INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE TSO-4 OUT-OF-STEP BLOCKING RELAY
(WITH OFFSET TRANSFORMER 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 setting and electrical connections.

APPLICATION

The type TSO-4 blocking relay is a single-phase, two-unit 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-4 relay has a modified impedance characteristic so that it can be used in conjunction with type HZ-4 or 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-4 relay are shown on the overall schematic diagram applying to the order on which this relay is supplied.

CONSTRUCTION

The type TSO-4 blocking relay consists of two instantaneous impedance units, two offset transformers with angular displacement resistors, a contactor switch, and two telephone type relays mounted in the type FT32 Flexitest relay case. The construction of the units is described below.

Impedance Units

The impedance units 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 unit permits changing the number of turns on the current coil, and a core screw on the bottom of the unit changes an air gap in the magnetic path. These two adjustments make it possible to set the units.

This type TSO-4 relay has impedance units that are identical to the conventional balanced beam impedance unit 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 in the offset transformer and the resultant energy is fed into potential coils of the beam impedance unit.

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

Telephone Relays

There are two telephone-type relay units designated X and Y. The X unit 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 unit 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

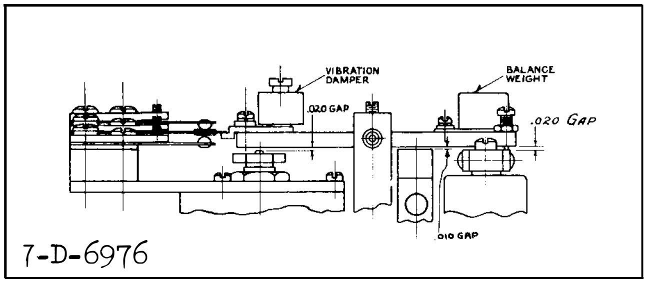

Fig. 1. Sectional View of the Impedance Unit Beam and Contact Assembly.

plunger travels upward, the disc bridges three silver stationary contacts.

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 unit will operate followed after a short time delay by the Z_2 impedance unit as the apparent short circuit drifts toward the relay. In case of a fault, one or two units may be operated, but if more than the Z_3 unit 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 X 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 6 cycles to drop out. Upon the occurrance of an out-of-step condition, im-

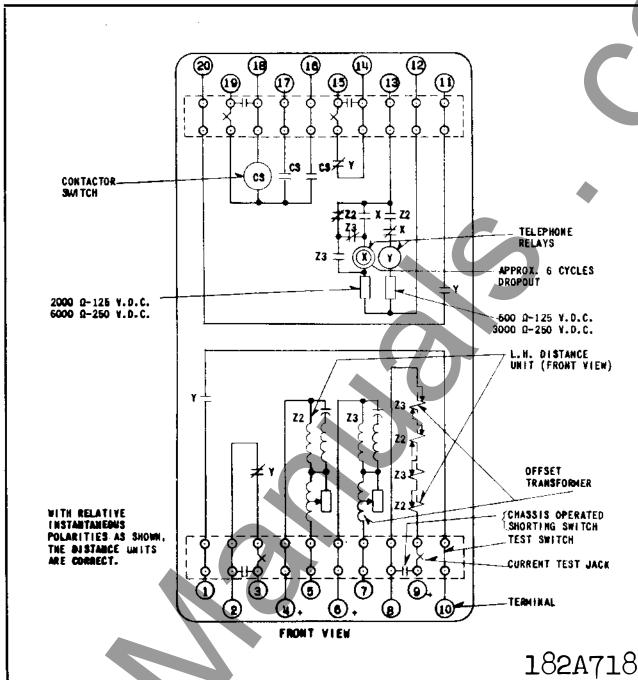

Fig. 2. Internal Schematic of the Type TSO-4 Relay in the Type FT32 Case.

pedance unit Z_3 will operate, short circuiting the operating coil of relay X, and causing it to drop out if in the meantime impedance unit Z_2 does not also operate. If Z_2 impedance unit 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 unit 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 unit operations which could be expected under fault conditions would not allow the sequence of operations to be completed, and blocking would not occur.

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

CHARACTERISTICS

The modified characteristic of the type TSO-4 relay is shown in Fig. 3. A pure impedance unit char-

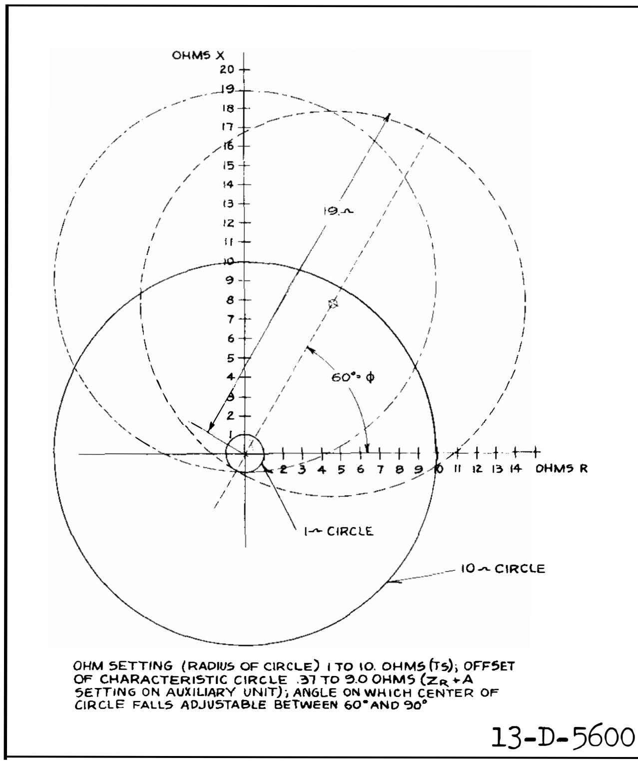

Fig. 3. Operating Characteristics and Range of the Type TSO-4 Relay.

acteristic plotted on the "R" and "X" coordinates is a circle with the center at the origin. The type TSO-4 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 unit.

2. The magnitude of displacement of the center of the impedance circle from the origin is determined by the offset 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 phase angle adjustment (ϕ).

The type TSO-4 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 (ϕ). Both impedance units are identical and hence have the same range of adjustment. The tap and scale marking on the relay units as as follows: (All impedances are in terms of secondary ohms).

Impedance units (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

Offset Transformer

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

Phase Angle Displacement (ϕ)
60° to 90° Current lag

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

SETTINGS

The type TSO-4 relay requires an ohm setting (radius of the impedance circle) for each of the two impedance units. 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-4 relay can be properly set in conjunction with type HZ-4 or HZM distance relays. When so applied, the TSO-4 relay is usually connected to block tripping through Z_1, Z_2 plus carrier, or Z_2 plus T2 time delay. However, T_3 time delay is connected around the TSO-4 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-4 relay settings must meet the following requirements.

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

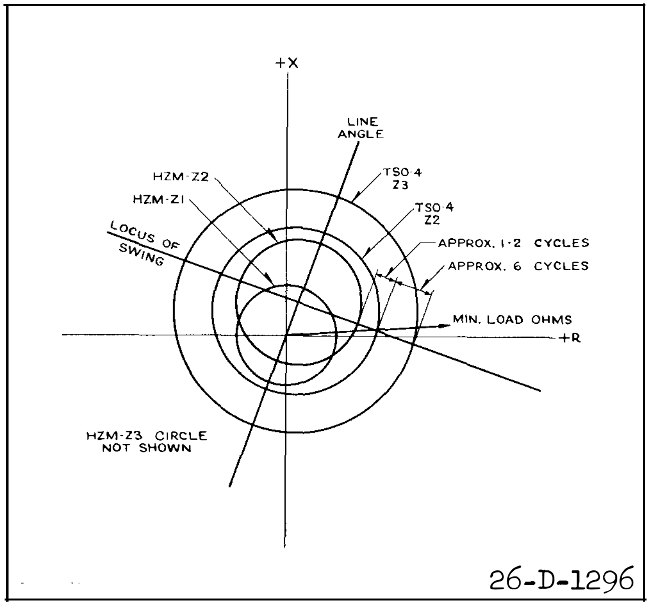

Fig. 4. Transmission Line and Relay Characteristics Plotted on R and X Coordinates.

Z_1 and Z_2 units of the HZ-4 or HZM.

2. The Z2 element of the TSO-4 relay must be set so that it operates at least one or two cycles befor Z_2 of the HZ-4 or HZM relay.

3. The relative settings of the Z_2 and Z_3 units of the TSO-4 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 before Z_2. Z_3 must be set so that it does not operate on load ohms.

The above requirements are shown graphically in Fig. 4. It will expedite the application by similarly plotting on "R" and "X" coordinate the actual HZ-4 or 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-4 relay can then be determined which will meet the foregoing requirements.

In the TSO-4 relay Z_2 is the left hand unit, front view, and Z_3 is the right hand unit. Three 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.

Circle Radius

The tap and core screw settings of the impedance element proper determine the radius in accordance with the following formula:

$$TS = \frac{10 Z_0 R_c}{R_v}$$

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_0 = 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 product by S to give an available tap number. 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.

Offset Angle

From the operating circle previously constructed measure the offset angle, ϕ, which is the angle measured from the R-axis.

Setting for angle, ϕ, is made by varying the resistance of the resistor associated with the offset transformer in accordance with the curve of Fig. 5 to obtain the displacement of angle (ϕ) desired. The phase angle of displacement is normally set at 75^o unless otherwise specified.

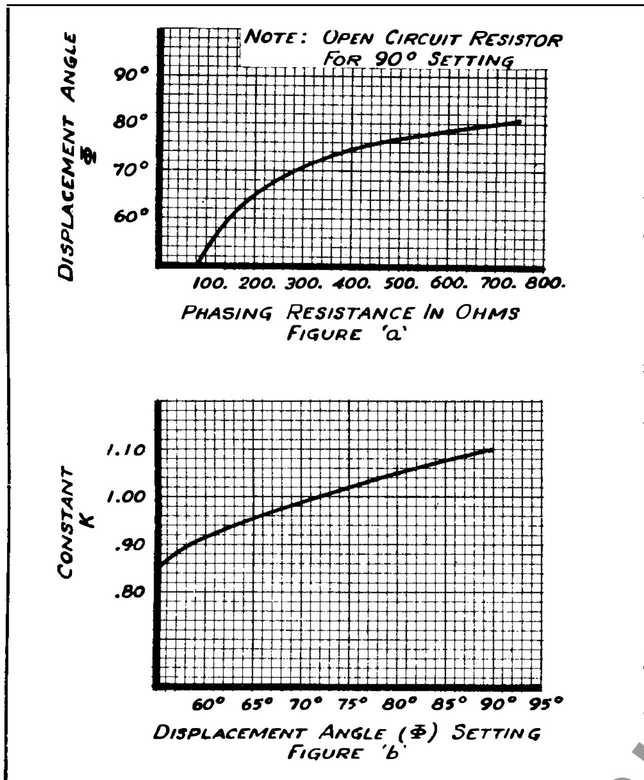

Fig. 5. Adjustment Curve for the Angular Displacement of the Operating Circle Center.

Offset Magnitude

From the operating circle previously constructed measure the magnitude of the displacement of the center of the circle from the intersection of the "R" and "X" axis.

The setting for displacement is made on the offset transformer in accordance with the forula:

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

where

$Z_R + A$ = Offset transformer tap values.

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

K = Constant determined from curve Fig. 5b.

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 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, 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 offset transformer 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 four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

Electrical Check Points

To check the electrical operation of the relay, the following instruction should be followed.

Connect the relay per Fig. 6 and make the following settings. (At regular maintenance periods the settings of each particular relay with the voltage and current expected at the balance point should be used, if available. During factory testing, the settings are cascaded as indicated below.)

IMPEDANCE UNIT			OFFSET TRANSFORMER		
ZONE	T	S	Z_R	A	ϕ
Z_2	29.8	1.8	3.7	0.0	75°
Z_3	45	1.8	5.6	0.0	75°

With 60 volts on the relay the impedance units should trip when the following currents at 75 degrees lagging are suddenly applied.

Z-3 I = 4.4 amperes

Z-2 I = 6.6 amperes

When Z-3 operates (Z-2 not operated) the X relay

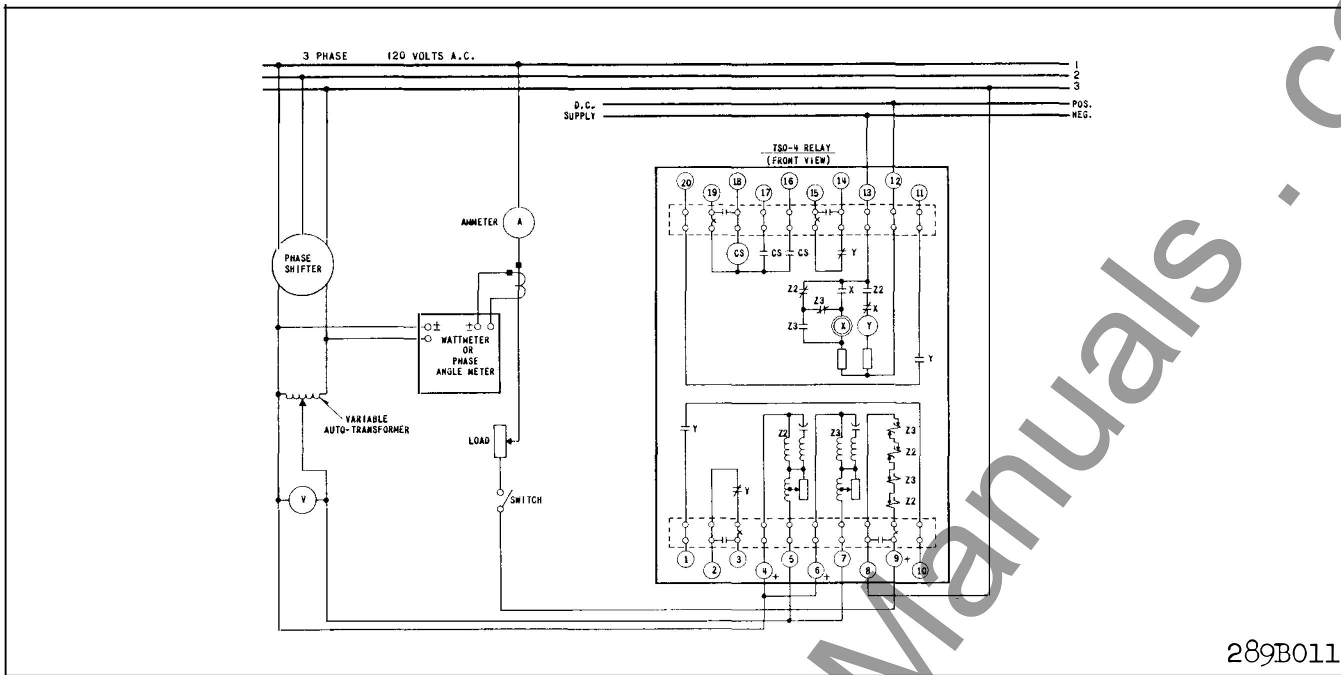

Fig. 6. Diagram of Test Connections for the Type TSO-4 Relay.

should drop out in approximately six cycles. Then the operation of Z-2 should cause the Y relay to pick up. When Z-3 and Z-2 are operated at the same time, the X relay should not drop out and the Y relay should not pick up.

ADJUSTMENTS AND MAINTENANCE

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

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.

Impedance Units

The voltage circuit on the impedance units is designed to have a comparatively flat phase angle curve. This is accomplished by energizing the two coils with currents that are essentially equal and 90° out of phase. The gaps as shown in Fig. 1 are nominal dimensions which yield equal restraints from the two coils. The actual gaps on any particular relay may vary a few thousandths from these values.

If the voltage circuits have been disassembled, the gaps referred to in Fig. 1 provide a nominal starting point for calibration. This is accomplished as follows:

Adjust the stop screw on the rear of the beam to give a clearance of .020 inch between the beam and the voltage iron circuit. With the beam in the reset position, i.e., with the stop screw against the stop, adjust the vertical gap for .010 inch between the adjustable iron and the beam. Care should be taken in this adjustment to keep the gap the same on both sides. Also, with the beam in the same position, adjust the gap between the front end of the beam and the stop in the upper core screw to .020 inch.

Further adjustment in the gaps may be necessary to obtain a reasonably flat phase angle curve at 100 volts.

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. 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 unit beams should be balanced as follows. Set the offset transformer taps Z_R and A on zero and ϕ for 75°. With any tap and scale setting, check the impedance measured by the relay with 60 volts potential restraint at 75° current lagging. 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. With this adjustment the beam will require from 10 to 15 volts restraint to close the break-contact.

With the tap set on 45 and 60 volts applied to the potential circuit, remark the core screws (or check the markings) so that the current to trip the beam at 75° lag will satisfy the formula.

$$\frac{E}{I} = \frac{TS}{10}$$

The "S" markings should be as shown under characteristics of the relay.

The offset of the impedance circle can be checked by setting Z_R + A to any value with ϕ = 75° and seeing that the current to trip the beam satisfies the equation

$$\frac{E}{I} = \frac{TS}{10} + (Z_R + A)K$$

Telephone Relays

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

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 .025 inch when the switch is picked up. This can be done by disconnecting the switch, turning it upside-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 through 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

Typical burden data of the various circuits are as follows:

Potential Circuits at 120 Volts, 60 Cycles

Circuit	V.A.	P.F. Angle
All Impedance Circuits		
Displacement angle 90°	4.8	48° lag
Displacement angle 60°	4.5	29° lag

Potential Circuits at 120 Volts, 50 Cycles

Circuit	V.A.	P.F. Angle
All Impedance Circuits		
Displacement Angle 90°	4.3	40° lag
Displacement Angle 60°	4.0	22° lag

Current Circuits at 60 Cycles

Circuit	Amps.	V.A.	P.F. Angle
Impedance Circuit			
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 burdens of the current circuits, at 50 cycles, are slightly less than the above values.

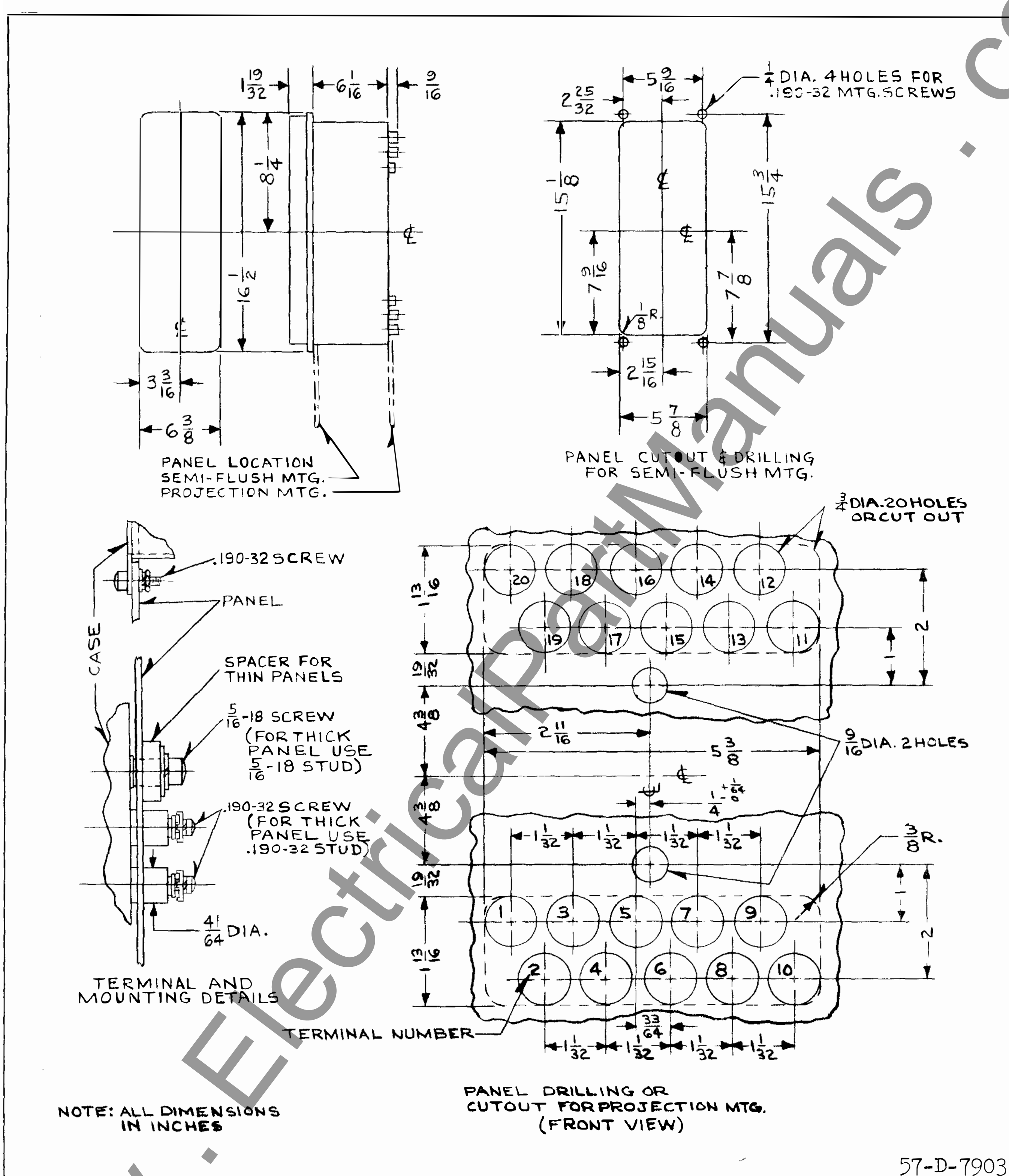

Fig. 7. Outline and Drilling Plan of the Type TSO-4 Relay in the Type FT32 Case.