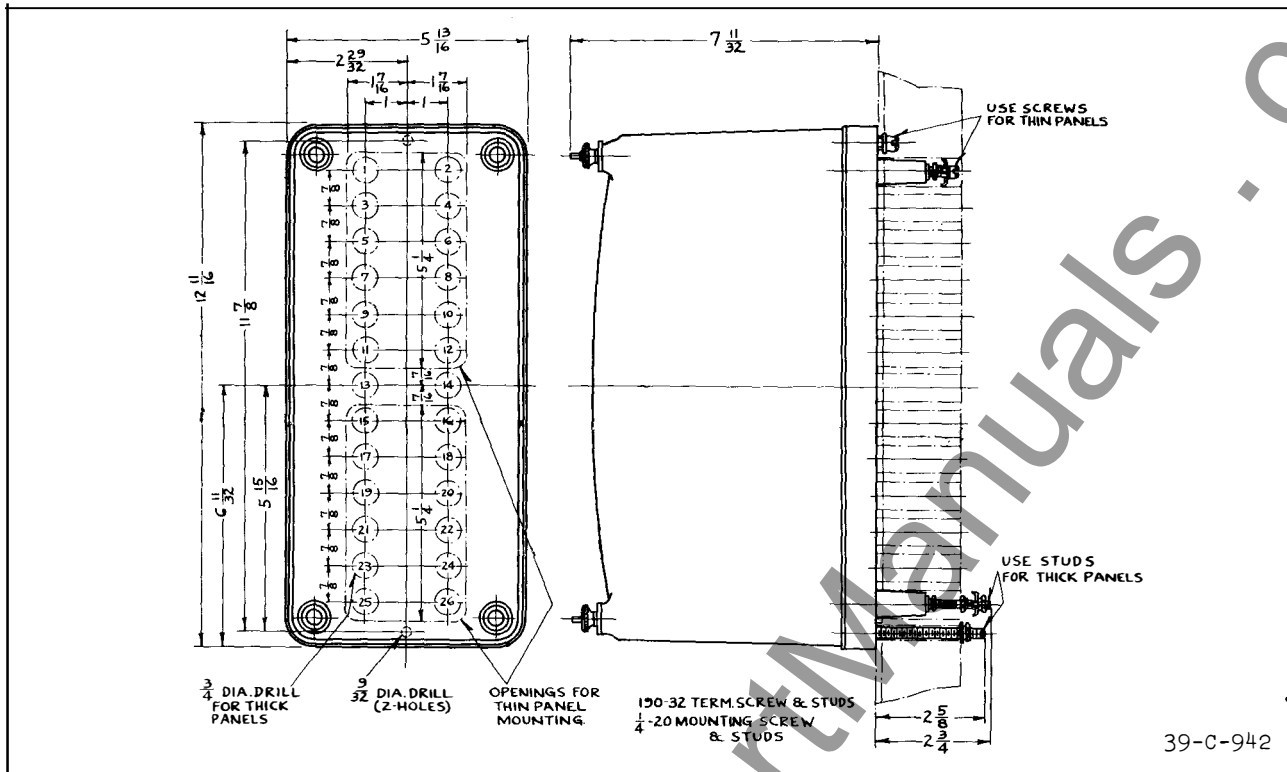


Fig. 6—Outline and Drilling Plan for the Standard Projection Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.

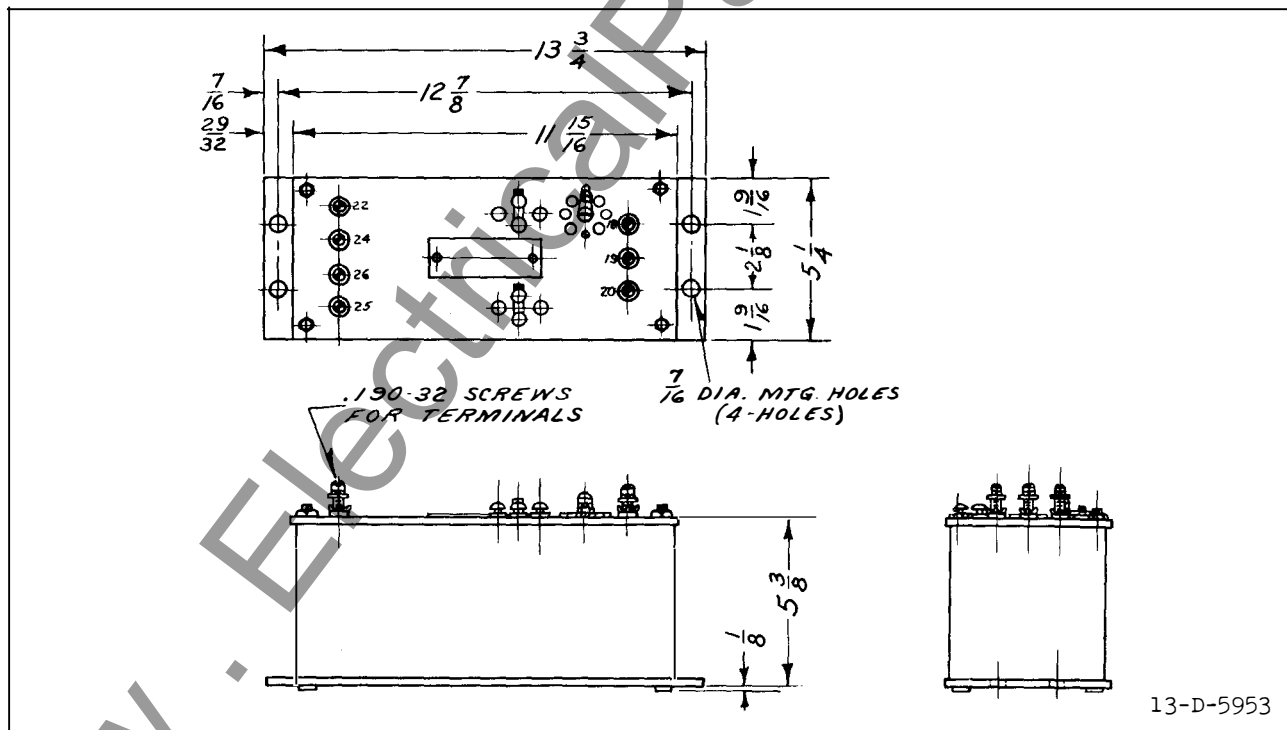


Fig. 7—Outline and Drilling Plan for the Sequence Filter Used with the Type HKB Relay in the Standard Case. For Reference Only.

nected one. Now open test switches D and E on the relay at one end of the line section (station A) and insert a current test plug or strip of insulating material into the test jack on switch E to open the circuit through that switch. The above operation shorts the phase A to neutral circuit ahead of the sequence filter and disconnects the phase A lead from the filter. This causes the phase B and C currents to return to the current transformers through the zero-sequence resistor in the filter, thus simulating a phase A-to-ground fault fed from one end of the line only. As a result, both the fault detectors and operating element at Station A should close their contacts. Completion of the trip circuit can be checked by connecting a small lamp (not over 10 watts) across the terminals of test switch J.

Now perform the above operations at the opposite end of the line-section (station B) without resetting the switches at Station A. This simulates a phase-to-ground fault external to the protected line-section. The fault detectors, but not the operation element at B should pick up, and the operating element at A should reset. Restore test switches D and E at Station A to normal (closed). The line conditions now represent a phase-to-ground fault fed from Station B only. The fault detectors at A should reset and the operating element at B should pick up. Restore test switches D and E at Station B to normal, and all elements of the relay at Station B should reset. For the relay in the standard case, the above test can be performed using suitable external test switches.

The above tests have checked phase rotation, the polarity of the sequence filter output, the interconnections between the relay and the carrier set and the Phase A current connections to the relay at both stations. Phase B and C can be similarly checked by opening test switches F and G for phase B, and switches H and I for phase C. The same procedure described for Phase A is then followed.

If all the tests have been completed with satisfactory results, the test switches at

both line terminals should be closed (close the trip circuit test switch last) and the relay cover replaced. The equipment is now ready to protect the line-section to which it is connected.

## PART III — TYPE HKB TEST FACILITIES

### APPLICATION

The type HKB test facilities provide a simple manually operated test procedure that will check the combined relay and carrier equipment. The test can be performed without the aid of instruments. The results given assurance that all equipment is in normal operating condition without resorting to more elaborate test procedures.

### CONSTRUCTION

#### Test Switch

The type W test switch is provided with eight pairs of contacts, two pairs of which are closed in the "carrier on" position. The contact arrangement is shown in Fig. 8, and the outline and drilling plan in Fig. 11. These contacts are used to complete the HKB trip circuit and the alarm circuit is indicated in Fig. 8 by contacts 1, 2, and 7, 8. In the "carrier off" position the HKB trip circuit is opened through contacts 1 and 2, but the alarm circuit remains closed. Two test positions to the right of the "carrier off" positions are provided. When the switch is moved to either of these positions, the relay trip and alarm circuits are interrupted and a red alarm light is turned on by switch contact 3 and 4. Moving the switch to the TEST 1 position will connect the output of the auxiliary test transformer directly to the HKB terminals number 25 and 26, through the type W contacts number 9 and 10, 11 and 12. Moving the switch to the TEST 2 position will connect the test transformer with a reversed polarity to the HKB relay through switch contacts 13, 14 and 15, 16.

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## Auxiliary Test Transformer

The auxiliary test transformer is designed to operate from a 115 volt, 60 cycle power source. Four secondary taps numbered 1, 2, 3, and 4 are provided to vary the magnitude of the test current, as follows:

Trans. Tap	Relay Tap	
	G	H
1	3 amp.	2 amp.
2	5	4
3	7.5	5.5
4	9.5	7

The outline and drilling plan of the transformer is shown in Fig. 9.

## Indicating Lamps

The red and blue indicating lamps are standard rectangular Minalites. Outline and drilling dimensions are given in Fig. 11.

## ADJUSTMENT

Choose a transformer tap that will provide approximately two times the phase-to-ground current setting of the FD-2 fault detector as previously determined.

## OPERATION

A multi-contact switch is provided at each line terminal which serves the dual functions of a carrier on-off switch and a test switch. This switch is arranged to apply a single phase current to the HKB relay to simulated internal and through fault conditions. Relay operation is noted by observing a blue indicating lamp connected in the HKB relay trip circuit. During the test the HKB trip circuit to the line breaker is opened and a red warning light is energized through auxiliary contacts on the test switch.

Use of the auxiliary test equipment is to be limited to provide a simplified test after the initial installation tests have been performed as described in part II of this instruction leaflet.

The test apparatus is to be connected as shown in Fig. 8 with the auxiliary test trans-

formers energized from 115 volt, 60 cycle power sources at each line terminal that are in phase with each other. The following operation procedure assumes that the same polarity is used in connecting the test transformer at each line terminal.

1. Turn the carrier test switch at both line terminals to CARRIER OFF.

2. Turn the carrier test switch to TEST 1 at line terminal #1. The local relay should operate to transmit half cycle impulses of carrier, and trip. Tripping will be indicated by the blue light.

3. Turn the HKB test switch at the remote line terminal #2 to TEST 1. This will simulate an internal fault fed from both line terminals. The relay at line terminal #2 will trip, and the relay at line terminal #1 will remain tripped. Tripping will be indicated by the blue lights at each line terminal. Carrier will be transmitted in half cycle impulses simultaneously from each end of the line.

4. Reset the HKB test switch at line terminal #1. The relay at terminal #1 will reset and turn off the blue light. The relay at terminal #2 will hold its trip contact closed, lighting the blue light.

5. Turn the HKB test switch at line terminal #1 to TEST 2. This condition will simulate an external fault. The trip contacts of both relay, will be held open and the blue light will be extinguished.

6. Reset the test switches at both line terminals to CARRIER OFF before returning to CARRIER ON for normal service. Push in handle to turn in ON position.

This completes the test procedure.

## Component Style Numbers

Test Transformer	S #1338284
Type W Test Switch	S #1584284 for 1/8" panel mounting.
Type W Test Switch	S #1584285 for 1-1/2" panel mounting.

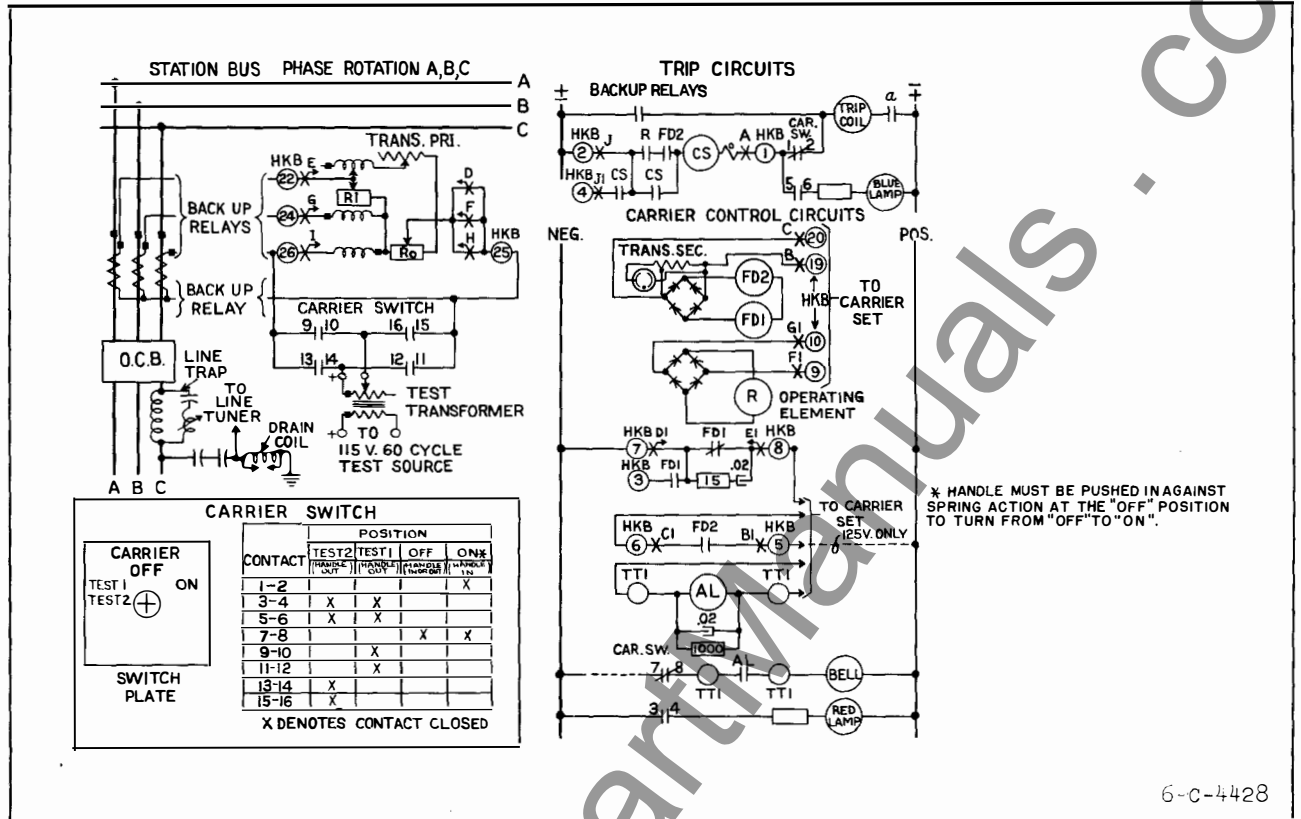


Fig. 8—Schematic Connections of Type HKB Relay and Test Facilities.

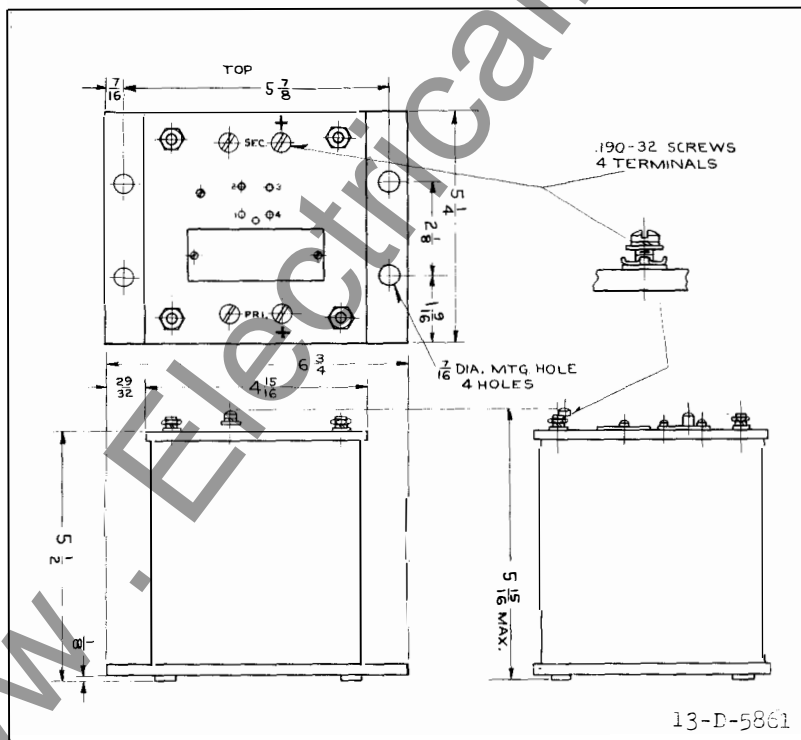


Fig. 9—Outline and Drilling Plan of the Type HKB Test Transformer. For Reference Only.

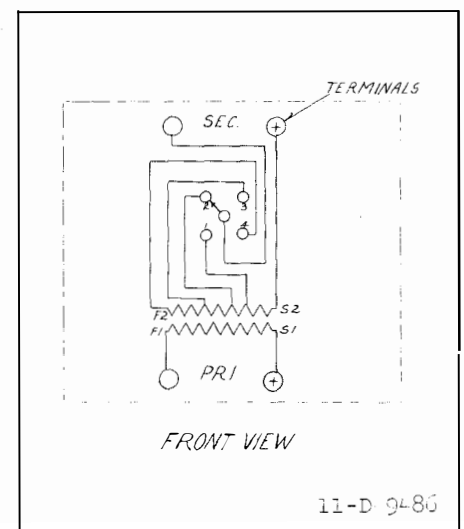


Fig. 10—Internal Schematic of the Type HKB Test Transformer.

# TYPE HKB RELAY

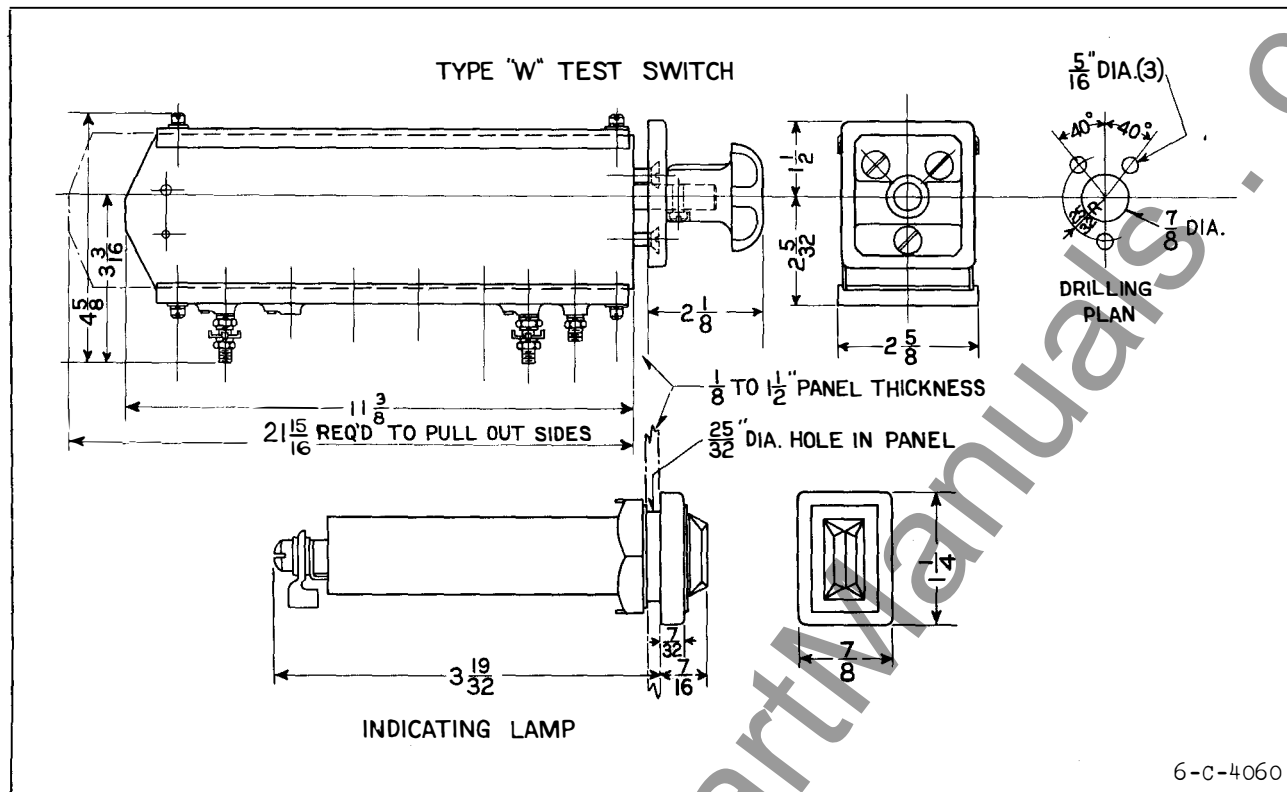


Fig. 11—Outline and Drilling Plan of the Type W Test Switch and Indicating Lamps which are Part of the Type HKB Test Facilities. For Reference Only.