

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

## TYPE KST OUT OF STEP TRIPPING RELAY

**CAUTION:** Before putting protective relays into service 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.

### APPLICATIONS

The KST relay is used with another distance relay such as a KD-3 relay or KD-4 3 $\phi$  (3 phase) unit to sense an out-of-step condition on a power system and to initiate tripping.

For tripping to occur:

- 1) The distance unit of the KST must operate 3 cycles or more sooner than the KD-4 3 $\phi$  unit.
- 2) The KD-4 3 $\phi$  unit must operate for 6 cycles.
- 3) The KD-4 3 $\phi$  unit must reset 3 cycles ahead of the KST distance unit.

When fault occur within the reach of the KST, the distance unit and the KD-4 3 $\phi$  units operate essentially simultaneously and, fault removal reset essentially simultaneously. Out of step conditions produce the sequential action necessary for tripping to be initiated.

### CONSTRUCTION

The type KST relay consists of 3 air-gap transformers (compensators), 2 tapped auto-transformers, a cylinder type operating unit, 3 telephone relays, and an ICS (indicating contactor switch).

#### Compensator

The compensators which are designed as  $T_A$ ,  $T_B$ , and  $T_C$ , are two winding air-gap transformers, (Figure 2). The primary, or current winding, has seven taps which terminate at the tap block.  $T_A$  and  $T_C$  are marked .87, 1.16, 1.6, 2.2, 3.0, 4.2\* and 5.8.  $T_B + T_B$  can be set from 2.85 ohms to 5.85

ohms in steps of 0.15 ohms. Current flowing through the primary coil provides an MMF which produces magnetic lines of flux in the core.

A voltage is induced in the secondary which is proportional to the primary tap and current magnitude. This proportionality is established by the cross sectional area of the laminated steel core, the length of an air-gap which is located in the center of the coil, and the tightness of the laminations. All of these factors which influence the secondary voltage proportionality have been precisely set at the factory. The clamps which hold the laminations should not be disturbed by either tightening or loosening the clamp screws.

The secondary winding has a single tap which divides the winding into two sections. One section is connected subtractively in series with the relay terminal voltage. Thus a voltage which is proportional to the line current is subtracted vectorially from the relay terminal voltage. The second section is connected to an adjustable loading resistor and provides a means of adjusting the phase angle relation between primary current and the induced secondary voltage. The phase angle may be set for any value between 60° and 80° by adjusting the resistor between its minimum and maximum values respectively or for 89° by open circuiting the resistor. The factory setting is for a maximum torque angle of 75° (current lagging voltage).

#### Auto - Transformer

The auto-transformer has three taps, S, on its main winding which are numbered 1, 2, and 3 on the tap block. A tertiary winding has four taps, M, which may be connected additively, or subtractively to inversely modify the "S" setting by any value from -15 to +15 percent in steps of 3 percent.

The sign of M is negative when the R lead is above the L lead. M is positive when L is in a tap location which is above the tap location of the R lead. The M setting is determined by the sum of per unit values between the R and L lead. The

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\*Denotes changes from superseded issue.

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actual per unit values which appear on the tap plate between taps are 0, .03, and 06.

The auto-transformer makes it possible to expand the basic range of the compensators by a multiplier of  $\frac{S}{1 \pm M}$ . Therefore, any relay ohm setting can be

made within  $\pm 1.5$  percent from 0.75 ohms to 20 ohms by combining the compensator taps  $T_A$ ,  $T'_B$ - $T_B$ , and  $T_C$  with the auto-transformer taps  $S_A$  and  $M_A$ , and  $S_C$  and  $M_C$ .

### Cylinder Unit

The device which acts to initiate blocking is a four pole cylinder unit which is connected open delta and operates as a three-phase induction motor.

Mechanically, the cylinder unit is composed of four basic components: a die-case aluminum frame, an electromagnet, a moving element assembly, and a molded bridge.

The frame serves as the mounting structure for the magnetic core. The magnetic core which houses the lower pin bearing is secured to the frame by a locking nut. The bearing can be replaced, if necessary, without having to remove the magnetic core from the frame.

The electromagnet has two series-connected coils mounted diametrically opposite one another, to excite each set of poles, and two locating pins. The locating pins are used to accurately position the lower pin bearing, which is mounted on the frame, with respect to the upper pin bearing, which is threaded into the bridge. The electromagnet is secured to the frame by four mounting screws.

The moving element assembly consists of a spiral spring, contact carrying member, and an aluminum cylinder assembled to a molded hub which holds the shaft. The shaft has removable top and bottom jewel bearings. The shaft rides between the bottom pin bearing and the upper pin bearing which is adjustable to .025 inch from the top of the shaft bearing. The cylinder rotates in the air gap formed by the electromagnet and the magnetic core. The stops for the moving element contact arm are an integral part of the bridge.

The bridge is secured to the electromagnet and frame by two mounting screws. In addition to holding the upper pin bearing, the bridge is used for mounting

the adjustable stationary contact housing. The stationary contact housing is held in position by a spring type clamp. The spring adjuster is located on the underside of the bridge and is attached to the moving contact arm by a spiral spring. The spring adjuster is also held in place by a spring type clamp.

When the ZOS contacts (shown in Figure 3) close, the electrical connection is made through the stationary contact housing clamp, to the moving contact, through the spiral spring out to the spring adjuster clamp to energize the telephone type relay coil, OS. When operating torque causes the contacts to open, then the OS, becomes de-energized.

### Telephone Relays

The telephone-type relay units, OS and T2 are slow-to-operate type, and T1 is a slow-to-operate, extra slow-to-release type. In all three cases an electromagnet attracts a right-angle iron bracket which in turn operates a set of make-and-break contacts. The delay in operation is obtained by a copper slug which acts as a lag coil and delays the build-up of magnetic lines of force in the core. If the copper slug is placed at the other end of the coil, it will delay the reset or drop-out operation of the relay.

When the telephone relay, OS, is energized ahead of KD relay, by the closing of ZOS cylinder unit normally open contacts, it opens and closes its several sets of contacts which are normally connected in series with the KD relay contacts. This starts an out-of-step sensing sequence followed by T1 and T2 operations, depending on whether or not an out-of-step condition exists.

## **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. When the line impedance to the apparent fault ( $Z_F$ ) is less than the compensator setting ( $Z_C$ ),  $I Z_C$  becomes greater than the line voltage drop to the fault. This reverses the compensated voltage and thereby reverses the phase sequence of the voltage applied to the relay and contact-opening-

closing torque is produced in the cylinder unit. Under out-of-step conditions, the apparent impedance measured by the relay anywhere near the electrical center starts at a high value, gradually decreases to a much lower value, and then gradually increases again to a higher value, and thus the system goes through a complete beat oscillation. On the other hand, if the disturbance is a fault, the impedance 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 KST relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KST relay will operate the OS telephone-type relay. For this to happen (Refer to fig. 4), KST must operate 3 cycles ahead of KD relay unit. In order for trip to occur, ZOS (KST) must operate 3 cycles ahead of the KD unit, the KD must stay tripped for 6 cycles, and reset 3 cycles ahead of ZOS (KST Unit). The basic scheme for out-of-step sensing and trip to occur is shown by figure 4. Where the KD relay unit is not equipped with a back contact or where isolation is desired, a high speed auxiliary unit such as (W) type AR is suggested. This alternative is also shown in Figure 4:

#### **Blocking Unit**

The four-pole cylinder unit which acts to initiate sensing of an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact torque (to the right) is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-closing (to the left) torque is produced when negative-phase sequence voltages are applied. Hence, the cylinder unit has restraint or operating torque as determined by the phase sequence of the voltage applied to its terminals.

#### **Compensator**

Sensitivity to the out-of-step condition is provided by compensators designated as  $T_A$ ,  $T_B$ , and  $T_C$  in figure 3. Each compensator is proportioned so that its mutual impedance,  $Z_C$ , has known and adjustable values from  $T = 0.87$  to  $T = 5.8$  ohms in 30-percent steps. Compensator mutual impedance  $Z_C$  is defined

as the ratio of secondary induced voltage to primary current and is equal to  $T$ . The secondary (voltage) winding of the compensator is in series with the applied voltage and vectorially subtracts a value from the applied voltage which is proportional to  $IZ_C$  where  $I$  is the relay current. When the line impedance to the electrical center or to a fault ( $Z_F$ ) is less than the compensator setting ( $Z_C$ ),  $IZ_C$  becomes greater than the line voltage drop to the electrical center or fault. This reverses the phase sequence of the voltage applied to the relay, and contact-closing (to the right) torque is produced in the cylinder unit.

## **CHARACTERISTICS**

### **General Characteristics**

Impedance settings in ohms reach can be made for any value from .75 ohms to 20 ohms in steps of 3 percent. The maximum torque angle which is set for 75 degrees at the factory, may be set for any value from 60 degrees to 80 degrees. A change in maximum torque angle will produce a slight change in reach for any given setting of the relay. Referring to Fig. 2 note that the compensator secondary voltage output  $V$ , is largest when  $V$  leads the primary current,  $I$ , by  $90^\circ$ . This  $90^\circ$  relationship is approached, if the compensator loading resistor ( $R_{2A}$ ,  $R_{2B}$  or  $R_{2C}$ ) is open-circuited. The effect of the loading resistor, when connected, is to produce an internal drop in the compensator, which is out-of-phase with the induced voltage,  $I_{TA}$ ,  $I_{TB}$ , or  $I_{TC}$ . Thus the net voltage,  $V$  is phase-shifted to change the compensator maximum torque angle. As a result of this phase shift the magnitude of  $V$  is reduced, as shown in Fig. 2.

Tap markings in Fig. 5 are based upon a  $75^\circ$  compensator angle setting. If the resistors  $R_{2A}$ ,  $R_{2B}$ , and  $R_{2C}$ , are adjusted for some other maximum torque angle the nominal reach is different than indicated by the taps. The reach,  $Z\theta$ , varies with the maximum torque angle,  $\theta$ , as follows:

$$Z\theta = \frac{TS \sin \theta}{(1 \pm M) \sin 75^\circ}$$

## TAP PLATE MARKINGS

$$\frac{(T_A \text{ and } T_C)}{.87 \ 1.16 \ 1.6 \ 2.2 \ 3.0 \ 4.2 \ 5.8}$$

$$\frac{(T_B)}{0 \ .15 \ .3 \ .45 \ .6 \ .75 \ .9}$$

$$\frac{T_B'}{2.85 \ 3.9 \ 4.95}$$

$$\frac{(S_A \ S_C \ R_B)}{1 \ 2 \ 3}$$

$$\begin{array}{l} \pm \text{ Values} \\ \text{between taps} \end{array} \quad \frac{(M_A \ M_C)}{.03 \ .06 \ .06}$$

## Current Circuit Rating in Amperes

Tap Setting	Continuous	1 Second
5.8	5	240
4.2	7	240
3.0	10	240
2.2	10	240
1.6	10	240
1.16	10	240
0.87	10	240

## Burden

The burden which the relays impose upon potential and current transformers in each phase is shown by the tables 2 and 3.

## SETTING CALCULATIONS

The type KST relay requires an ohm setting high enough that its impedance circle completely surrounds the impedance circle of the KD relay (or similar unit) with sufficient margin to accommodate the fastest swing rate. Usually a 2 ohm larger radius ( $Z_{DF}$ ) for the KS relay will suffice.

The forward reach,  $Z_L$ , is established by:

$$Z_L = \frac{TS}{1 \pm M}$$

$T_A$  and  $T_C$  are set equal to  $T$ ,  $S_A$  and  $S_C$  are set equal to  $S$ , and  $M_A$  and  $M_C$  are set equal to  $M$  as des-

cribed under "Sample Calculations."

The reverse reach,  $Z_{LR}$  in figure 5, is determined by the formula:

$$Z_{LR} = 2/3 Z_B - 1/3 Z_L$$

$Z_B$  can be calculated by:

$$Z_B = 1/2 Z_L + 3/2 Z_{LR}$$

The setting is then determined by:

$$Z_B = \frac{(T_B' + T_B)S}{(1 \pm M)} \quad \text{where } M \text{ is the value chosen for } M_A \text{ and } M_C \text{ and } S \text{ is the value chosen for } S_A \text{ and } S_C$$

The more general formula for setting the forward reach of the relay is required where the maximum torque angle of the relay is adjusted for an angle different from  $75^\circ$ .

$$Z_{L\theta} = Z_L \frac{\sin \theta}{\sin 75^\circ} = Z_{\text{zone 2}} + Z_{DF}$$

Note that  $\theta$  should be adjusted for the same angle as the 3-phase unit of the zone 2 relay.

The terms used in this formula are defined as follows:

$Z_{L\theta}$  = the desired ohmic forward reach of the relay

$$Z_L = \frac{TS}{1 \pm M} = \text{the tap plate setting} = Z_A = Z_C$$

$T$  = compensator tap value =  $T_A = T_C$

$S$  = autotransformer primary tap value =  $S_A = S_C$

$\theta$  = maximum torque angle adjustment

$$\left( \text{For a factory setting of } 75^\circ \text{ then } \frac{\sin \theta}{\sin 75^\circ} = 1. \right)$$

$M$  = Auto-transformer secondary tap value.

(This is a Per Unit value and is determined by the sum of the value between the "L" and the secondaries ( $M_A$  and  $M_C$ ), and the balancing resistor  $R_B$  which should be set at the same value as  $S_A$

and  $S_C$ . All of these settings are made with taps on the tap plate which is located above the operating unit.

### Compensator ( $T_A$ , $T_B$ , and $T_C$ )

Each set of compensator taps terminate in inserts which are grouped on a socket and form approximately three quarters of a circle around a center which is the common connection for all of the taps. Electrical connections between common insert and tap inserts are made with a link that is held in place with two connector screws, one in the common and one in the tap.

A compensator tap setting is made by loosening the connector screw in the center, remove the connector screw in the tap end of the link, swing the link around until it is in position over the insert for the desired tap setting, replace the connector screw to bind the link to this insert, and retighten the connector screw in the center. Since the link and connector screws carry operating current, be sure that the screws are turned to bind snugly. Do not overtighten because damage may result.

### Auto-Transformer Primary ( $S_A$ and $S_C$ )

Primary tap connections are made through a single lead for each transformer. The lead comes out of the tap plate through a small hole located just below the taps and is held in place on the proper tap by a connector screw, (Figure 5).

An "S" setting is made by removing the connector screw, placing the connector in position over the insert of the desired setting, replacing and tightening the connector screw. The connector should never make electrical contact with more than one tap at a time.

### Auto-Transformer Secondary ( $M_A$ and $M_C$ )

Secondary tap connections are made through two leads identified as L and R for each transformer. Each of these leads come out of the tap plate through a small hole, one on each side of the vertical row of "M" tap inserts. The lead connectors are held in place on the proper tap by connector screws.

Values for which an "M" setting can be made are from  $-.15$  to  $+.15$  in steps of  $.03$ . The value of a setting is the sum of the numbers that are crossed when going from the R lead position to the L lead position. The sign of the "M" value is determined

by which lead is in the higher position on the tap plate. The sign is positive (+) if the L lead is higher and negative (−) if the R lead is higher.

An "M" setting may be made in the following manner. Remove the connector screws so that the L and R leads are free. Determine from the following table the desired "M" value. Neither lead connector should make electrical contact with more than one tap at a time.

Tabulated Settings

$Z_{75^\circ}$	M	L Lead	R Lead
0.87 TS	+.15	Upper .06	0
0.89 TS	+.12	Upper .06	.03
0.92 TS	+.09	Lower .06	0
0.94 TS	+.06	Upper .06	Lower .06
0.97 TS	+.03	.03	0
TS	0	0	0
1.03 TS	−.03	0	.03
1.06 TS	−.06	Lower .06	Upper .06
1.1 TS	−.09	0	Lower .06
1.14 TS	−.12	.03	Upper .06
1.18 TS	−.15	0	Upper .06

### $R_B$ Settings

$R_B$  is a circuit balancing resistor. The  $R_B$  tap setting should be the same as  $S_A$  and  $S_C$  settings.

### Line Angle Adjustment

The maximum torque angle of the relay is set at the factory to be  $75^\circ$  current lagging voltage and the tap values are based on this angle. Generally speaking, the  $75^\circ$  setting can be applied on lines with angles from  $65^\circ$  to  $90^\circ$  and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between  $60^\circ$  and  $80^\circ$  by adjusting the compensator loading resistors  $R_{2A}$ ,  $R_{2B}$ , and  $R_{2C}$ . Refer to the section titled Calibration when a change in maximum torque angle is desired.

## 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 mounting studs provided for projection mounting or by means of the four mounting holes on the flange for semi-

flush mounting. Either the studs 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 stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the study and then turning the proper nut with a wrench.

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

## RECEIVING ACCEPTANCE

KST relays have a very small number of moving parts and mechanical devices which might become inoperative. Acceptance tests in general consist of:

1. A visual inspection to make sure there are no loose connections, broken resistors, or broken wires.
2. An electrical test to make certain that the relay measures the balance point impedance accurately.

Check the electrical response of the impedance unit by using the test connections shown in Figure 6. Set  $T_A$  and  $T_C$  for 5.8;  $T_B' - T_B$  for 5.85;  $S_A$ ,  $S_C$ , and  $R_B$  for 1;  $M_A$  and  $M_C$  for +.15.

- A. Use connection for Test No. 4 and adjust the voltage between PH.1 and 1F and between PH.2 and 2F for 45 volts each so that the resultant voltage  $V_{1F2F}$  equals 30 volts (120-45V-45V = 30V).
- B. The current required to make the cylinder unit contacts swing to the left should be between 2.95 and 3.05 amperes at an angle of 75° current lag.
- C. Repeat B while using connections for Test No. 5 and Test No. 6. The difference in values of current that make the contacts swing to the right for each of the three test connections should not be greater than 4% of the smallest value.

If the electrical response is outside the limits a more complete series of test outlined in the section "Calibration" may be performed to determine which component is fault or out of calibration.

Check the wiring to the telephone-type relays by referring to fig. 6 and connecting per test no. 4. Apply voltage and current as per parts A and B above (moving contact should swing to the left thus closing the KST normally open contacts).

Perform the following checks

Test #	Operation	Effect
1	Close S1	0 <sub>S</sub> should operate, T1, T2 remain the same
2	Close S3	0 <sub>S</sub> remain operating, T1 should operate, T2 unchanged
3	Close S2	0 <sub>S</sub> , T1 remain operating, T2 operates indicating light goes on.
4	Open S3	0 <sub>S</sub> remain operating, T1 and T2 should reset. Light should go off.

## ROUTINE MAINTENANCE

All relays should be inspected periodically, at such time intervals as may be dictated by experience, to insure that the relays have retained their calibration and are in proper condition.

All contacts should be cleaned periodically. A contact burnisher #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.

### Electrical Checkpoints

#### A. Cylinder Unit

Using the connections for Tests Nos. 8 and 9 of Figure 6 set the phase shifter so that the current lags by  $\theta^\circ$ . The current required to open-close the contacts should be within the limits specified for each voltage. Note that for the forward reach, test 8, the impedance measured by the relay is  $Z_L = \frac{V_{L-L}}{2I_L}$ . For the reverse

reach, connection 9, the impedance measured by the relay in this test is  $Z_{LR} = \frac{V_{L-L}}{\sqrt{3}I_L} - 1/3Z_L$ .

Here  $V_{L-L}$  is phase current, and  $Z_L = \frac{V_{LL}}{2I_{L1}}$ ,

where  $I_{L1}$  is the current found in test #8.

Test No.	Volts	Amperes ( $\theta = 75^\circ$ ) & †	
	V <sub>1F2F</sub> & V <sub>2F3F</sub>	I <sub>min</sub>	I <sub>max</sub>
8	30	2.95	3.05
	70	6.90	* 7.15
9	30	5.06 ††	5.24 ††
	70	11.8	12.2

†† Phase Angle Meter Set for  $\theta + 30^\circ$

† To determine the limits of current when  $\theta$  is not equal to  $75^\circ$ , multiply the nominal values tabulated above by the ratio  $\frac{\sin 75^\circ}{\sin \theta}$

**Note** that Tests Nos. 8 and 9 are artificial methods of checking the forward and reverse balance points.

These tests require a polyphase voltage supply and only a single-phase current.

Referring to vector diagrams of Figure 7, one can see how the forward and reverse balance points are determined with a balanced three-phase current. Comparing this to the artificial single-phase current method in Figure 8 it is obvious that a similarity exists between the two. This similarity makes it possible to accurately check the relay balance points using a single-phase current at the relay maximum torque angle only.

The circle characteristics of Figure 4 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 6 Figure 6, to plot the characteristic circle. The reach of the relay for this connection

$$\text{is } Z = \frac{V_{L-L}}{\sqrt{3} I_L} \text{ Ohms.}$$

## REPAIR CALIBRATION

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed.

Connect the relay for testing as shown in Figure 6. The four-pole-double-throw switch shown in the test circuit, selects the type of voltage condition, that will be applied to the relay voltage terminals. The rotary switch switches the fault voltage to

various terminals and thereby provides a number of test combinations without the tester having to change connections or readjust the phase shifter and variable auto-transformers.

For best results in checking calibration, the relay should be allowed to warm up for approximately one hour at rated voltage. However, a cold relay will probably check to within two percent of the warm relay.

### Auto-Transformer Check:

Auto-transformers may be check for turns ratio and polarity by using the No. 1 test connections of Figure 6, and following the procedure outlined below.

Set  $S_A$  and  $S_C$  on tap number 3. Set the "R" lead of  $M_A$  and  $M_C$  all on 0.0 and disconnect the "L" leads. Adjust the voltages  $V_{1F2F}$  and  $V_{2F3F}$  for 90 volts. Measure the voltage from terminal 8 to the #1 tap of  $S_A$ . It should be 30 volts. From 8 to the #2 tap of  $S_A$  should be 60 volts. The voltage should read 30 volts from 8 to  $S_C = 1$  and 60 volts from 8 to  $S_C = 2$ .

Set  $S_A$  and  $S_C$  on 1 and adjust  $V_{1F2F}$  and  $V_{2F3F}$  for 100 volts. Measure the voltage drop from terminal 8 to each of the  $M_A$  taps. This voltage should be equal to 100 (1 + the sum of values between R and the tap being measure). Example:  $100 (1 + .03 + .06) = 109$  volts.

Check the taps of  $M_C$  in the same manner. Transformers that have an output different from nominal by more than 1.0 volt probably have been injured and should be replaced.

### Settings:

Check to see that the taps on front of the tap block are set as follows:

$T_A$  and  $T_C$  set on 5.8;  $T_B'$  for 4.95 and  $T_B$  for 0.9

$S_A$ ,  $R_B$  and  $S_C$  set on 1

"R" for  $M_A$  and  $M_C$  set on 0.0

"L" for  $M_A$  and  $M_C$  set in the top position

(.03 + .06 + .06 = .15 between L & R).

### Cylinder Unit:

#### A. Rough Adjustment of $R_{MA}$ and $R_{MC}$

Set  $R_{MA}$  to slightly less than half the adjustable range so that the adjustable band is nearer the end.

- Using connections for test #1 of Figure 6 brush #1 so that  $V_{1F2F} = V_{78} = 0$ . Adjust brush #2 for rated voltage across terminals 8 and 9. Adjust  $R_B$  so that the contact floats or has a minimum of torque. This is rough adjustment for making the impedance angle of phase 1 to be equal to impedance of phase 2.
- Using test #1 to Figure 6, adjust brush #2 so that  $V_{2F3F} = V_{89} = 0$ . Adjust  $R_{MC}$  so that the contact floats or has a minimum of torque. This is a rough adjustment for making the impedance angle of phase 3 equal to the impedance of phase 2.

B. Maximum torque angle adjustment. Note that a change in the maximum torque angle adjustment may upset the calibration of the resistor  $R_{MA}$  and  $R_{MC}$ . Therefore, the  $R_{MA}$  and  $R_{MC}$  calibration should be checked after any change in the maximum torque angle. If there is an indication that the  $R_{MA}$  and  $R_{MC}$  adjustments should be changed due to a maximum torque angle adjustments should be changed due to a maximum torque angle adjustments re-calibration can be accomplished by adjusting  $R_B$  only.

- Use the No. 1 test switch positions and lead connections. This connection is for checking and adjusting the maximum torque angle of the phase-1 compensator.
- Adjust the voltage  $V_{1F2F}$  and  $V_{2F3F}$  for 50 volts with Brush No. 1 and Brush No. 2 respectively.
- Adjust the current to 10 amperes and rotate the phase shifter to find the two angles,  $\theta_1$  and  $\theta_2$ , at which the contacts just open. The maximum torque angle then is  $(\frac{\theta_1 + \theta_2}{2} - 30)$  degrees.

This angle should be between  $73^\circ$  and  $77^\circ$  when received from the factory.

- The angle  $\theta$  can be changed by adjusting  $R_{2A}$ . A lower value of resistance gives a smaller angle and a higher resistance value gives a greater angle.
- Use the No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 (figure 6) to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying  $R_{2B}$ .

- Use the No. 3 Test connections and repeat the above procedure to check and adjust the angle of the phase-3 compensator. This adjustment is made with  $R_{2C}$ .

### C. $R_{MA}$ and $R_{MC}$ Calibration.

These components,  $R_{MA}$  and  $R_{MC}$ , are adjusted so that their respective circuits have the same impedance angle as the circuit of the tapped resistor  $R_B$ . These adjustments can be checked by simulating all three combinations of phase-to-phase faults, 1-2, 2-3, and 3-1, as shown in the test circuit Figure 6. Each value of current required to trip the cylinder unit for each of the three conditions should be within 4% of the other two values when the circuits have been allowed to warm up with normal voltage applied to the relay terminals. An inaccurate setting of  $R_{MA}$  or  $R_{MC}$  can cause the spread in current values to increase to more than 10%.

- Connect the relay for a 1-2 fault as indicated for Test No. 4:
- Adjust the voltage between PH.1 and 1F and between PH.2 and 2F for 57.5 volts each using Brush No. 1 and Brush No. 2 respectively. This will provide 5 volts between 1F and 2F ( $V_{1F2F} = 120 - 57.5 - 57.5 = 5$  volts).
- Adjust the phase shifter for  $\theta$  degrees between load current and  $V_{PH.1-PH.2}$ .
- With load current set for 0.51 amperes, adjust  $R_{MA}$  so that the cylinder unit contacts just closes the left hand side contact.
- Reconnect the relay for a 2-3 fault in test no. 5 and adjust  $R_{MC}$  using procedures of steps 2, 3 and 4.
- Determine the current value at which the contacts swing to the left for a 3-1 fault using Test No. 6. If the 3-1 fault current is greater than 0.51 amperes then  $R_{MA}$  is too low and  $R_{MC}$  is too high.
- Increase  $R_{MA}$  a slight amount and reduce  $R_{MC}$  an equal amount until the contacts just closes to the left for 0.51 amperes.
- Check the current required to close the right side contacts for Test Nos. 4 and 5. The values should be equal to each other and to test No. 7 within  $\pm 3\%$ .



9. If the currents are not equal  $\pm 3\%$  then use the average value for Tests Nos. 4 and 5 determined in steps 8 and repeat steps 1 through 8. At first there may be an over-correcting or pendulum action as one balances the  $R_{MA}$  and  $R_{MC}$  resistors. However, with a little experience the circuits can be balanced after two or three trials.

#### D. Spring Restraint

1. Use Test No. 1 connections except reverse the voltage phase sequence by interchanging the Brush connections so that brush 1 is connected to 3F and Brush 2 is connected to 1F.
2. Adjust the voltages  $V_{1F2F}$  and  $V_{2F3F}$  for 3.5 volts each with Brush No. 2 and Brush No. 1 respectively. Position the moving-contact spring adjuster so that the contact just floats and then return the circuit connections to normal with Brush 1 to 1F and Brush 2 to 3F.

#### E. Contact Adjustment

With moving contact arm against right hand side of the bridge screw the right hand contact in to just touch the moving contact and then continue for one more complete turn.

With moving contact against right hand contact screw the left hand stationary contact in until it just touches the moving contact (check for contact by using an indicator light). Then back the contact (left-hand) out  $3/4$  of one turn to give about .025-inch gap between contacts.

The cylinder unit is now calibrated and should be accurate to within  $\pm 3\%$  of the corrected tap value setting over the range of voltages from 60  $V_{L-L}$  to 120  $V_{L-L}$ . The corrected tap value is the actual relay reach at a given maximum torque angle  $\theta$  and is equal to

$$Z_{\theta} = \frac{TS \sin \theta}{(1 \pm M) (\sin 75^\circ)}$$

#### Compensator Check

Accuracy of the mutual impedance  $Z_C$  of the compensators is set within very close tolerances at the factory and should not change under normal conditions. The mutual impedance of the compen-

sators can be checked with accurate instruments by the procedure outlined below.

- A. Set  $T_A$  and  $T_C$  on the 5.8 tap,  $T_B^1 = 4:95$ ,  $T_B = 0.9$ .
- B. Disconnect the "L" leads of section  $M_A$  and  $M_C$  and the brush leads of  $R_{2A}$ ,  $R_{2B}$ , and  $R_{2C}$ .
- C. Connect terminals 13 to 15, 14 to 16 and pass 10 amperes a.c. current in terminal 17 and out of terminal 12.
- D. Measure the compensator voltage  $V_C$  with a high resistance voltmeter 2000 ohm/volt as tabulated below. Refer to Figure 1 for the location of  $R_{2A}$ ,  $R_{2B}$ , and  $R_{2C}$ .

Measure $V_C$		Voltmeter Read
From Terminal	To Fixed End of	
"L" of $M_A$	$R_{2A}$	$V_C = IT \frac{\sin \theta}{\sin 75^\circ}$
8	$R_{2B}$	
"L" of $M_C$	$R_{2C}$	= 60.1 volts ( $\theta = 90^\circ$ )

- E. Any compensator that has an output which is 2 volts more or less than the nominal values given above should be replaced.

#### Telephone Relays

Connect per fig. 6 (dc connections only) and close KST left hand side contacts. Close S1 and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between 3 and 4 cycles (50-66 ms). The operating time can be adjusted by bending the contact-spring (OS telephone relay) and by changing the armature gap. Do not open S1.

Close S3, then close S2 and measure the time required for the T2 contact to energize the indicating light. This operating time should be between 50 and 56 ms. The time can be adjusted as for the OS relay.

Now open S2 keeping S1 and S3 closed (if accidentally S1 and S3 were opened, close S1 first, then close S3).

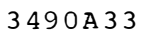
## TYPE KST OUT OF STEP TRIPPING RELAY

Close S2 and measure the time for T2 relay to be energized (relay terminal 19 and front end of resistor R2). Use S2 to start and the resistor R2 to stop the counter. This operating time should be  $97 \pm 10$  ms.

**TABLE I**  
**NOMENCLATURE FOR TYPE KST RELAY**

Item	Description
ZOS	Two Element-Coils; Total D.C. Resistance = 560 to 605 ohms
R <sub>MA</sub> & R <sub>MC</sub>	3-½ Inch Resistor – 2000 to 3000 ohms Adjustable
R <sub>B</sub>	2 Inch Resistor - Fixed adjustable Taps at 30 & 55 ohms; adjustable 55 to 328 ohms.
R <sub>2A</sub> , R <sub>2B</sub> , R <sub>2C</sub>	2 Inch Resistor - 600 ohms adjustable.
C <sub>2A</sub> , C <sub>2C</sub>	1.6 MFD Capacitors
T <sub>A</sub> , T <sub>C</sub>	Compensator (Primary Taps - .87; 1.16; 1.6; 2.2; 3.0; 4.2; 5.8)
T <sub>B</sub> ' - T <sub>B</sub>	Compensator (Primary Taps - T <sub>B</sub> ' = 2.85; 3.9; 4.95. T <sub>B</sub> = .0; .15; .3; .45; .6; .75; .9)
S <sub>A</sub> , S <sub>C</sub>	Auto-Transformer (Primary Taps- 1; 2; 3)
M <sub>A</sub> , M <sub>C</sub>	Auto- Transformer (Secondary Between Taps - 0.0; .03; .06; .06)
OS	Telephone Type Relay-D.C. Resistance = 475 to 525 ohms
R <sub>OS</sub>	Fixed Resistor – 2000 Ω
T1	Telephone Type Relay
T2	Telephone Type Relay - 500 Ω DC resistance

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**Fig. 3 Internal Schematic**

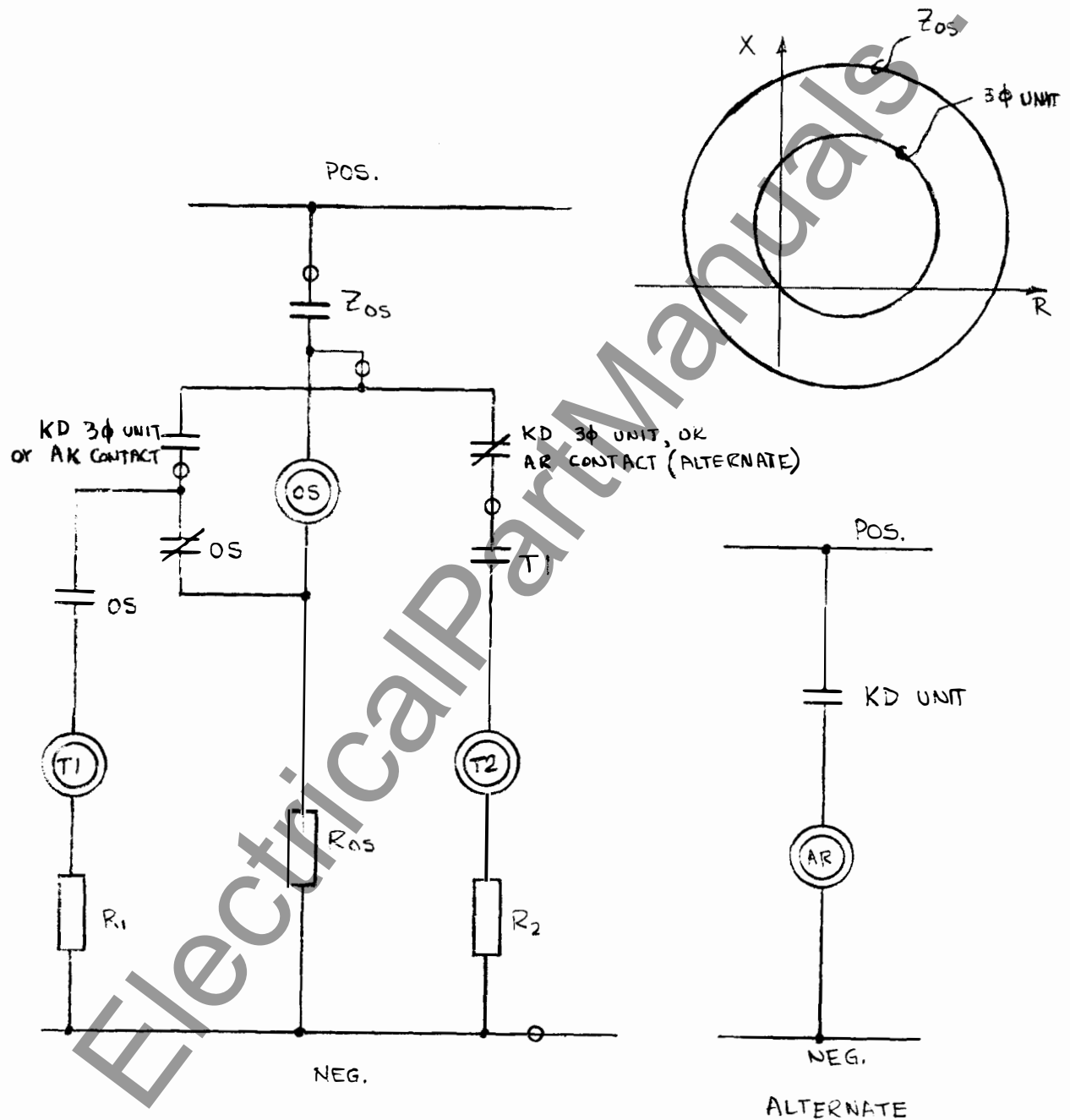
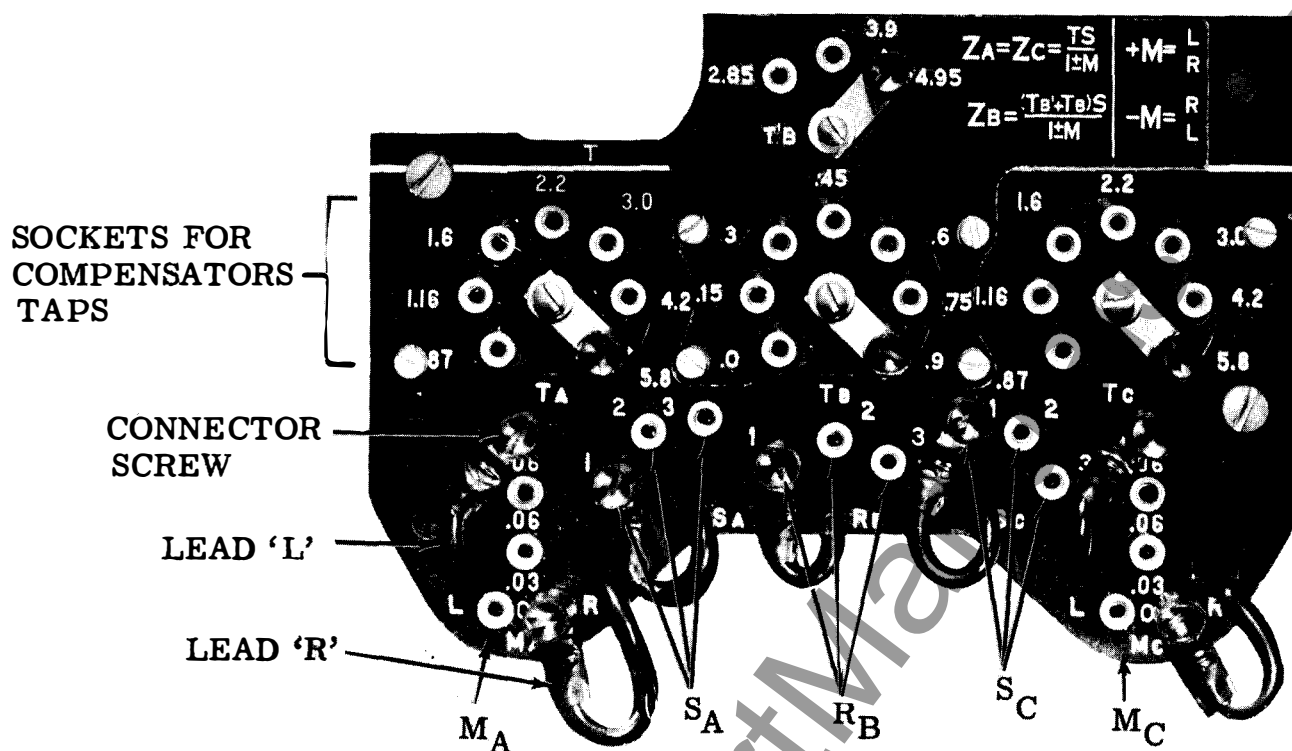
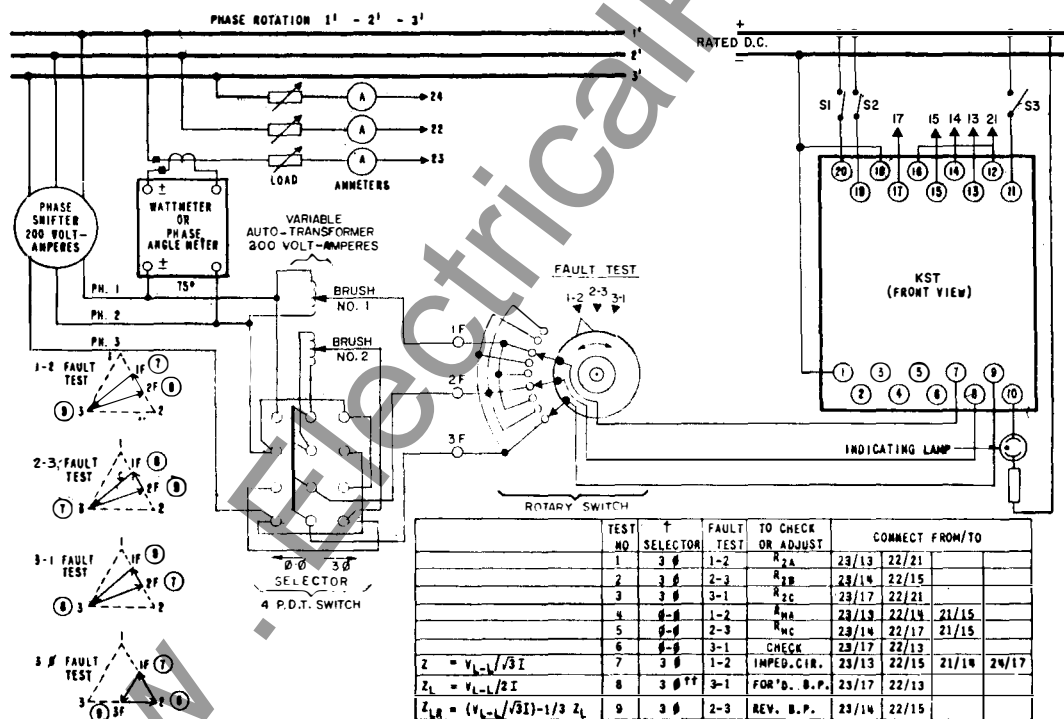


Fig. 4 Out-of-step Sensing Sequence

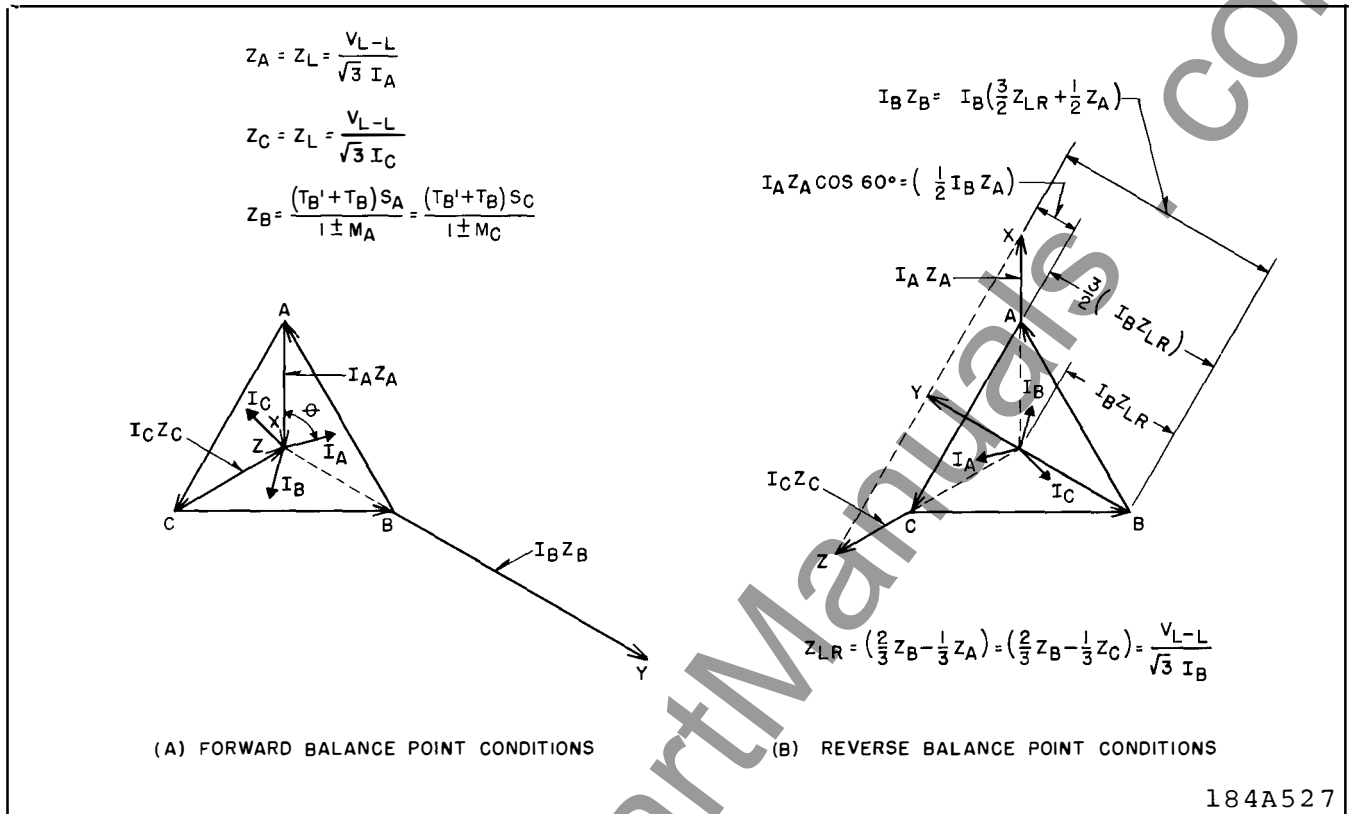


**Fig. 5 Tap Plate**

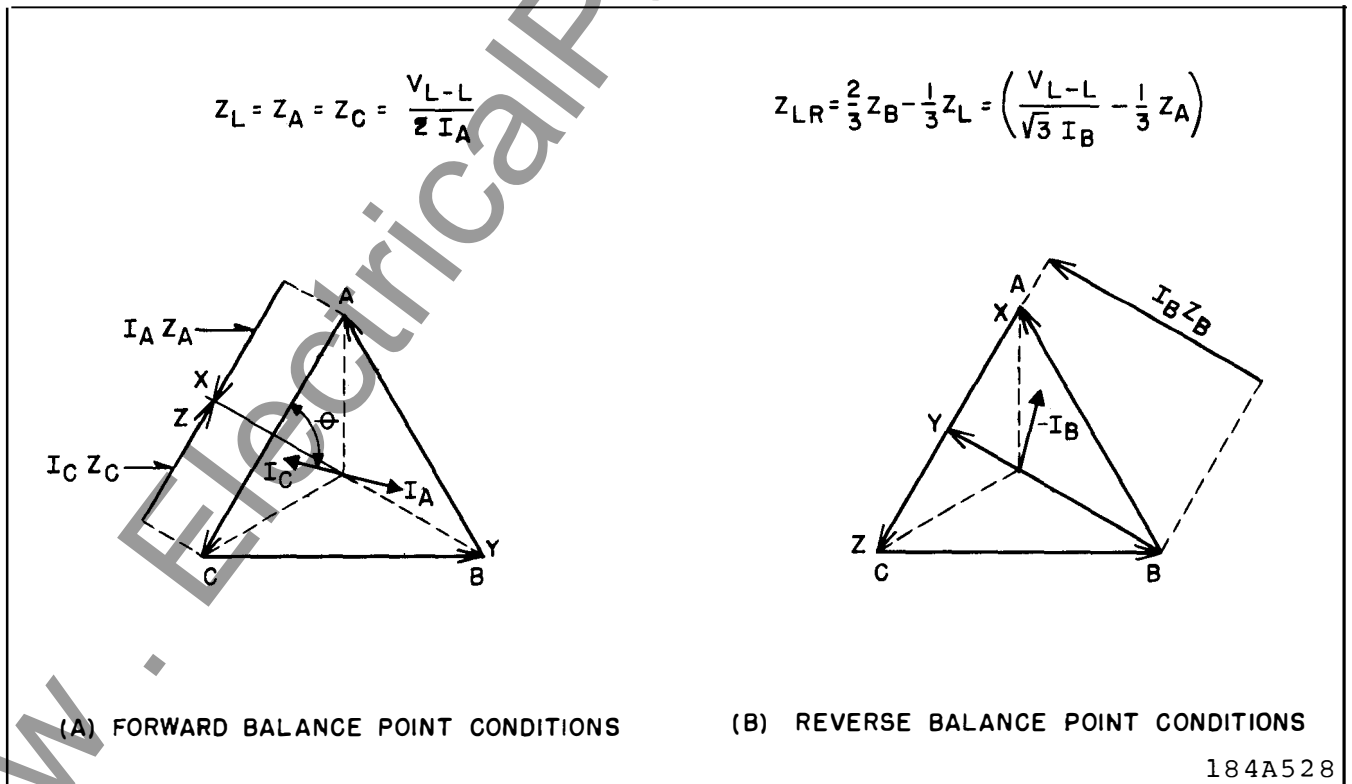


† -  
 SUBTRACT 30° FROM THE PHASE-ANGLE-  
 METER READING TO DETERMINE THE RELAY  
 MAXIMUM TORQUE ANGLE WHEN THE  
 SELECTOR IS IN THE 3<sup>rd</sup> POSITION, UNLESS  
 THE TABULATED POSITION IS FOLLOWED  
 BY THE DOUBLED NOTE ††.

**Fig. 6 Test Connections**



\* Fig. 7 Vector Diagram of the Forward and Reverse B.P.

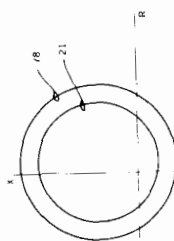


\* Fig. 8 Vector Diagram for the Artificial Reverse Balance Point Condenser when Testing with Single Phase Current.



DEVICE CHART			
DEVICE NO	TYPE	FUNCTION	INTERNAL SCHEMATIC
2	T/D 5	TIMER	1B7A293
21	WD 41	GENERATOR BACK-UP	862A196 *
21K	AR	AUXILIARY TO 21	837A113
78	KST	OUT OF STEP SWP	340A633
WI	WI	TRIP AND LOCK-OUT	

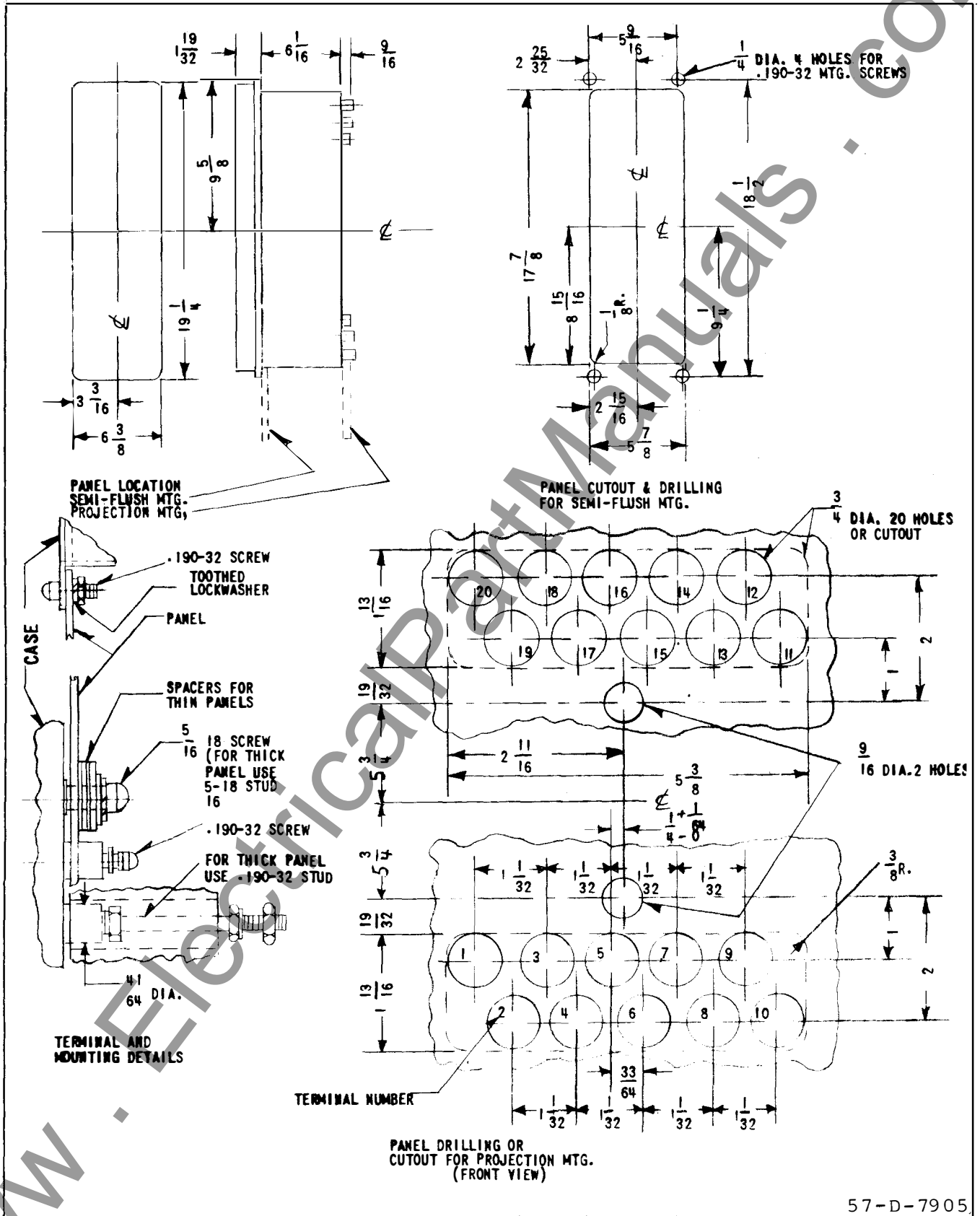
\* NOTE SPECIAL MD 41 CONTACT CONFIGURATION



6663D62

**Fig. 9 External Schematic**





57-D-7905

Fig. 10 Outline - Drilling Plan for the KST Relay.

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