INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TSO-3 OUT-OF-STEP BLOCKING RELAY

(WITH ANGULAR DISPLACEMENT 60° to 90°)

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. Operate the relay to check the settings and electrical connections.

APPLICATION

The type TSO-3 blocking relay is a single-phase, two-element distance-type relay which can be used for either one of the following two functions:

1. Out-of-step blocking of the trip circuit at a point in a power transmission system where it is not desired to trip the breaker during synchronizing surges or an out-of-step condition.

2. Blocking of reclosing at a selector location following an intentional tripout caused by out-of-step condition.

This type TSO-3 relay has a modified impedance characteristic so that it can be used in conjunction with type HZM distance relays. It will not operate on any type of fault, but will open the trip or reclosing circuit during the first slip cycle of an out-of-step condition. Relay contacts are also provided to use the relay for out-of-step indication, if so desired.

The external connections of the TSO-3 relay are shown on the overall schematic diagram applying to the order on which this relay is supplied.

CONSTRUCTION

The type TSO-3 blocking relay consists of two instantaneous impedance elements, a contactor switch, and two telephone-type relays mounted in the standard projection or Flexitest relay case. In addition, an external auxiliary unit is supplied to obtain the offset impedance characteristic. The construction of the elements is described below.

Impedance Elements

The impedance elements consist of a balanced beam pulled downward on the contact end by a current coil and restrained on the other end by two voltage coils. The fluxes of these two voltage coils are shifted out of phase with respect to each other to produce a steady pull so that practically a constant balance can be obtained regardless of the phase angle between the current and voltage. A tap screw on the front of the element permits changing the number of turns on the current coil, and a core screw on the bottom of the element changes an air gap in the magnetic path. These two adjustments make it possible to set the elements.

This type TSO-3 relay has impedance elements that are identical to the conventional balanced beam impedance element except that the restraint is produced by potential and current instead of by potential alone. The mixing of the current and the potential energy to produce restraint torque is done external to the relay and the resultant energy is fed into potential coils of the beam impedance element.

The two impedance elements (Z_2 and Z_3) have a make-and-break contact assembly consisting of three contacts--two hemispherical silver contacts mounted on leaf springs as the stationary contacts, and a flat silver contact

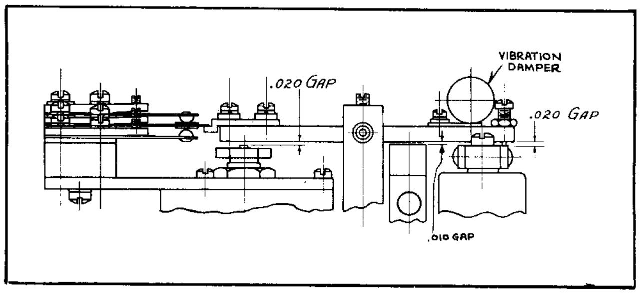

Fig. 1—Sectional View of the Impedance Element Beam and Contact Assembly.

also mounted on a leaf spring as the moving contact. The moving contact is operated by the beam of the impedance element as shown in Fig. 1.

Telephone Relays

There are two telephone-type relay elements designated X and Y. The X element is a slow-to-release type. An electromagnet attracts a right-angle iron bracket which in turn operates a set of make-and-break contacts. Drop out delay is obtained by the copper slug on the core, and can be varied by adjusting the air gap between the core and the armature.

The Y element is a fast-operating type. It has a set of make-and-break contacts, but no air gap adjustment.

Contactor Switch

This is a small solenoid-type d.c. 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.

Auxiliary Unit

The auxiliary unit is a 3-element external box for rear-of-switchboard mounting. It contains 3 adjustable resistors to obtain the desired modified impedance characteristics. Only 2 elements of this unit are used, one for each impedance element of the TSO-3 relay. One side of the box is removable to get access to the adjustable resistors.

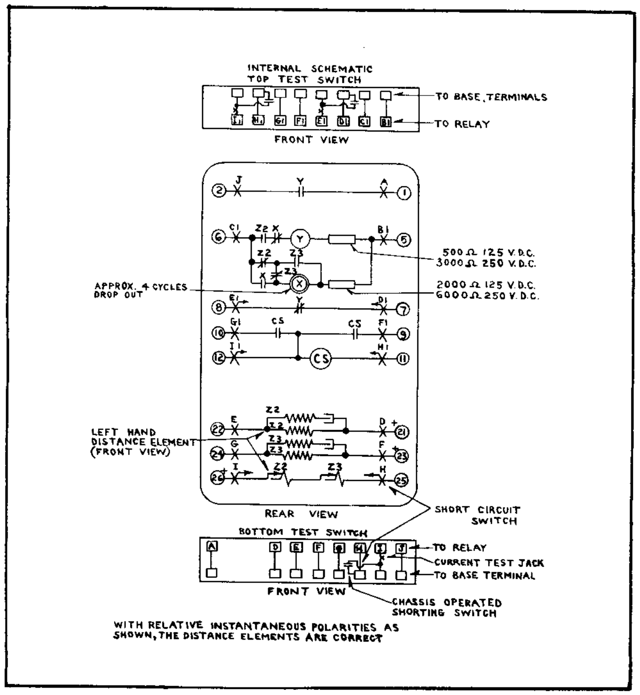

Fig. 2—Internal Schematic of the Type TSO-3 Relay in the Type FT Case. Omit Test Switches for the Relay in the Standard Case.

OPERATION

One fundamental difference between a three-phase fault and an out-of-step or out-of-synchronism condition is that a fault suddenly reduces the voltage and increases the current, whereas during the approach of an out-of-step condition, the voltage and current changes are comparatively gradual. Under out-of-step conditions, the apparent impedance as measured by a relay anywhere near the electrical center would start at a high value, and gradually decrease to a much lower value, and then gradually increase again to a higher value, if there is no fault at the time, and the system goes through a complete beat oscillation. On the other hand, if the disturbance is a fault, the impedance as seen by the relay will suddenly drop to a much lower value, and then either retain this value or slightly increase due to the effects of fault resistance, until the fault is cleared.

The relay takes advantage of this distinction between a fault and an out-of-step condition. Under out-of-step conditions, the Z_3 impedance element will operate followed

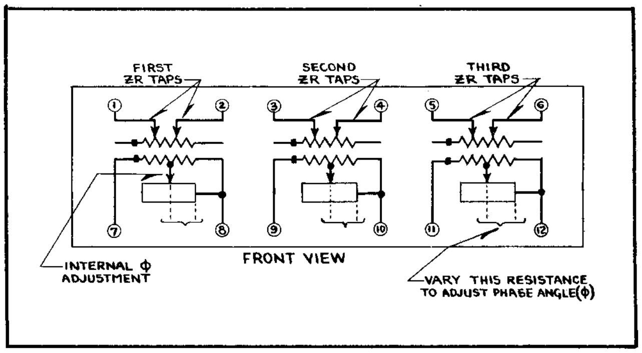

Fig. 3—Internal Schematic of the Auxiliary Unit Used to Obtain a Modified Impedence Characteristic.

after a short time delay by the Z_2 impedance element, as the apparent short circuit drifts toward the relay. In case of a fault, one or two elements may be operated, but if more than the Z_3 element is to be operated, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Referring to Figure 2, the scheme of operation is described below. The relay marked is of the slow-to-release type and is normally energized from the station battery through the Z_2 and Z_3 normally closed contacts, as well as through its own make contact. It will require approximately 4 cycles to drop out. Upon the occurrence of an out-of-step condition, impedance element Z_3 will operate, short circuiting the operating coil of relay X, and causing it to drop out if in the meantime impedance element Z_2 does not also operate. If Z_2 impedance element operates after this auxiliary relay X has dropped out, auxiliary relay Y will be energized and the trip circuit will be opened. Under any other conditions, the trip circuit cannot be opened. For example, if impedance element Z_2 operates before auxiliary relay X drops out, the shorting circuit is opened, and relay X remains energized, thus preventing auxiliary relay Y from picking up.

Thus, any sequence of impedance element operations which could be expected under fault conditions would not allow the sequence of operations to be completed, and blocking would not occur.

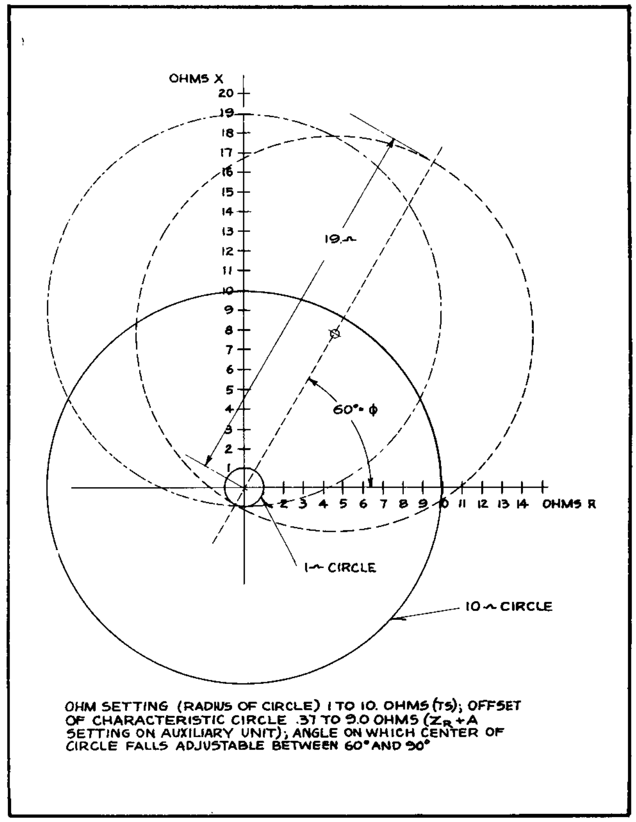

Fig. 4—Operating Characteristics and Range of the Type TSO-3 Relay.

When conditions are returned to normal on the system, both impedance elements reset, and relay X is energized through the back contacts of impedance elements Z_2 and Z_3. The energizing of relay X and the resetting of impedance element Z_2 will de-energize relay Y and thus restore both auxiliary relays to normal.

CHARACTERISTICS

The modified characteristic of the type TSO-3 relay is shown in Fig. 4. A pure impedance element characteristic plotted on the "R" and "X" coordinates is a circle with the center at the origin. The type TSO-3 relay is so designed that it is possible to displace the center of any impedance circle from the axis over an angle from 60° to 90° current lag.

There are three variables that can be controlled to fit the transmission line protection requirements making the modified impedance relay very flexible in its applications.

1. The radius of the impedance circle on the "R" and "X" coordinates is entirely determined by the tap (T) and core screw (S) settings of the impedance element.

2. The magnitude of displacement of the center of the impedance circle from the origin is determined by the auxiliary box current transformer primary tap Z_R + A).

3. The angle of displacement of the impedance circle can be varied from 60° to 90° current lag by the auxiliary box phase angle adjustment (Ø).

The type TSO-3 relay is available in one impedance range 1.00 to 10.0 ohms impedance circle radius (TS) with 0.37 to 9.0 ohm impedance circle center displacement (Z_R + A) over a phase angle from 60° to 90° current lag (Ø). Both impedance elements are identical and hence have the same range of adjustment. The tap and scale marking on the relay elements are as follows: (All impedances are in terms in secondary ohms).

Impedance Elements (1.0 to 10.0 ohms)

Radius of Impedance Circle

TAPS (T)

6.2	9.4	13.5	20.8	29.8	45

Core Screw Markings (S)

1.4	1.6	1.8	2.0	2.2

Auxiliary Box

Displacement of impedance circle.

Coarse Ohm Taps (Z_R)

0.0	1.9	3.7	5.6	7.5

Fine Ohm Taps (A)

0.0	.37	.75	1.1	1.5

3. Phase Angle Displacement (Ø)

60° to 90° Current lag

The Phase Angle of Displacement is normally set at 75° unless otherwise specified.

The phase angle characteristic of both the impedance elements is flat within ± 7% over 360°.

SETTINGS

The type TSO-3 relay requires an ohm setting (radius of the impedance circle) for each of the two impedance elements. In addition, the magnitude and angle of offset of the impedance circle are set by adjustments on the auxiliary unit. The offset characteristic is provided so that this type TSO-3 relay can be properly set in conjunction with type HZM distance relays. When so applied, the TSO-3 relay is usually connected to block tripping through Z_1, Z_2 plus carrier, or Z_2 plus T2 time delay. However, T3 time delay is connected around the TSO-3 out-of-step blocking contacts so that tripping can occur after the T3 time delay in the event of a sustained system swing.

The type TSO-3 relay settings must meet the following requirements.

1. The ohmic reach of its Z_2 and Z_3 elements must completely surround the impedance circles of the Z_1 and Z_2 elements of the HZM.

2. The Z_2 element of the TSO-3 relay must be set so that it operates at least one or two cycles before Z_2 of the HZM relay.

3. The relative settings of the Z_2 and Z_3 elements of the TSO-3 relay must be such that for any power swing for which out-of-step blocking is required, Z_3 operates in not less than 6 cycles for Z_2. Z_3 must be set so that it does not operate on load ohms.

The above requirements are shown graphically in Fig. 5. It will expedite the application by similarly plotting on "R" and "X" coordinates the actual HZM impedance circles and load swing curve of the power system to which this relay is applied. From an examination of the plot and the known performance of the power system, the settings of the TSO-3 relay can then be determined which will meet the foregoing requirements.

In the TSO-3 relay, Z_2 is the left hand

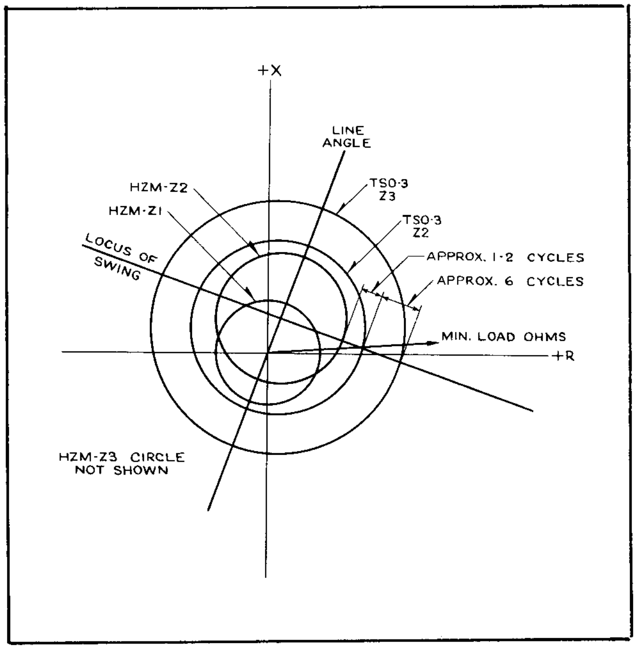

Fig. 5—Transmission Line and Relay Characteristics Plotted on R and X Coordinates.

element, front view, and Z_3 is the right hand element. Two settings must now be made: the radius of the impedance circle in ohms, and the angle and ohms offset of the center of the impedance circle. The tap and core screw settings of the impedance element proper determine the radius in accordance with the following formula:

$$TS = \frac{10 Z_o R_c}{R_v}$$

where

T = The impedance element current tap value.

S = The impedance element current core screw value. The values appear as a series of dots on the drum of the lower core screw adjusting knob.

Z_o= Radius of circle, as determined in the preceding paragraphs, in ohms primary.

R_c= The current transformer ratio.

R_v= The potential transformer ratio.

The tap, T, is obtained by dividing the TS produce by S to give an available tap number.

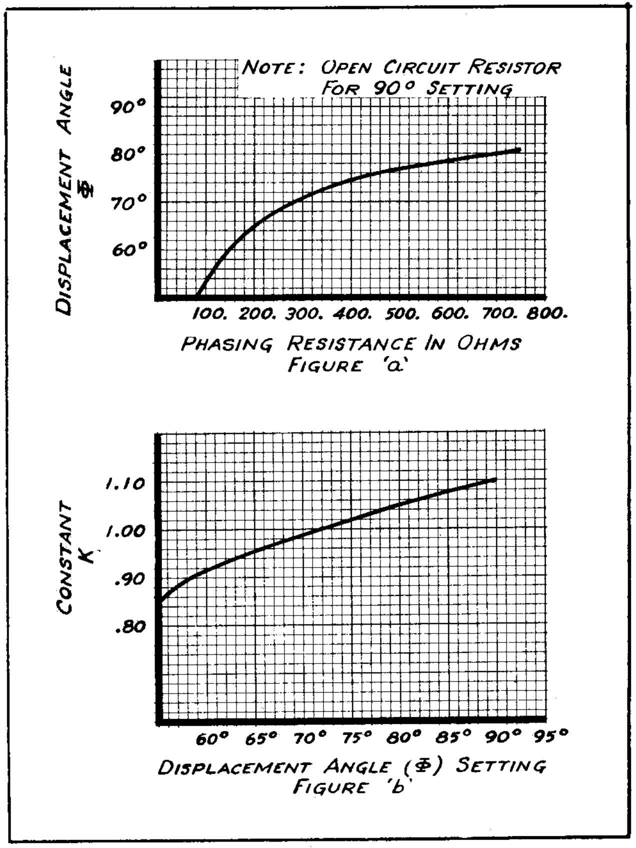

Fig. 6—Adjustment Curve for the Angular Displacement of the Operating Circle Center by Varying Auxiliary Box Internal Resistor.

When changing taps with the relay energized, the extra tap screw should be screwed in the desired tap before removing the existing tap screw to prevent open circuiting the current transformers.

The numbers on the core screw appear in ascending order as the core screw is screwed into the core. In some cases, a question of doubt may arise whether the scale setting is correct, or is out by one full turn of the core screw. In such a case, the point may be verified by turning the core screw all the way in. Then back out the core screw until the highest scale marking just comes under the end of the pointer. This will occur in approximately one turn. Then turn to correct setting. Sufficiently accurate setting can be made by interpolating between the marked points when necessary.

From the operating circle, previously constructed, measure the displacement of the

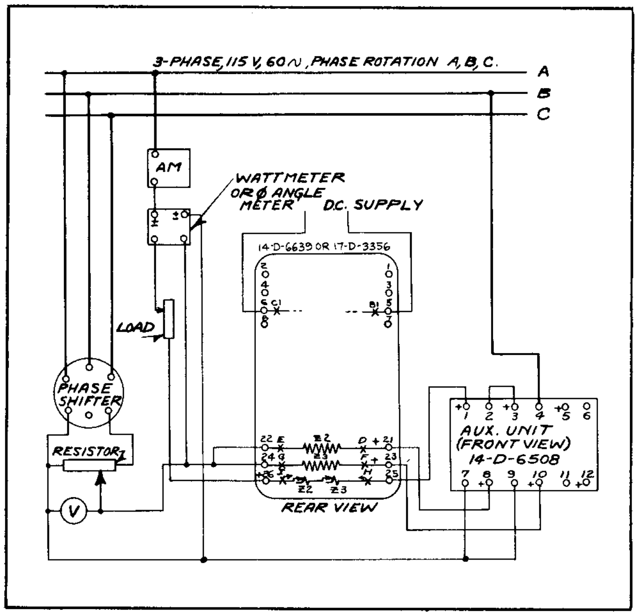

Fig. 7—Test Connections for the Type TSO-3 Relay With Modified Impedance Elements.

center of the circle from the intersection of the "R" and "X" axis in magnitude and angle.

The auxiliary box should be set in accordance with the formula:

$$Z_R + A = \frac{Z_D \; R_C}{R_V K}$$

(Ø) = Angular displacement of center of operating circle. This setting is made by varying the resistance of the resistor located as shown in Fig. 3 in the auxiliary box in accordance with the curve of Fig. #6a to obtain the displacement of angle (Ø) desired. The phase angle of displacement is normally set at 75° unless otherwise specified.

where

Z_R = Auxiliary box tap value.

A = Auxiliary box tap value.

Z_D = Displacement of the center of the operating circle in ohms primary.

K = Constant determined from curve Fig. # 6b.

R_c = The current transformer ratio.

R_V = The potential transformer ratio.

When changing the Z_R or a tap with the relay energized, the current terminals of the auxiliary box should be shorted before unscrewing the tap screw to prevent open circuiting the transformers.

The formula settings are sufficiently accurate for most installations. Where it is desired to set the balance point more accurately the tap and scale values may be checked by applying to the relay and the auxiliary box, the voltage, current, and phase angle conditions which will be impressed on it for a fault at the desired balance point. A slight change in the scale value or in the auxiliary box setting from that calculated may be required so that the relay will just trip for the simulated fault at the balance point.

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. Either of these studs may be utilized for grounding the relay base. 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

All contacts should be periodically cleaned with a fine file. S#1002110 file is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

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 or the relay taken apart for repairs, the following instructions should be followed in reassembling and setting it.

The gap dimensions indicated in Figure 1 and discussed above are average values. The actual gaps on any particular relay may vary a few thousandths from these values.

Impedance Elements

Connect the relay with polarity as per Fig. 2 or 3. Refer to Figure 1. Adjust stop screw on moving beam for .020 inch clearance between the rear of the beam and the voltage iron. With the beam in this position, adjust the vertical gap for .010 inch between the beam and the vertical post. Also, with the beam in this position, adjust for .020 inch clearance between the front of the beam and the stop on the upper core screw.

Adjust the lower contact of make and break pile-up so that it does not touch the middle contact when the beam is in the operated position and against the stop. With the beam in this position, adjust the middle contact so that the spring just touches the Micarta on the end of the beam, then give the adjusting set screw one half turn to the right to secure the proper bias. Next, with the beam still in the operated position, adjust the lower contact until there is .008 inch clearance between the end of the middle contact spring and the Micarta on the end of the beam.

Adjust the top contact of the make and break pile-up so that with the beam in the operated position, there is .007 inch gap between the top and middle contacts. There should be not more than .008 inch deflection of the top contact spring when the beam is in the reset position. If there is more than .008 inch deflection, the gap between the middle contact spring and the Micarta on the end of the beam should be increased. This will require readjusting the contacts to maintain the .007 inch gap between the top and middle contacts.

The impedance element beams should be balanced as follows. Connect the relay with polarities as shown in the test diagram, Fig. 7. Set the auxiliary box tap Z_R and A on zero and Ø on any setting. With any tap and scale setting, check the impedance measured by the relay with 60 volts potential restraint. Apply 20 volts restraint and adjust the balance weight on the beam until the beam just trips with 1/3 of the current required to trip with 60 volts restraint. The current should be suddenly applied.

Telephone Relays

The armature set screw on the X relay is adjusted normally for 4-6 cycles dropout time. The Y relay requires no adjustment. The coil resistance of both relays is 2000 ohms.

Calibration of Impedance Elements

The auxiliary box has been calibrated at the factory and this calibration should not be disturbed except to adjust the internal resistor to obtain the correct phase angle (Ø).

If the auxiliary box circle displacement setting is set on zero, that is $Z_R = 0$ and $A = 0$, then the type TSO-3 relay will have a characteristic similar to the type HZ relay and may be calibrated in the same manner as follows. The current required to operate the impedance elements against any given voltage is obtained from the equation=

$$TSI = 10\ E$$

where TSI is the operating force which is equal to T, the current tap setting times S, the setting of the calibrated core screw, times I, the current applied to the relay and 10E is the restraining force which is equal to E, the voltage applied to the relay multiplied by the constant ten. Thus, if the setting is T = 20.8, S = 1.8 and the voltage is 60 volts, then the current required at 60° lagging is

$$I = \frac{10\ E}{TS} = \frac{10 \times 60}{20.8 \times 1.8} = 16 \text{ amperes}$$

When calibrating the impedance elements it is best to do so at a phase angle equal to the phase angle between current and voltage on the transmission line to be protected by the relay.

CAUTION Make certain that the stops on the rear and front of each beam are absolutely clean otherwise the impedance at which the beam trips may be affected, particularly at low voltages. The stop can be easily cleaned by drawing a piece of clean white paper between the beam and the stop while the beam is firmly pressed down.

Contactor Switch (Seal-In Switch) CS

Adjust the stationary core of the switch for clearance between the stationary core and the moving core of 1/64 inch when the switch is picked up. This can be done by disconnecting the switch, turning it up-side-down and screwing up the core screw until the contact just separates. Then back off the core screw approximately one turn and lock in place. This prevents the moving core from striking and sticking to the stationary core because of residual magnetism. Adjust the contact clearance for 3/32 inch by means of the two small nuts on either side of the Micarta disc. The switch should pick up at 2.0 amperes d-c. Test for sticking after 30 amperes d-c are passed thru the coil.

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 nameplate data.

ENERGY REQUIREMENTS

The 60 cycle burden of the various circuits of this relay are as follows:

POTENTIAL CIRCUITS

Circuit	Volts	V.A.	P.F. Angle
All impedance elements including external auxiliary box.			
Displacement angle of 90°	120	5.5	46° Lag
Displacement angle of 60°	120	5.2	30° Lag

CURRENT CIRCUITS

Both impedance elements including external auxiliary box.

Taps	Amps.	V.A.	P.F. Angle
T=45, S=1.8, Z_R =7.5, A=0.0	8.66	14.0	52° Lag
T=13.5, S=1.4, Z_R=0.0, A=1.1	8.66	3.0	55° Lag

The continuous rating of the voltage coil is 120 volts, and of the current coils 8.66 amperes.

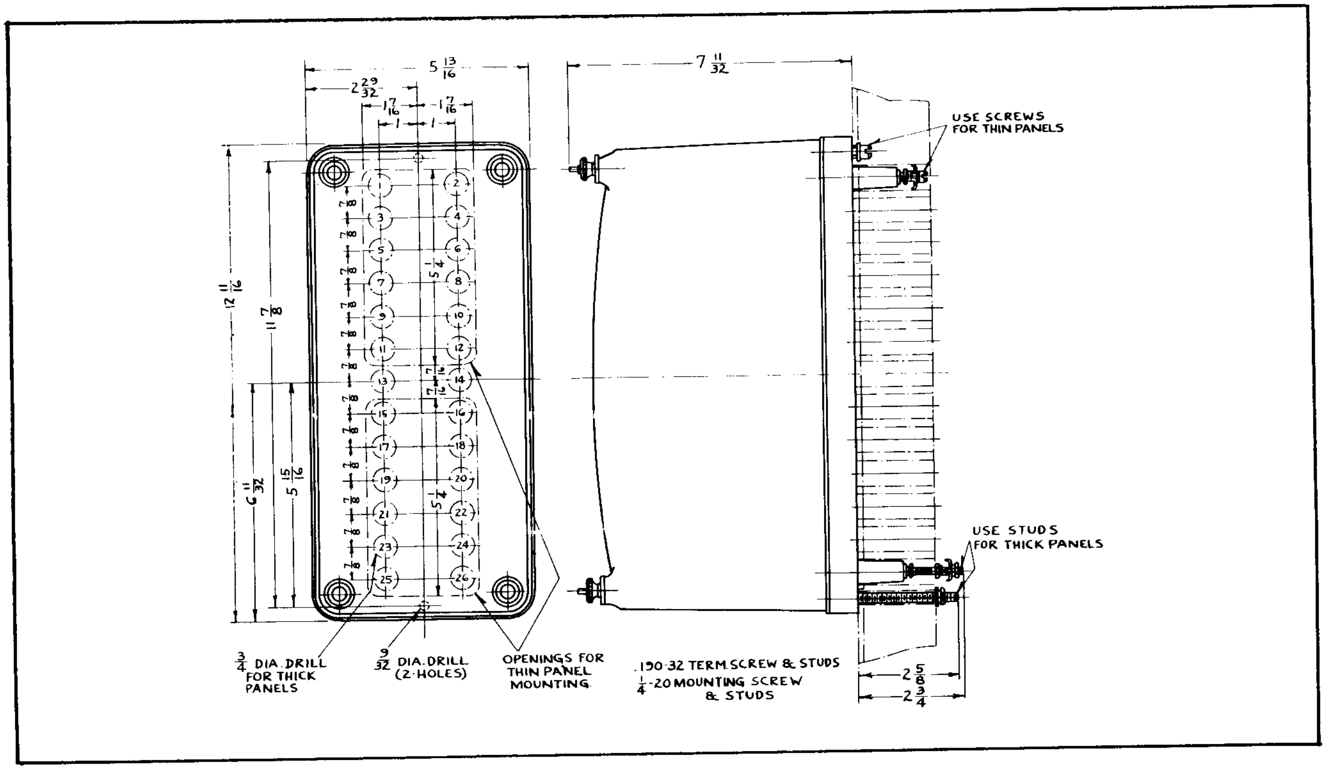

Fig. 8—Outline and Drilling Plan of the Standard Projection Type Case. See the Internal Schematic For the Terminals Supplied. For Reference Only.

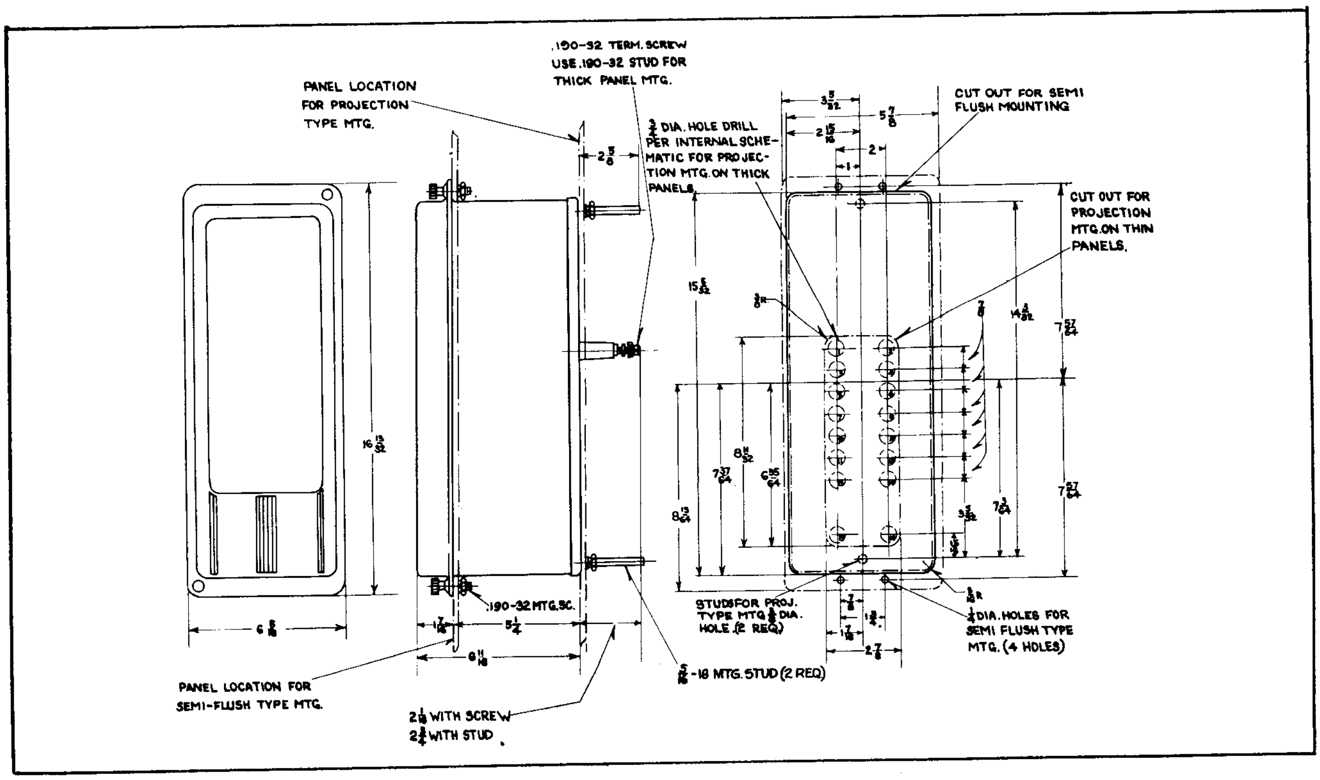

Fig. 9—Outline and Drilling Plan of the M10 Projection or Semi-flush Type FT Flexitest Case. See the Internal Schematic For the Terminals Supplied. For Reference Only.

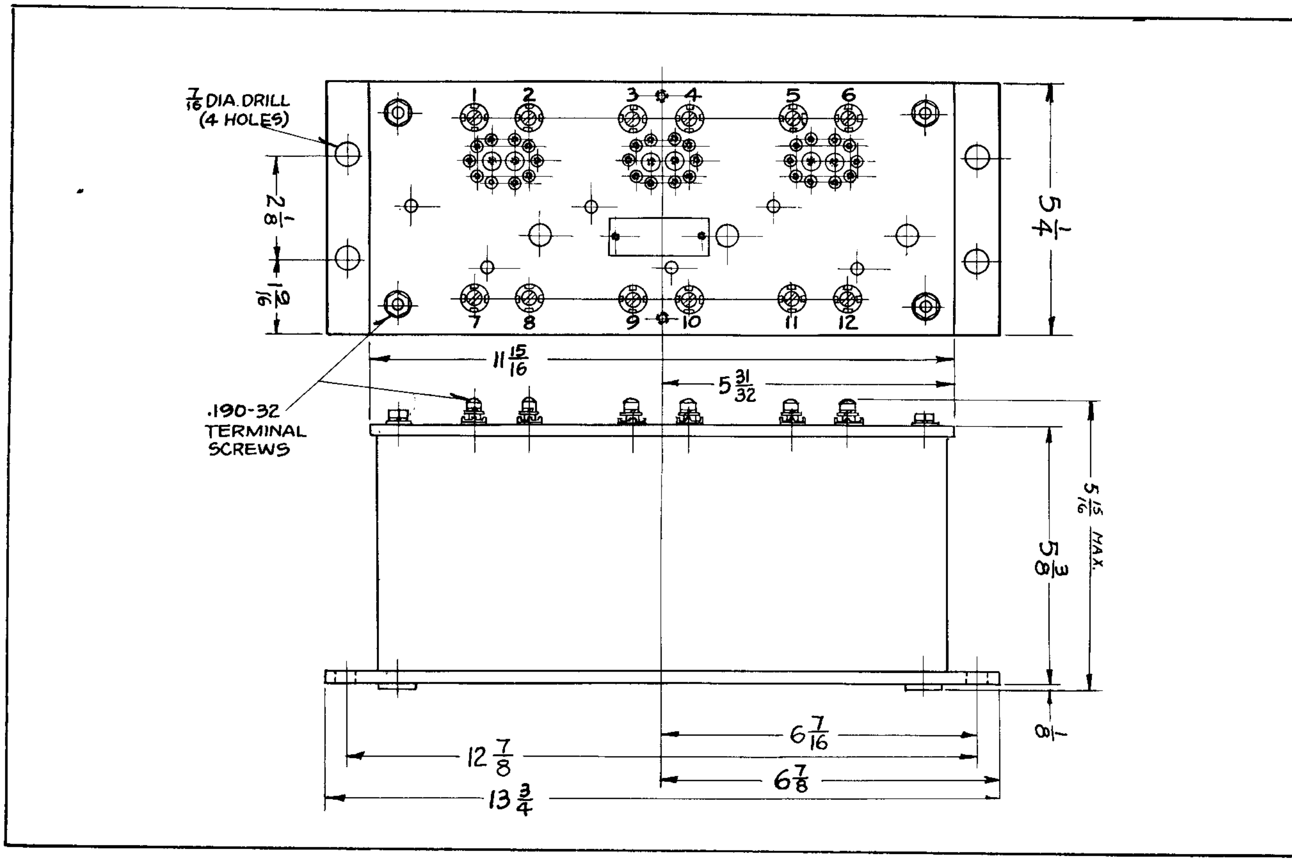

Fig. 10—Outline and Drilling Plan of the Auxiliary Unit. For Reference Only.

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