Westinghouse

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ENGINEERING DIVISION
BUFFALO OFFICE
WESTINGHOUSE ELEC. & MFG. CO.

TYPE TSO OUT-OF-STEP TRIPPING RELAY

INSTRUCTIONS

TSO-2

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 TSO tripping relay is a single phase, three-element impedance type relay used to provide out-of-step tripping at a desired point in a system where synchronizing equipment is located. It will not operate on any type of fault, but will close the trip circuit during the first slip cycle of an out-of-step condition. By a slight circuit modification, the relay can also be used for out-of-step blocking.

In order to apply this relay it is necessary to know the impedance between the relay and the electrical center of the system under all operating conditions.

CONSTRUCTION

The Type TSO tripping relay consists of three instantaneous impedance elements, two telephone-type relays, auxiliary contactor switch and operation indicator. 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 coil fluxes. 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 element.

On the first impedance element (Z_1) the moving contact is a hollow, silver, egg-shaped capsule practically filled with tungsten powder. When this contact strikes the rigid stationary contact, the movement of the tungsten powder creates sufficient friction to absorb practically all the energy of impact, and thus the tendency of the contact to bounce is reduced to a minimum. The moving contact is loosely mounted on the first element beam and held in place by a leaf spring. The construction is such that the beam continues to move slightly after the contacts close, thus deflecting the spring. This provides the required contact follow. Current is conducted into the moving contact by means of a flexible metal ribbon. This construction is shown in figure 1.

The second and third 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 with 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 element as shown in figure 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.

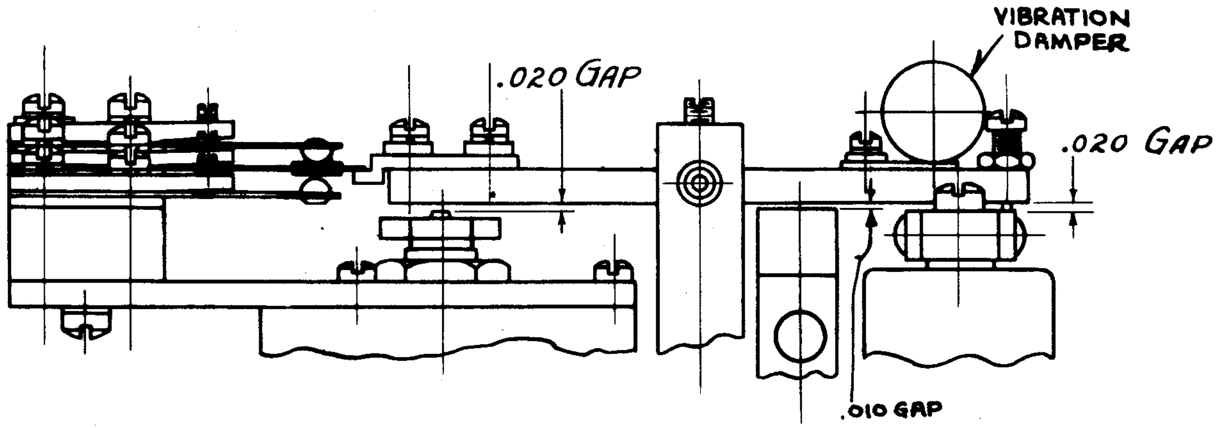
Auxiliary Contactor Switch

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.

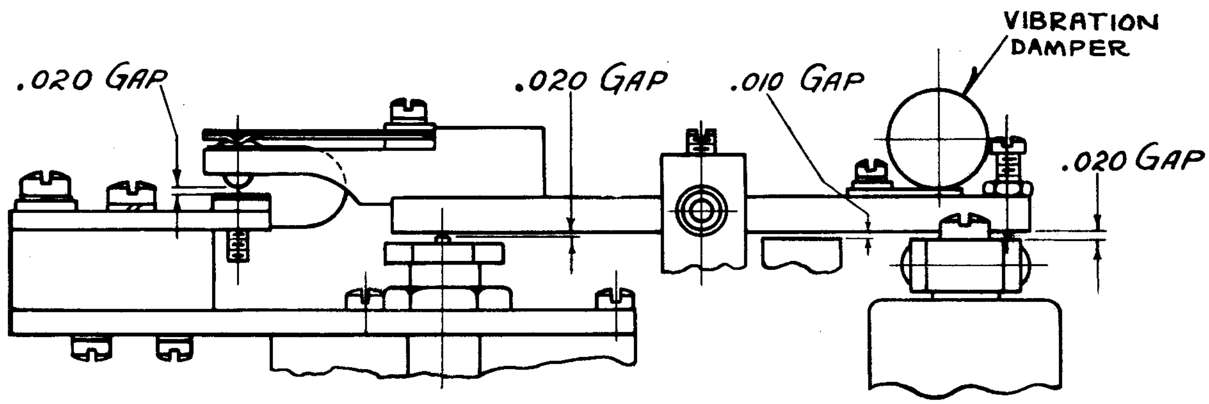
OPERATION

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 covered by the relay will sudenly 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



SECOND AND THIRD ELEMENT BEAMS



FIRST ELEMENT BEAM

Figure 1
Sectional View of the Impedance Element Beams and Contact Assemblies.

condition. Under out-of-step conditions the third impedance element will operate followed after a short time delay by the second impedance element, and then followed by the first impedance element, as the apparent short circuit drifts toward the relay. In case of a fault, one, two, or three impedance elements may be operated, but if more than the third element is to be operated, the others will operate within a very short time, and will not follow the sequence described for an out-of-step condition. In case a fault is very close to the balance point of the first or second element, then these elements would operate comparatively slowly, thus simulating part of the out-of-step condition. For this reason three elements have been used, but all three must operate in a pre-determined sequence and with a suitable delay in order to cause tripping.

Referring to figure 2, the scheme of operation is described below. The relay marked X is normally energized from the station battery and is of the slow-to-release type, and 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 completed if impedance element Z_1 now operated. Under any other conditions the trip circuit cannot be completed. 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. If impedance element Z_1 should operate before the sequence of X dropping out and impedance element Z_2 operating is completed, a circuit is provided around the operating coil of auxiliary relay Y through Z_1 contact and Y back contact so that relay Y is not energized.

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 tripping would not occur.

When conditions are returned to normal on the system, all 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.

If a fault occurs within the impedance zone setting of the out-of-step relay and after the fault is cleared, the systems should pull out of step due to the disturbance caused by the fault, the type TSO relay will still operate properly. Under the fault condition, the impedance elements will take up a definite position corresponding to the location of the fault. After the fault is cleared, and the systems subse-

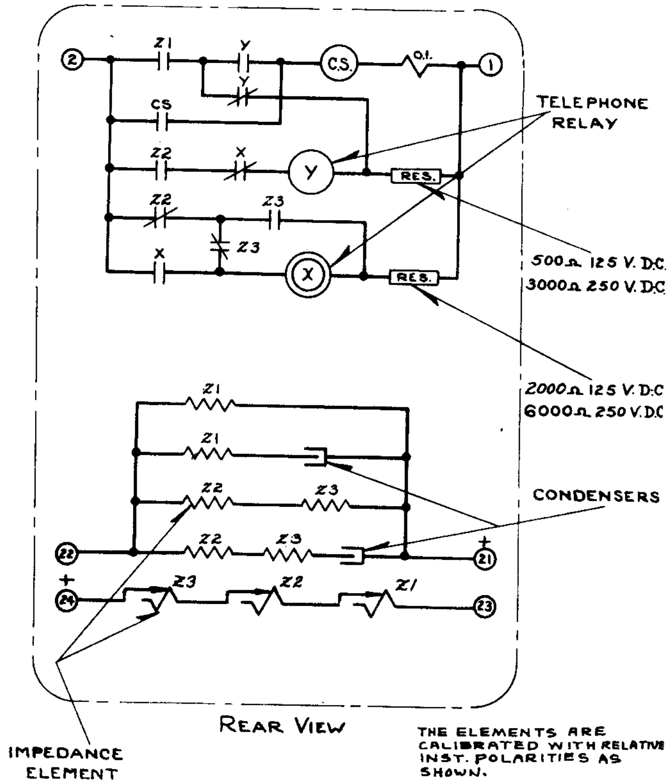


Figure 2
Internal Connections of the Type TSO Out-of-Step Tripping Relay.

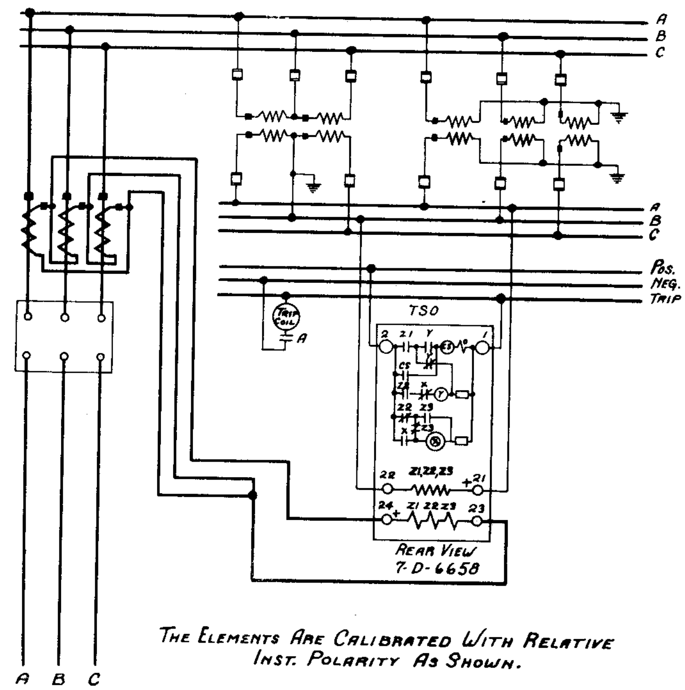


Figure 3
Typical External Connections of the Type TSO Out-of-Step Tripping Relay. Star Connected Current Transformers May Be Used.

quently pull out of step, the out-of-step relay may or may not trip on the first swing as this would depend upon which zone was indicated by the original fault. However, at the conclusion of the first swing, all three impedance elements of the relay will be reset. On the second swing, as the system pulls out of step these impedance elements will close in order and the system will trip on the second swing, assuming that the electrical center of the out-of-step condition will fall within the zone covered by the relay impedance setting.

When out of step blocking is desired from this relay, the sequence of operation is the same except that the Z_1 element is omitted and the back contact of the Y relay is used to open the trip circuit of the protective relays.

CHARACTERISTICS

The relay is available in an 0.6 to 6.0 ohm range. The tap and scale markings are as follows:

Taps

All elements:	6.2	9.4	13.5	20.8	29.8	45

Element	Core Screw Markings				
First	0.8	1.0	1.2	1.4	
Second	1.4	1.6	1.8	2.0	2.2
Third	1.4	1.6	1.8	2.0	2.2

The phase angle characteristic of the first impedance element is flat within ± 4% over 360°, and within ± 7% over 360° for the second and third impedance elements.

SETTINGS

The type TSO tripping relay requires a setting for each of the three impedance elements. The first element must be set so that under the most unfavorable condition its balance point is 15 to 20% beyond the electrical center of the system when the generators are 180° out of phase. This is to assure the operation of all three impedance elements during the slip cycle. If Zc is the line-to-neutral ohmic impedance of the line from the relay to the electrical center of the system, the impedance settings are as follows:

For the first element - 115 to 120% of Zc
For the second element - Approx. 225% of Zc
For the third element - Approx. 300% of Zc

The following nomenclature will be used in the formula for determining the relay settings:

Z = line-to-neutral ohmic impedance of the line from the relay to the desired balance point.
Rc = the current transformer ratio.
Rv = the potential transformer ratio.
T = the impedance element current tap value.
S = the impedance element core screw value. The values appear as a series of dots on the lower core screw adjusting knob.

The relay tap setting is found by the use of the following formula:

$$TS = \frac{10\ Z\ Rc}{Rv}$$

This formula applies when the relay receives delta current. If the impedance elements receive star current, the following formula is used:

$$TS = \frac{17.3\ Z\ Rc}{Rv}$$

The nomenclature is as defined above. The tap, T, is obtained by dividing the TS product by S to give an available tap number. When changing taps, the extra tap screw should be screwed into 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 less than 3/4 of a turn. To prevent such doubt it is recommended that the core screw setting be made by thus locating the highest scale marking and then continuing to back it off until the desired value appears exactly under the end of the pointer. Sufficiently accurate setting can be made by interpolating between the marked points when necessary.

The formula settings are sufficiently accurate for most installations. Where it is desired to set the balance points more accurately, the tap and scale values may be checked by applying to the relay the voltage and current which will be impressed on it in service.

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.

ADJUSTMENT 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.

First Impedance Element

Refer to figure 1. Adjust the stop screw on the moving beam for .020 inches clearance between the rear of the beam and the voltage iron. With the beam in this position, adjust the vertical gap for .010 inches clearance between the adjustable iron and the beam, also adjust for .020 inches clearance between the front of the beam and the stop on the upper core screw.

The stationary contact should be adjusted for an .020 inch gap when the beam is in the reset position. When the beam is in the operated position there should be a .015 inch deflection of the moving contact. The spring that carries the moving contact should lie flat on the micarta arm with no initail tension on the contact. The flexible pigtail should be at least 3/32 inches from the end of the stationary contact.

Connect the relay with polarity as per figure 2. Using any tap and scale setting, check the impedance measured by the relay with 35 volts potential restraint. Apply 5 volts restraint and adjust the balance weight on the beam until the beam just trips with 1/7 of the current required to trip with 35 volts restraint. The phase angle characteristic is flat within ± 4% over 3600°.

Second and Third Impedance Elements

Refer again 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.

Move the balance weight along the beam until the beam resets sufficiently to allow the top and middle contact to barely "Make" contact. Move the weight back 50 mils and lock it in place.

Telephone Relays

The armature set screw on the X relay should be adjusted so it does not extend beyond the armature surface. Otherwise, the X and Y relays require no adjustment. The drop-out of the X element is adjusted normally for 4 cycles.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving core when the switch is picked up. This can be most 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 1.0 amperes d-c. Test for sticking after 30 amperes d-c. have been passed thru the coil. The coil resistance is approximately 0.85 ohms.

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 ohm.

Calibration of Impedance Elements

The current required to operate the impedance elements against any given voltage is obtained from the equation:

$$TS = \frac{10\ E}{I} \qquad (3)$$

where T is the current tap and S is the setting of the calibrated core screw, E and I are the voltage and current respectively applied to the relay. Thus, if the setting is T = 20.8, S= 1.2 and the voltage is 30 volts, then the current required at 60° lagging is:

$$I = \frac{10\ E}{TS} \qquad I = \frac{10 \times 30}{20.8 \times 1.2} = 12 \text{ amperes}$$

When checking the calibration, it is essential that the polarity be as given in figure 2, otherwise an error will be introduced.

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.

Also, when checking the impedance elements at low voltage, observe the tripping of the beam instead of an indication in the trip circuit. This will prevent an error in the contact adjustment which might otherwise affect the beam calibration.

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 impedance elements is as follows:

Potential Circuit at 115 Volts

	VA.	P.F.Angle
All impedance elements in parallel	4.3	8° lead

Current Circuit at 5 Amperes

	Tap	VA.	P.F.Angle
All impedance elements in series	13.5	1.2	10°
	45	3.5	37°

The continuous rating of voltage coil is 115 volts, and of the current coils 8.66 amperes.

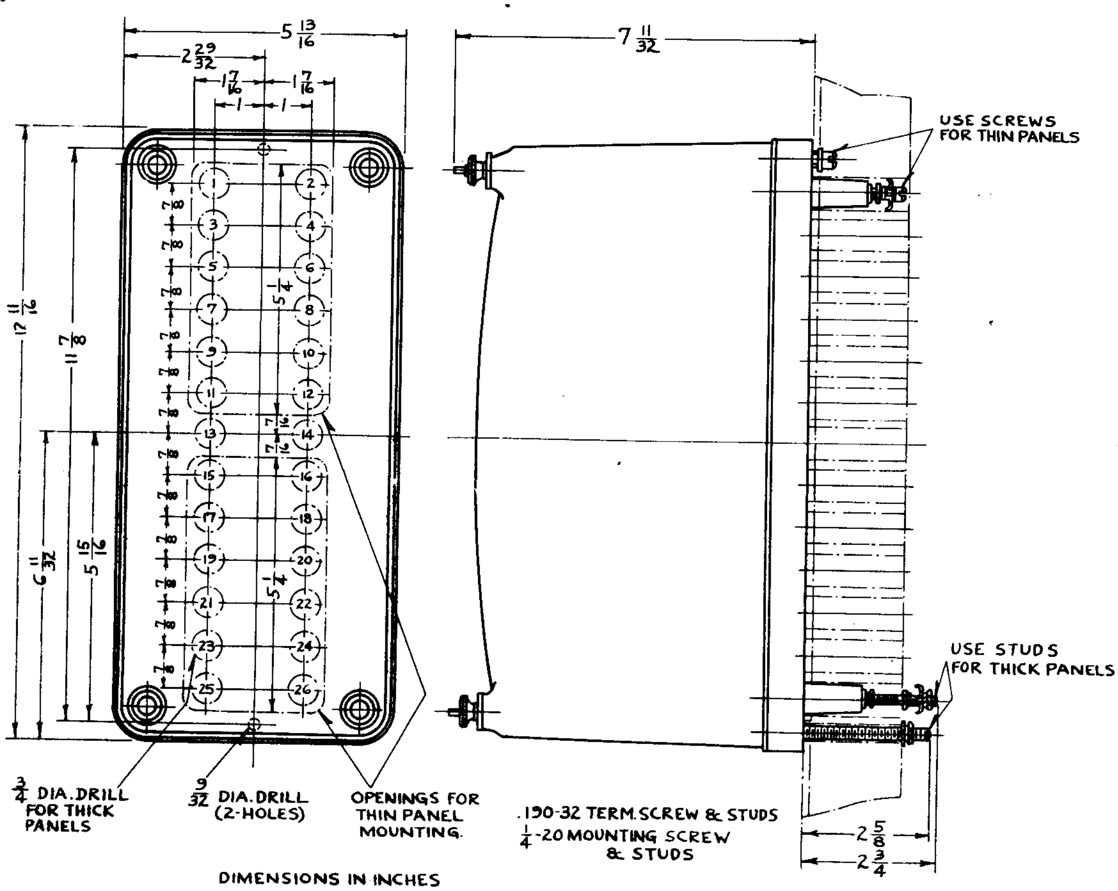


Figure 4
Outline and Drilling Plan of the Standard Projection Type Case (See Figure 2 for Terminals Supplied.)

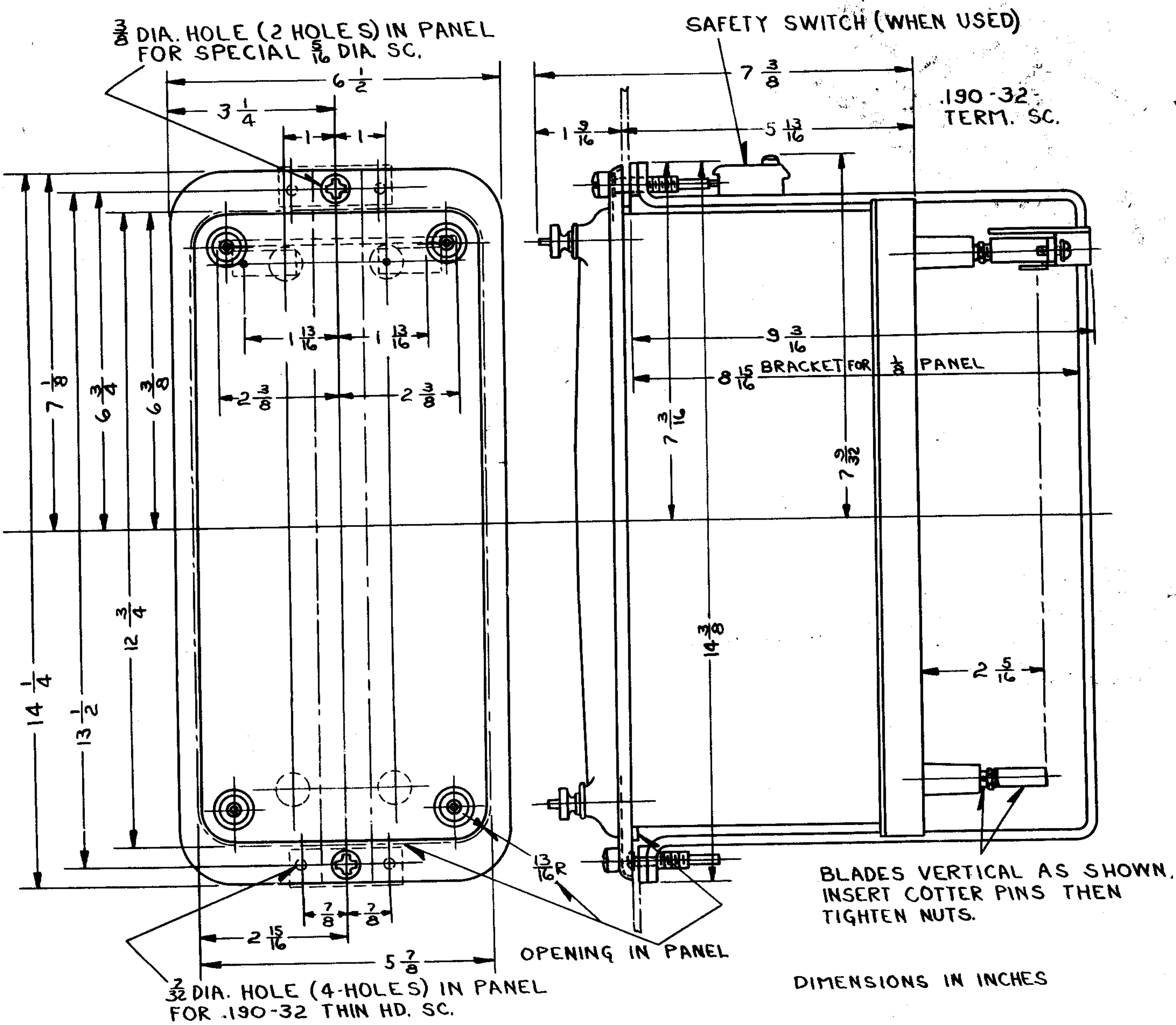


Figure 5
Outline and Drilling Plan of the Standard Plug-in Semi-Flush Type Case for 1/8" Panel Mounting.

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TYPE TSO-2 OUT-OF-STEP TRIPPING RELAY

INSTRUCTIONS

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-2 tripping relay is a single phase, three-element impedance type relay used to provide out-of-step tripping at a desired point in a system where synchronizing equipment is located. It will not operate on any type of fault, but will close the trip circuit during the first slip cycle of an out-of-step condition.

In order to apply this relay it is necessary to know the impedance between the relay and the electrical center of the system under all operating conditions.

CONSTRUCTION

The Type TSO-2 tripping relay consists of three instantaneous impedance elements, two telephone-type relays, seal-in contactor switch, and operation indicator. 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 element.

On the first impedance element (Z_1) the moving contact is a hollow, silver, egg-shaped capsule practically filled with tungsten powder. When this contact strikes the rigid stationary contact, the movement of the tungsten powder creates sufficient friction to absorb practically all the energy of impact, and thus the tendency of the contact to bounce is reduced to a minimum. The moving contact is loosely mounted on the first element beam and held in place by a leaf spring. The construction is such that the beam continues to move slightly after the contacts close, thus deflecting the spring. This provides the required contact follow. Current is conducted into the moving contact by means of a flexible metal ribbon. This construction is shown in Figure 1.

The second and third 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 with 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 element as shown in Figure 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.

Seal-In 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.

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 covered by the relay will suddenly drop to a much lower

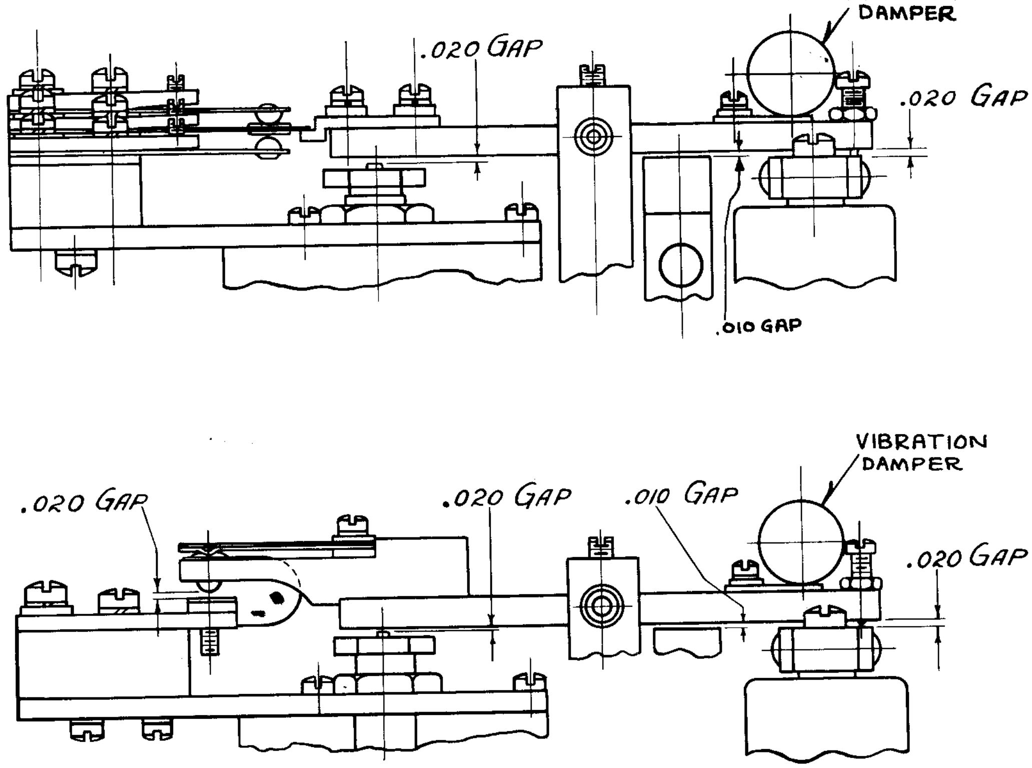

Figure 1
Sectional View of the Impedance Element Beams and Contact Assemblies.

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 third impedance element will operate followed after a short time delay by the second impedance element, and then followed by the first impedance element, as the apparent short circuit drifts toward the relay. In case of a fault, one, two, or three impedance elements may be operated, but if more than the third element is to be operated, the others will operate within a very short time, and will not follow the sequence described for an out-of-step condition. In case a fault is very close to the balance point of the first or second element, then these elements would operate comparatively slowly, thus simulating part of the out-of-step condition. For this reason, three elements have been used, but all three must operate in a pre-determined sequence and with a suitable delay in order to cause tripping.

Referring to Figure 2, the scheme of operation is described below. The relay marked X is normally energized from the station battery and is of the slow-to-release type, and 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 completed if impedance element Z_1 now operates. Under any other conditions, the trip circuit cannot be completed. 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. If impedance element Z_1 should operate before the sequence of X dropping out and impedance element Z_2 operating is completed, a circuit is provided around the operating coil of auxiliary relay Y through Z_1 contact and Y back contact so that relay Y is not energized.

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 tripping would not occur.

When conditions are returned to normal on the system, all 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.

If a fault occurs within the impedance zone setting of the out-of-step relay and after the fault is cleared, and the systems should pull out of step due to the disturbance caused by the fault, the type TSO-2 relay will still operate properly. Under the fault condition, the impedance elements will take up a definite position corresponding to the location of the fault. After the fault is cleared, and the systems subsequently pull out of step, the out-of-step relay may or may not trip on the first swing as this would depend upon which zone was indicated by the original fault. However, at the conclusion of the first swing, all three impedance elements of the relay will be reset. On the second swing, as the system pulls out of step, these impedance elements will close in order and the system will trip on the second swing, assuming that the electrical center of the out-of-step condition will fall within the zone covered by the relay impedance setting.

CHARACTERISTICS

The relay is available in an 0.6 to 6.0 ohm range. The tap and scale markings are as follows:

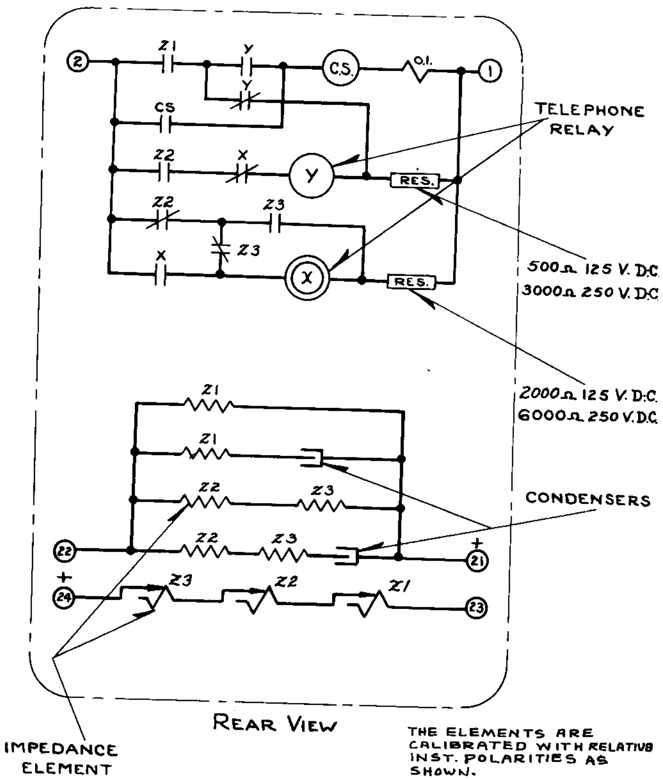

Figure 2
Internal Schematic of the Type TSO-2 Relay In The Standard Case.

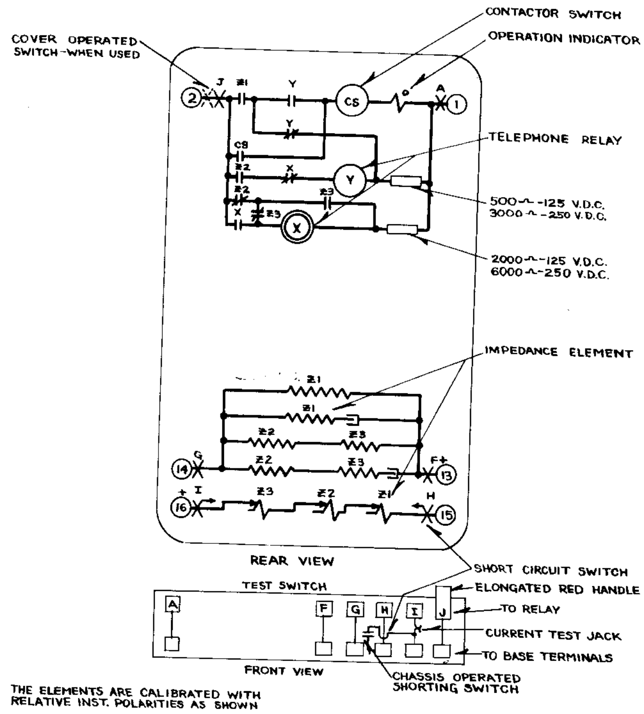

Figure 3
Internal Schematic of the Type TSO-2 Relay In The Type FT Case.

Taps

All elements: 6.2, 9.4, 13.5, 20.8, 29.7, 45.

Element	Core Screw Markings				
First	0.8	1.0	1.2	1.4	
Second	1.4	1.6	1.8	2.0	2.2
Third	1.4	1.6	1.8	2.0	2.2

The phase angle characteristic of the first impedance element is flat within ± 4% over 360°, and within ± 7% over 360° for the second and third impedance elements.

SETTINGS

The type TSO-2 tripping relay requires a setting for each of the three impedance elements. The first element must be set so that under the most unfavorable condition its balance point is 15 to 20% beyond the electrical center of the system when the generators are 180° out of phase. This is to assure the operation of all three impedance elements during the slip cycle. If Zc is the line-to-neutral ohmic impedance of the line from the relay to the electrical center of the system, the impedance settings are as follows:

For the first element - 115 to 120% of Zc
For the second element - Approx. 225% of Zc
For the Third element - Approx. 300% of Zc

The following nomenclature will be used in the formula for determining the relay settings:

Z = line-to-neutral ohmic impedance of the line from the relay to the desired balance point.
Rc= the current transformer ratio.
Rv= the potential transformer ratio.
T = the impedance element current tap value.
S = the impedance element core screw value. The values appear as a series of dots on the lower core screw adjusting knob.

The relay tap setting is found by the use of the following formula:

$$TS = \frac{10\ Z\ Rc}{Rv}$$

This formula applies when the relay receives delta current. If the impedance elements receive star current, the following formula is used:

$$TS = \frac{17.3\ Z\ Rc}{Rv}$$

The nomenclature is as defined above. The tap, T, is obtained by dividing the TS product by S to give an available tap number. When changing taps, the extra tap screw should be screwed into 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 less than 3/4 of a turn. To prevent such doubt it is recommended that the core screw setting be made by thus locating the highest scale marking and then continuing to back it off until the desired value appears exactly under the end of the pointer. Sufficiently accurate setting can be made by interpolating between the marked points when necessary.

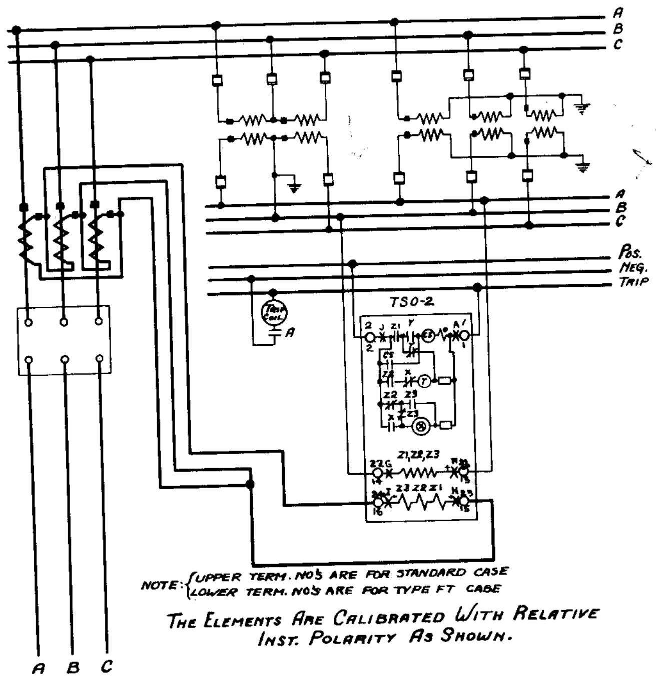

Figure 4
Typical External Connections of the Type TSO-2 Relay. Star Connected Current Transformers May Be Used.

The formula settings are sufficiently accurate for most installations. Where it is desired to set the balance points more accurately, the tap and scale values may be checked by applying to the relay the voltage and current which will be impressed on it in service.

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.

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

First Impedance Element

Refer to Figure 1. Adjust the stop screw on the 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 clearance between the adjustable iron and the beam, also adjust for .020 inch clearance between the front of the beam and the stop on the upper core screw.

The stationary contact should be adjusted for an .020 inch gap when the beam is in the reset position. When the beam is in the operated position, there should be a .015 inch deflection of the moving contact. The spring that carries the moving contact should lie flat on the Micarta arm with no initial tension on the contact. The flexible pigtail should be at least 3/32 inch from the end of the stationary contact.

Connect the relay with polarity as per Figure 2. Using any tap and scale setting, check the impedance measured by the relay with 35 volts potential restraint. Apply 5 volts restraint and adjust the balance weight on the beam until the beam just trips with 1/7 of the current required to trip with 35 volts restraint. The phase angle characteristic is flat within $\pm4\%$ over 360°.

Second and Third Impedance Elements

Refer again 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.

Move the balance weight along the beam until the beam resets sufficiently to allow the top and middle contact to barely "make" contact. Move the weight back 50 mils and lock it in place.

Telephone

The armature set screw on the X relay should be adjusted so it does not extend beyond the armature surface. Otherwise, the X and Y relays require no adjustment. The drop-out of the X element is adjusted normally for 4 cycles.

Contactor Switch

Adjust the stationary core of the switch for a clearance between the stationary core and the moving 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 1.0 ampere d-c. Test for sticking after 30 amperes d-c have been passed thru the coil. The coil resistance is approximately 0.85 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 ohm.

Calibration of Impedance Elements

The current required to operate the impedance elements against any given voltage is obtained from the equation:

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

where T is the current tap and S is the setting of the calibrated core screw, E and I are the voltage and current respectively applied to the relay. Thus, if the setting is T = 20.8, S= 1.2 and the voltage is 30 volts, then the current required at 60° lagging is:

$$I = \frac{10\,E}{TS} \qquad I = \frac{10 \times 30}{20.8 \times 1.2} = 12 \text{ amps.}$$

When checking the calibration, it is essential that the polarity be as given in Figure 2, otherwise an error will be introduced.

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.

Also, when checking the impedance elements at low voltage, observe the tripping of the beam instead of an indication in the trip circuits. This will prevent an error in the contact adjustment which might otherwise affect the beam calibration.

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 impedance elements is as follows:

Potential Circuit at 115 Volts

	VA.	P.F. Angle
All impedance elements in parallel	4.3	8° lead

Current Circuit at 5 Amperes

	Tap	VA.	P.F. Angle
All impedance elements in series	13.5	1.2	10° lag
	45	3.5	37° "

The continuous rating of the voltage coils is 115 volts, and of the current coils 8.66 amperes.

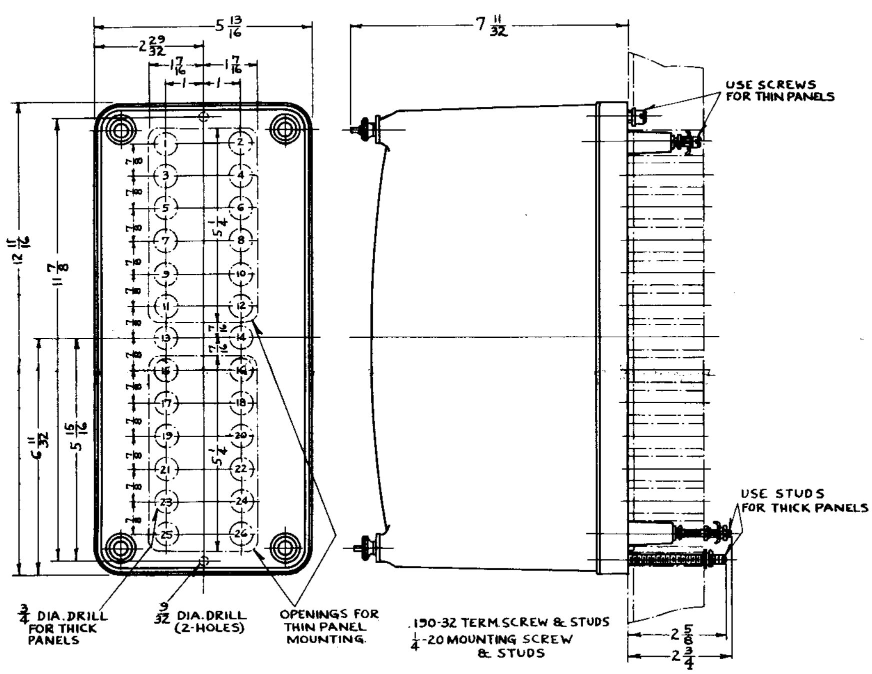

Figure 5
Outline and Drilling Plan of the Standard Projection Type Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.

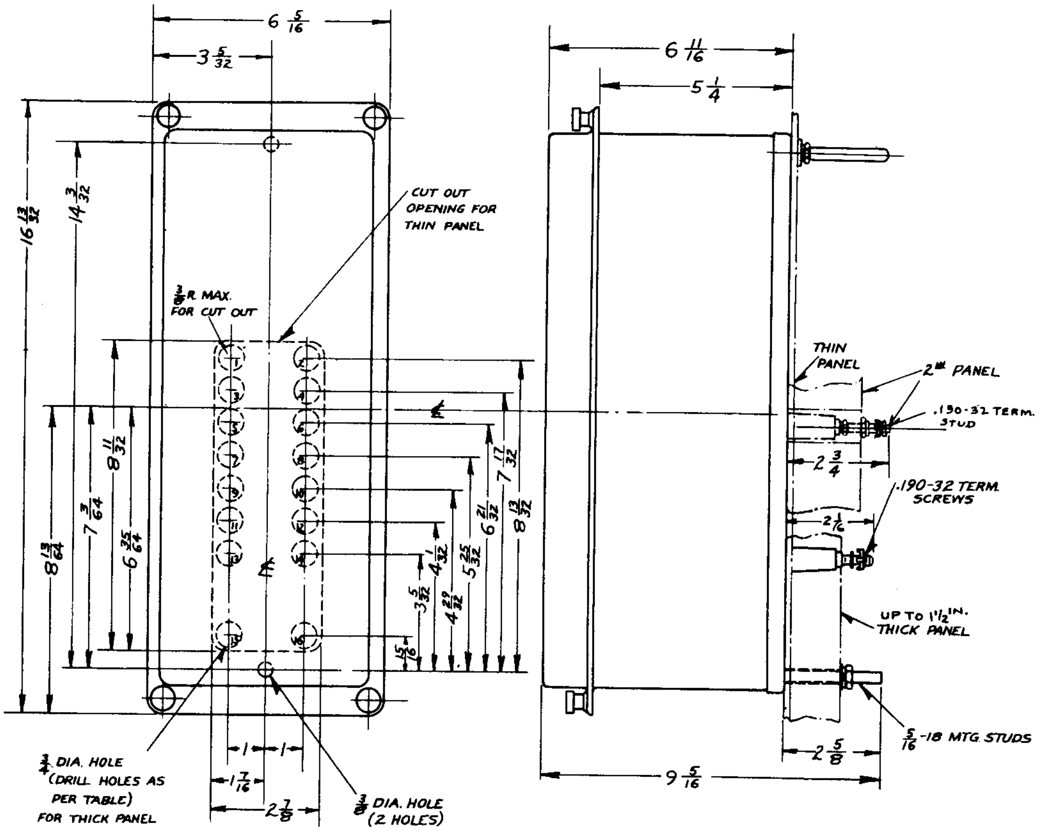

Figure 6
Outline and Drilling Plan for the M10 Projection Type FT Flexitest Case. See the Internal Schematic for the Terminals Supplied. For Reference Only.

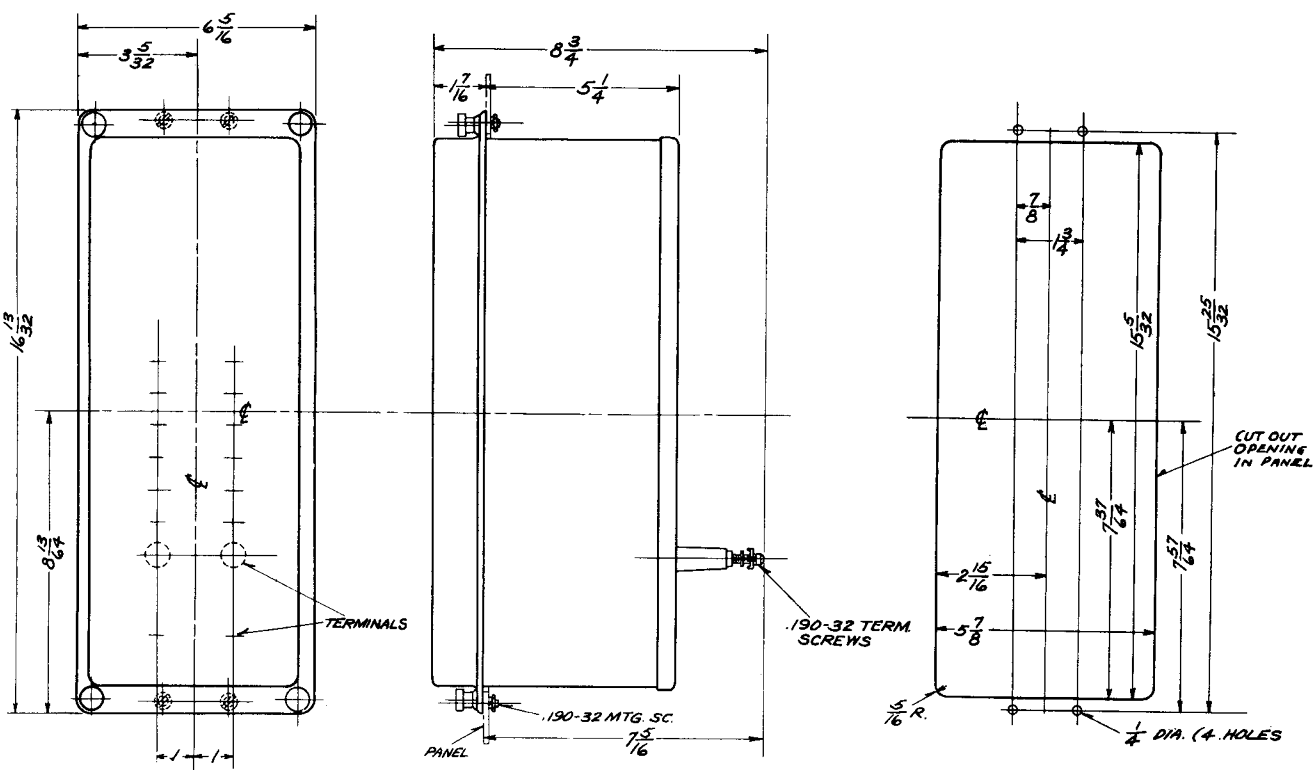

Figure 7
Outline and Drilling Plan for the M10 Semi-flush Type FT Flexitest Case. For Reference Only.