ABB Power T&D Company Inc.
Relay Division
Coral Springs, FL 33065

Instruction Leaflet

I.L. 41-492.5C

Type KST
Out of Step Tripping Relay
0.75-20 Ohms

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(|) Denotes change since previous issue

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.

1. APPLICATIONS

The KST relay is used with another distance relay such as a KD-3 relay or the 3ø (3-phase) unit of a KD-4, KD-10, or a KD-11 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-10 3ø unit.

2) The KD-10 3ø unit must operate for 6 cycles.

3) The KD-10 3ø unit must reset 3 cycles ahead of the KST distance unit.

When fault occurs within the reach of the KST, the distance unit and the KD-10 3ø units operate essentially simultaneously and, for fault removal, reset essentially simultaneously. Out of step conditions produce the sequential action necessary for tripping to be initiated.

2. 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).

2.1. Compensator

The compensators which are designed as T_A, T_B+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, 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).

2.2. 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 actual per unit values which appear on the tap plate between taps are 0,.03, 06, and.09.

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 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 SA and M_A, and S_C and M_C.

2.3. 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 9***) 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.

2.4. 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 for 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.

3. 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), IZ_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-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, KST must operate 3 cycles ahead of KD relay unit. In order for out-of-step tripping to occur, ZOS (KST) must operate 3 cycles ahead of the KD unit, the KD must stay tripped by 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 in ***Figure 9***. Where the KD relay unit is not equipped with a back contact or where isolation is desired, a high speed auxiliary unit such as ABB's type AR is suggested. This is also shown in ***Figure 9***.

3.1. ZOS 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.

3.2. 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 left) torque is produced in the cylinder unit.

4. CHARACTERISTICS

4.1. General Characteristics

Impedance settings in ohms reach can be made for any value from .74 ohms to 21.22 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 ***Figure 2*** note that the compensator secondary voltage output V, is largest when V leads the primary current, I, by 90 degree. This 90 degree 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 ***Figure 2***.

Tap markings in ***Figure 4*** are based upon a 75° compensator angle setting. If the resistor 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 Zθ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

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

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

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

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

± Values between taps

$$\frac{(M_A, M_C)}{.03 \ .09 \ .06}$$

4.2. 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

4.3. Burden

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

5. 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 3 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.

The reverse reach, Z_{LR} in ***Figure 7***, 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:

$$Z_B = \frac{(T_B' + T_B)S}{(1 \pm M)}$$

Where M is the value chosen for M_A and M_C and S is the value chosen for S_A 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°.

$$Z_{L\theta} = Z_L \frac{\sin\theta}{\sin 75°} = Z_{\text{Zone 2}} + Z_{DF}$$

Note that θ 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.

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

T = compensator tap value = $T_A = T_C$

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

θ = maximum torque angle adjustment

Z_{DF} = margin between Zone-2 characteristic and KST characteristic, in ohms

(for a factory setting of 75° then $\frac{\sin\theta}{\sin 75°} = 1$.)

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.

5.1. Compensator (T_A, T_B[1] + 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.

5.2. 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 (***see Figure 4***).

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.

5.3. 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 -.18 to +.18 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.

$Z_{75°}$	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

Tabulated Settings

5.4. 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.

5.5. Line Angle Adjustment

The maximum torque angle of the relay is set at the factory to be 75° current lagging voltage and the tap values are based on this angle. Generally speaking, the 75° setting can be applied on lines with angles from 65° to 90° and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between 60° and 80° 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.

6. 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.

6.1. RECEIVEING 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 5***. Set T_A and T_C for 5.8; 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 (120-25V-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 ***Figures 3 and 5*** 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	O_S should operate, T1, T2 remains the same
2	Close S3	O_S remain operating, T1 should operate, T2 unchanged
3	Close S2	O_S, T1 remain operating, T2 operates indicating light goes on
4	Open S3	O_S remain operating, T1 and T2 should reset. Light should go off

7. 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.

7.1. Electrical Checkpoints

A. Cylinder Unit

Using the connections for Tests No's. 8 and 9 of ***Figure 5*** set the phase shifter so that the current lags by θ°. 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 I_L is phase current, and $Z_L = \frac{V_{LL}}{2I_{L1}}$, where I_{L1} is the current found in Test No. 8.

Test Number	Volts	Amperes (θ = 75°) & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
8	30 70	2.95 6.90	3.05 7.15
9	30 70	5.06 ‡ 11.8 ‡	5.24 ‡ 12.2 ‡

‡ Phase Angle Meter Set for θ +30°

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

NOTE: Test No's. 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 6*** 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 is $\frac{V_{L-L}}{\sqrt{3}\, I_L}$ Ohms.

8. 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 5***. 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.

8.1. Auto-Transformer Check

Auto-transformers may be checked for turns ratio and polarity by using the no. 1 test connections of ***Figure 5***, 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.

8.2. 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 between 0.03 and .09.

"L" for M_A and M_C set in the top position above .06 (.09 + 0.6 =.15 between L & R).

8.3. 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.

1. Using connections for test #1 of ***Figure 5*** 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.
2. Using test #1 of ***Figure 5***, 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, re-calibration can be accomplished by adjusting RB only.

1. Use the No. 1 test switch position and lead connection. This connection is for checking and adjusting the maximum torque angle of the phase-1 compensator.
2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with brush #1 and brush #2 respectively.
3. Adjust the current to 10 amperes and rotate the phase shifter to find the two angles, θ1 and θ2, at which the contacts just open. The maximum torque angle then is $\left(\frac{\theta_1 + \theta_2}{2} - 30\right)$ degrees.

   This angle should be between 73° and 77° when received from the factory.
4. The angle θ 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.
5. Use the #2 test connection and repeat the procedures numbered 2, 3 and 4 (***Figure 5***) to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.
6. Use the #3 test connection 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 5***. 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%.

1. Connect the relay for a 1-2 fault as indicated for test #4.

2. Adjust the voltage between PH.1 and 1_F and between PH.2 and 2_F for 57.5 volts each using brush #1 and brush #2 respectively. This will provide 5 volts between 1_F and 2_F (V_{1F2F} = 120 - 57.5 -57.5 = 5 volts).
3. Adjust the phase shifter for θ degrees between load current and $V_{PH.1-PH.2}$.
4. With load current set for 0.51 amperes, adjust R_{MA} so that the cylinder unit contacts just closes the left hand side contact.
5. Reconnect the relay for a 2-3 fault in test #5 and adjust R_{MC} using procedures of steps 2, 3 and 4.
6. Determine the current value at which the contacts swing to the left for a 3-1 fault using test #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.
7. 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.
8. Check the current required to close the right side contacts for test #'s 4 and 5. The values should be equal to each other and to test #7 within ±3%.
9. If the currents are not equal ±3% then use the average value for test #'s 4 and 5 as determined in step 8 then repeat steps 1 through 8. At first there may be over-correction as one balances the R_{MA} and R_{MC} resistors. However, with a little experience the circuits can be balanced after two or three tries.

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 # 2 and brush #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 into 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 abut .025-inch gap between contacts.

The cylinder unit is now calibrated and should be accurate to within 3% of the corrected tap value setting over the range of voltages from 60 VL-L to 120 VL-L. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \dfrac{TS \qquad \sin\theta}{(1 \pm M)\ (\sin""75°)}$

8.4. 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 manual impedance of the compensators 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 = 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 ac 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}.

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

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

8.5. Telephone Relays

Connect per ***Figure 5*** (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 can be adjusted by bending the contract-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 accidently S1 and S3 were opened, close S1 first, then close S3).

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 ±10 ms.

Table 1
Nomenclature for Type KST Relay

ITEM	DESCRIPTION
Z_{OS}	Two Element-Coils – Total dc Resistance = 560 to 605 ohms
R_{MA} & R_{MC}	3-1/2 Inch Resistor – 2000 to 3000 ohms adjustable
R_B	2 Inch Resistor – Fixed adjustable taps at 30 & 55 ohms; adjustable 55 to 328 ohms
R_{2A}, R_{2B} R_{2C}	2 Inch Resistor – 600 ohms adjustable
C_{2A}, C_{2C}	1.6 MFD Capacitors
T_A, T_C	Compensator – (Primary Taps – .87; 1.16; 1.6; 2.2; 3.0; 4.2; 5.8)
$T'_B + T_B$	Compensator – (Primary Taps – T'_B = 2.85; 3.9; 4.95. T_B = .0; .15; .3; .45; .6; .75; .9)
S_A, S_C	Auto-Transformer – (Primary Taps - 1; 2; 3)
M_A, M_C	Auto-Transformer – (Secondary between Taps - 0.0; .03; .09; .06)
O_S	Telephone Type Relay – dc Resistance = 475 to 525 ohms
R_{OS}	Fixed Resistor – 2000Ω
T^1	Telephone Type Relay
T^2	Telephone Type Relay – 500Ω dc resistance

TABLE 2

VOLTAGE BURDEN (S = 1)									
M TAP SETTING	I = 0 V_{AN} = V_{BN} = V_{CN} = 69 Volts 3 Phase								
	Phase A			Phase B			Phase C		
	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ
-.15	4.4	**4.02**	**1.80**	6.8	4.0	5.5	3.40	1.0	3.25
-.12	4.6	**4.23**	**1.80**	6.9	4.15	5.4	3.50	1.08	3.33
-.09	4.8	**4.45**	**1.79**	7.1	4.35	5.6	3.60	1.17	3.40
-.06	5.0	4.65	1.79	7.35	4.65	5.7	3.75	1.27	3.53
-.03	5.2	4.85	1.78	7.6	4.40	5.8	3.90	1.40	3.65
0	5.5	5.15	1.78	7.95	5.20	6.0	4.05	1.52	3.77
+.03	5.65	5.35	1.75	8.3	5.30	6.15	4.15	1.63	3.84
+.06	5.9	5.60	1.72	8.55	5.55	6.30	4.35	1.77	4.0
+.09	6.1	5.80	1.69	8.85	5.75	6.4	4.45	1.87	4.08
+.12	6.4	6.15	1.66	9.1	5.10	6.45	4.60	2.0	4.20
+.15	6.6	6.40	1.60	9.45	6.30	6.55	4.75	2.15	4.30

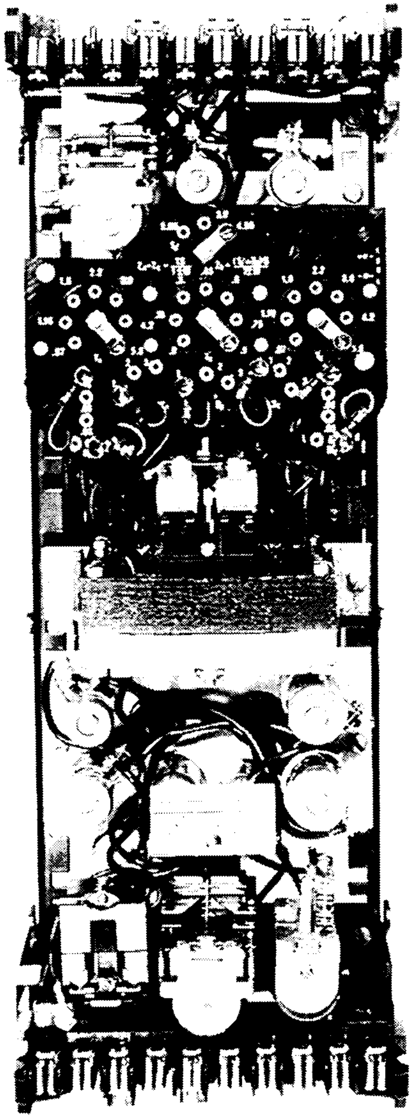
VOLTAGE BURDEN (S = 2)									
M TAP SETTING	I = 0 V_{AN} = V_{BN} = V_{CN} = 69 Volts 3 Phase								
	Phase A			Phase B			Phase C		
	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ
-.15	1.00	.98	.21	1.4	1.07	.9	.55	.275	.475
-.12	1.07	1.05	.214	1.47	1.14	.92	.57	.29	.49
-.09	1.12	1.10	.216	.155	1.21	.97	.59	.306	.505
-.06	1.17	1.15	.217	.165	1.29	1.01	.61	.322	.52
-.03	1.24	1.22	.222	.170	1.34	1.03	.63	.34	.53
0	1.30	1.28	.224	1.78	1.42	1.06	.65	.358	.545
+.03	1.36	1.34	.225	1.86	1.49	1.09	.67	.357	.56
+.06	1.42	1.40	.226	1.95	1.57	1.12	.76	.415	.61
+.09	1.50	1.48	.227	2.04	1.67	1.15	.79	.45	.64
+.12	1.55	1.53	.228	2.10	1.74	1.18	.83	.49	.68
+.15	1.65	1.62	.220	2.20	1.84	1.20	.90	.54	.73

VOLTAGE BURDEN (S = 3)									
M TAP SETTING	I = 0 V_{AN} = V_{BN} = V_{CN} = 69 Volts 3 Phase								
	Phase A			Phase B			Phase C		
	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ
-.15	.45	.445	.096	.69	.56	.407	.286	.152	.243
-.12	.47	.465	.095	.72	.58	.417	.296	.165	.250
-.09	.50	.495	.095	.78	.64	.445	.310	.169	.360
-.06	.52	.415	.094	.83	.685	.465	.320	.177	.268
-.03	.54	.43	.092	.86	.71	.475	.336	.188	.280
0	.56	.445	.090	.90	.75	.485	.346	.196	.286
+.03	.58	.465	.088	.93	.78	.495	.36	.207	.295
+.06	.60	.485	.084	.99	.83	.515	.376	.218	.306
+.09	.62	.61	.080	1.03	.87	.525	.386	.228	.312
+.12	.65	.64	.076	1.06	.90	.53	.405	.242	.324
+.15	.69	.69	.072	1.10	.945	.54	.415	.250	.330

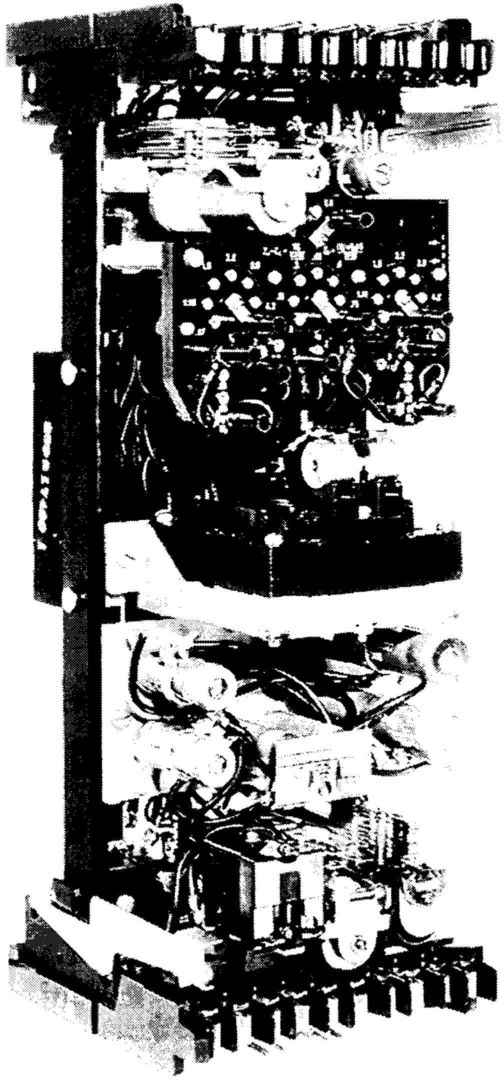
TABLE 3

CURRENT BURDEN $3Ø\ I = 5\ Amp \angle 0°$											
$3Ø\ V = 69\ V_{L-N}$ M = 0 S = 1											
TAP T_A	PHASE A			TAP $T_B + T_B$	PHASE B			TAP T_C	PHASE C		
	Z	R	J_X		Z	R	J_X		Z	R	J_X
.87	.032	.031	**.0079**	0.0 - 2.85	.115	.097	**.062**	.87	.026	.025	**.007**
1.16	.044	.042	**.0131**	.15 + 2.85	.14	.116	**.078**	1.16	.030	.026	**.015**
1.6	.064	.060	**.0223**	.3 + 2.85	.165	.13	**.102**	1.6	.039	**.027**	**.028**
2.2	.074	.062	**.0404**	.45 + 3.9	.19	.15	**.117**	2.2	.052	.030	.043
3.0	.12	.083	**.0867**	.6 + 3.9	.2	.13	**.152**	3.0	.068	.029	.062
4.2	.21	.114	**.176**	.75 + 3.9	.22	.14	**.170**	4.2	.110	.034	.105
5.8	.32	.115	**.299**	.9 - 4.95	.3	.16	**.254**	5.8	.197	.052	.190

CURRENT BURDEN $3Ø\ I = 50\ Amp \angle 0°$											
$3Ø\ V = 69\ V_{L-N}$ M = 0 S = 1											
TAP T_A	PHASE A			TAP $T_B + T_B$	PHASE B			TAP T_C	PHASE C		
	Z	R	J_X		Z	R	J_X		Z	R	J_X
.87	.032	.031	**.008**	0.0 + 2.85	.086	.070	**.050**	.87	.034	.034	.004
1.16	.034	.033	**.008**	.15 + 2.85	.092	.073	.056	1.16	.038	.037	**.009**
1.6	.05	.047	**.017**	.3 + 2.85	.10	.078	.063	1.6	.046	.043	.016
2.2	.06	.051	.032	.45 + 3.9	.154	.105	**.113**	2.2	.066	.056	.035
3.0	.098	.075	.063	.6 + 3.9	.16	.107	**.119**	3.0	.094	.073	.059
4.2	.15	.096	.115	.75 + 3.9	.17	.11	**.130**	4.2	.144	.092	**.111**
5.8	.24	.14	.195	.9 + 4.95	.24	.15	**.187**	5.8	.230	.134	.187

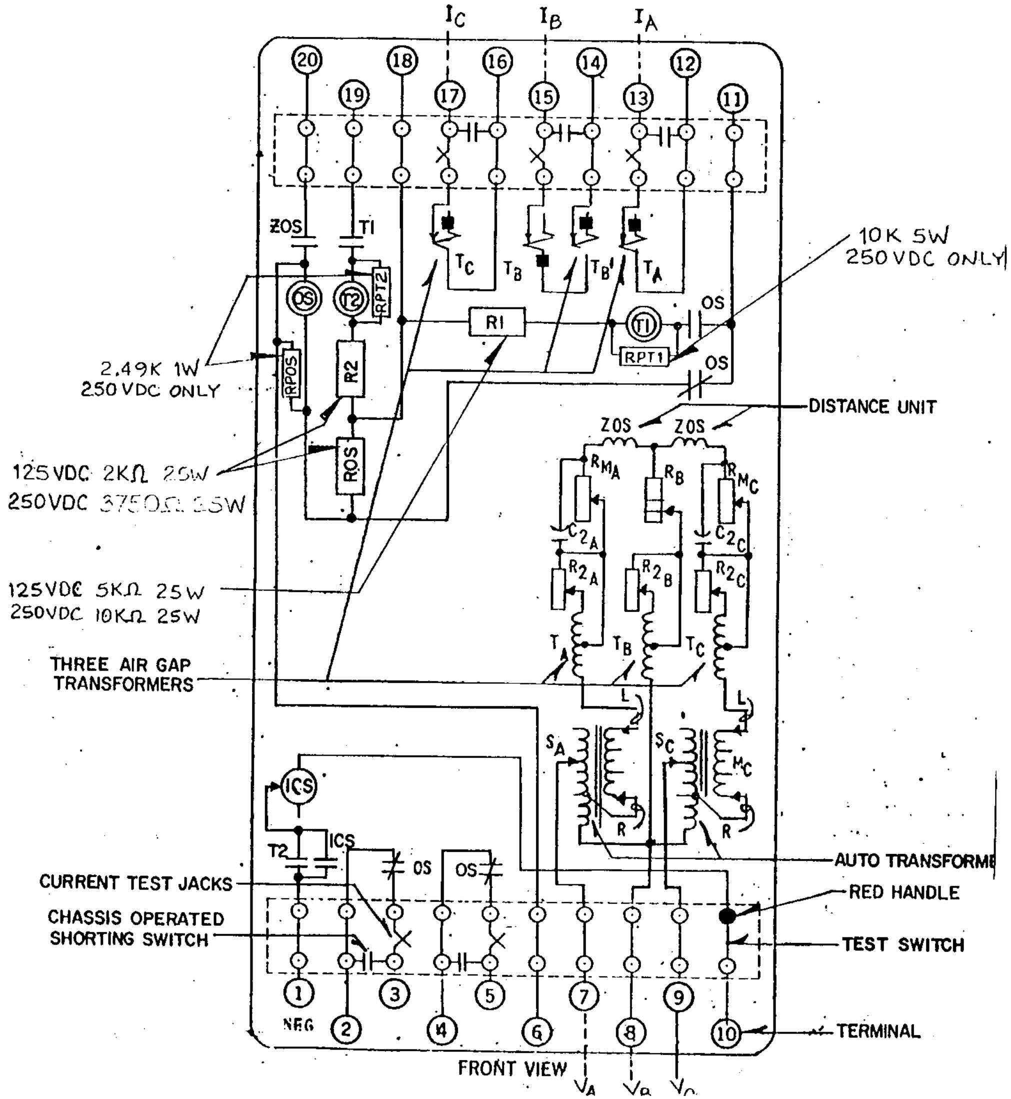


Front View Photo



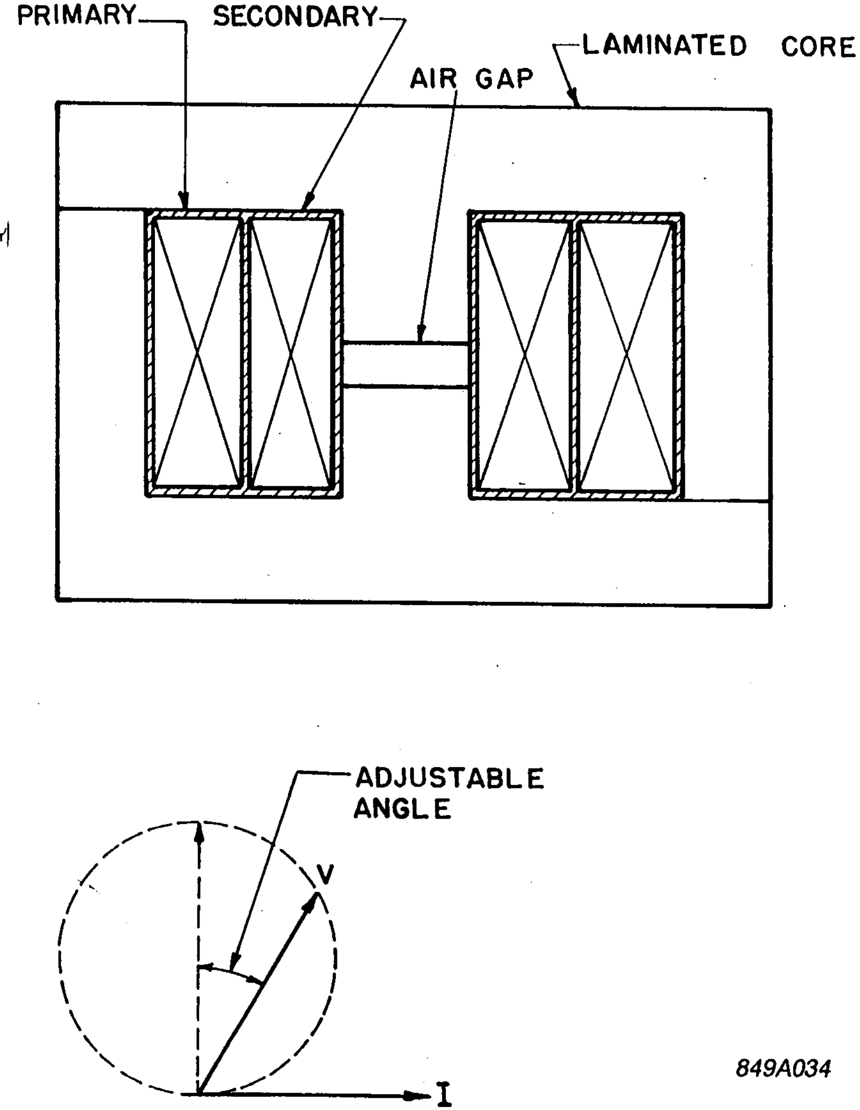
Side View Photo

Figure 1. Type KST Relay Chassis



3490A33

Figure 3. Internal Schematic



849A034

Figure 2. Compensator Construction

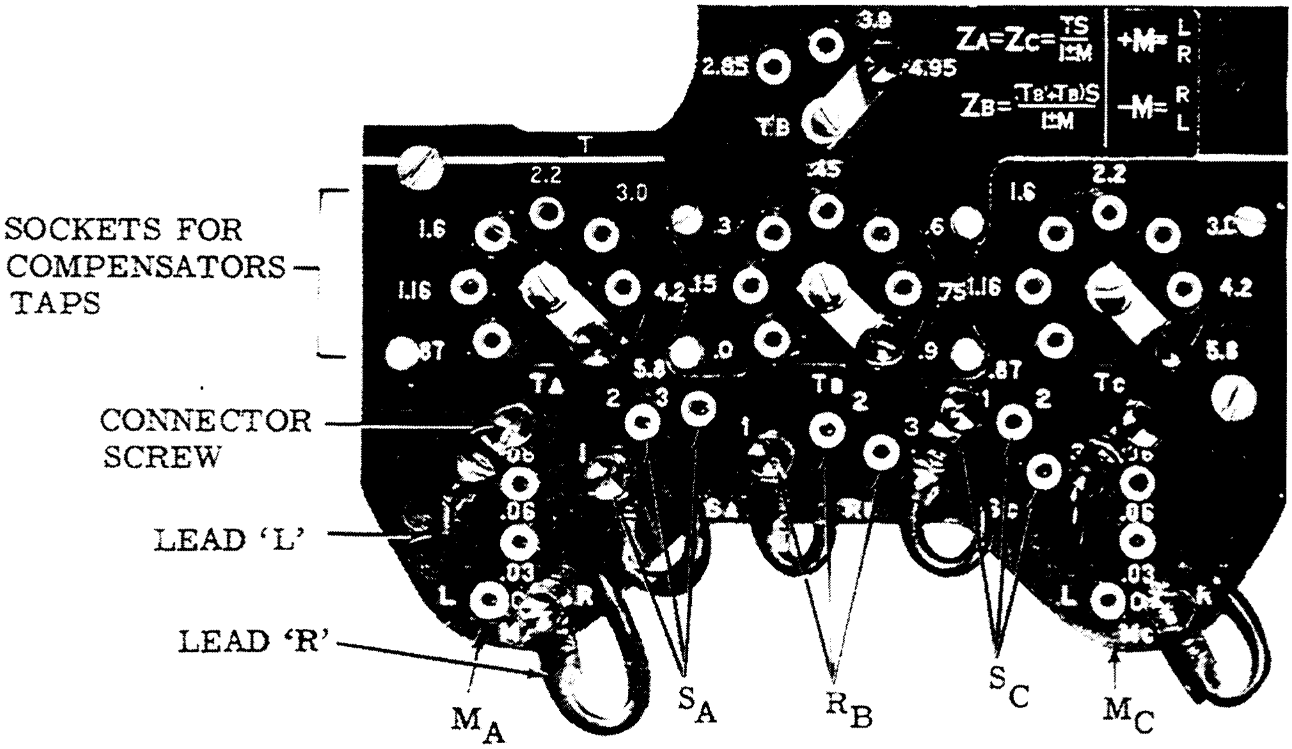
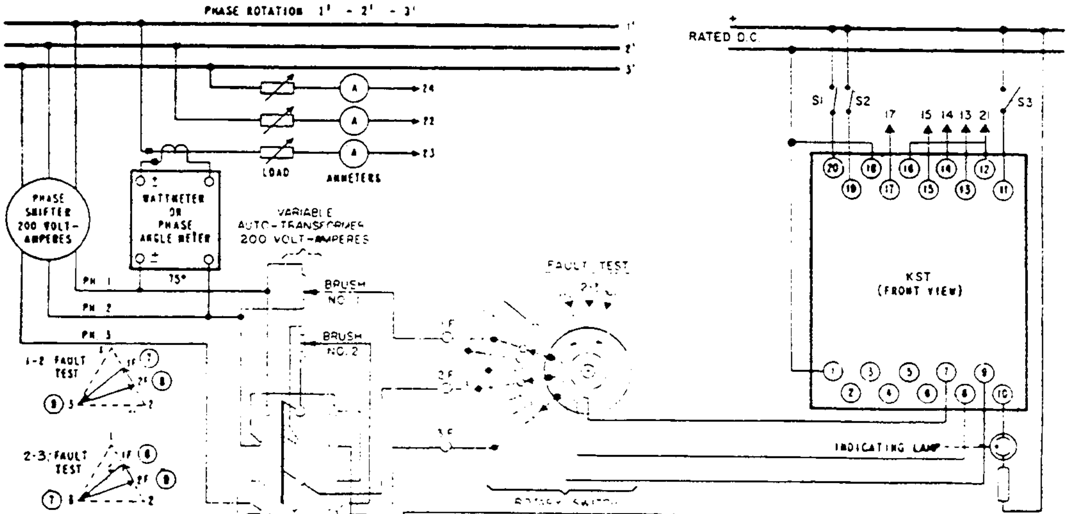


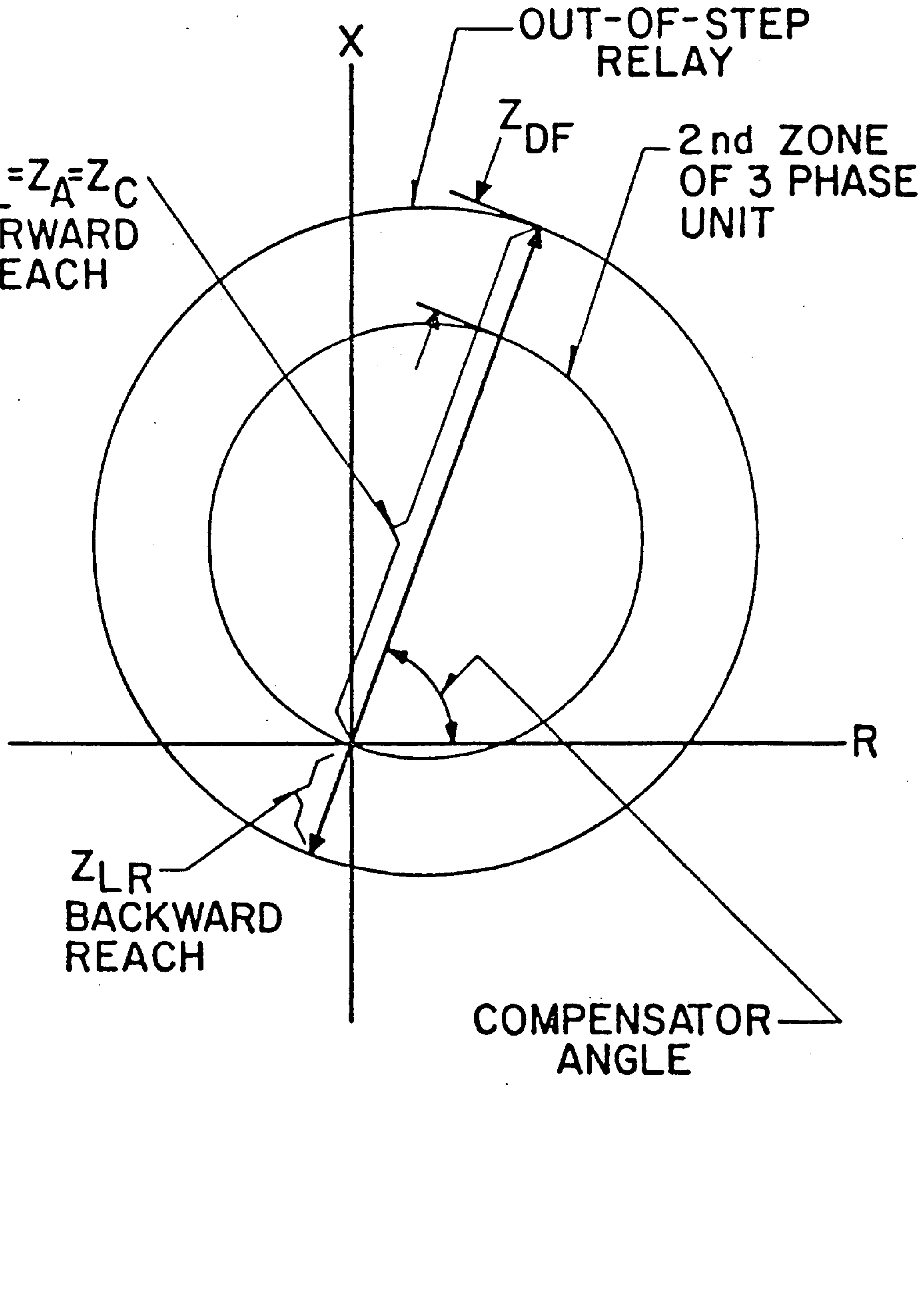
Figure 4. Tap Plate



	TEST NO	SELECTOR*	FAULT TEST	TO CHECK OR ADJUST	CONNECT FROM/TO			
	1	3 Ø	1-2	R_{2A}	23/13	22/21		
	2	3 Ø	2-3	R_{2B}	23/14	22/15		
	3	3 Ø	3-1	R_{2C}	23/17	22/21		
	4	Ø-Ø	1-2	R_{MA}	23/13	22/14	21/15	
	5	Ø-Ø	2-3	R_{MC}	23/14	22/17	21/15	
	6	Ø-Ø	3-1	CHECK	23/17	22/13		
$Z = V_{L-L}/\sqrt{3}I$	7	3 Ø	1-2	IMPED. CIR.	23/13	22/15	21/14	24/17
$Z_L = V_{L-L}/2I$	8	3 Ø††	3-1	FOR'D. B.P.	23/17	22/13		
$Z_{LR} = (V_{L-L}/\sqrt{3}I)-1/3\ Z_L$	9	3 Ø	2-3	REV. B.P.	23/14	22/15		

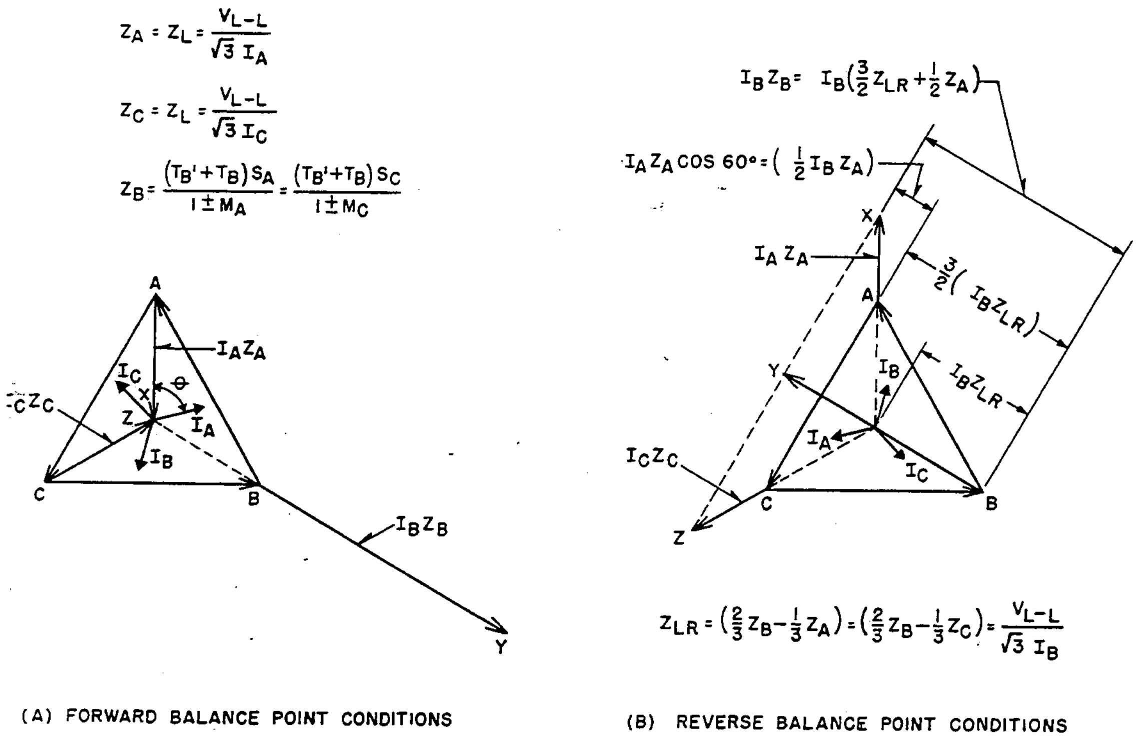
†— SUBTRACT 30° FROM THE PHASE-ANGLE-METER READING TO DETERMINE THE RELAY MAXIMUM TORQUE ANGLE WHEN THE SELECTOR IS IN THE 3Ø POSITION, UNLESS THE TABULATED POSITION IS FOLLOWED BY THE DOUBLED NOTE ††.

Figure 5. Test Connections



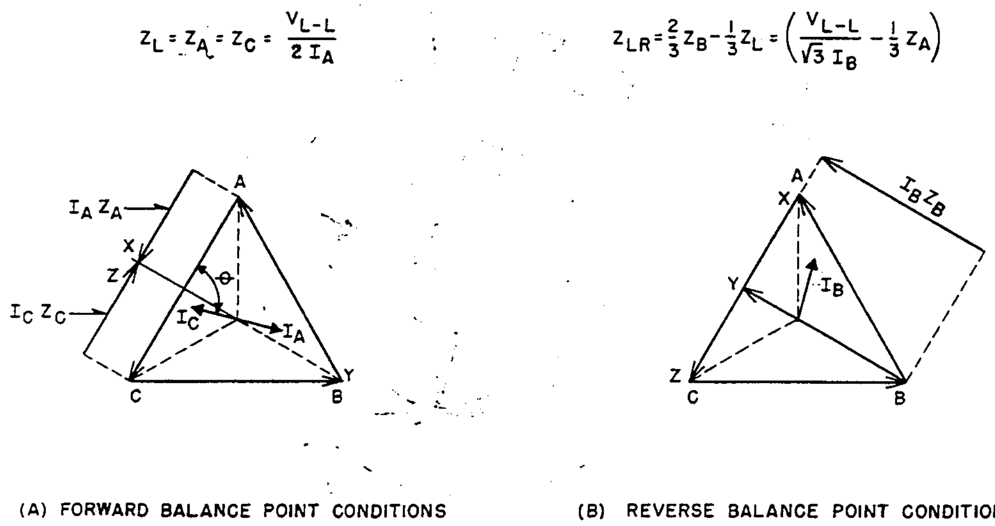
9642A98

Figure 6. KST Relay Characteristics



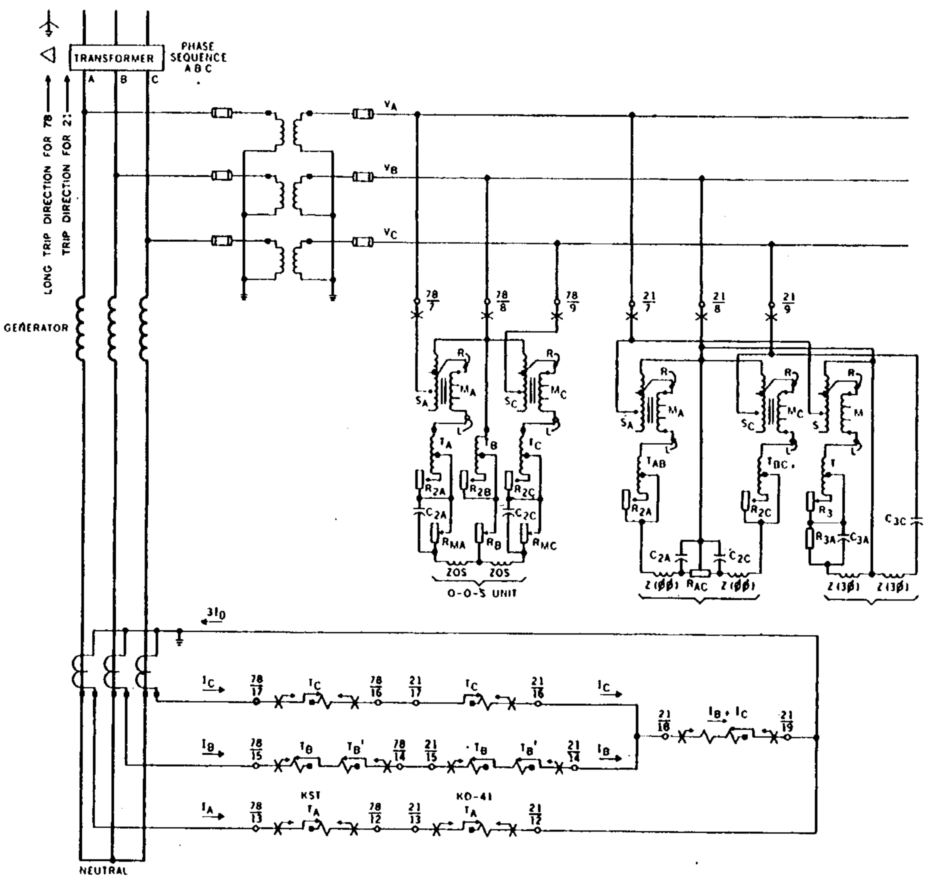
184A527

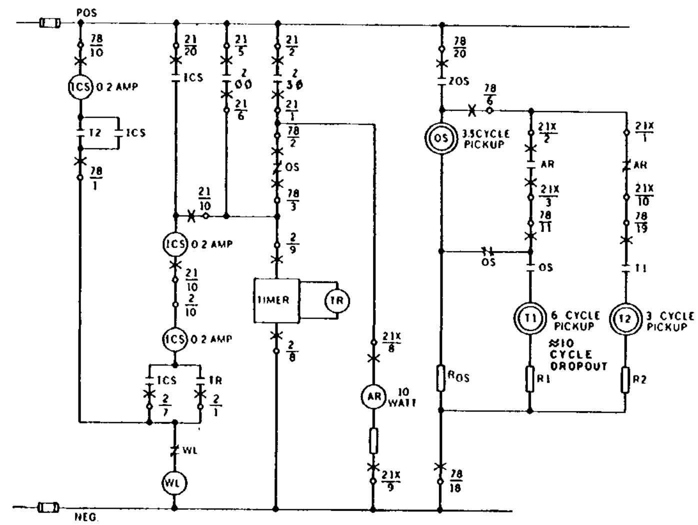
Figure 7. Vector Diagram of the forward and Reverse B.P.



184A528

Figure 8. Vector Diagram for the Artificial Reverse Balance Point condenser when Testing with Single Phase Current.



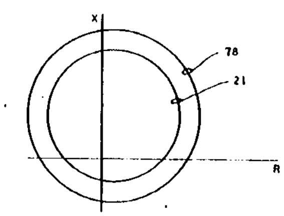


NOTE: OPERATE TIMES SHOWN FOR TELEPHONE RELAYS ARE NOMINAL RATED VOLTAGE VALUES

DEVICE CHART

DEVICE NO	TYPE	FUNCTION	INTERNAL SCHEMATIC
2	TD-5	TIMER	187A293
21	KD-41	GENERATOR BACKUP	862A196 *
21X	AR	AUXILIARY TO 21	837A113
78	KST	OUT OF STEP TRIP	3490A33
WL	WL	TRIP AND LOCKOUT	

* NOTE SPECIAL KD-41 CONTACT CONFIGURATION



6663D62

Fig. 9 External Schematic

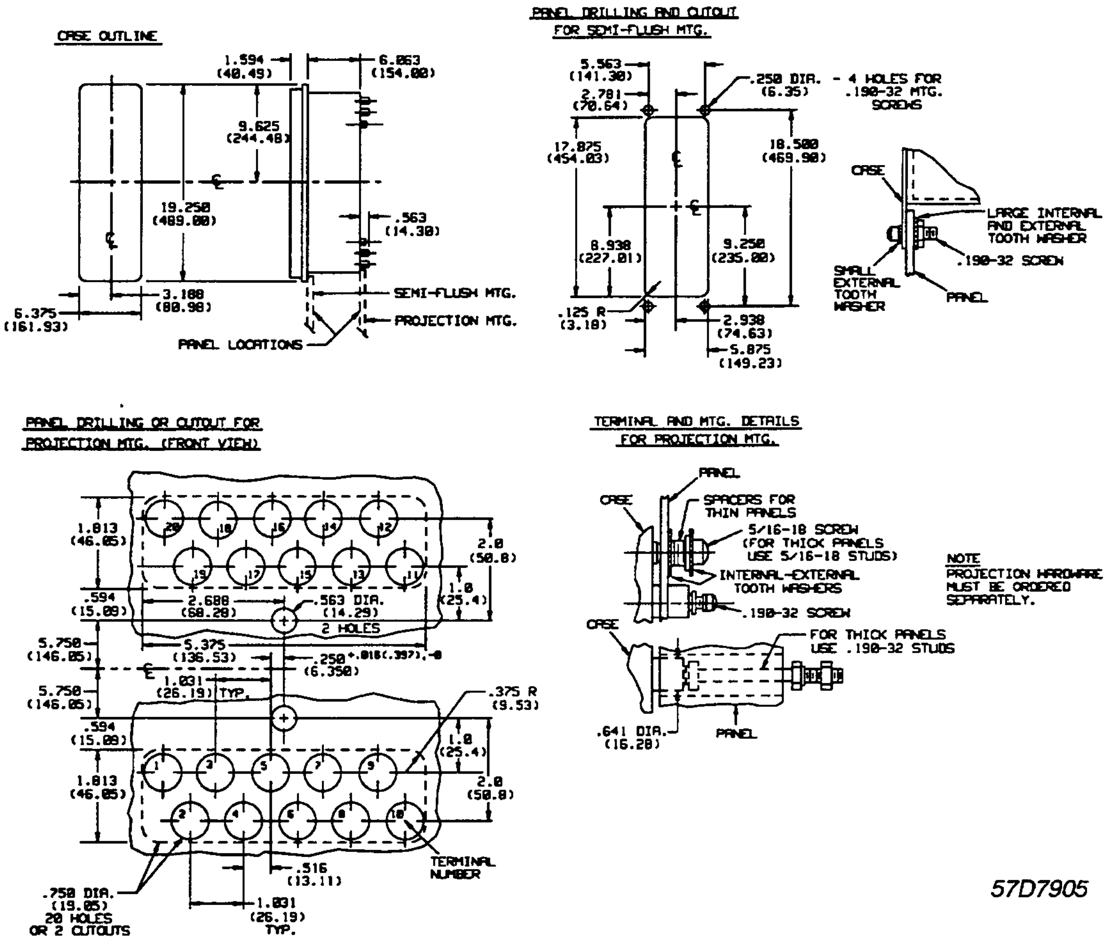


Figure 10. Outline-Drilling Plan for the KST Relay.