INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION AND OPERATION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay mounted in the type FT32 relay case.

Compensator

Sensitivity to out-of-step conditions is provided by three single-air-gap transformer-type compensators designated as T_A, T_B'-T_B, and T_C. Each of the compensators is proportioned so that its mutual impedance Z_C has a known and adjustable value. T_A and T_C are adjustable from 0.87 ohm to 5.8 ohms in 30 percent steps and T_B'-T_B can be set from 2.85 ohms to 5.85 ohms in steps of 0.15 ohms.

Compensator mutual impedance is defined as the ratio of secondary induced voltage to primary current. The secondary (voltage) winding of the compensator is in two sections. One section is provided with an adjustable loading resistor and serves as a lag coil for varying the phase-angle relation between primary current and secondary induced voltage over a range from 60 to 85 degrees. The other section 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.

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 increase 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.

Auto-Transformer

An auto-transformer with a buck or boost fine-tap secondary (M) makes it possible to expand the basic range of the compensators T_A, T_B'-T_B, and T_C by multipliers (S) of 2 or 3. Voltage of the first section of the primary can be changed by the use of the S = 2 of S = 3 tap. When connected to S = 1, the auto-transformer serves only to excite the secondary M which has four taps. The value between each of the secondary taps is a percentage of the first section of the primary across which the cylinder unit circuit is always connected. The arrangement is such that any multiple of 3 percent (from 3 to 15 percent) may be added to or subtracted from the compensator tap value. Therefore, any setting can be made within plus or minus 1.5 percent from 0.75 ohm to 20 ohms by combining the compensator tap T with the auto-transformer taps S and M.

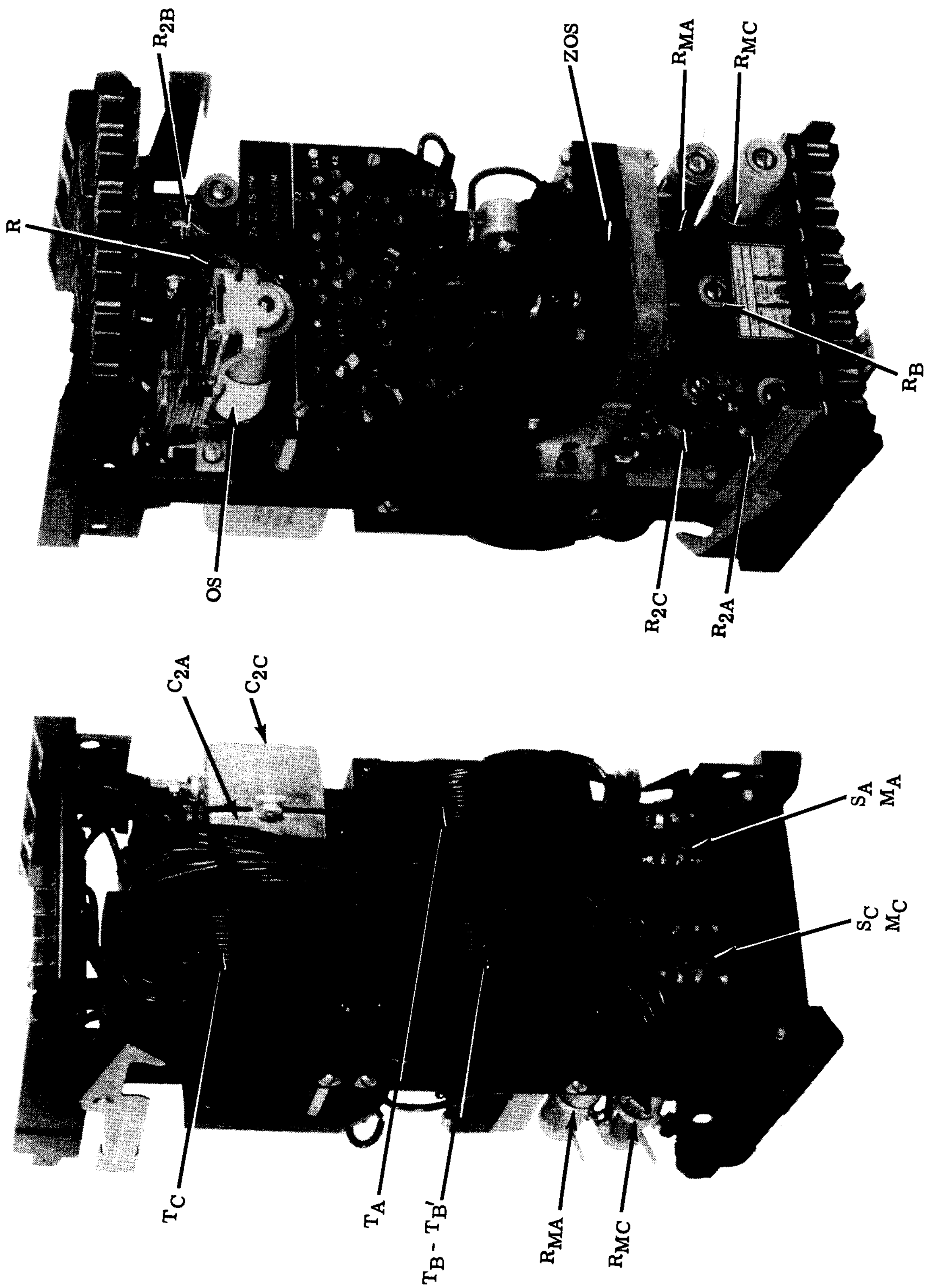


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

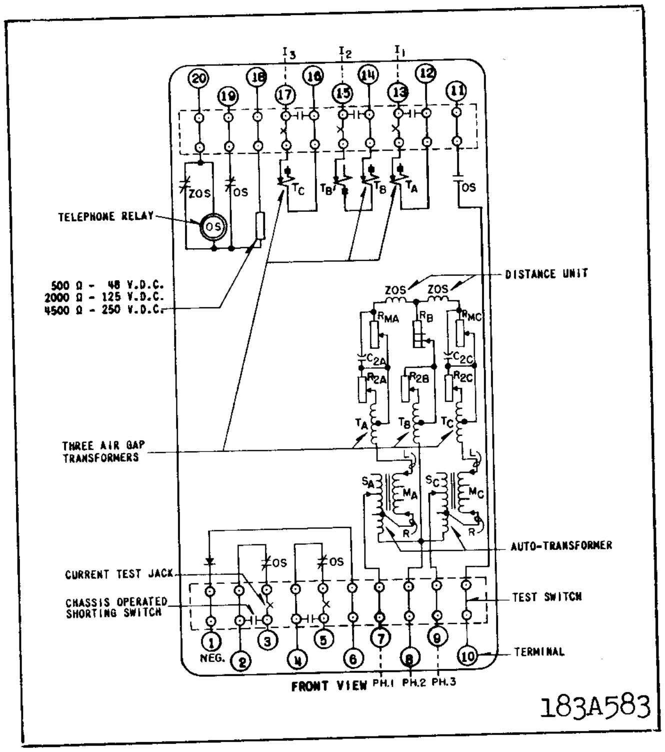


Fig. 2. Internal Schematic of the Type KS Relay in FT32 Case.

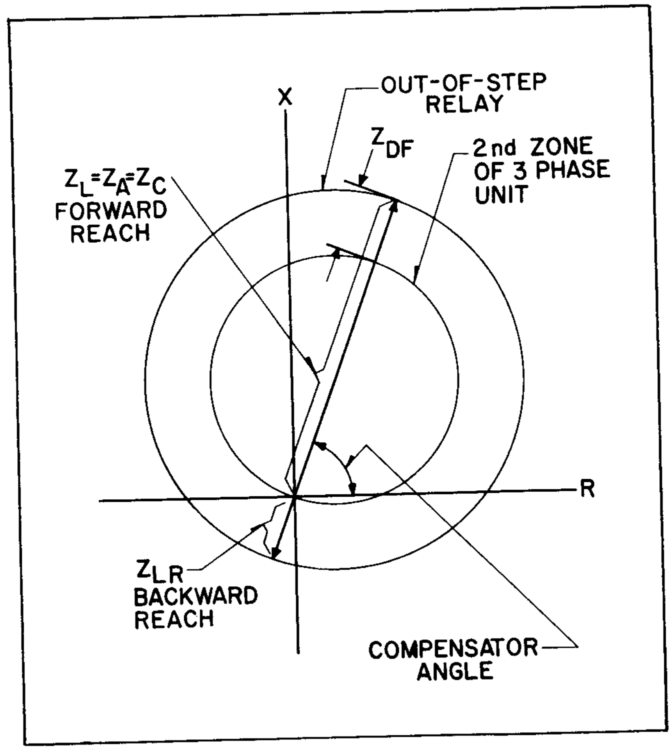


Fig. 3. Relay Characteristic on an R-X Diagram.

Cylinder Unit

The device which acts to initiate tripping is a four-pole cylinder unit which is connected open delta and operates as a three-phase induction motor. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 magentic core from the frame.

The electromagnet has two series-connected coils mounted diametrically opposite one another to excite each set of poles; two magnetic adjusting plugs; upper and lower adjusting plug clips, 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 magnetic adjusting plugs are not used for calibration in the KS relay and should be screwed all the way down.

The moving element assembly consists of a spiral spring, contact carrying member, and an aluminum cylinder assembled to a moulded 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 with the cylinder rotating in an 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 1, 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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit in Figure 2, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition.

The KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the Z_2 KD relay will operate followed after a short time delay by the Z_1 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, one or two relays may be operated, but if more than the Z_2 relay is to be operated, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

CHARACTERISTICS

Referring to Figure 3, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay's three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of Z_2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles, its OS contacts located between the $\frac{78}{4}$ and $\frac{78}{5}$ terminals shown in the trip circuits section of Figure 3. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the Z_2 contacts close. When Z_2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

SETTINGS

The type relay requires an ohm setting high enough so that its impedance circle completely surrounds, with a 2 ohm margin, the impedance circle of the Z_2 KD relay's three-phase unit. The angle of maximum torque should be the same as that of the KD relay. The forward-looking reach Z_L is equal to the setting Z_A and Z_C. $Z_A = Z_C = TS\,(1 \pm M)$ and the sub-letters refer to the T_A and T_C compensators. The backward reach Z_{LR} is a function of Z_B as well as Z_L where $Z_B = (T_B' - T_B)S\,(1 \pm M)$. When the proper value of Z_{LR} is determined (usually 2 ohms) then the setting for Z_B can be calculated.

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

The S & M settings of the auto-transformer are determined in the setting of the forward reach.

At the line angle in the forward direction, the ohmic difference, Z_{DF} will generally be set for two ohms. When the two circles are concentric, the backward reach, Z_{LR}, is equal to Z_{DF}. The forward reach, Z_L, can be set up to 20 ohms. The reverse reach, Z_{LR}, can be set at most any practical value with the best coverage at two ohms.

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}.

The induced compensator secondary voltage V_c varies with the sine of the maximum torque angle when the primary current is maintained at a constant value. A 90° setting occurs when the compensator loading resistor is open-circuited and the reach of the compensator is at its maximum value for a given tap setting T.

$$Z_{(90^{\circ})} = \frac{T}{\text{SIN } 75^{\circ}}$$

$$= \frac{V_c}{I} \quad \text{For the Phase-to-phase unit.}$$

At any maximum torque angle θ, the actual compensator setting (value of T in ohms) is given by the formula

$$Z_{(\theta)} = Z_{(90^o)} \text{ SIN } \theta$$

$$= \frac{T \text{ SIN } \theta}{\text{SIN } 75^o}$$

The compensator induced voltage V_c is directly proportional to Z when the primary current is constant. Therefore

$$V_{c\ (\theta)} = V_{c\ (90^o)} \text{ SIN } \theta$$

A simple method of adjusting the maximum torque angle to any value, θ, is as follows:

1. Set T_A and T_C on the 5.8 tap, T_B' on 4.95 and T_B on 9.
2. Disconnect the "L" leads of sections M_A and M_C.
3. Connect terminals 13 to 15, 14 to 16 and pass 5 to 10 amperes A.C. current in terminal 17, and out of terminal 12.
4. Measure the compensator voltage with a high resistance voltmeters (5,000 ohm/volt) and adjust the loading resistors as tabulated below:

Measure			
From terminal	To fixed end of	Adjust	So that
"L" of M_A	R_{2A}	R_{2A}	$V_c\ (\theta) = V_{c(90^o)} \text{ SIN } \theta$
8	R_{2B}	R_{2B}	$= \frac{TI \text{ SIN } \theta}{\text{SIN } 75^o}$
"L" of M_C	R_{2C}	R_{2C}	

5. All of the "L" leads should be reconnected to the M tap after the line-angle adjustment is completed.

The following procedure should be followed in order to obtain an optimum forward setting of the relay.

1. Select the lowest tap, S, which gives a product of 6.7 S greater than Z_L.
2. Select a value for T that is nearest the value $\frac{Z_L}{S}$.
3. Determine the value of M that is nearest $\frac{Z-TS}{TS}$. If the sign is positive, then the M taps are connected to raise TS. ("R" connected above "L" raises the value of TS.)

For example, assume the desired value of Z_L to be (7 + 2) = 9 ohms.

1. The lowest tap, S, for 6.7 S which is greater than 9 ohms is S = 2.
3. $\frac{9-8.4}{8.4} = +\ 0.071$ (use M = 0.06)
4. Then Z_L = 4.2 X 2 (1 + 0.06) = 8.91 ohms which is 99.0% of the desired value.

Set the reverse reach as follows:

1. Solve for $Z_B = 1/2\ Z_L + 3/2\ Z_{LR}$.
2. Since $Z_B = (T_B' + T_B)S\ (1 \pm M)$ and $S(1 \pm M)$ is known, then set (1) equal to (2) and solve for $(T_B' + T_B)$.
3. Determine the highest value of T_B which is less than $(T_B' + T_B)$ and subtract it to find T_B.

For example, the forward reach is set for 8.91 and Z_{LR} is 2 ohms.

1. $Z_B = 1/2\ (8.91) + 3/2\ (2) = 7.45$.
2. $(T_B' + T_B) = \frac{7.45}{2(1.06)} = 3.52$.
3. Maximum T_B' which is less than 3.52 is T_B' = 2.85. Therefore T_B = 3.52 - 2.85 = 0.67. Use the 0.6 tap.

Now, Z_B = (2.85 + 0.6) (2) (1 + 0.06) = 7.32 ohms

And, Z_L = 8.91 ohms

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

$$= -\ 1.91 \text{ ohms}$$

If a backward reach of slightly more than 2 ohms is desired, choose T_B = 0.85; then Z_{LR} = -2.11 ohms.

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 for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either of the studs or the mounting screws may be utilized for grounding the relay. The

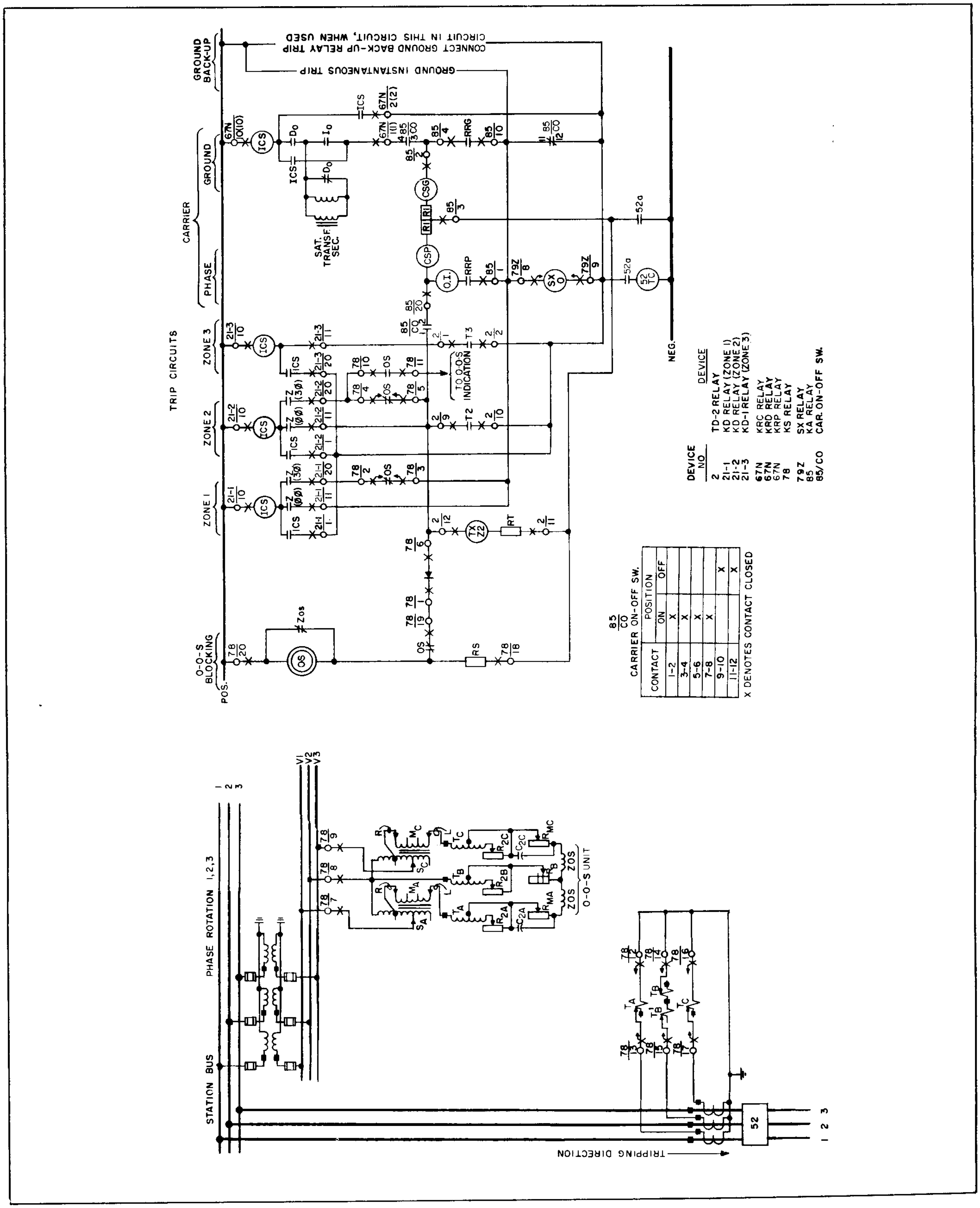
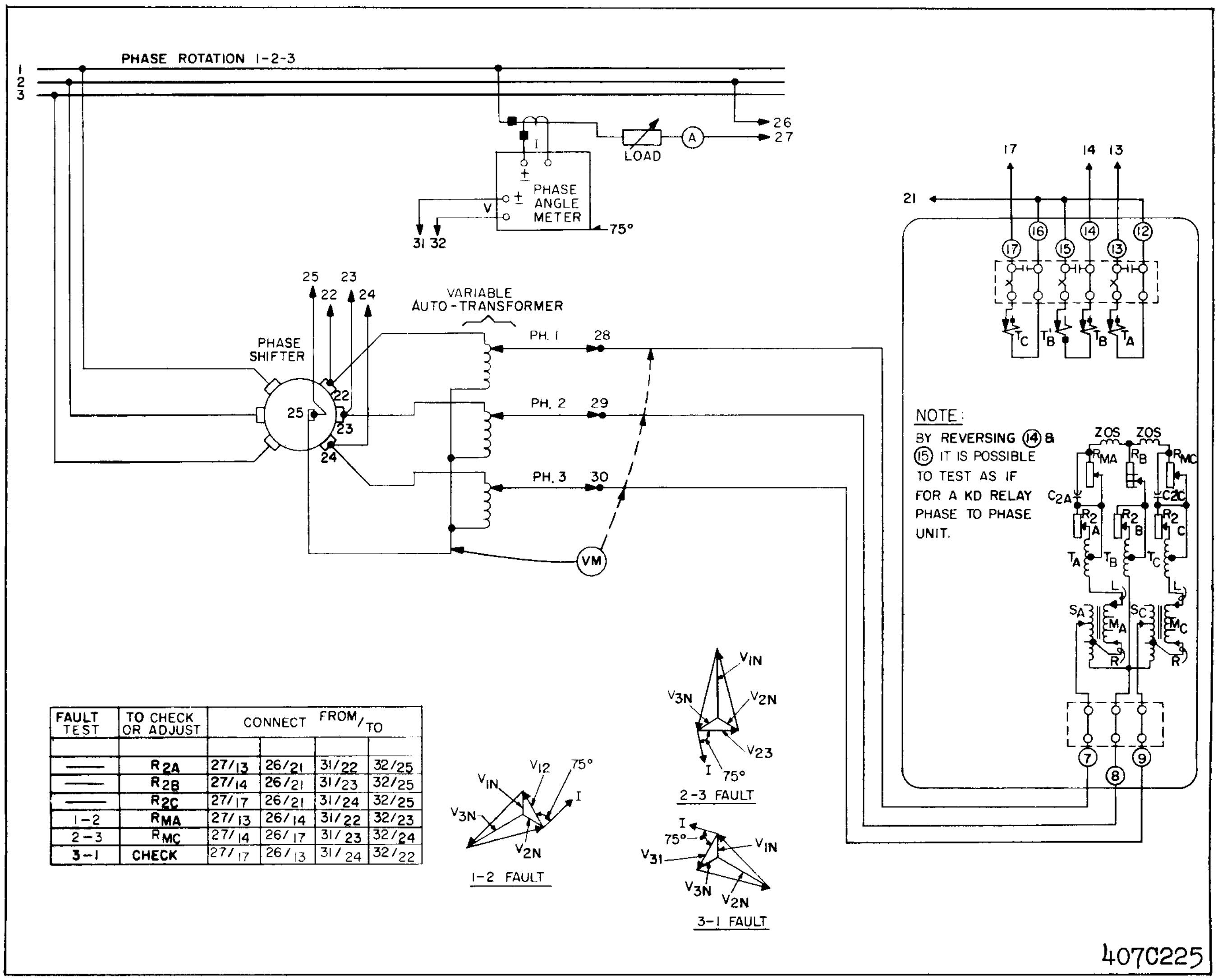


Fig. 4. External Schematic of the Type KS Relay with K-DAR Carrier Relaying.



FAULT TEST	TO CHECK OR ADJUST	CONNECT FROM/TO			
——	R_{2A}	27/13	26/21	31/22	32/25
——	R_{2B}	27/14	26/21	31/23	32/25
——	R_{2C}	27/17	26/21	31/24	32/25
1-2	R_{MA}	27/13	26/14	31/22	32/23
2-3	R_{MC}	27/14	26/17	31/23	32/24
3-1	CHECK	27/17	26/13	31/24	32/22

Fig. 5. Test Connections for the Type KS Relay.

electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the studs and then turning the proper nut with a wrench.

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

Acceptance Check

The following check is recommended to insure that the relay is in proper working order:

Use the same procedure as outlined in the section titled "Line Angle Adjustment" to check the compensator mutual impedance and angle of maximum torque. A more complete check can be made by connecting the relay as is shown in Figure 5.

Maximum Torque Angle

Refer to Figure 5 and the line of connections titled "To Adjust R_{2A}". Set phase -1, phase -2, and phase -3 all equal to 30 volts and pass 10 amperes through the current circuit. Turn the phase shifter until the moving-contact breaks contact with the stationary-contact. Record the degrees of phase angle, at this position, by which the current in the phase angle meter lags the voltage. Now continue to swing the phase shifter in the same direction until the contacts close again. Record this angle. The angle of maximum torque for the T_A compensator is equal to

$$\frac{(\text{Degrees to open left}) + (\text{Degrees to close right})}{2} = \theta$$

θ should be 75^0. This maximum torque angle may be changed or adjusted by adjusting R_{2A}.

With these values of voltage and current, the difference in the two angles will be about 50 degrees. An increase in the resistance of R_{2A} will give an increase in the maximum torque angle.

Reconnect the relay as shown on the lines, To Adjust R_{2B} and R_{2C}. The procedure for checking the angle and adjusting the resistors is the same as for adjusting R_{2A}.

Compensator Reach

The operation of the KS relay's impedance measuring unit is very similar to the phase-to-phase unit of the KD relay. The primary difference is that the compensator T_{B}' -T_B has its polarity reversed so that its secondary induced voltage is additive rather than subtractive. By reversing the polarity of the current in the primary winding in the manner indicated by the test connections of Figure 5, the relay can be checked and tested as a phase-to-phase impedance measuring unit.

Set T_A and T_C at 5.8; T_B'-T_B at 5.85, S_A & S_C = 1; and M_A and M_C = 0. Use the connections listed for a "3-1 Fault Test" and adjust the phase shifter so that the phase angle between current and voltage, read on the phase angle meter, is the same as the maximum torque angle setting of the compensators. Set the voltages V_{3-N} and V_{1-N} equal to 30 volts and V_{2-N} equal to 56 volts. (56 volts is the equivalent of $V_{2-N} + V_C$ for an actual operating condition where $V_C = IZ_B$). Vary the current to determine at what value the contacts just open. The forward reach of the relay then is

$$Z_L = \frac{\sqrt{3} \text{ X } 30 \text{ volts}}{2 \text{ X } I}$$

This value should be Z_L= 5.8 ohms.

Reverse reach: use the same settings as before and connect the relay as if to adjust R_{2B}. Set V_{3-N} and V_{1-N} equal to 45 volts. Set V_{2-N} equal to 15 volts. (This simulates the voltage conditions at the cylinder unit for an actual operation). Set the phase angle between current and voltage equal to the maximum torque angle setting of the compensators. Record the current at which the cylinder unit contacts open. The reverse reach of the relay then is

$$Z_{LR} = \frac{15 \text{ volts}}{I}$$

This value should be

$$Z_{LR} = 2/3\ Z_B - 1/3\ Z_L$$
$$= 1.97 \text{ ohms}$$

Telephone Relay

Energize the telephone relay circuit through terminals 18 and 20 with rated D-C voltage. The relay, OS, should not operate because the ZOS contacts held closed by the spring restraint on the cylinder short circuit its coil. Open the ZOS contacts and see that the OS unit operates.

ADJUSTMENTS AND MAINTENANCE

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, or if it is desired to check the adjustments at regular maintenance periods, the instructions below should be followed.

All contacts should be periodically cleaned. 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.

The procedure for adjusting the maximum torque angle of the relay has been described in the section titled "SETTINGS" and also under "Acceptance Check". It is necessary then to only calibrate the cylinder unit circuits.

With the stationary contacts open so that the moving contact will not touch them, set the moving-contact spring adjuster so that the contact floats freely in the gap. Make sure that there is no friction which prevents free movement of the cylinder and contact arm. The cylinder unit can be withdrawn for easy access to the bearings by removing the two screws (one on each side) which anchor the cylinder unit casting to the relay frame. The screws are held by nut-plates which remain in position after the screws are removed. Thus the cylinder unit can be dismantled, inspected, and remounted with very little effort.

1. Set T_A, T_B'-T_B, and T_C all on their highest tap value; S_A, R_B, and S_C on the No. 1 tap; M_A and M_C set for .09 between L and R with L over R.

2. Adjust R_{2A}, R_{2B}, and R_{2C} for the desired angle.

3. Connect terminals 7 and 8 together with a short jumper and apply rated voltage between 8 and 9. Adjust R_{MA} so that the contact floats or has a minimum of torque. This is a rough adjustment for balancing the impedance angle of phase-1 equal to the impedance angle of phase-2.

Connect terminals 8 and 9 together and apply rated voltage between 7 and 9. This time adjust R_{MC} so that the contact floats or has a minimum of torque. This rough adjustment is for balancing the angle of phase-3 equal to the angle of phase-2.

4. Three-phase test: connect the relay as shown in Figure 5. The phase shifter should be rotated so that the phase angle between current and voltage, read on the phase angle meter, is the same as the compensator maximum torque angle setting.

a. For a 1-2 fault with V_{1-N} and V_{2-N} adjusted to 2.9 volts and V_{3-N} adjusted to 69 volts record the current that will cause the moving contact to float between the two stops.

b. Connect for a 2-3 float. V_{2-N} and $V_{3-N} = 2.9$ volts; $V_{1-N} = 69$ volts. Record the current that floats the contact for this fault.

c. Connect for a 3-1 fault. V_{3-N} and $V_{1-N} = 2.0$ volts; $V_{2-N} = 69$ volts and record this current.

d. Now divide the sum of the three current values by 3 to obtain an average current at which the contact should float. Repeat part (a) for 1-2 but this time set the current equal to the average value just determined and make the moving contact float (or have a minimum of torque) by adjusting R_{MA} again. Repeat part (b) for a 2-3 fault and make the moving contact have a minimum force by adjusting R_{MC} with current set to the average value. Repeat part (c) for a 3-1 fault. No adjustment is made with this connection, but the current is recorded, as before, to be used for determining a new average current.

e. The values of current for a 1-2 and a 2-3 fault are now both equal to one another, (they were set that way), and probably different from the value for a 3-1 fault. So determine the new average current by taking 1/10 the difference between the two values and use that value to add to or subtract from the value for 1-2 and 2-3 faults in order to make it approach the value for a 3-1 fault. Repeat part (d) until the contact-floating current is equal for all three fault combinations. At first there might 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 three or four trails.

f. Reverse the voltage phase sequence by connecting phase-1 of the voltage supply to terminal 9 and phase-3 to terminal 7. Adjust the voltages V_{1-N}, V_{2-N}, V_{3-N} to 2.0 volts and position the moving contact spring adjuster so that the contact just floats. Then reconnect phase-1 and phase-3 leads to terminals 7 and 9 respectively.

g. Contact gap: with the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

Telephone relay: with the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

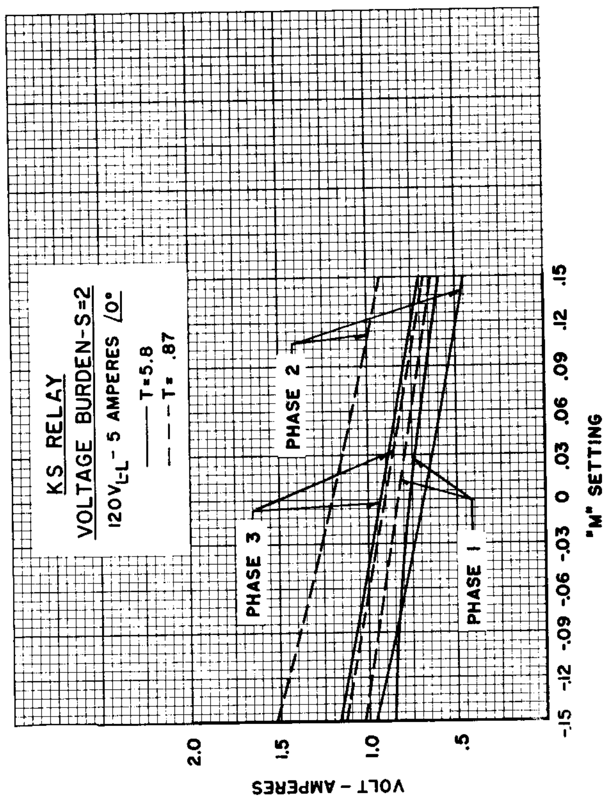
The relay is now calibrated and ready for service.

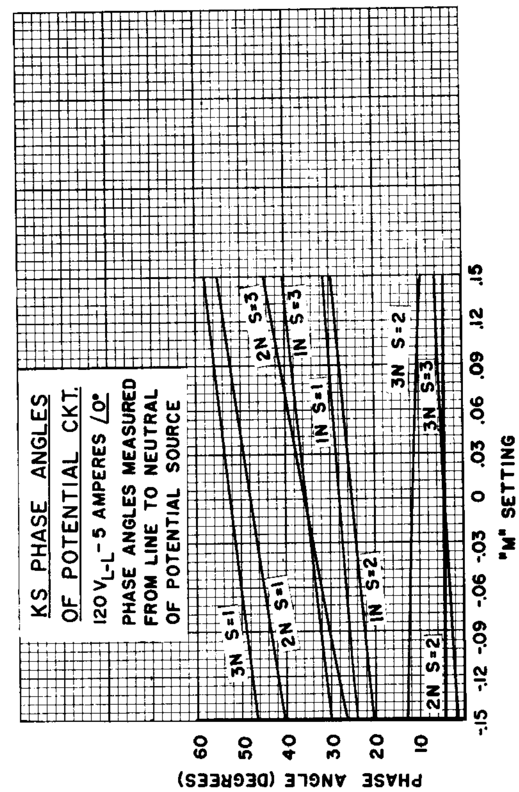
TABLE I

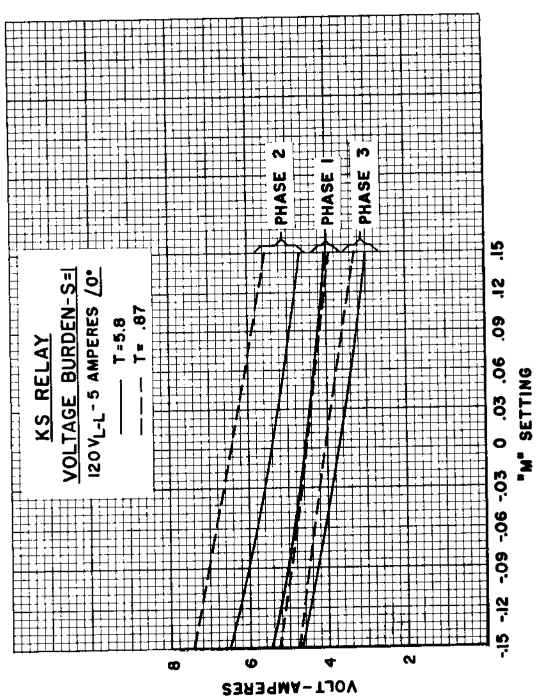
NOMENCLATURE FOR TYPE KS RELAY

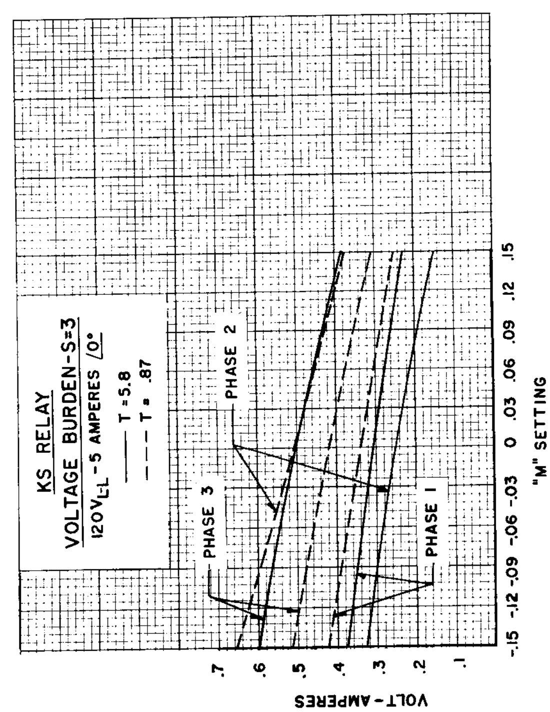
ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. Resistance = 560 to 605 ohms
R_{MA} & R_{MC}	3-1/2 Inch Resistor – 0 to 3000 ohms Adjustable
R_B	2 Inch Resistor – Fixed Taps at 273; 290; 328 ohms
R_{2A}, R_{2B}, R_{2C}	2 Inch Resistors – 600 ohms Adjustable
C_{2A}, C_{2C}	1.6 MFD Capacitors
T_A, T_C	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; 3.94; 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; .06; .06)
OS	Telephone Type Relay – D.C. Resistance = 475 to 525 ohms

ENERGY REQUIREMENTS

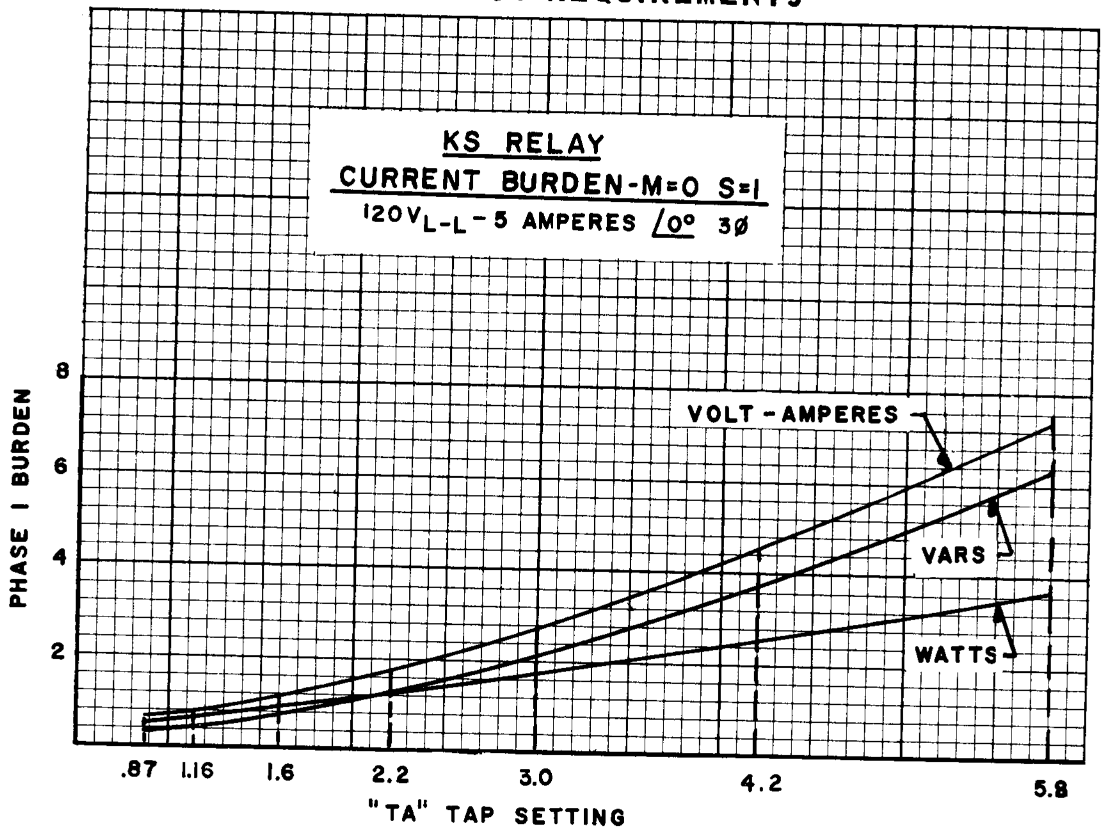


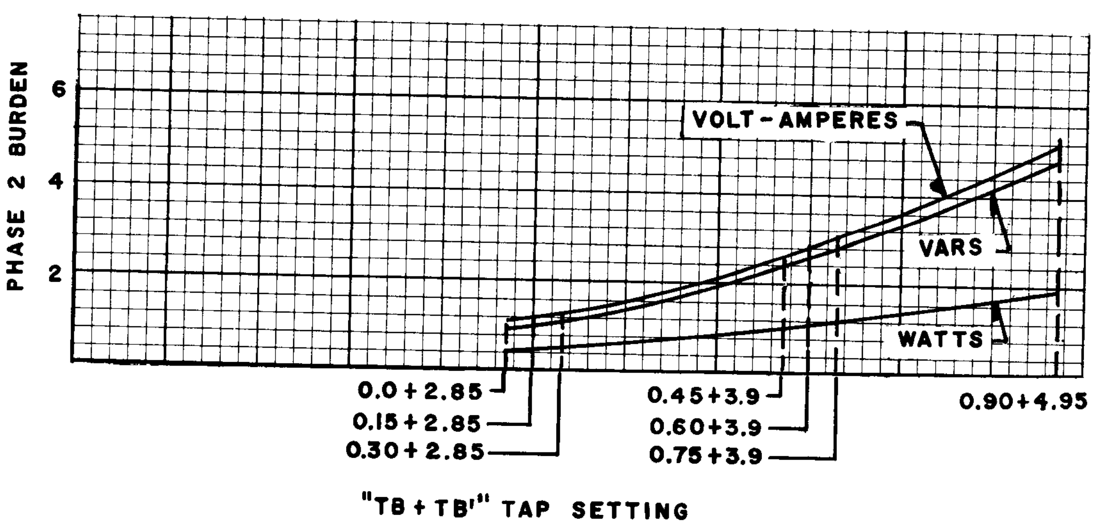


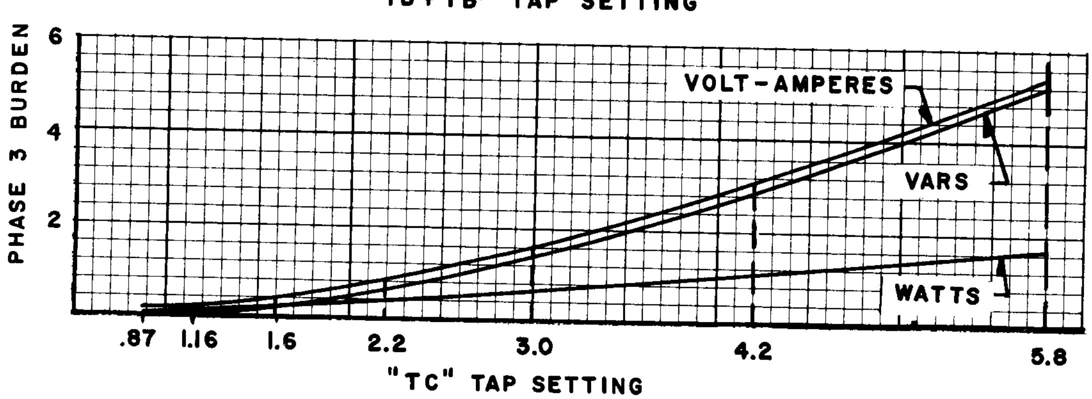




ENERGY REQUIREMENTS







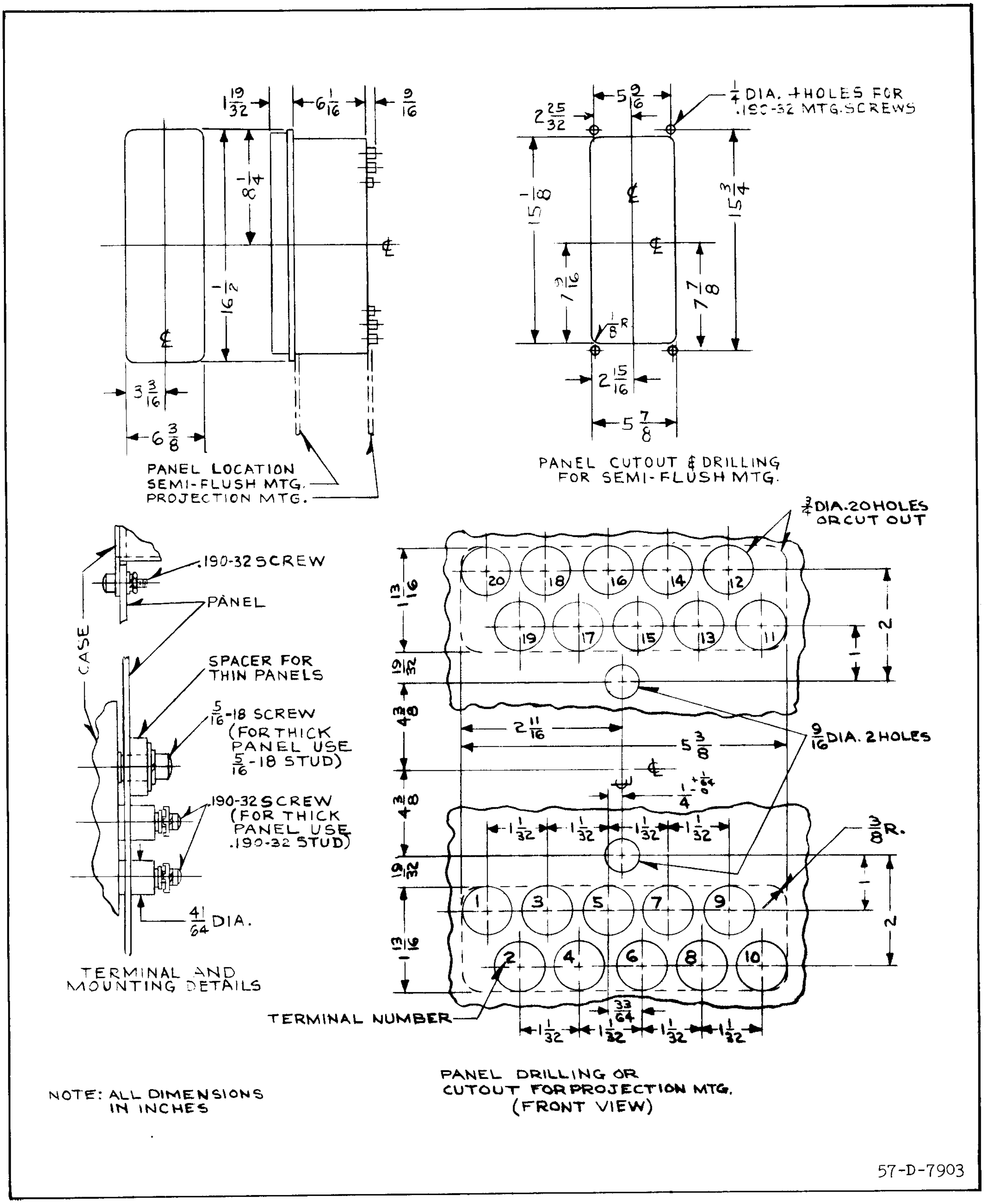


Fig. 6. Outline – Drilling Plan for the Type KS Relay in the FT32 Case.

WESTINGHOUSE ELECTRIC CORPORATION

METER DIVISION • NEWARK, N.J.

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INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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 previsely 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^{o} and 80^{o} by adjusting the resistor between its minimum and maximum values respectively. The factory setting is for a maximum torque angle of 75^{o} current lagging voltage.

Auto-Transformer

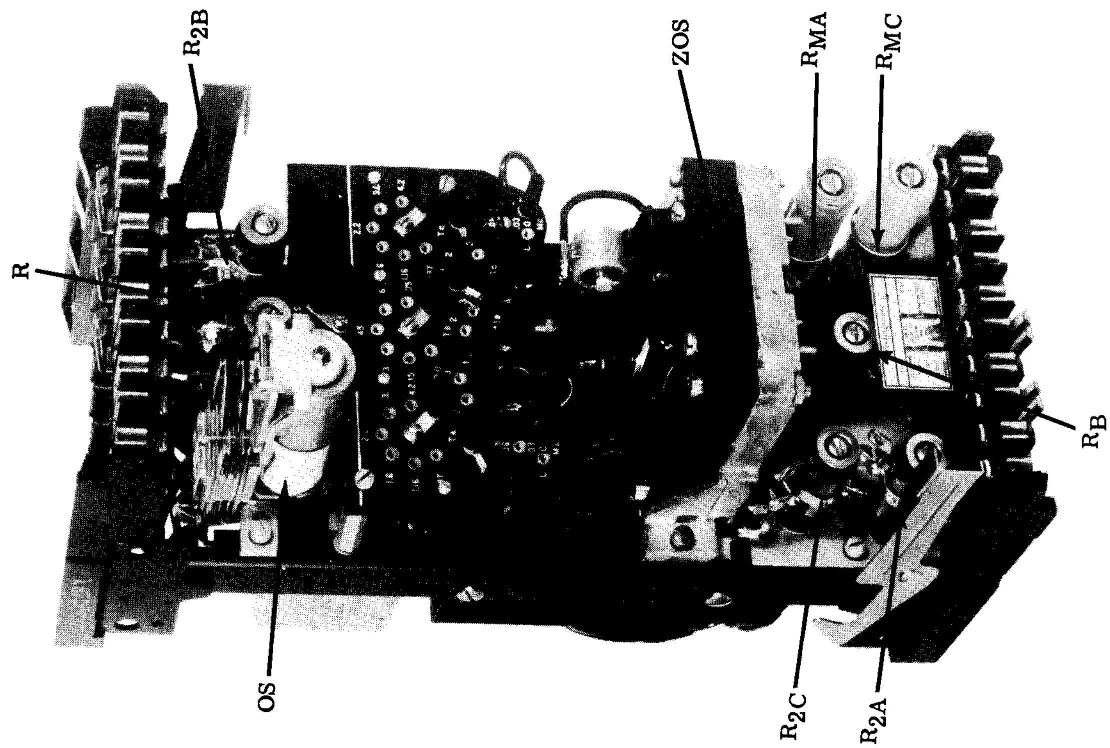
The auto-transformer has three taps on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps which may be connected additively, or subtractively to inversely modify the S setting by any value from -15 to +15 percent in steps of 3 percent.

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 .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 ralay 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 S_A and M_A, and S_C and M_C.

SUPERSEDES I.L. 41-492
Complete Revision

EFFECTIVE OCTOBER 1959



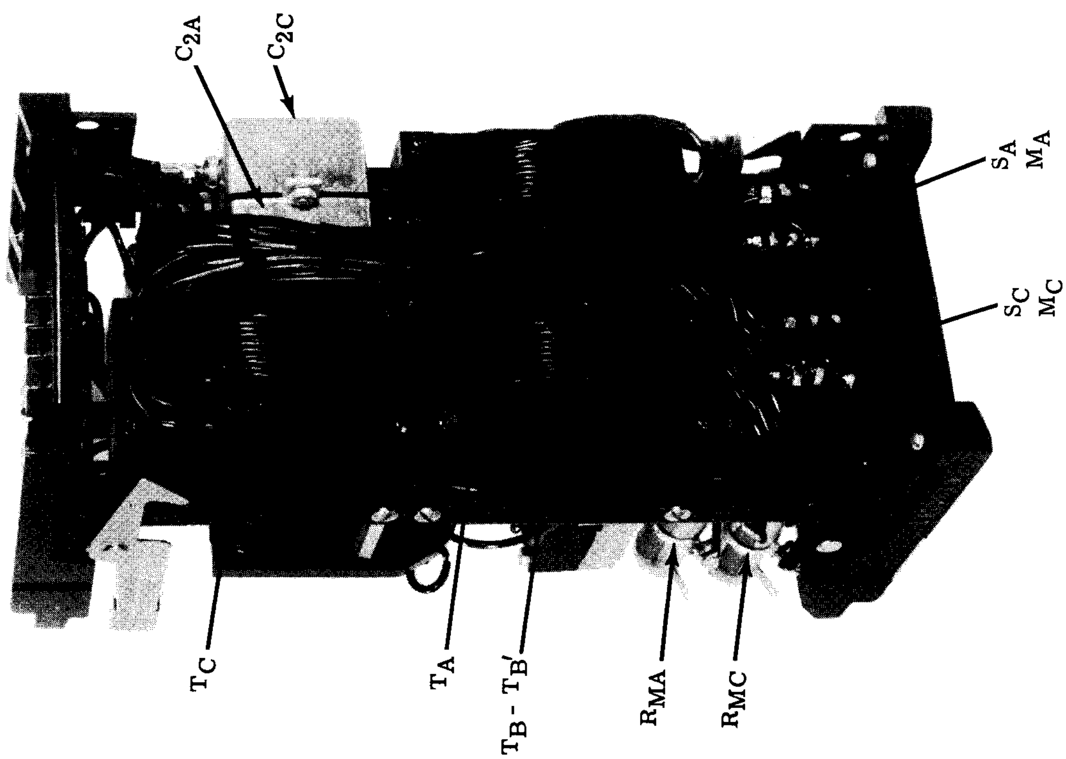


Fig. 1: Type KS Out-of-Step Blocking Relay without Case.

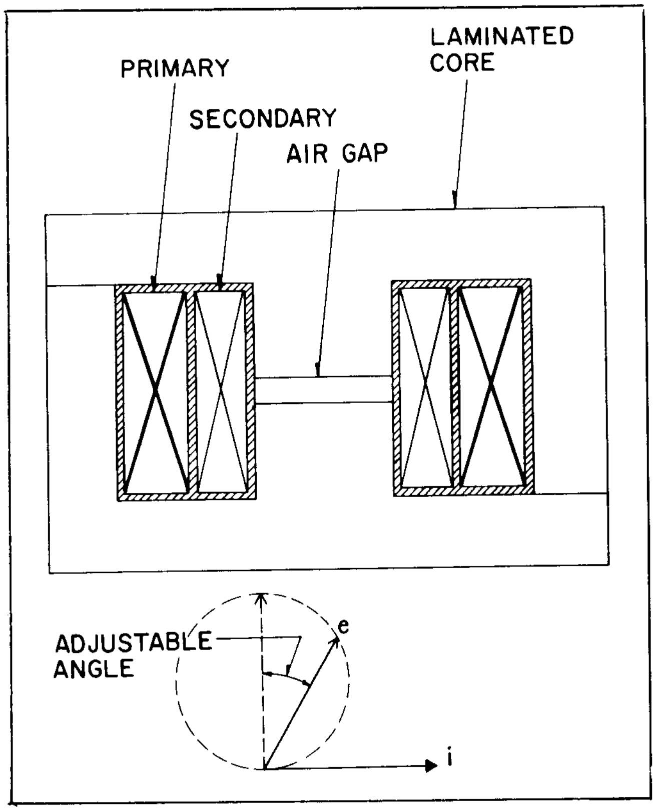


Fig. 2. Compensator Construction.

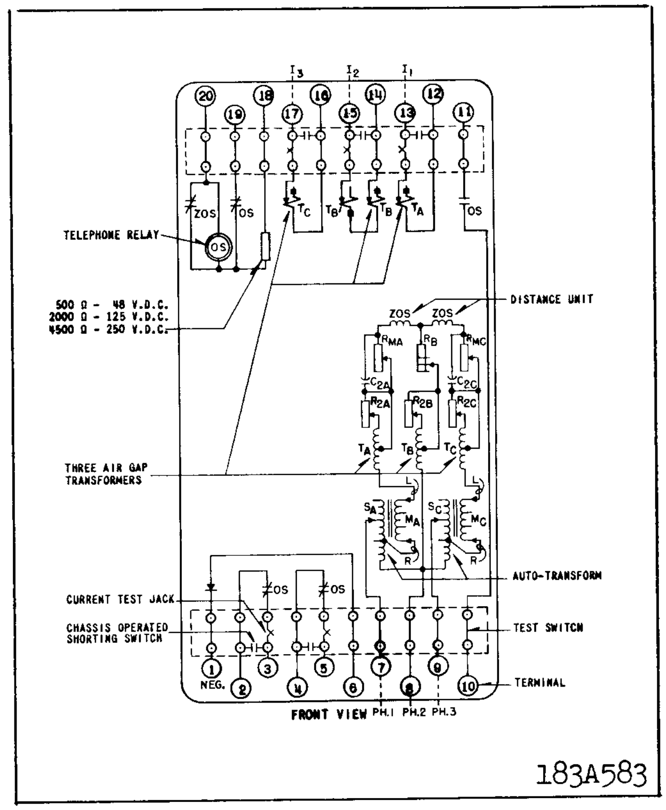


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

Cylinder Unit

The device which acts to initiate tripping is a four-pole cylinder unit which is connected open delta and operates as a three-phase induction motor. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 moulded 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 with the cylinder rotating in an 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.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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 on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps 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 .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 ±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.

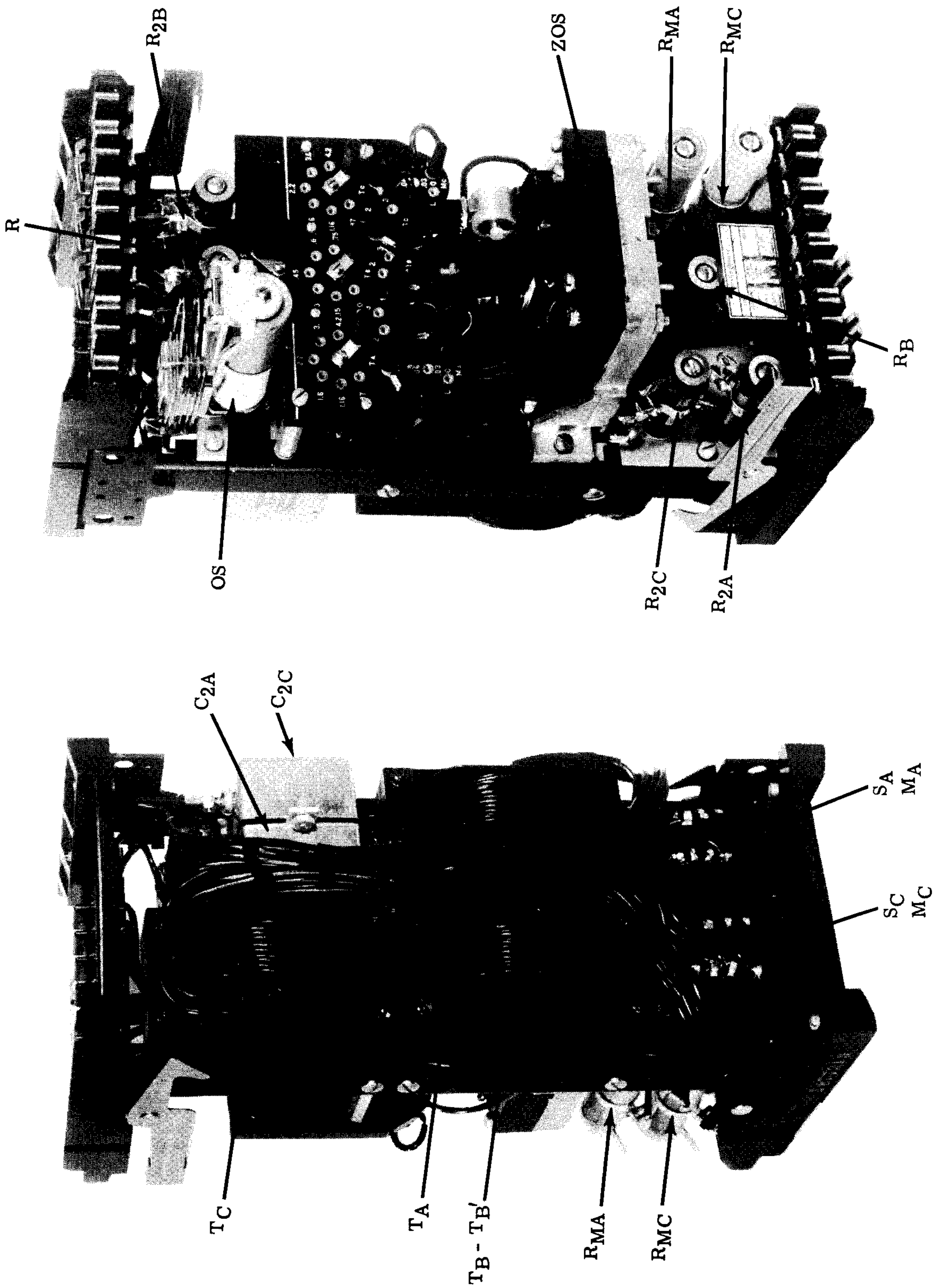


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

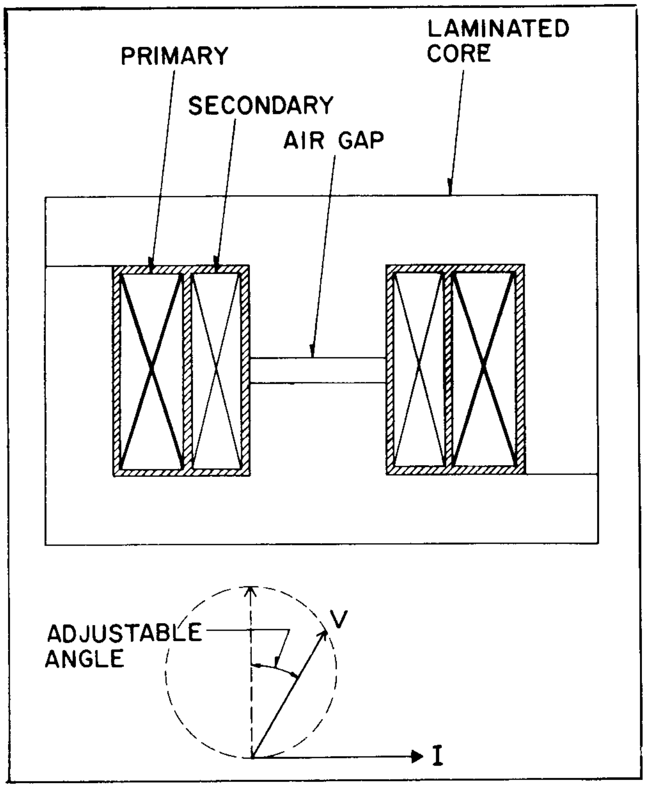


Fig. 2. Compensator Construction.

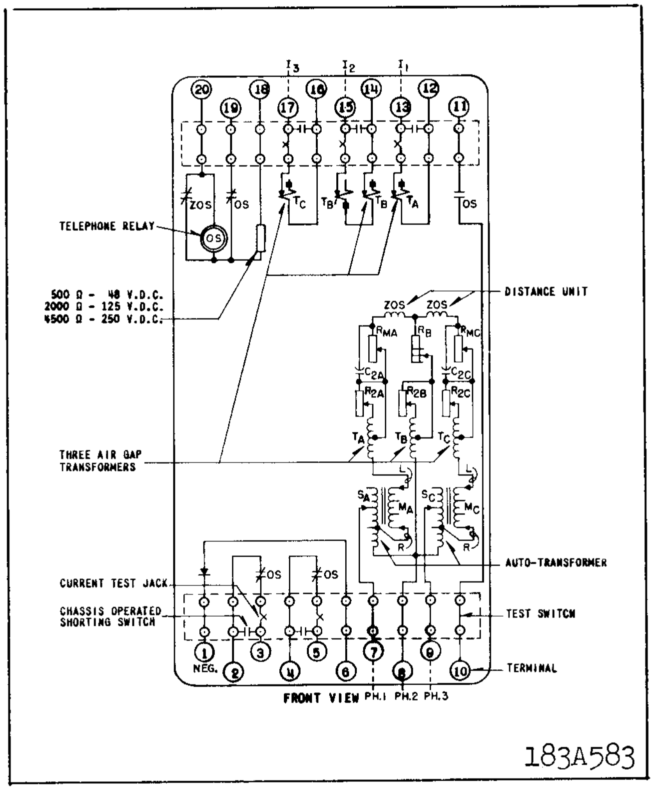


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 sprial 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 adjusted 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.

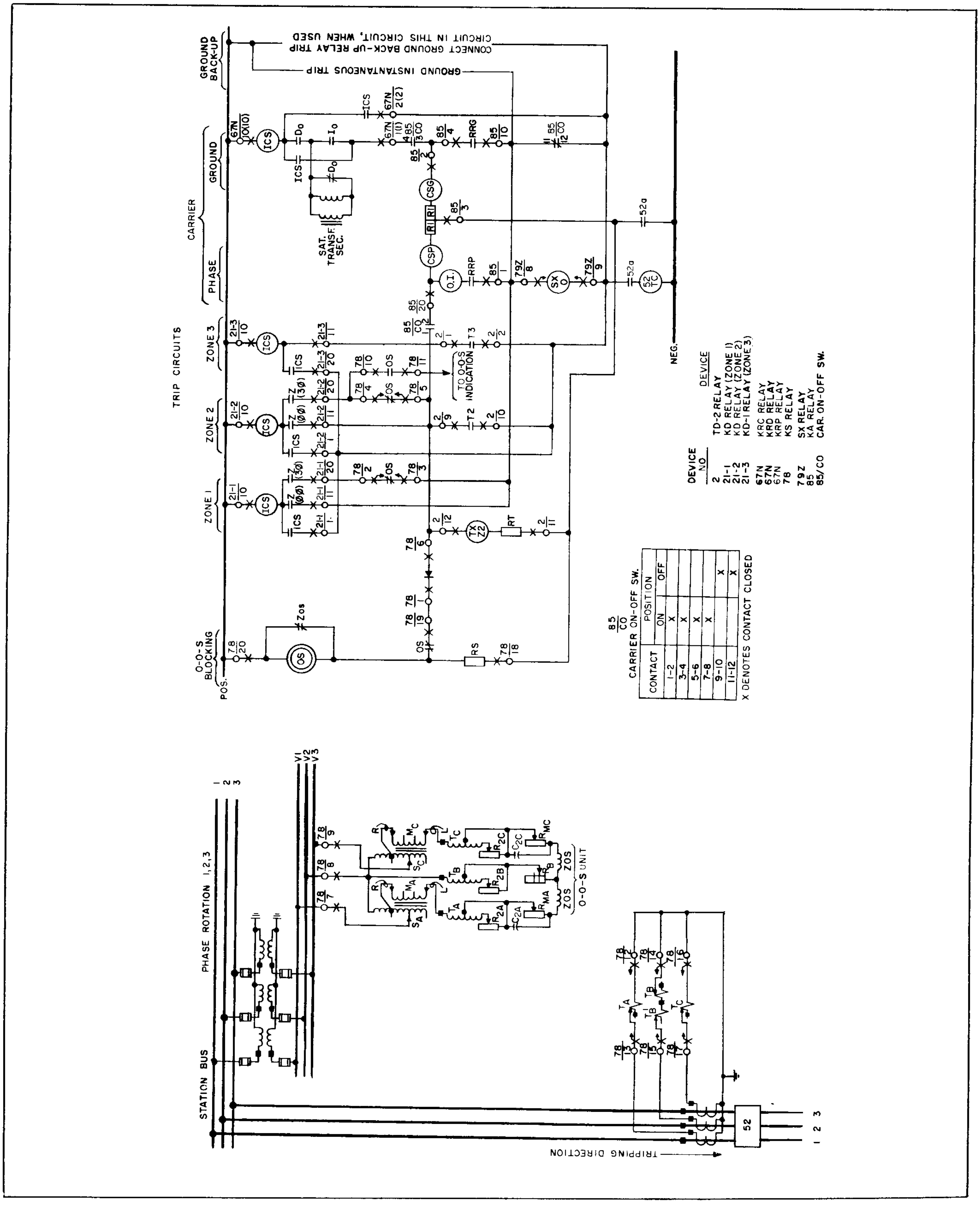


Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.

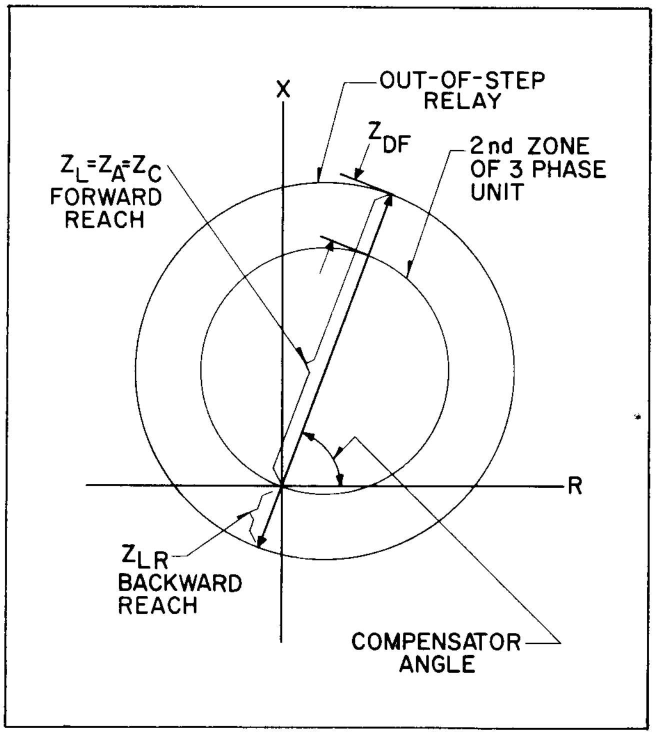


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figure 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles, its OS contacts located between the $\frac{78}{4}$ and $\frac{78}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 8 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)						
.87	1.16	1.6	2.2	3.0	4.2	5.8

(T_B)						
0	.15	.3	.45	.6	.75	.9

T_B'		
2.85	3.9	4.95

(S_A, S_C, R_B)		
1	2	3

	(M_A, M_C)		
± Values between taps	.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 Figure 6 and Figure 7. The potential burden and * burden phase angle are based on 69 volts line-to-neutral applied to the relay terminals.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay three-phase unit with a 2 ohm margin. The angle of maximum torque should be the same as that of the KD

relay. The forward-looking reach Z_L is equal to the setting Z_A and Z_C.

$$* \quad Z_L = Z_A = Z_C = \frac{TS}{(1 \pm M)}$$

(Sub-letters refer to the T_A and T_C compensators.) The backward reach Z_{LR} is a function of both Z_B and Z_L where

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

When the proper value of Z_{LR} is determined (usually 2 ohms) then the setting for Z_B can be calculated.

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

The S & M settings of the auto-transformer are determined in the setting of the forward reach.

At the line angle in the forward direction, the ohmic difference, Z_{DF} will generally be set for two ohms. When the two circles are concentric, the backward reach, Z_{LR}, is equal to Z_{DF}. The forward reach, Z_L, can be set up to 20 ohms. The reverse reach, Z_{LR}, can be set at most any practical value with the best coverage at two ohms.

Calculations for setting the KS relay are straightforward and apply familiar principles. Assume a desired balance point which is 2 (relay) ohms greater than the second-zone impedance-relay setting. The general formula for setting the ohms forward reach of the relay is:

$$Z_{L\theta} = Z_L \frac{(\sin\theta)}{(\sin 75^o)} = (Z_{Zone\ 2} + 2\text{ ohms})$$

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

S = Auto-transformer primary tap value

θ = Maximum torque angle setting of the relay

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

M = Auto-transformer secondary tap value.
(This is a Per Unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\ Z_{B\theta} - 1/3\ Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\sin\theta)}{(\sin 75^o)}$$

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

$T_B' + T_B$ = compensator tap value

$Z_{L\theta}$ S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{zone\ 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{zone\ 2}$.

2. Select the lowest tap, S,which gives a product of 6.9S greater than Z_L where

   $$Z_L = Z_{L\theta} \frac{(\sin 75^o)}{(\sin\theta)}$$

3. Select a value for T that is nearest the value
* $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.

4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms

2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta} \frac{(\sin 75^o)}{(\sin \theta)}$

$$Z_{B\theta} = 1/2\, Z_{L\theta} + 3/2\, Z_{LR\theta}$$

2. Solve for $(T_B' + T_B)$ where $(T_B' + T_B) = \frac{Z_B (1 \pm M)}{S}$

3. Select the highest possible value for T_B' and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

* 1. Then $Z_B = (\frac{9}{2} + \frac{3 \times 2}{2}) \times \frac{0.966}{0.866}$

$= 7.5 \times 1.11 = 8.36$ ohms

2. $(T_B' + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T_B' = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35 (\frac{.866}{.966}) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, T_B-T_B, and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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 – 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 insert 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.

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 8).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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^o}	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^o current lagging voltage and the tap values are based on this angle. Generally speaking, the 75^o setting can be applied on lines with angles from 65^o to 90^o and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between 60^o and 80^o 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 stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 9. 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 open should be between 2.95 and 3.05 amperes at an angle of 75^o 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 close 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 9 set the phase shifter so that the current lags voltage by θ^o. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L\text{-}L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is

$Z_{LR} = \frac{V_{L\text{-}L}}{\sqrt{3}\, I_L} - 1/3\ Z_L$. Here $V_{L\text{-}L}$ is phase-to-phase voltage and I_L is phase current.

Test No.	Volts	Amperes ($\theta = 75^o$) †† & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
8	30	2.95	3.05
	70	6.90	7.10
9	30	5.06	5.24
	70	11.8	12.2

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

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

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 10, 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 11 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 7 Figure 9, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L\text{-}L}}{\sqrt{3}\, I_L}$ 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 9. 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 checked for turns ratio and polarity by using the No. 1 test connections of Figure 9, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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'-T_B for 5.85

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 center than the end.

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

2. Using test #1 to Figure 9, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.

2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.

3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73^o and 76^o 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.

6. 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 9. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
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 open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. Check the current required to close the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 V_{L-L} to 120 V_{L-L}. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS}{(1 \pm M)} \frac{\sin \theta}{(\sin 75^o)}$.

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 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'-T_B on 5.85 tap.

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

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

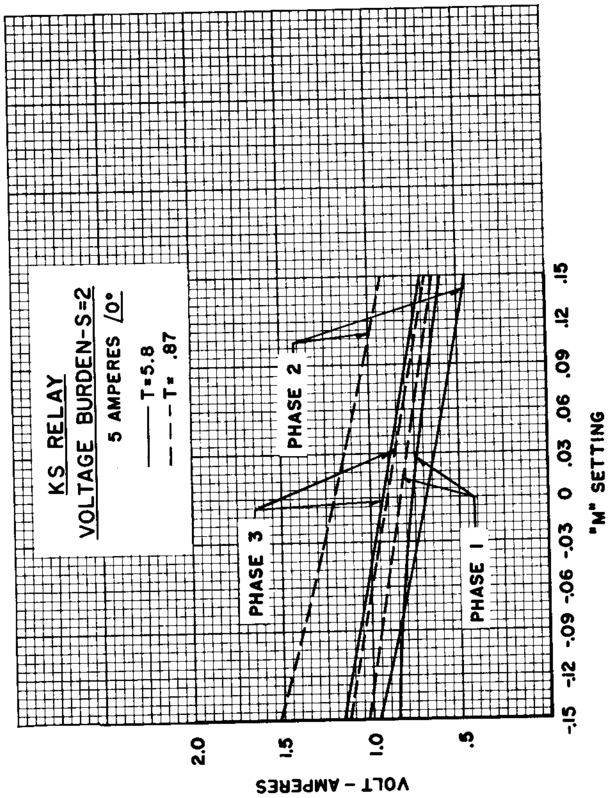
The relay is now calibrated and ready for service.

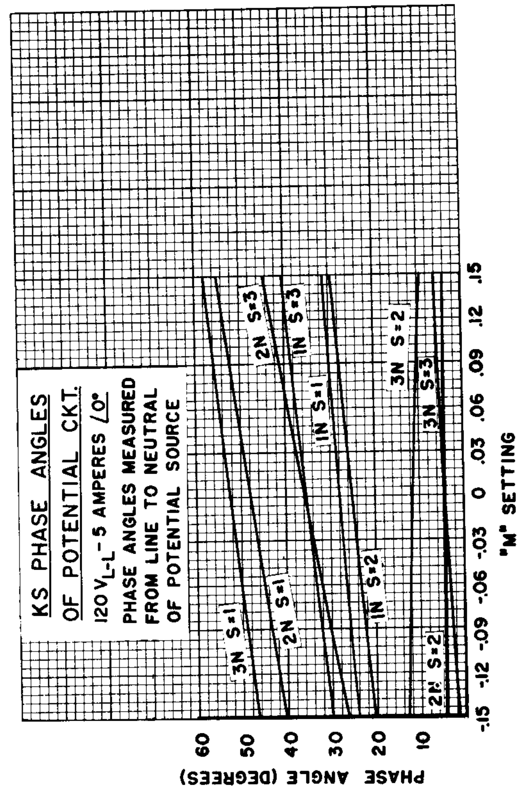
TABLE I

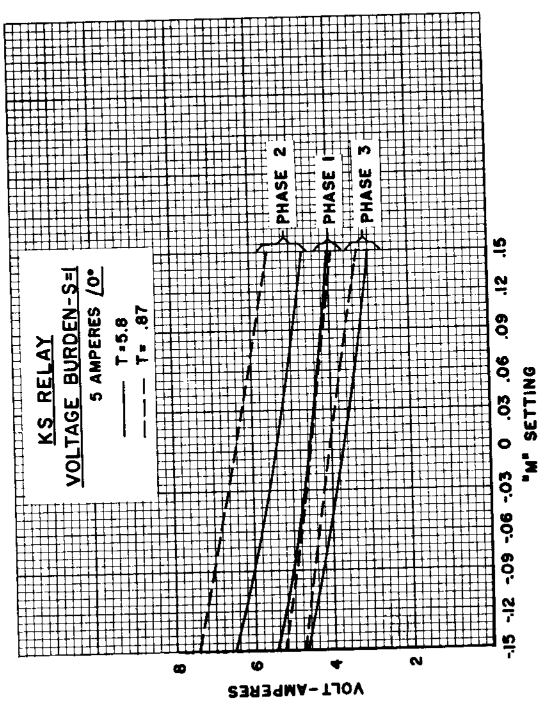
* NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors – 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; .06; .06)
OS	Telephone Type Relay – D.C. Resistance = 475 to 525 ohms

ENERGY REQUIREMENTS







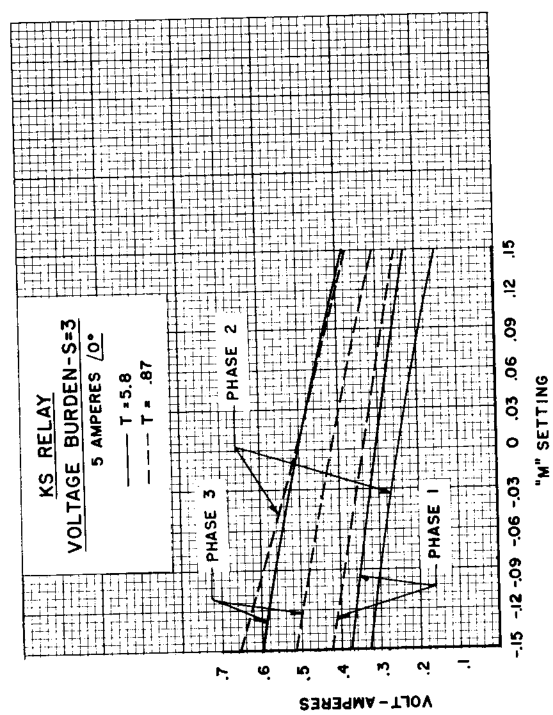


Fig. 6. Type KS Relay Potential Burden Data.

ENERGY REQUIREMENTS

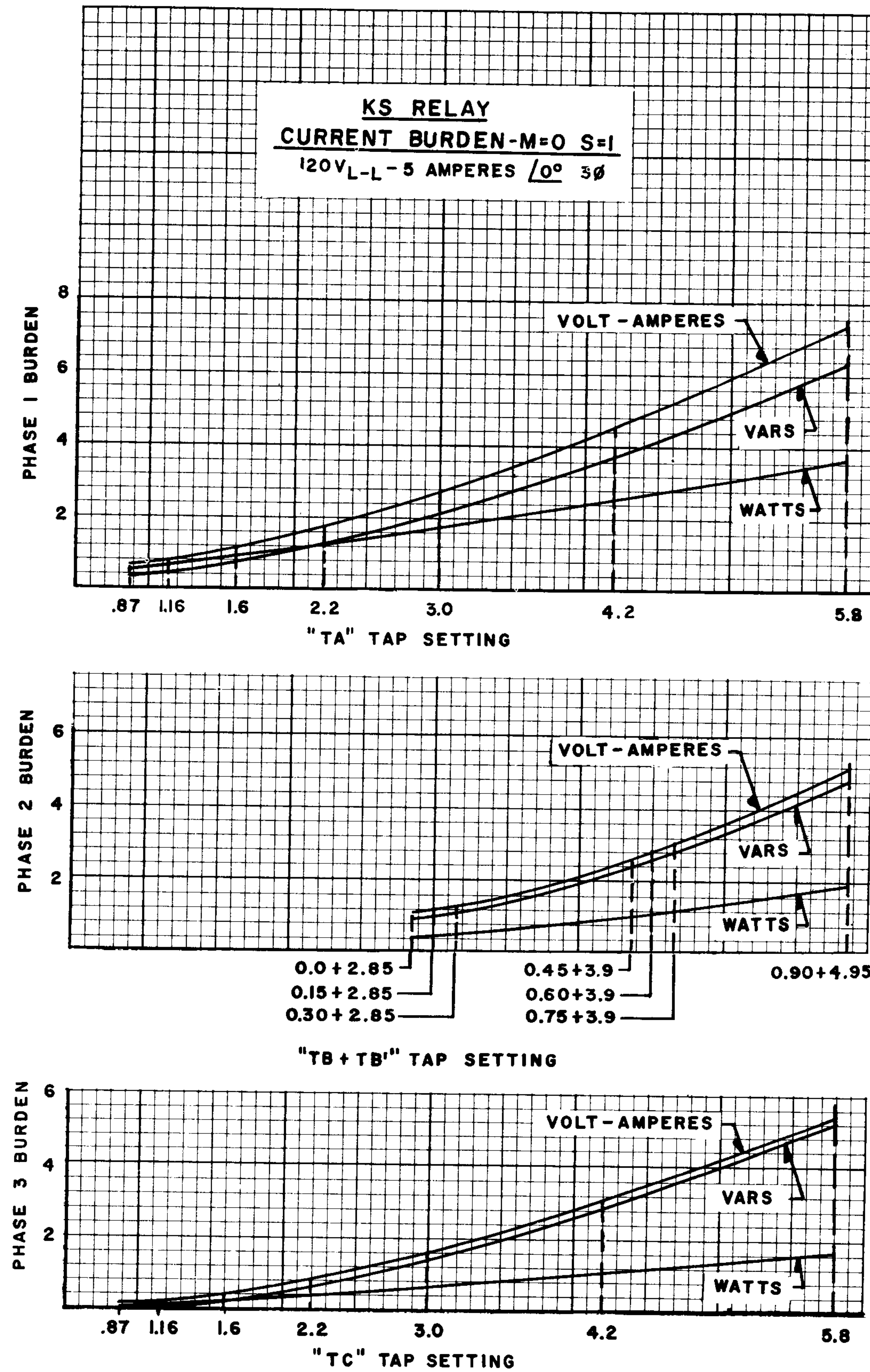


Fig. 7. Type KS Relay Current Burden Data.

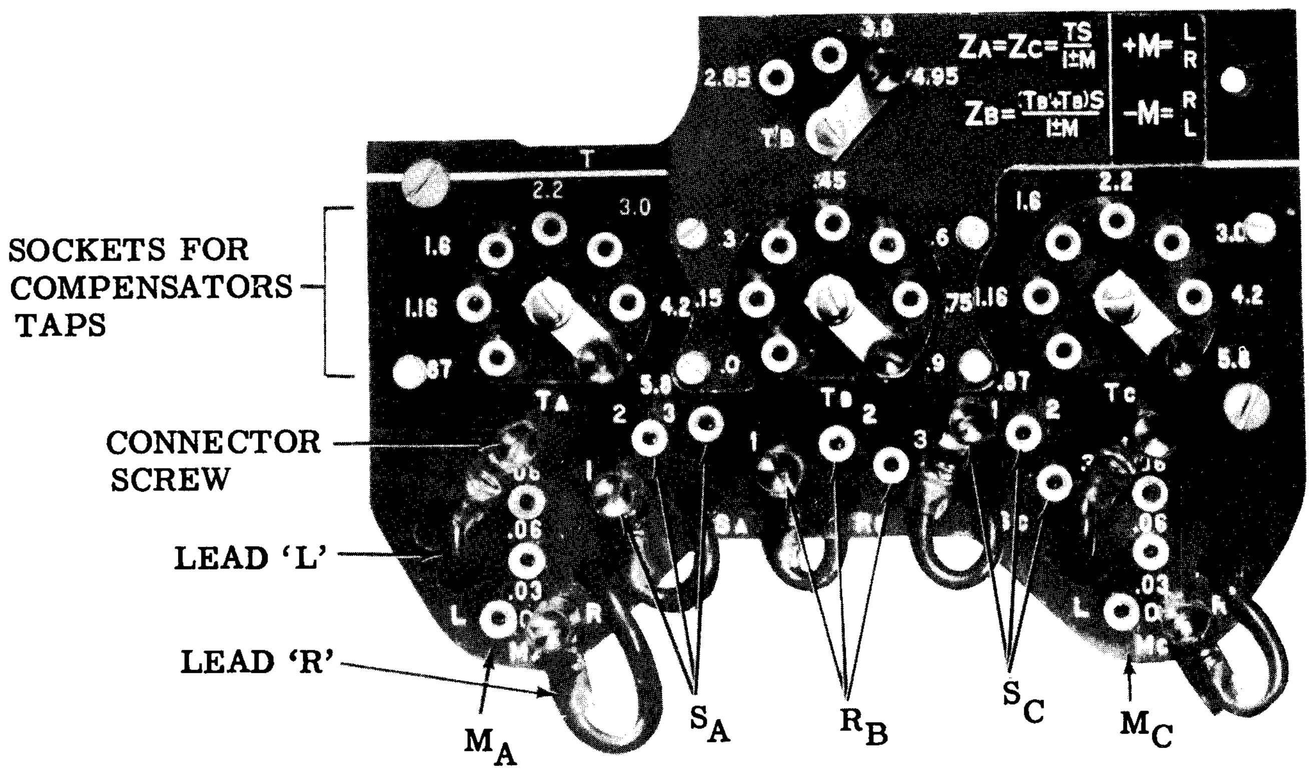
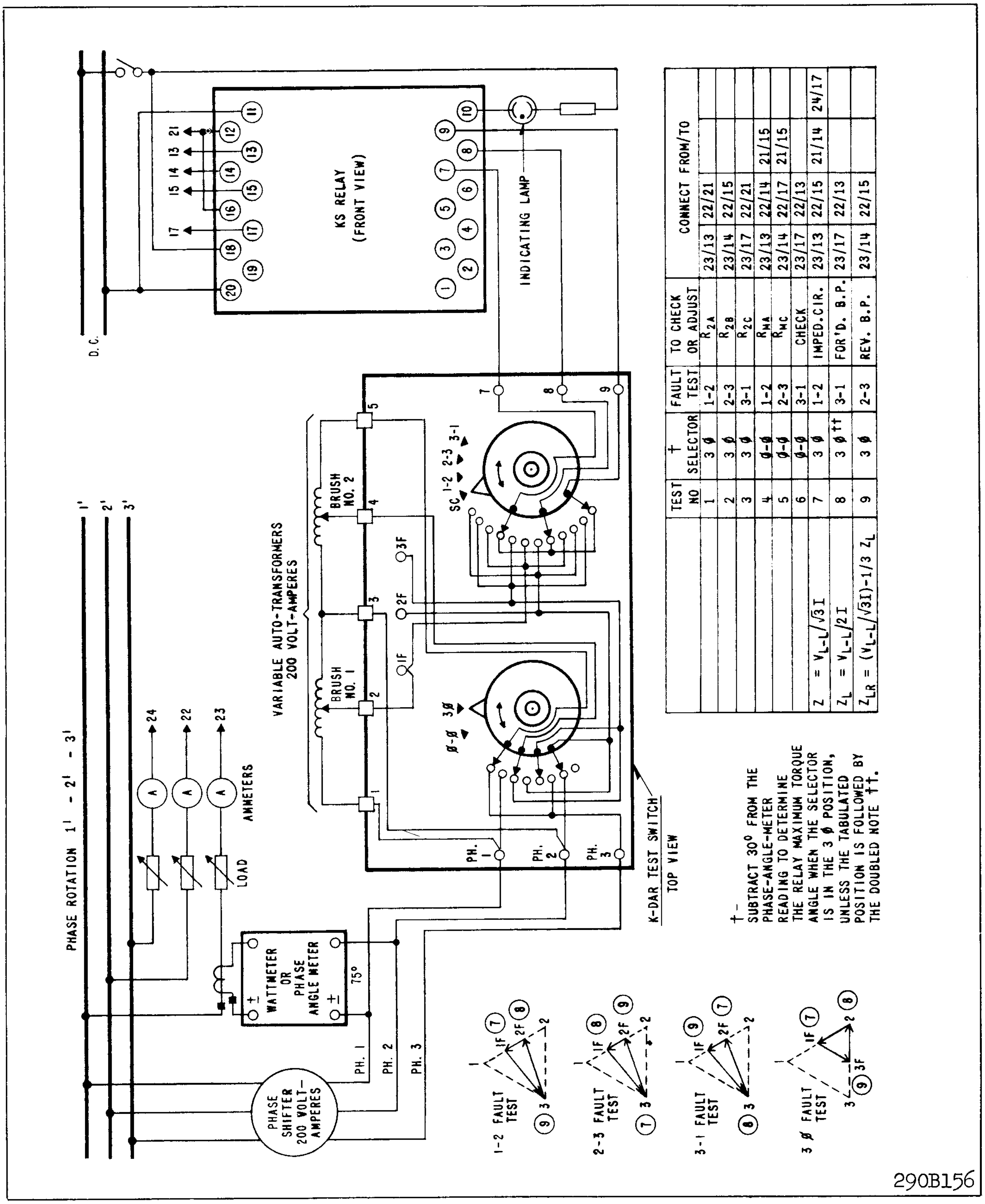


Fig. 8. Tap Plate.



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

Fig. 9. Test Connections for Type KS Relays.

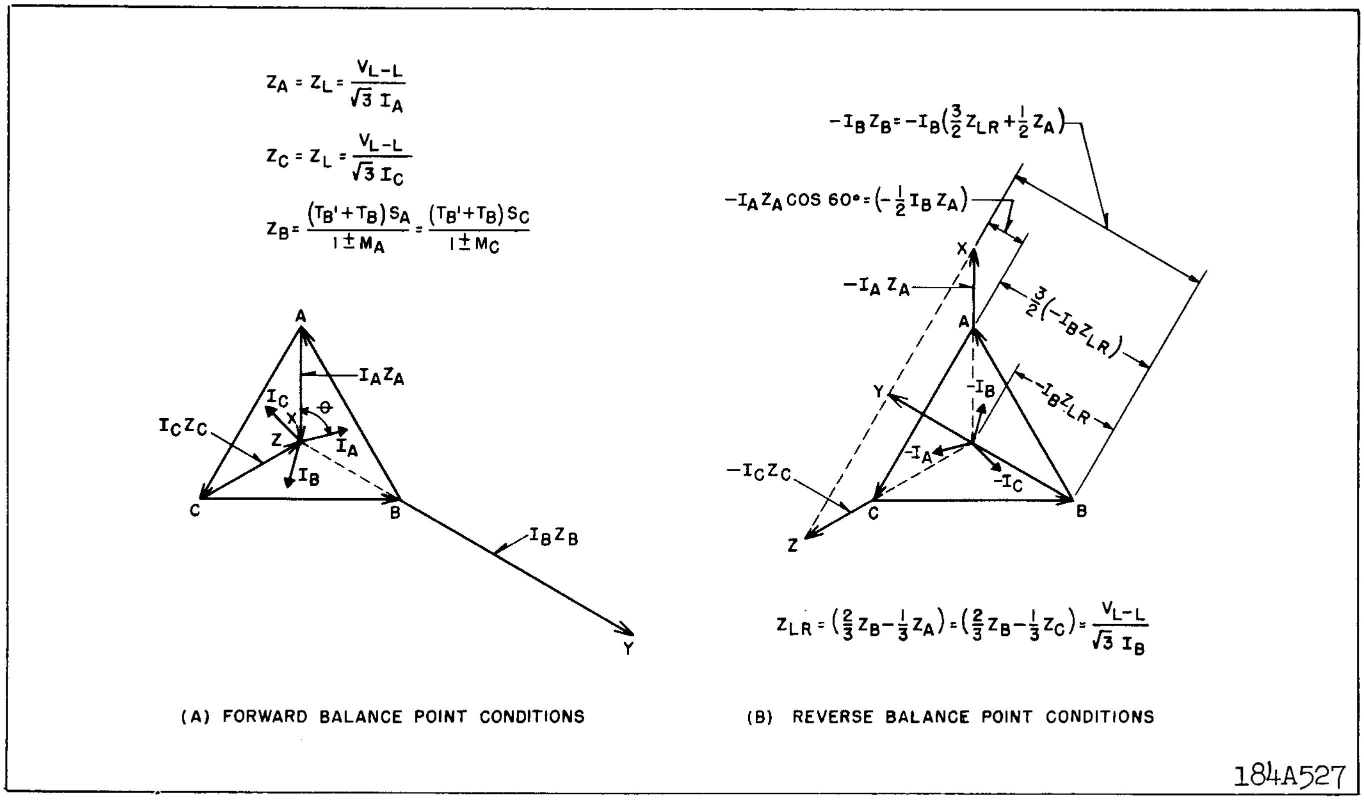


Fig. 10. Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.

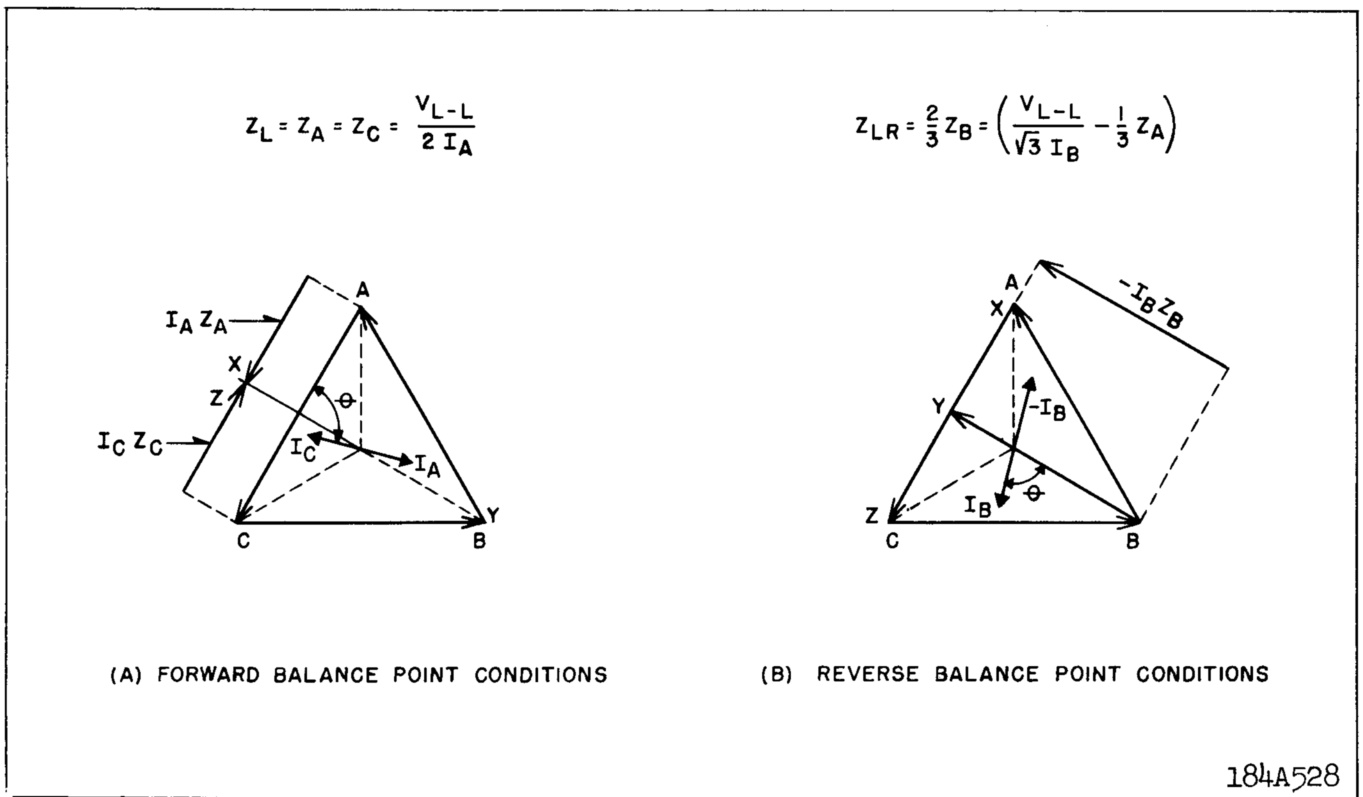


Fig. 11. Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.

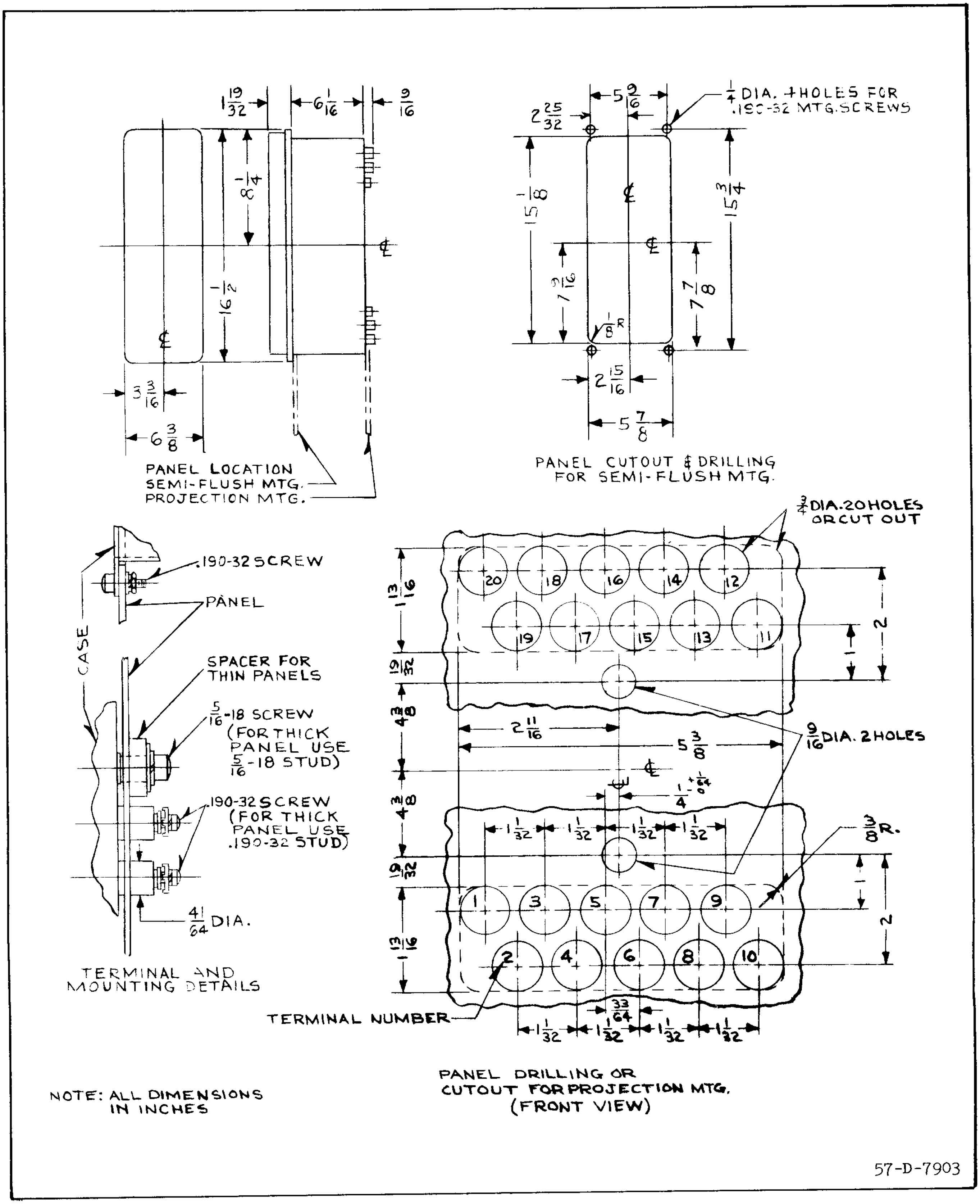


Fig. 12. Outline-Drilling Plan for the Type KS Relay in the FT32 Case.

WESTINGHOUSE ELECTRIC CORPORATION
RELAY DEPARTMENT **NEWARK, N. J.**
Printed in U. S. A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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^o and 80^o 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 on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps 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 .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 ±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.

SUPERSEDES I.L. 41-492B
*Denotes change from superseded issue.

EFFECTIVE FEBRUARY 1966

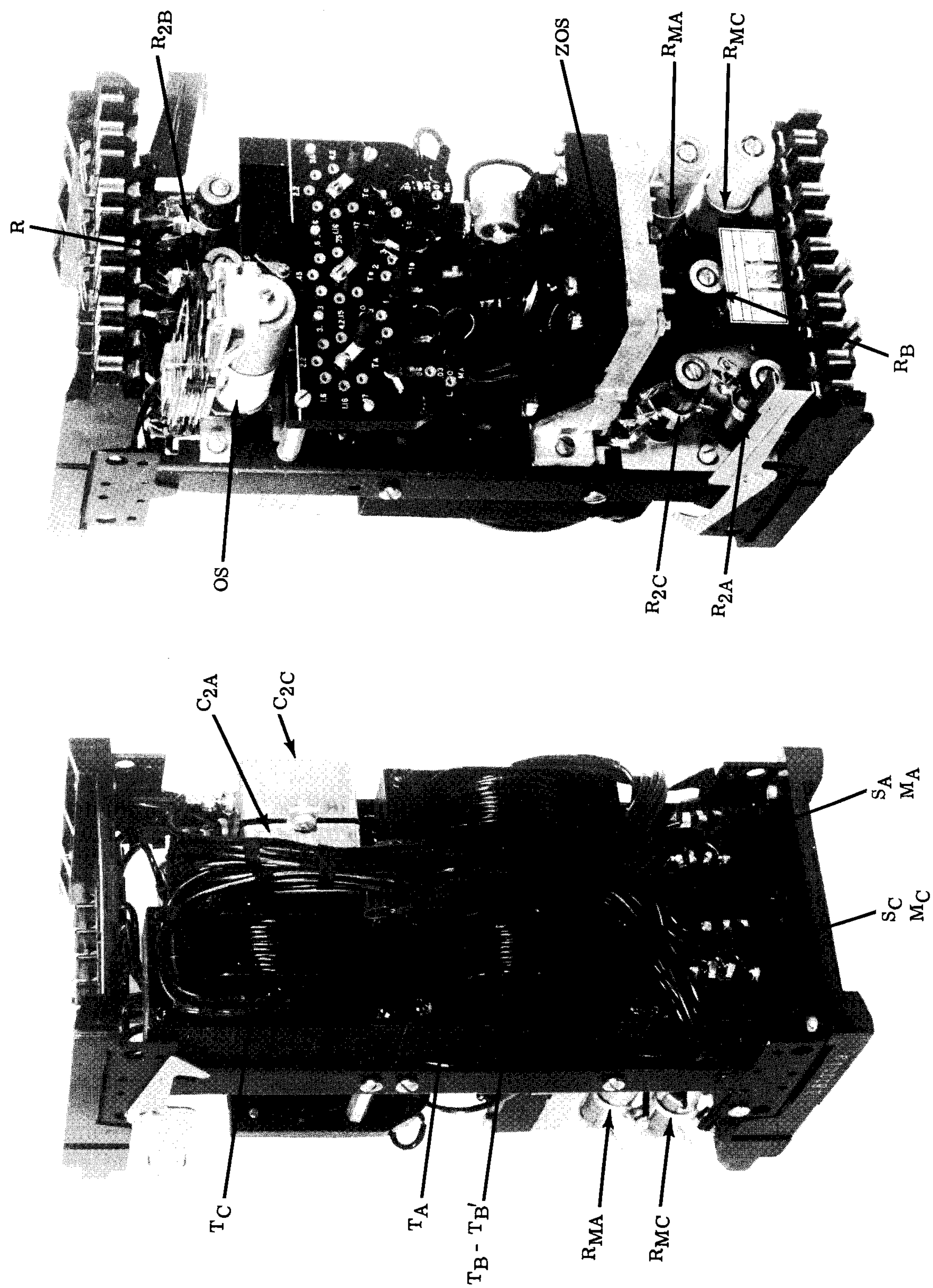


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

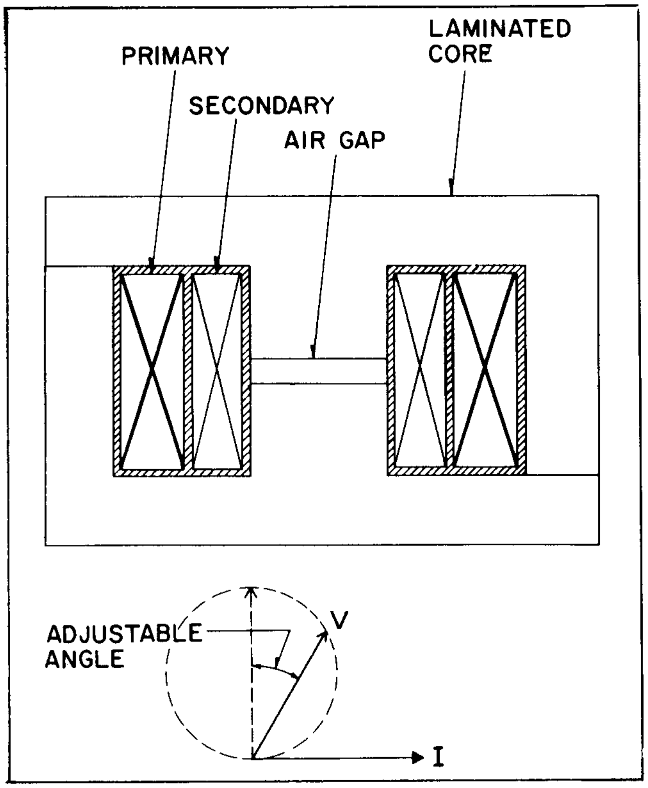


Fig. 2. Compensator Construction.

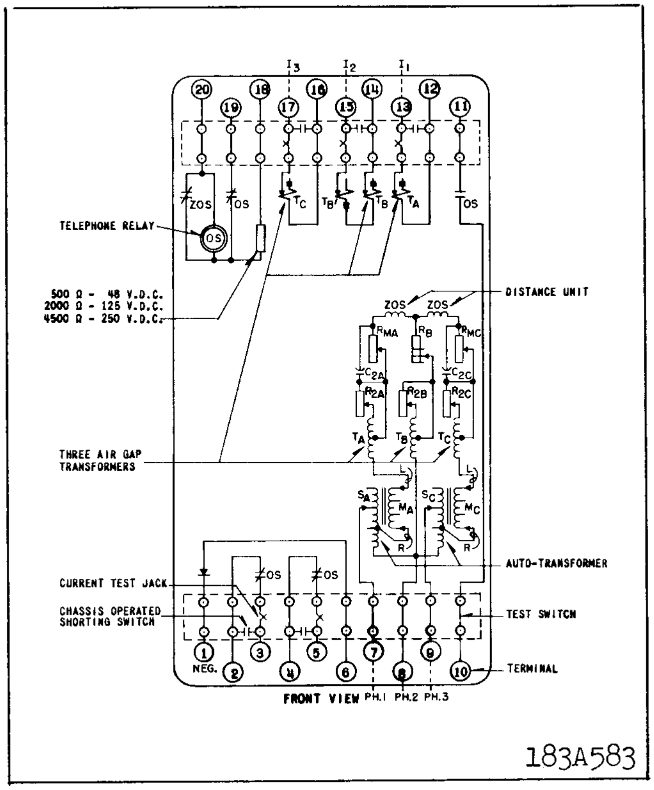


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

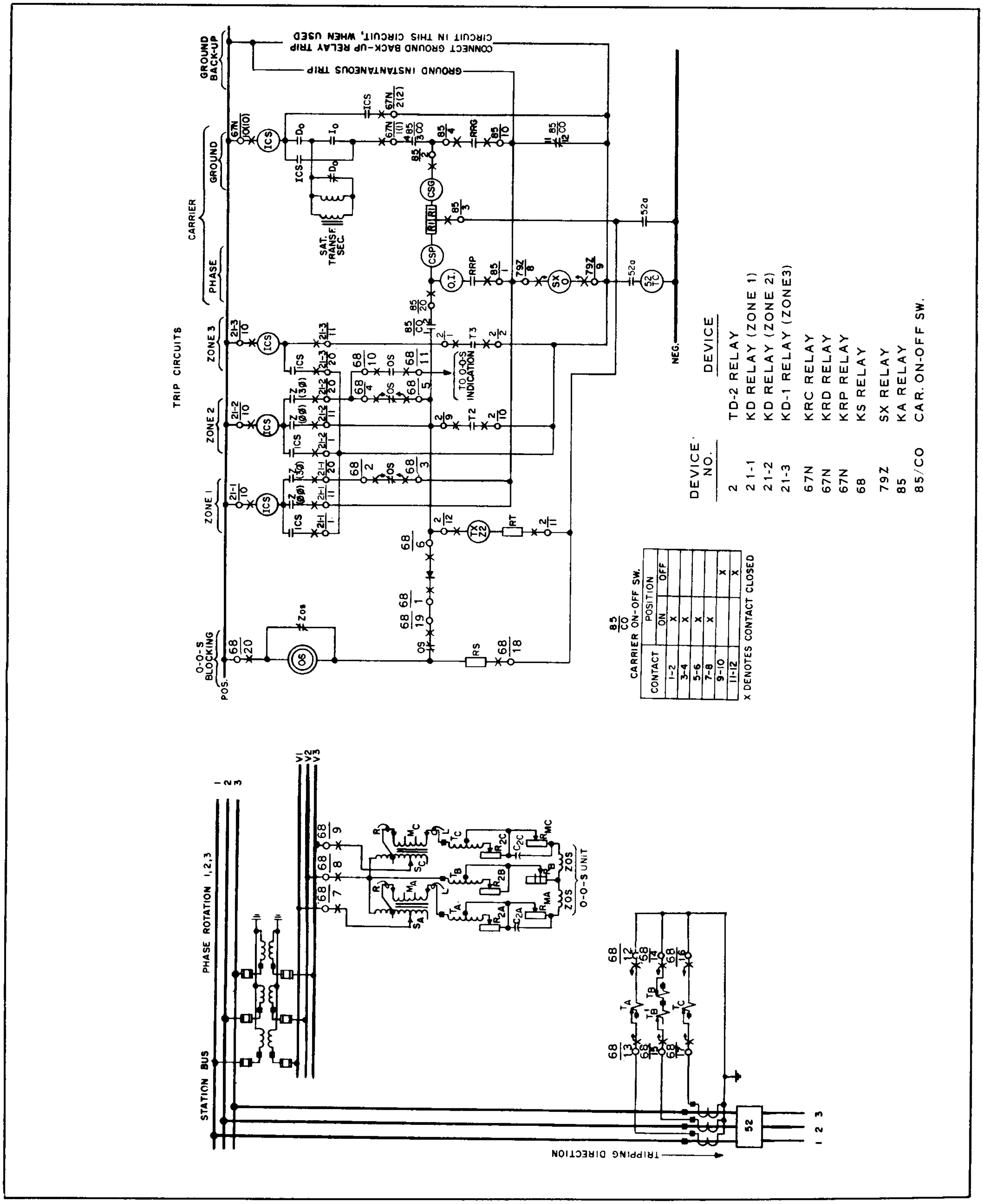
Mechanically, the cylinder unit is composed of four basic components: a die-cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge.

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 sprial 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 adjusted 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.



** Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.*

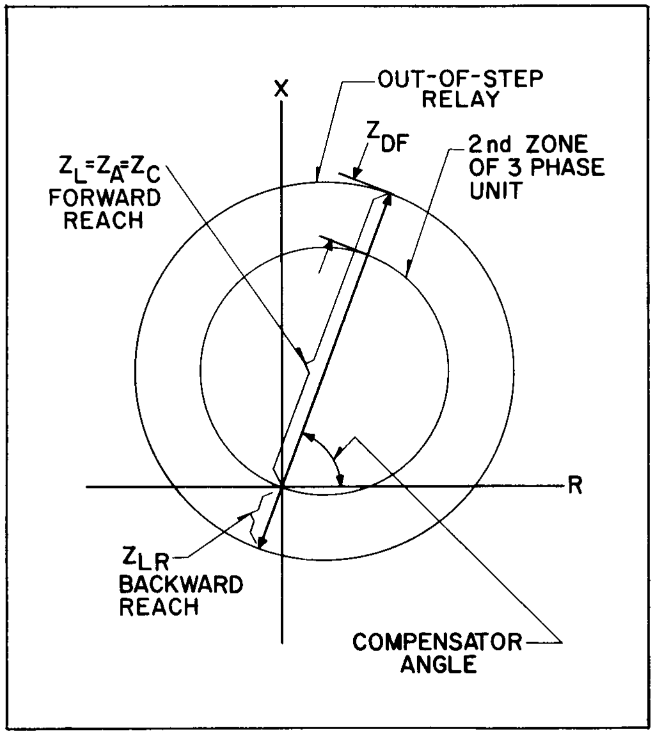


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figüre 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles, its OS contacts located between the $\frac{78}{4}$ and $\frac{78}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 8 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)

.87 1.16 1.6 2.2 3.0 4.2 5.8

(T_B)

0 .15 .3 .45 .6 .75 .9

T_B'

2.85 3.9 4.95

(S_A, S_C, R_B)

1 2 3

(M_A, M_C)

± Values between taps .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 Figure 6 and Figure 7. The potential burden and burden phase angle are based on 69 volts line-to-neutral applied to the relay terminals.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay three-phase unit with a 2 ohm margin. The angle of maximum torque should be the same as that of the KD

relay. The forward-looking reach Z_L is equal to the setting Z_A and Z_C.

$$Z_L = Z_A = Z_C = \frac{TS}{(1 \pm M)}$$

(Sub-letters refer to the T_A and T_C compensators.) The backward reach Z_{LR} is a function of both Z_B and Z_L where

$$Z_B = \frac{(T'_B + T_B)\,S}{*\ (1 \pm M).}$$

When the proper value of Z_{LR} is determined (usually 2 ohms) then the setting for Z_B can be calculated.

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

The S & M settings of the auto-transformer are determined in the setting of the forward reach.

At the line angle in the forward direction, the ohmic difference, Z_{DF} will generally be set for two ohms. When the two circles are concentric, the backward reach, Z_{LR}, is equal to Z_{DF}. The forward reach, Z_L, can be set up to 20 ohms. The reverse reach, Z_{LR}, can be set at most any practical value with the best coverage at two ohms.

Calculations for setting the KS relay are straightforward and apply familiar principles. Assume a desired balance point which is 2 (relay) ohms greater than the second-zone impedance-relay setting. The general formula for setting the ohms forward reach of the relay is:

$$Z_{L\theta} = Z_L \frac{(\text{Sin } \theta)}{(\text{Sin } 75^o)} = (Z_{\text{Zone } 2} + 2 \text{ ohms})$$

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

S = Auto-transformer primary tap value

θ = Maximum torque angle setting of the relay

(For a factory setting of 75^o then $\frac{\text{Sin } \theta}{\text{Sin } 75^o} = 1$.)

M = Auto-transformer secondary tap value. (This is a Per Unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\ Z_{B\theta} - 1/3\ Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\text{Sin } \theta)}{(\text{Sin } 75^o)}$$

$$Z_B = \frac{(T'_B + T_B)\,S}{1 \pm M}$$

$T'_B + T_B$ = compensator tap value

$Z_{L\theta}$, S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{\text{zone } 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{\text{zone } 2}$.

2. Select the lowest tap, S, which gives a product of 6.9S greater than Z_L where

   $$Z_L = Z_{L\theta} \frac{(\text{Sin } 75^o)}{(\text{Sin } \theta)}$$

3. Select a value for T that is nearest the value $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.

4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms

2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta} \frac{(\text{Sin } 75^o)}{(\text{Sin } \theta)}$

$$Z_{B\theta} = 1/2\ Z_{L\theta} + 3/2\ Z_{LR\theta}$$

2. Solve for $(T'_B + T_B)$ where $(T'_B + T_B) = \frac{Z_B\ (1 \pm M)}{S}$

3. Select the highest possible value for T'_B and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

1. Then $Z_B = (\frac{9}{2} + \frac{3 \times 2}{2}) \times \frac{0.966}{0.866}$

   $= 7.5 \times 1.11 = 8.36$ ohms

2. $(T'_B + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T'_B = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35\ (\frac{.866}{.966}) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, T_B -T_B, and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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 – 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 insert 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.

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 8).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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^o}	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° 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.

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

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 9. 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 open 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 close 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 9 set the phase shifter so that the current lags voltage by θ^0. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L-L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is

$Z_{LR} = \frac{V_{L-L}}{\sqrt{3}\, I_L} - 1/3\, Z_L$. Here V_{L-L} is phase-to-phase voltage and I_L is phase current.

Test No.	Volts	* Amperes (θ= 75°) & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
8	30	2.95	3.05
	70	6.90	7.10
9	30	* 5.06 ††	* 5.24 ††
	70	11.8	12.2

†† Phase Angle Meter Set for $\theta + 30^0$

† To determine the limits of current when θ is not equal to 75^0, multiply the nominal values tabulated above by the ratio $\frac{\sin 75^0}{\sin \theta}$

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 10, 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 11 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 7 Figure 9, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L-L}}{\sqrt{3}\, I_L}$ 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 9. 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 checked for turns ratio and polarity by using the No. 1 test connections of Figure 9, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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'-T_B for 5.85

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 center than the end.

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

2. Using test #1 to Figure 9, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.

2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.

3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73° and 76° 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.

6. 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 9. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
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 open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. Check the current required to close the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 V_{L-L} to 120 V_{L-L}. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS}{(1 \pm M)} \frac{\sin \theta}{(\sin 75^o)}$.

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 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'-T_B on 5.85 tap.

B. Disconnect the "L" leads of sections 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 From Terminal	To Fixed End of	Voltmeter Read.
"L" of M_A	R_{2A}	$V_C = IT(\frac{\sin\theta}{\sin 75^0})$
8	R_{2B}	= 60.1 volts
"L" of M_C	R_{2C}	($\theta = 90^0$)

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

The relay is now calibrated and ready for service.

TABLE I

NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors – 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; .06; .06)
OS	Telephone Type Relay – D.C. Resistance = 475 to 525 ohms

ENERGY REQUIREMENTS

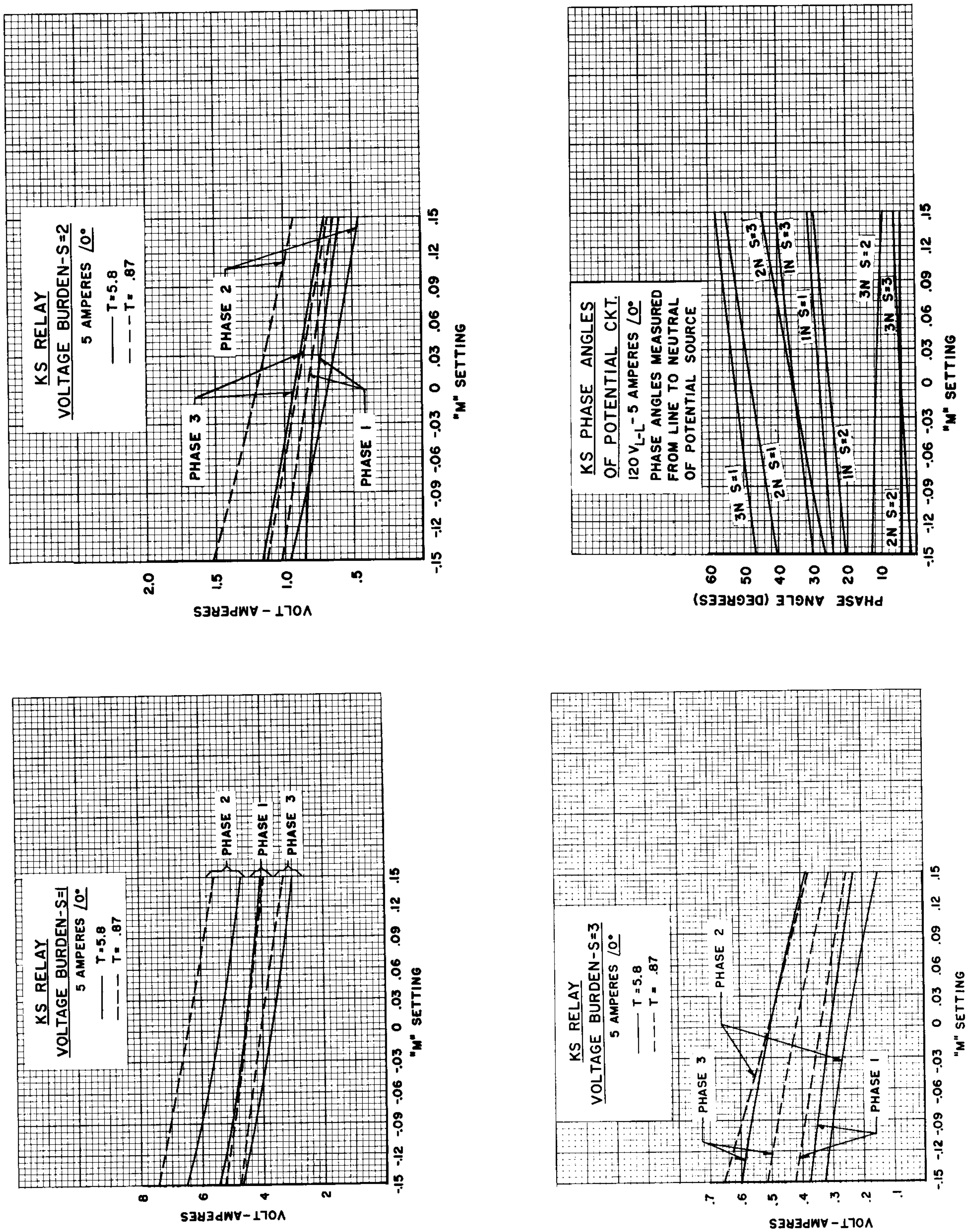


Fig. 6. Type KS Relay Potential Burden Data.

ENERGY REQUIREMENTS

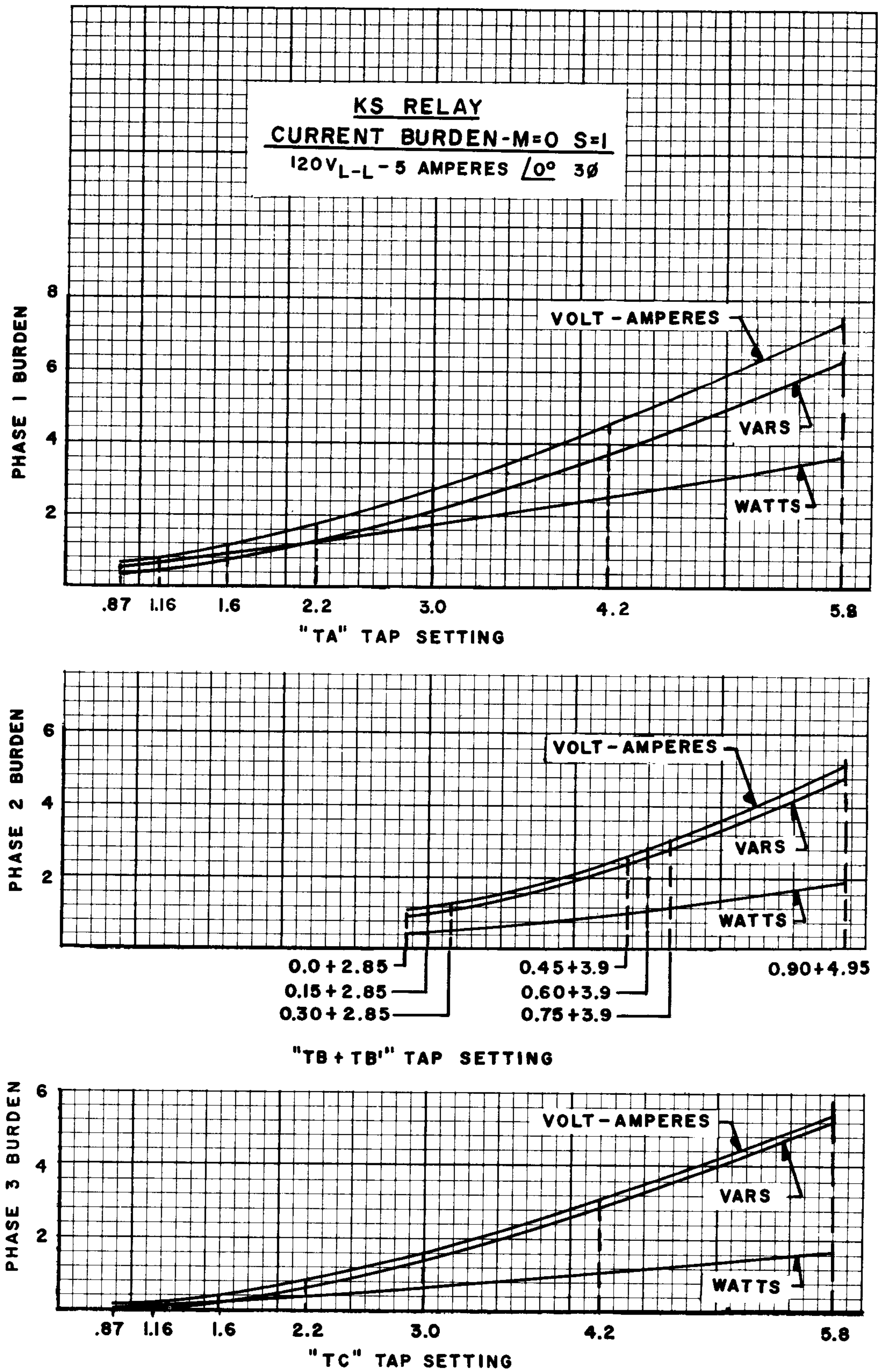


Fig. 7. Type KS Relay Current Burden Data.

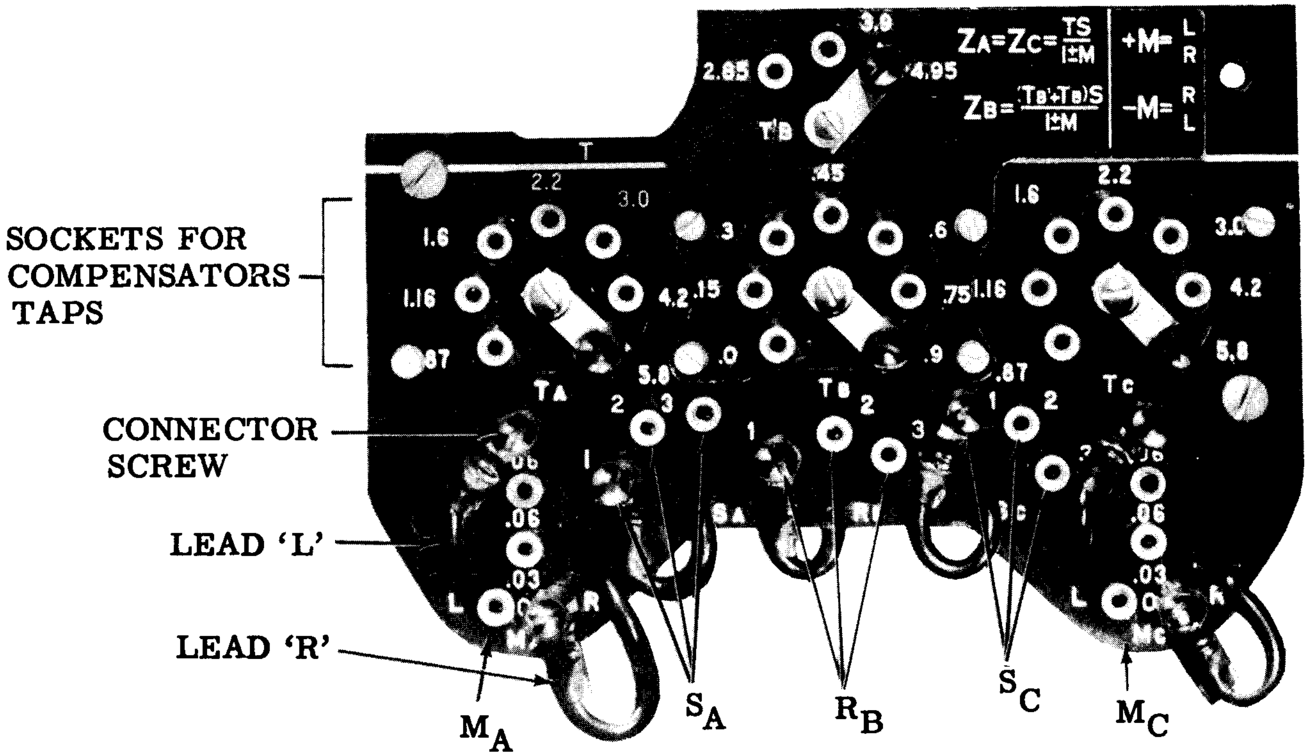
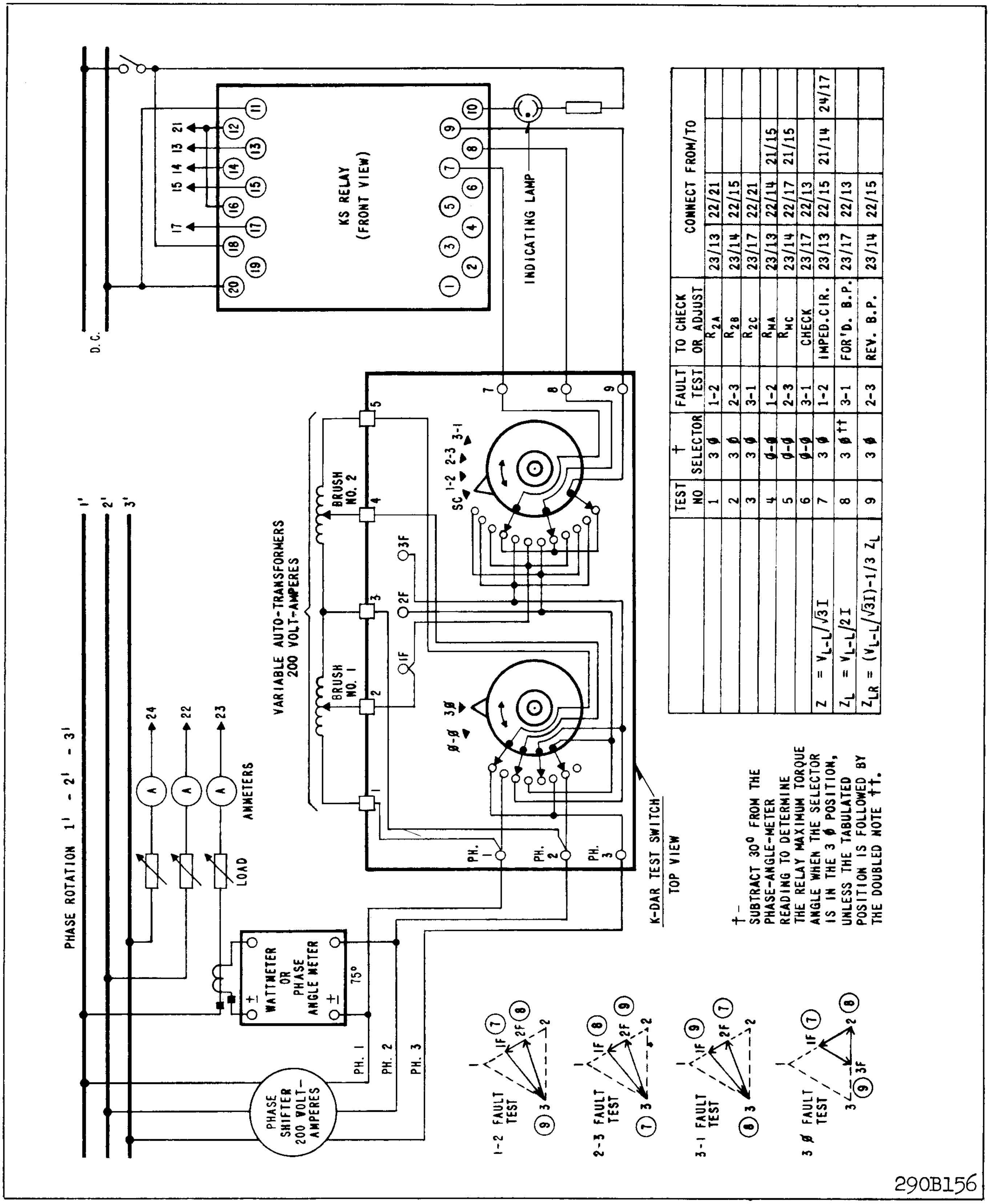


Fig. 8. Tap Plate.



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		
7	3 ø	1-2	IMPED.CIR.	23/13	22/15	21/14	24/17
8	3 ø††	3-1	FOR'D. B.P.	23/17	22/13		
9	3 ø	2-3	REV. B.P.	23/14	22/15		

$Z = V_{L-L}/\sqrt{3}I$

$Z_L = V_{L-L}/2I$

$Z_{LR} = (V_{L-L}/\sqrt{3}I) - 1/3\ Z_L$

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

Fig. 9. Test Connections for Type KS Relays.

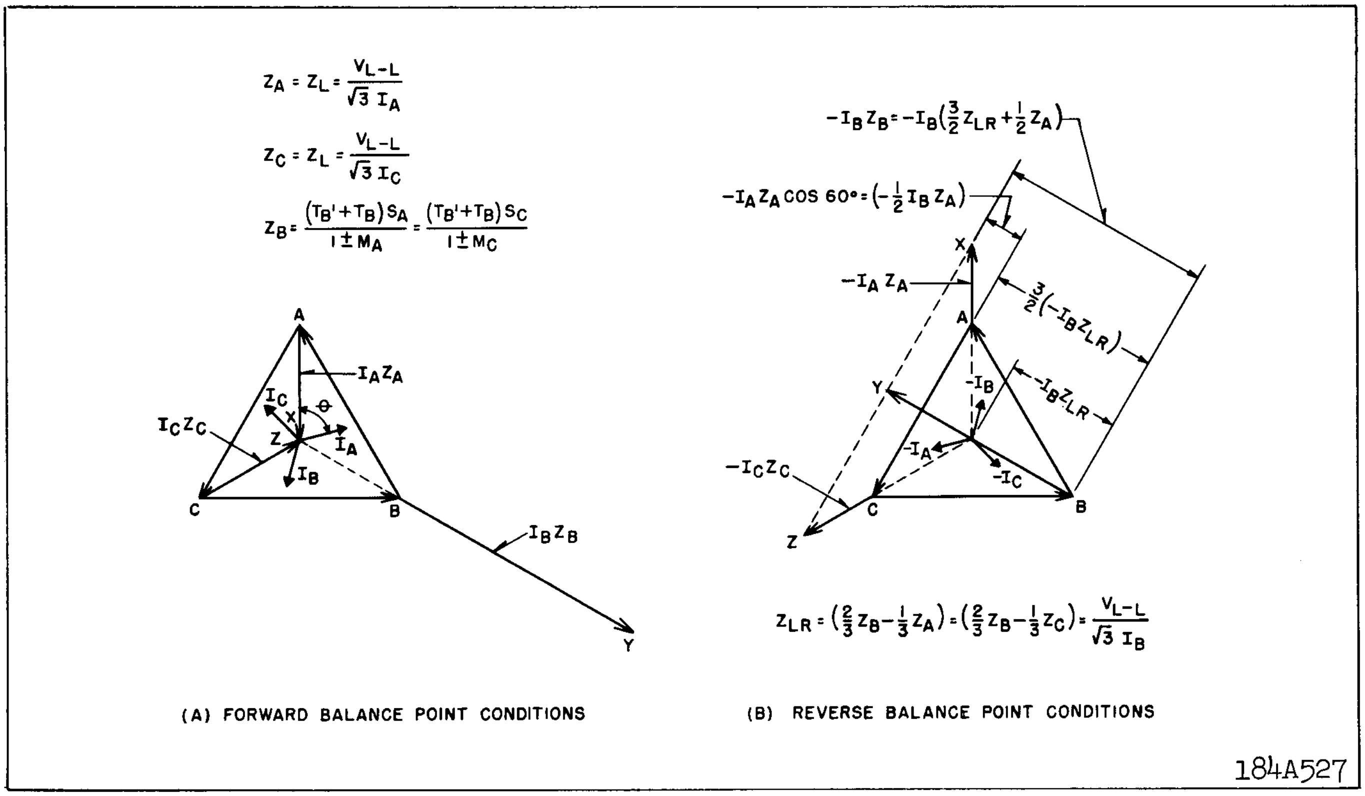


Fig. 10. Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.

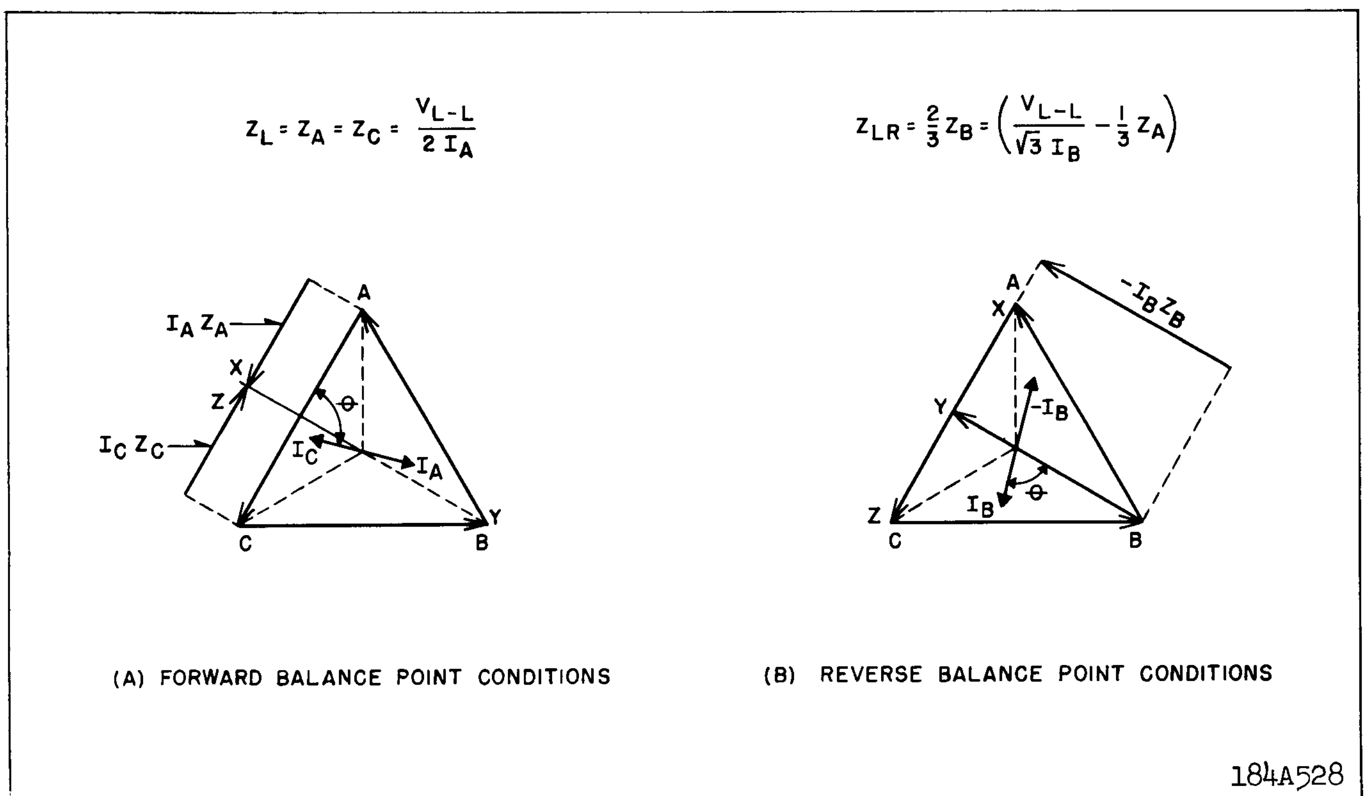


Fig. 11. Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.

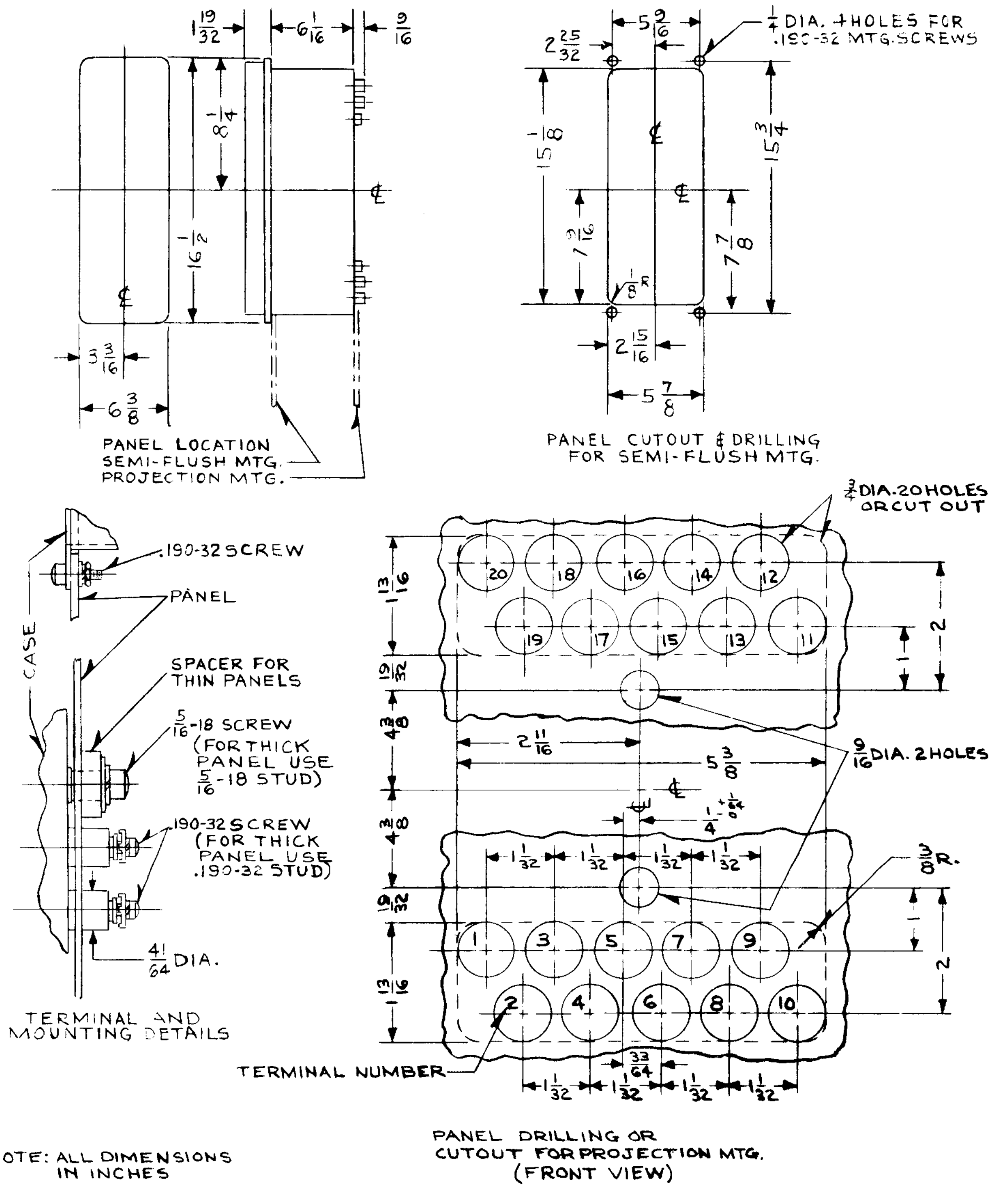


Fig. 12. Outline-Drilling Plan for the Type KS Relay in the FT32 Case.

WESTINGHOUSE ELECTRIC CORPORATION
RELAY DEPARTMENT **NEWARK, N. J.**
Printed in U. S. A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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^o and 80^o 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 on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps 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 .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 ±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.

SUPERSEDES I.L. 41-492C
*Denotes change from superseded issue.

EFFECTIVE JUNE 1966

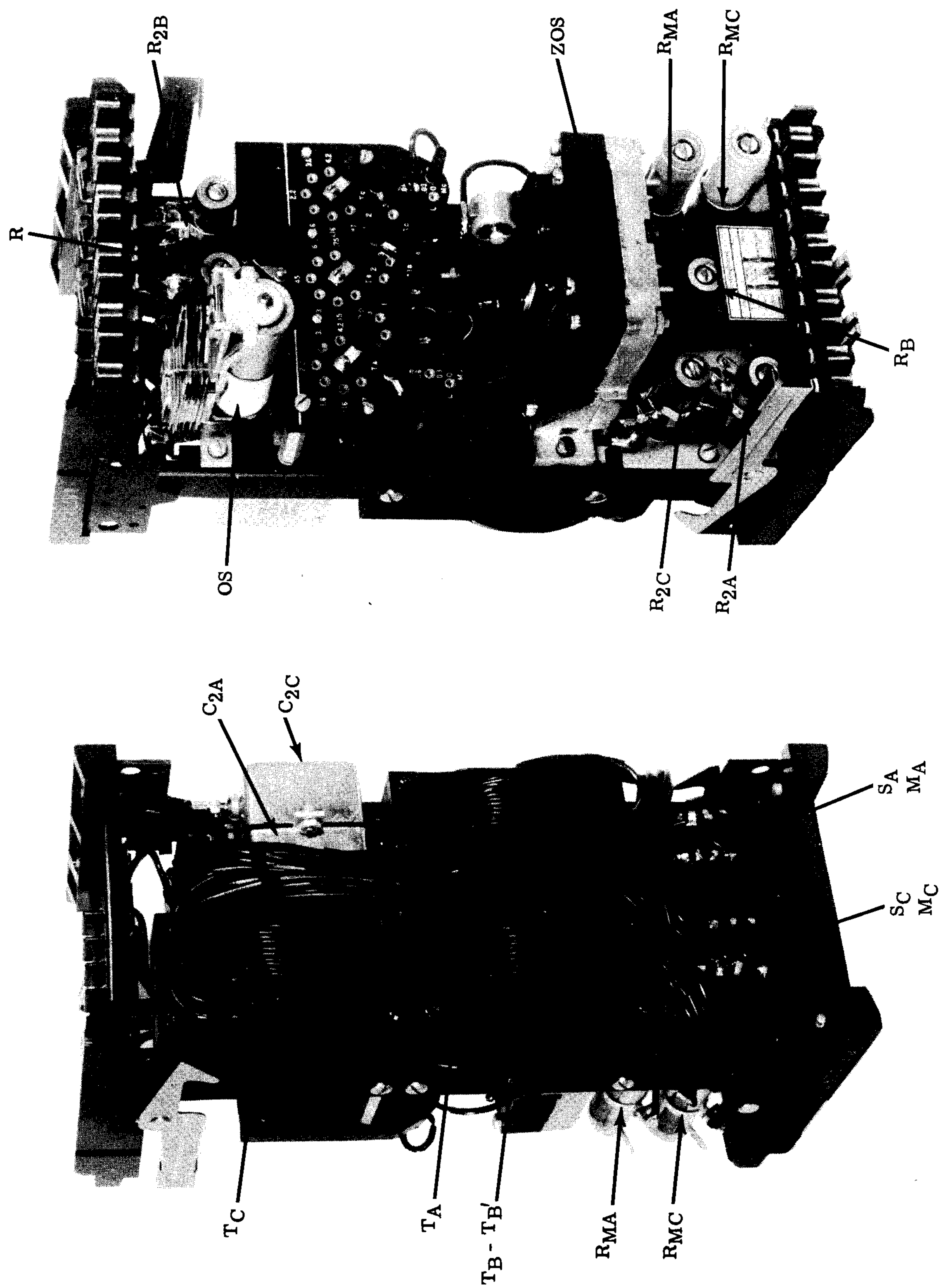


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

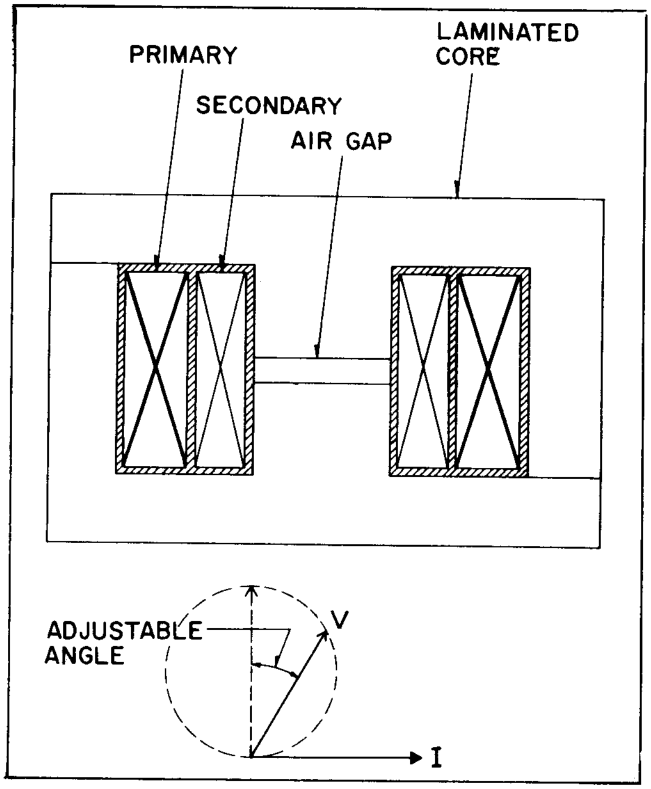


Fig. 2. Compensator Construction.

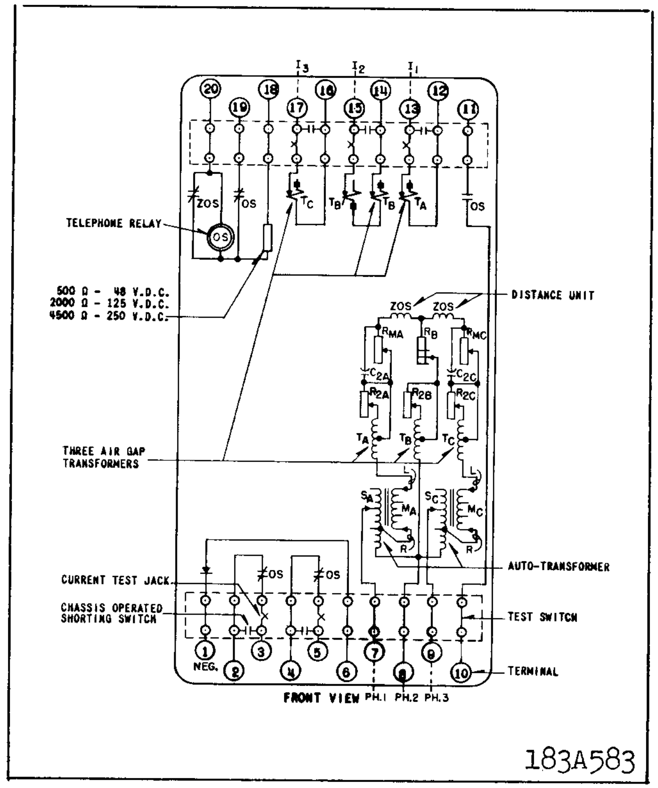


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 sprial 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 adjusted 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.

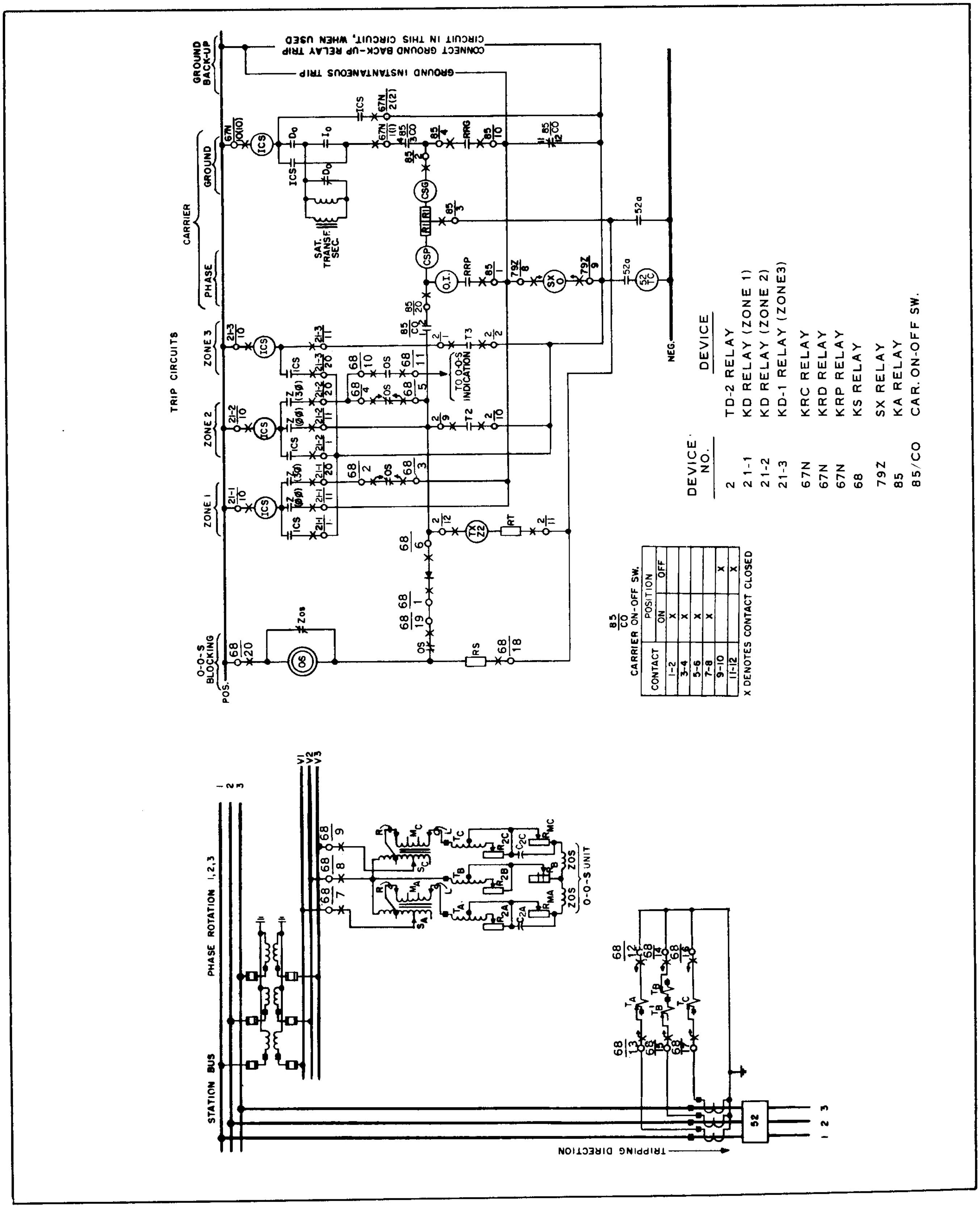


Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.

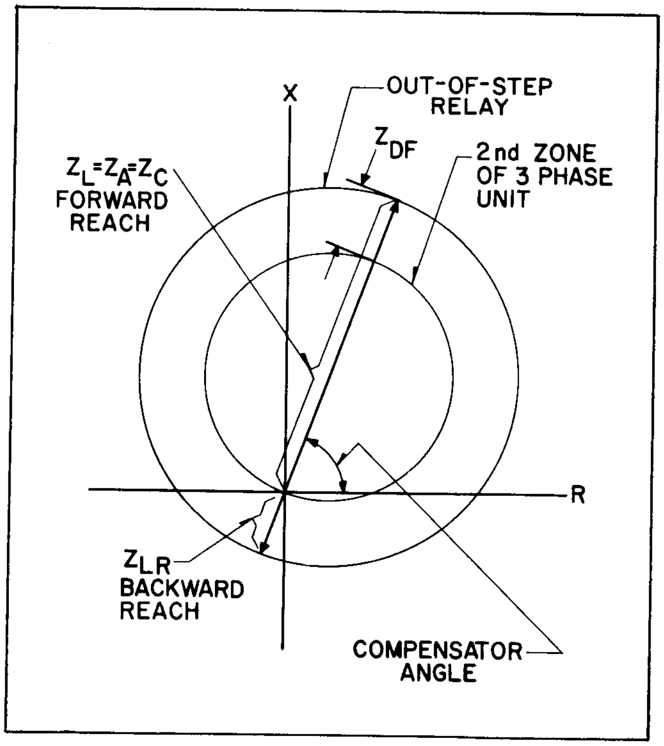


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figure 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles, * its OS contacts located between the $\frac{68}{4}$ and $\frac{68}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 8 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)

.87 1.16 1.6 2.2 3.0 4.2 5.8

(T_B)

0 .15 .3 .45 .6 .75 .9

T_B'

2.85 3.9 4.95

(S_A, S_C, R_B)

1 2 3

(M_A, M_C)

± Values between taps .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 Figure 6 and Figure 7. The potential burden and burden phase angle are based on 69 volts line-to-neutral applied to the relay terminals.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay three-phase unit with a 2 ohm margin. The angle of maximum torque should be the same as that of the KD

relay. The forward-looking reach Z_L is equal to the setting Z_A and Z_C.

$$Z_L = Z_A = Z_C = \frac{TS}{(1 \pm M)}$$

(Sub-letters refer to the T_A and T_C compensators.) The backward reach Z_{LR} is a function of both Z_B and Z_L where

$$Z_B = \frac{(T'_B + T_B)\,S}{(1 \pm M).}$$

When the proper value of Z_{LR} is determined (usually 2 ohms) then the setting for Z_B can be calculated.

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

The S & M settings of the auto-transformer are determined in the setting of the forward reach.

At the line angle in the forward direction, the ohmic difference, Z_{DF} will generally be set for two ohms. When the two circles are concentric, the backward reach, Z_{LR}, is equal to Z_{DF}. The forward reach, Z_L, can be set up to 20 ohms. The reverse reach, Z_{LR}, can be set at most any practical value with the best coverage at two ohms.

Calculations for setting the KS relay are straightforward and apply familiar principles. Assume a desired balance point which is 2 (relay) ohms greater than the second-zone impedance-relay setting. The general formula for setting the ohms forward reach of the relay is:

$$Z_{L\theta} = Z_L \frac{(\sin \theta)}{(\sin 75^o)} = (Z_{Zone\ 2} + 2 \text{ ohms})$$

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

S = Auto-transformer primary tap value

θ = Maximum torque angle setting of the relay

(For a factory setting of 75^0 then $\frac{\sin \theta}{\sin 75^o} = 1$.)

M = Auto-transformer secondary tap value. (This is a Per Unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\, Z_{B\theta} - 1/3\, Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\sin \theta)}{(\sin 75^o)}$$

$$Z_B = \frac{(T'_B + T_B)\,S}{1 \pm M}$$

$T'_B + T_B$ = compensator tap value

$Z_{L\theta}$, S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{zone\ 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{zone\ 2}$.

2. Select the lowest tap, S, which gives a product of 6.9S greater than Z_L where

   $$Z_L = Z_{L\theta} \frac{(\sin 75^o)}{(\sin \theta)}$$

3. Select a value for T that is nearest the value $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.

4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms

2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta} \frac{(\sin 75^\circ)}{(\sin \theta)}$

   $Z_{B\theta} = 1/2\, Z_{L\theta} + 3/2\, Z_{LR\theta}$

2. Solve for $(T_B' + T_B)$ where $(T_B' + T_B) = \frac{Z_B (1 \pm M)}{S}$

3. Select the highest possible value for T_B' and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

1. Then $Z_B = (\frac{9}{2} + \frac{3 \times 2}{2}) \times \frac{0.966}{0.866}$

   $= 7.5 \times 1.11 = 8.36$ ohms

2. $(T_B' + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T_B' = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35 \left(\frac{.866}{.966}\right) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, T_B-T_B, and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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 – 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 insert 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.

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 8).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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^o}	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^o current lagging voltage and the tap values are based on this angle. Generally speaking, the 75^o setting can be applied on lines with angles from 65^o to 90^o and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between 60^o and 80^o 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 stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 9. 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 open should be between 2.95 and 3.05 amperes at an angle of 75^o 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 close 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 9 set the phase shifter so that the current lags voltage by θ^{o}. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L-L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is

$Z_{LR} = \frac{V_{L-L}}{\sqrt{3}\, I_L} - 1/3\ Z_L$. Here V_{L-L} is phase-to-phase voltage and I_L is phase current.

Test No.	Volts	Amperes (θ= 75°) & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
8	30	2.95	3.05
	70	6.90	7.10
9	30	5.06 ††	5.24 ††
	70	11.8	12.2

†† Phase Angle Meter Set for $\theta + 30^{o}$

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

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 10, 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 11 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 7 Figure 9, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L-L}}{\sqrt{3}\, I_L}$ 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 9. 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 checked for turns ratio and polarity by using the No. 1 test connections of Figure 9, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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'-T_B for 5.85

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 center than the end.

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

2. Using test #1 to Figure 9, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.

2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.

3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73° and 76° 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.

6. 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 9. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
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 open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. Check the current required to close the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 V_{L-L} to 120 V_{L-L}. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS}{(1 \pm M)} \frac{\sin \theta}{(\sin 75^o)}$.

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 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'-T_B on 5.85 tap.

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

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

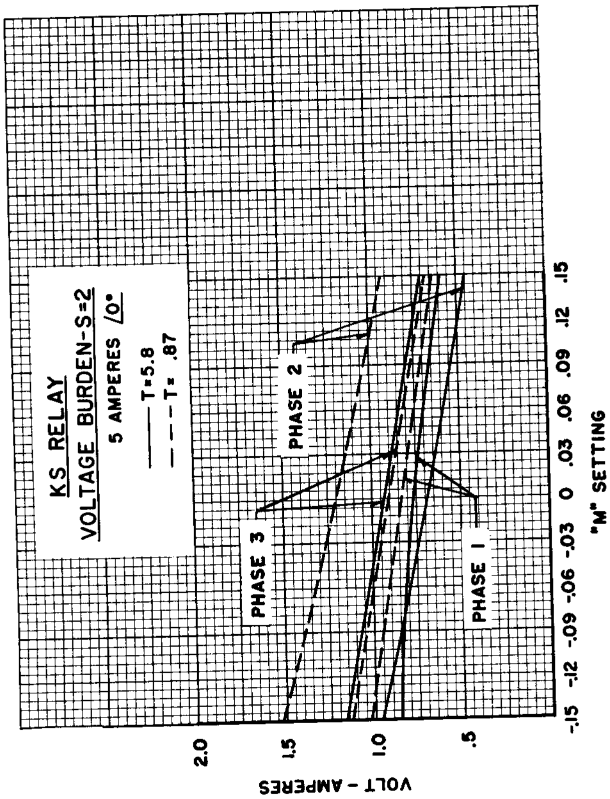
The relay is now calibrated and ready for service.

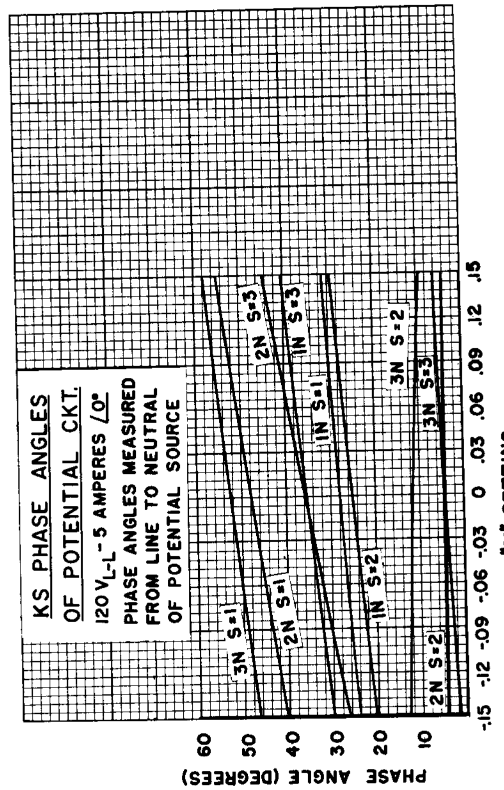
TABLE I

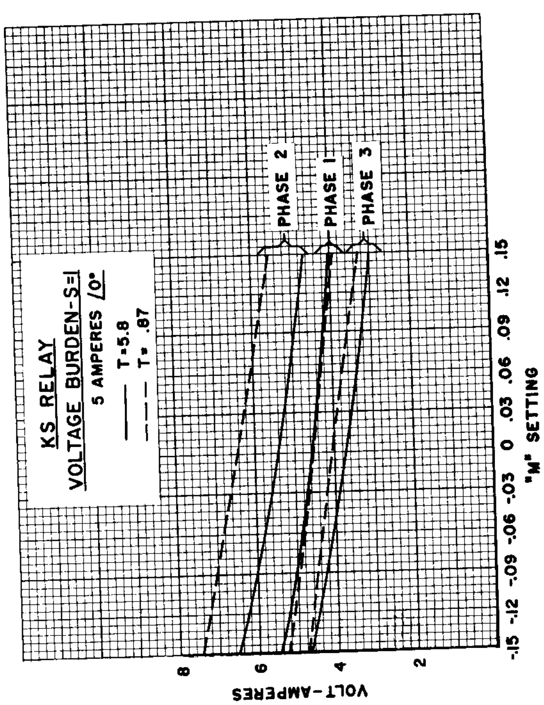
NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors – 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; .06; .06)
OS	Telephone Type Relay – D.C. Resistance = 475 to 525 ohms

ENERGY REQUIREMENTS







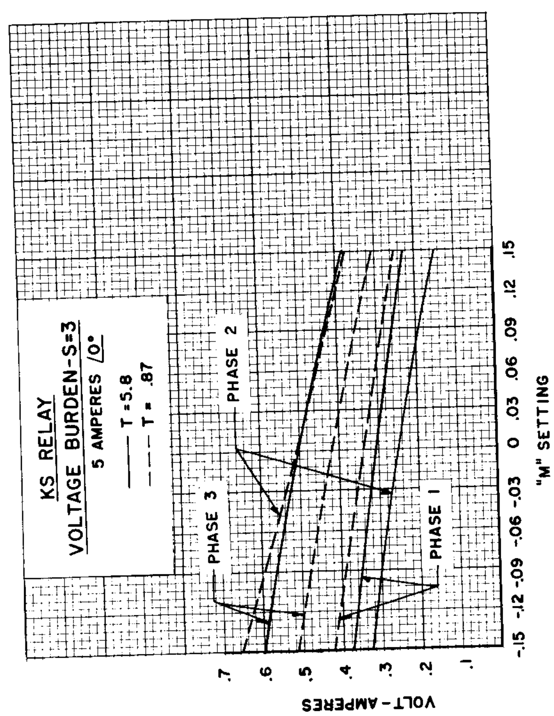


Fig. 6. Type KS Relay Potential Burden Data.

ENERGY REQUIREMENTS

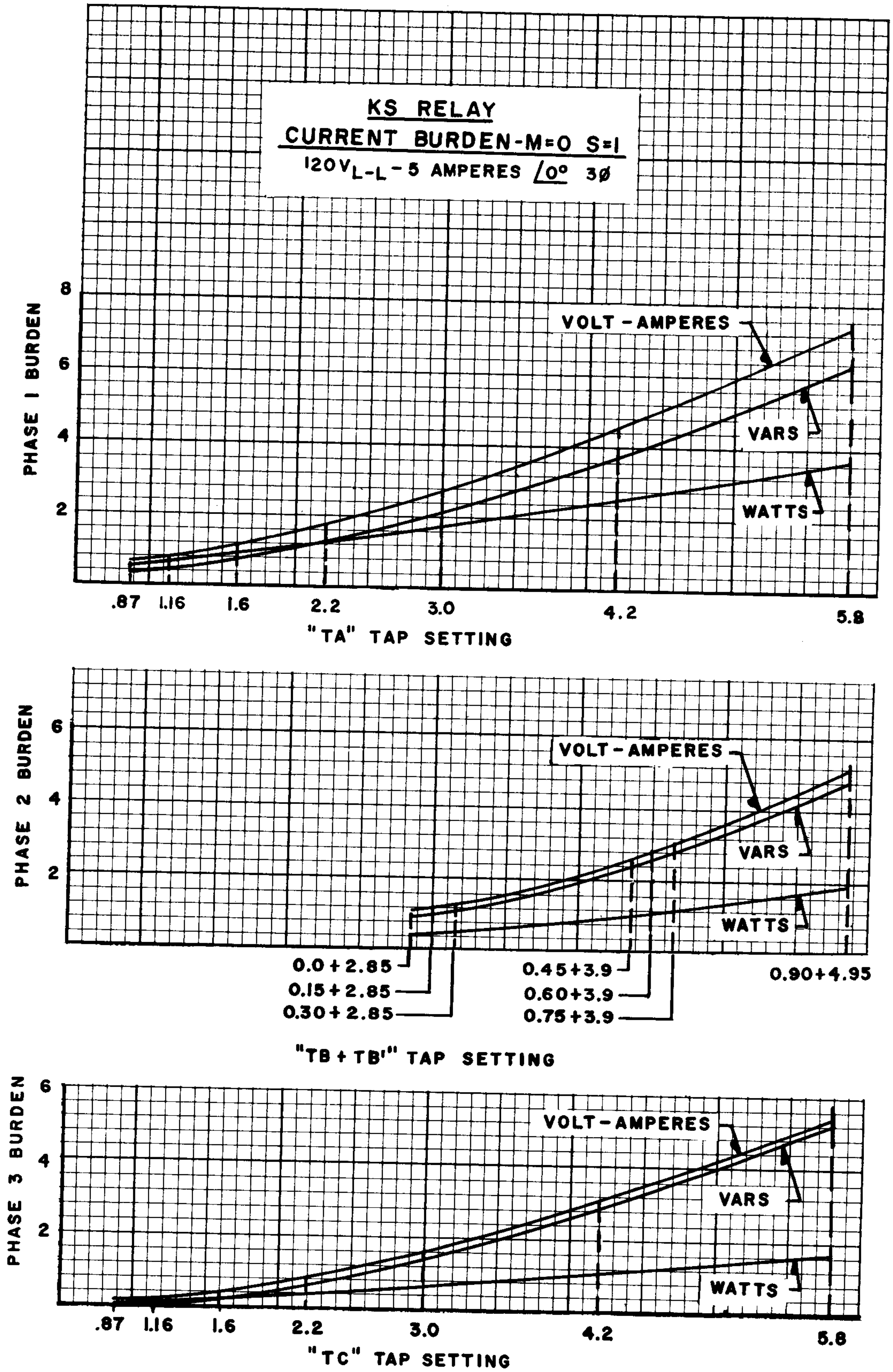


Fig. 7. Type KS Relay Current Burden Data.

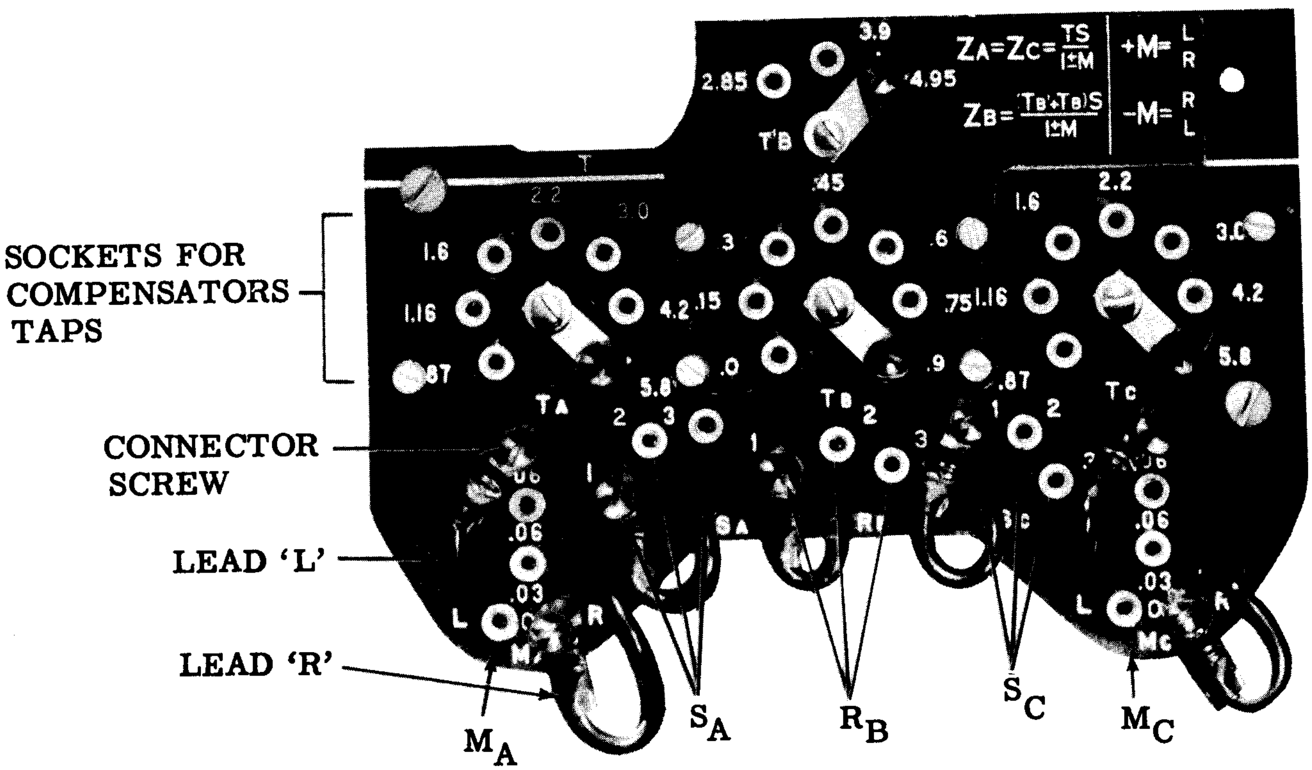
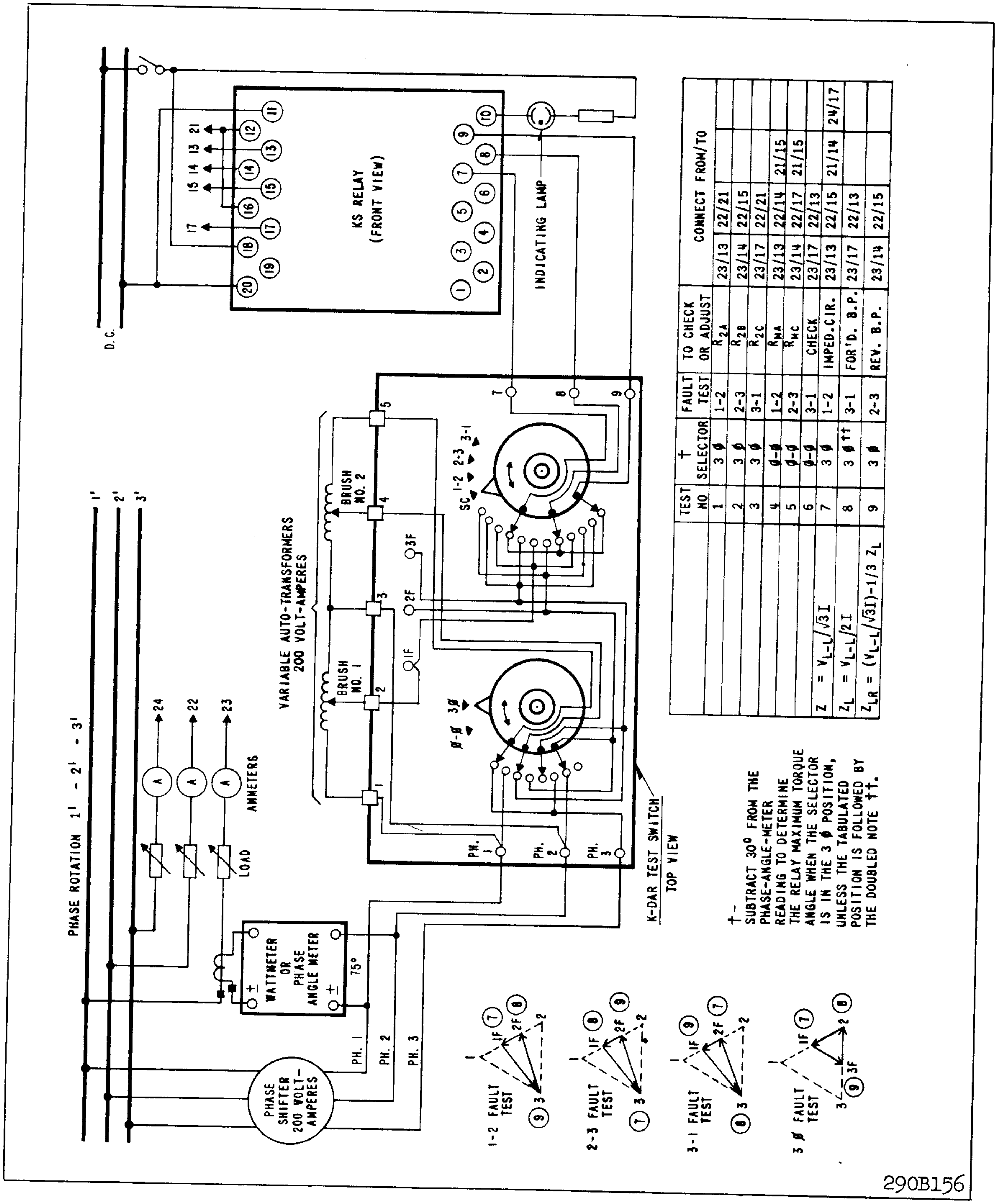


Fig. 8. Tap Plate.



	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 3 Ø POSITION, UNLESS THE TABULATED POSITION IS FOLLOWED BY THE DOUBLED NOTE ††.

Fig. 9. Test Connections for Type KS Relays.

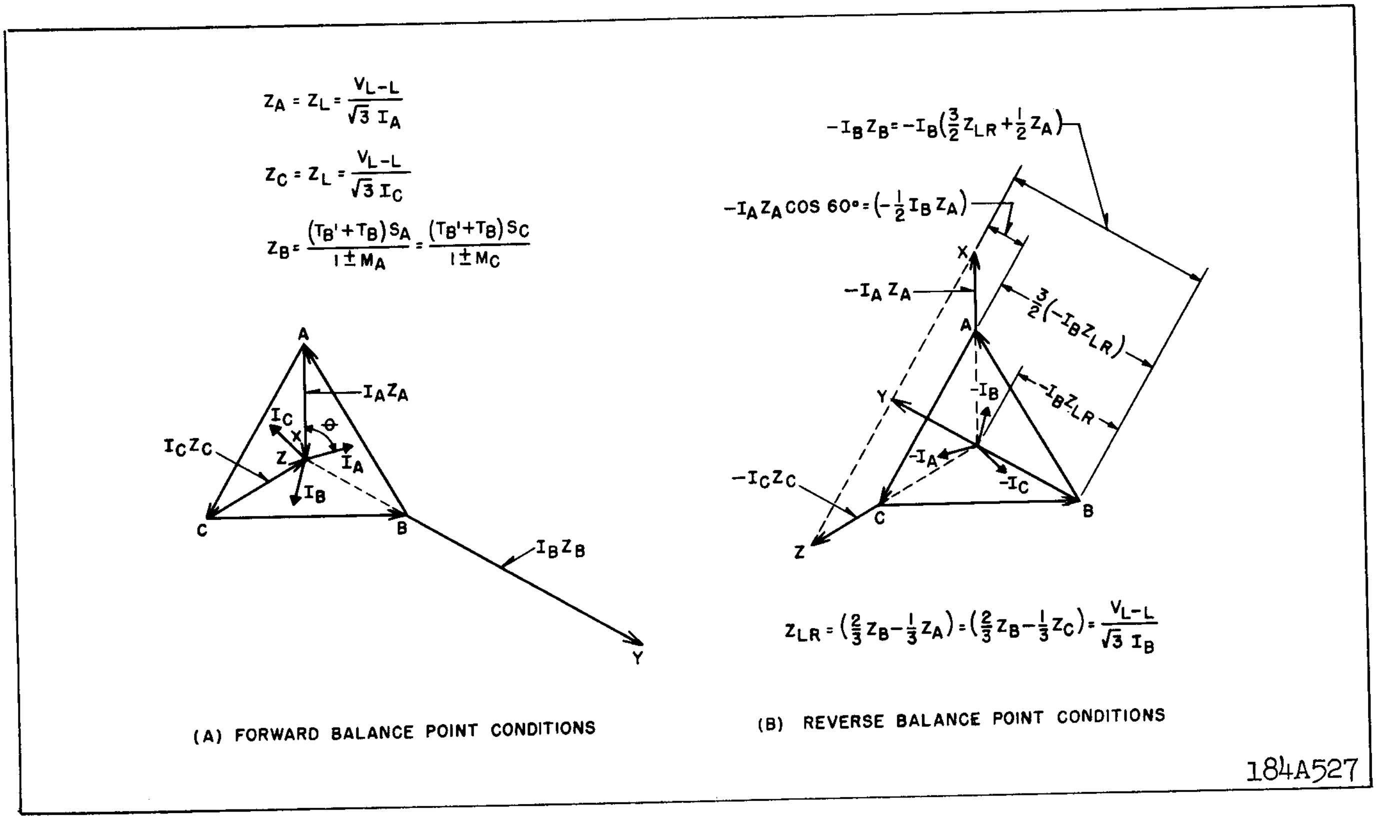


Fig. 10. Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.

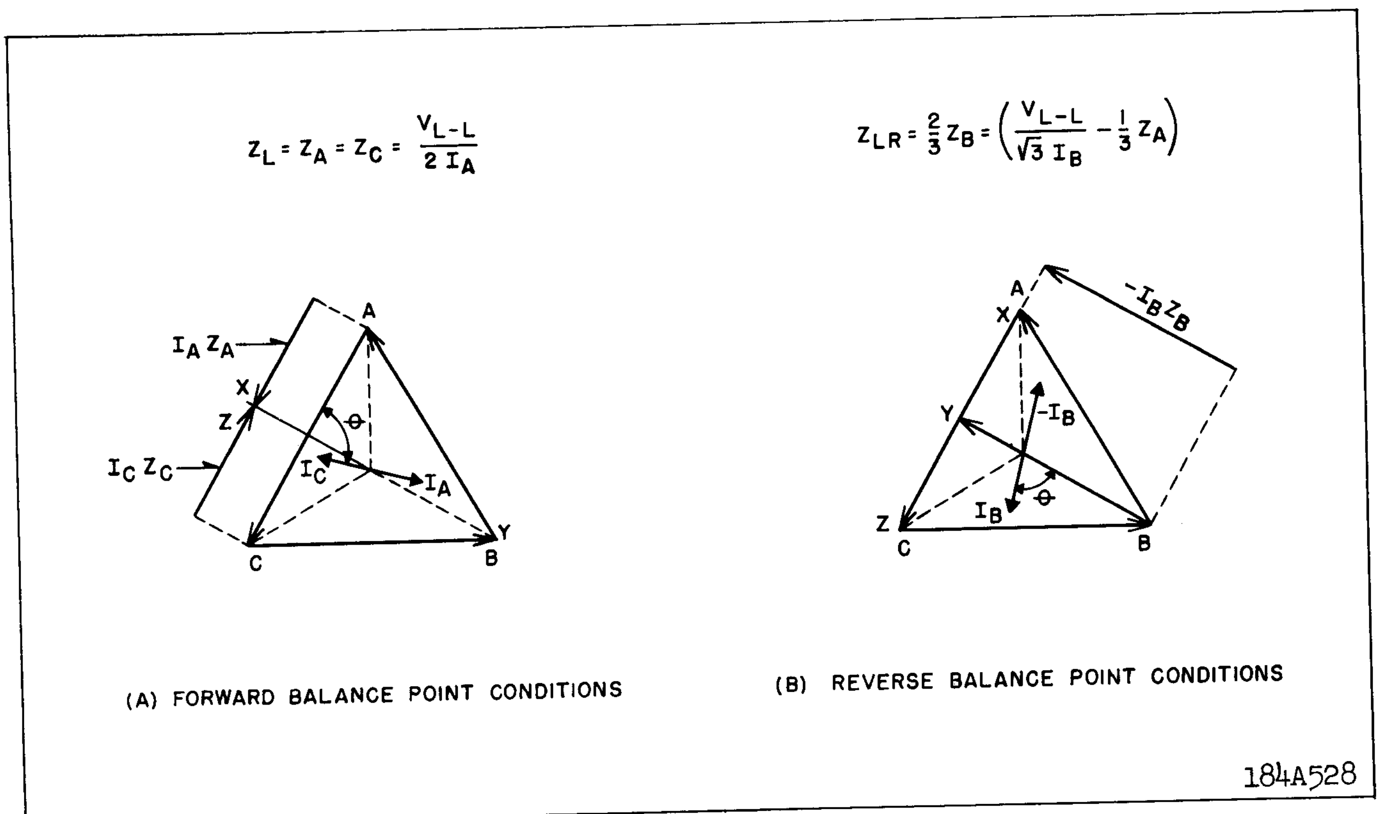


Fig. 11. Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.

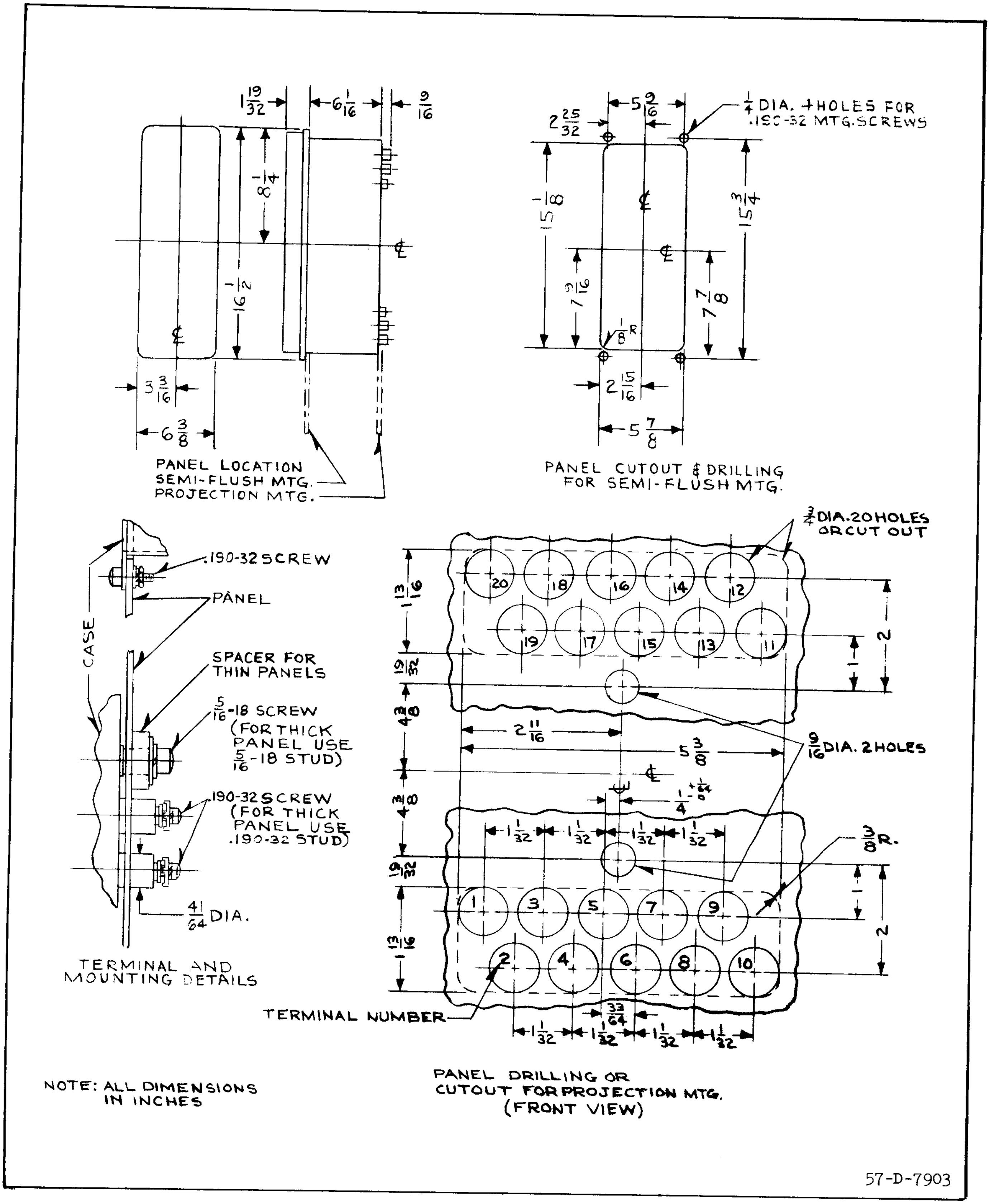


Fig. 12. Outline-Drilling Plan for the Type KS Relay in the FT32 Case.

WESTINGHOUSE ELECTRIC CORPORATION
RELAY-INSTRUMENT DIVISION
NEWARK, N. J.
Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

* The compensators which are designated 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, 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^o and 80^o 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 on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps 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 .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 ±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.

SUPERSEDES I.L. 41-492D
*Denotes change from superseded issue

EFFECTIVE MAY 1968

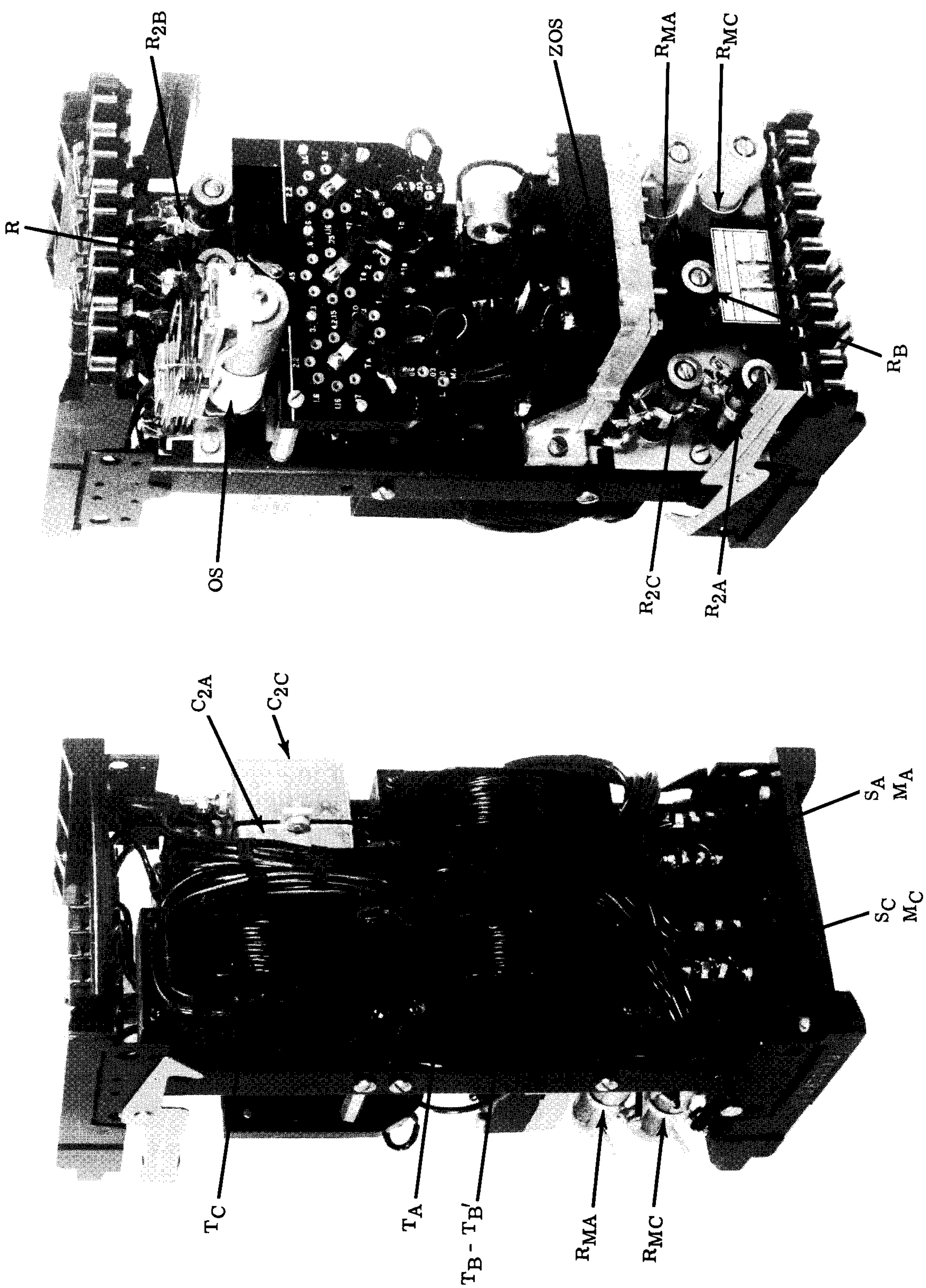


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

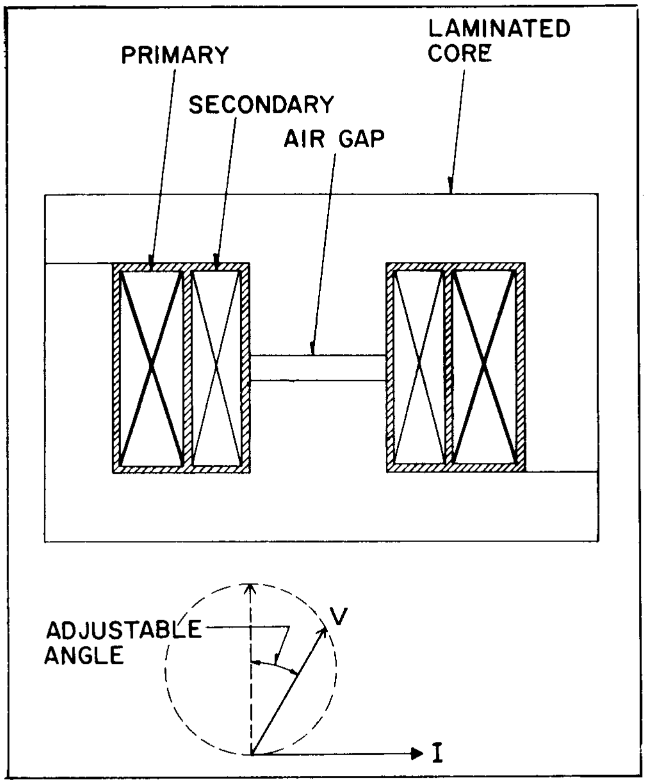


Fig. 2. Compensator Construction.

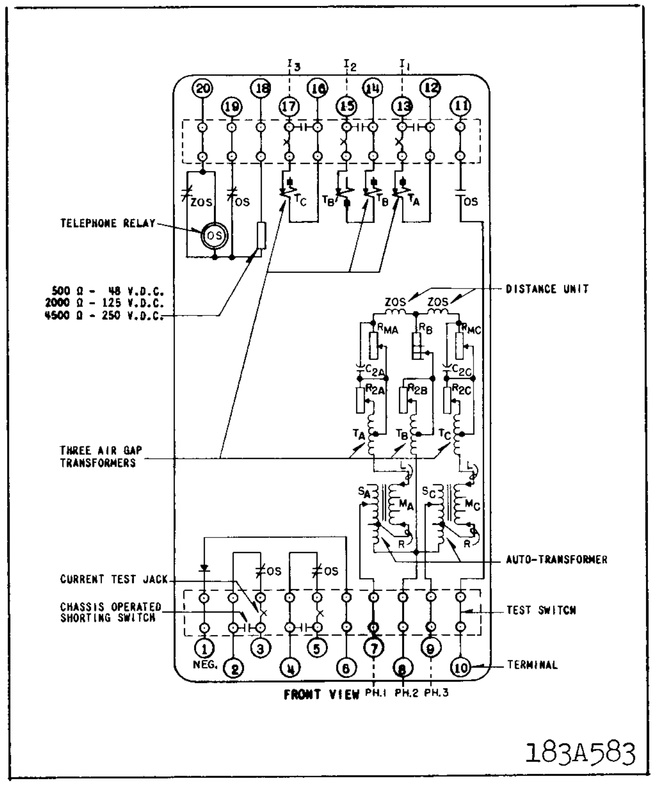


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 sprial 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 adjusted 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.

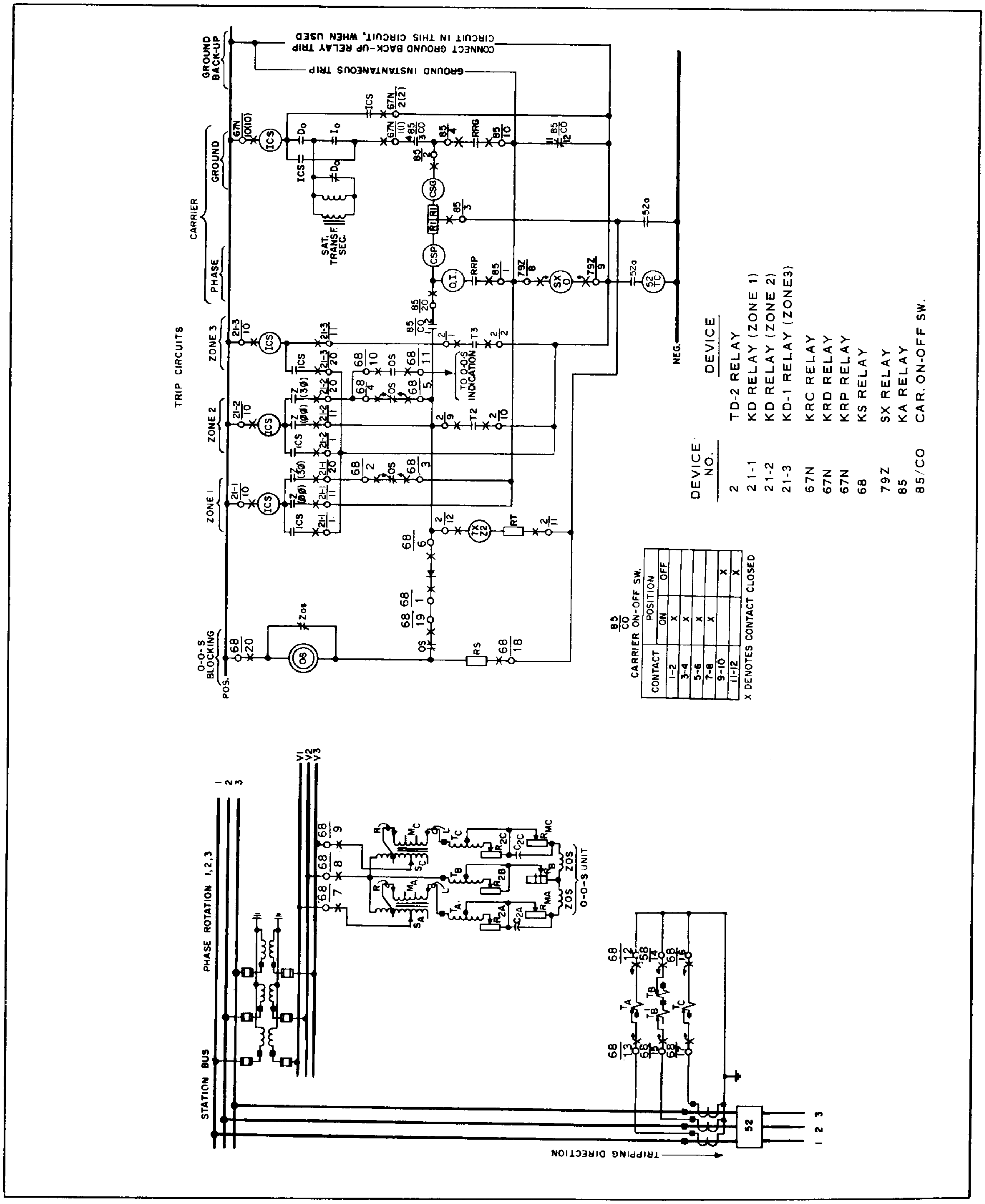


Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.

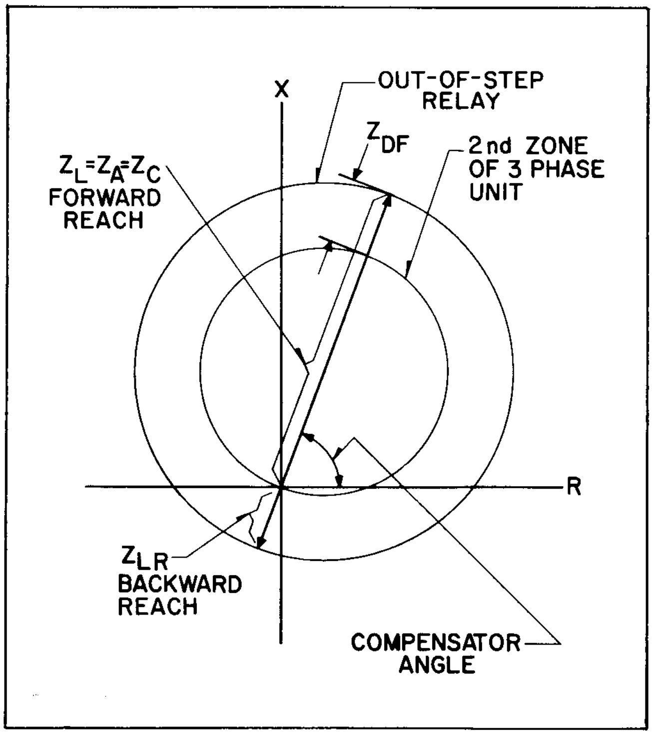


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figure 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles. its OS contacts located between the $\frac{68}{4}$ and $\frac{68}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 6 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)
.87 1.16 1.6 2.2 3.0 4.2 5.8

(T_B)
0 .15 .3 .45 .6 .75 .9

T_B'
2.85 3.9 4.95

(S_A, S_C, R_B)
1 2 3

(M_A, M_C)
± Values between taps .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 on page 14 and 15.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay three-phase unit with a 2 ohm margin. The angle of maximum torque should be the same as that of the KD

relay. The forward-looking reach Z_L is equal to the setting Z_A and Z_C.

$$Z_L = Z_A = Z_C = \frac{TS}{(1 \pm M)}$$

(Sub-letters refer to the T_A and T_C compensators.) The backward reach Z_{LR} is a function of both Z_B and Z_L where

$$Z_B = \frac{(T'_B + T_B)\,S}{(1 \pm M)}.$$

When the proper value of Z_{LR} is determined (usually 2 ohms) then the setting for Z_B can be calculated.

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

The S & M settings of the auto-transformer are determined in the setting of the forward reach.

At the line angle in the forward direction, the ohmic difference, Z_{DF} will generally be set for two ohms. When the two circles are concentric, the backward reach, Z_{LR}, is equal to Z_{DF}. The forward reach, Z_L, can be set up to 20 ohms. The reverse reach, Z_{LR}, can be set at most any practical value with the best coverage at two ohms.

Calculations for setting the KS relay are straightforward and apply familiar principles. Assume a desired balance point which is 2 (relay) ohms greater than the second-zone impedance-relay setting. The general formula for setting the ohms forward reach of the relay is:

$$Z_{L\theta} = Z_L \frac{(\text{Sin } \theta)}{(\text{Sin } 75^o)} = (Z_{Zone\ 2} + 2 \text{ ohms})$$

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

S = Auto-transformer primary tap value

θ = Maximum torque angle setting of the relay

(For a factory setting of 75^o then $\frac{\text{Sin } \theta}{\text{Sin } 75^o} = 1$.)

M = Auto-transformer secondary tap value.
(This is a Per Unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\, Z_{B\theta} - 1/3\, Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\text{Sin } \theta)}{(\text{Sin } 75^o)}$$

$$Z_B = \frac{(T'_B + T_B)\,S}{1 \pm M}$$

$T'_B + T_B$ = compensator tap value

$Z_{L\theta}$, S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{zone\ 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{zone\ 2}$.

2. Select the lowest tap, S, which gives a product of 6.9S greater than Z_L where

   $$Z_L = Z_{L\theta} \frac{(\text{Sin } 75^o)}{(\text{Sin } \theta)}$$

3. Select a value for T that is nearest the value $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.

4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms

2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta} \frac{(\sin 75^o)}{(\sin \theta)}$

$$Z_{B\theta} = 1/2\, Z_{L\theta} + 3/2\, Z_{LR\theta}$$

2. Solve for $(T_B' + T_B)$ where $(T_B' + T_B) = \frac{Z_B (1 \pm M)}{S}$

3. Select the highest possible value for T_B' and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

1. Then $Z_B = (\frac{9}{2} + \frac{3 \times 2}{2}) \times \frac{0.966}{0.866}$
$= 7.5 \times 1.11 = 8.36$ ohms

2. $(T_B' + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T_B' = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35 (\frac{.866}{.966}) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, T_B -T_B', and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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 – 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 insert 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.

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 8).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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^o}	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^o current lagging voltage and the tap values are based on this angle. Generally speaking, the 75^o setting can be applied on lines with angles from 65^o to 90^o and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between 60^o and 80^o 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 stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 * 7. 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 open should be between 2.95 and 3.05 amperes at an angle of 75^o 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 close 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 7 set the phase shifter so that the current lags voltage by θ°. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L-L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is $Z_{LR} = \frac{V_{L-L}}{\sqrt{3}\, I_L} - 1/3\ Z_L$. Here V_{L-L} is phase-to-phase voltage and I_L is phase current.

Test No.	Volts	Amperes ($\theta = 75^{\circ}$) & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
8	30	2.95	3.05
	70	6.90	7.10
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 θ is not equal to 75°, 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 8, 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 9 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per * Test No. 7 Figure 7, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L-L}}{\sqrt{3}\, I_L}$ 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 9. 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 checked for turns ratio and polarity by using the No. 1 test connections of * Figure 7, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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'-T_B for 5.85

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 center than the end.

* 1. Using connections for test #1 of Figure 7 adjust brush #1 so that $V_{1F2F} = V_{78} = 0$. Adjust brush #2 for rated voltage across terminals 8 & 9. Adjust R_B so that the contact floats or has a minimum of torque. This is a rough adjustment for making the impedance angle of phase 1 to be equal to impedance of phase 2.

* 2. Using test #1 to Figure 7, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.
2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.
3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73° and 76° 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.
6. 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 * 7. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
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 open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. Check the current required to close the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 V_{L-L} to 120 V_{L-L}. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS \quad \sin\theta}{(1 \pm M)(\sin 75^\circ)}$.

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 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'-T_B on 5.85 tap.

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

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

The relay is now calibrated and ready for service.

TABLE I

NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors – 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; .06; .06)
OS	Telephone Type Relay – D.C. Resistance = 475 to 525 ohms

TAP SETTING	VOLTAGE BURDEN — I = 0 — $V_{AN} = V_{BN} = V_{CN} = 69$ Volts — 3 ϕ — S = 1								
	ϕA			ϕB			ϕC		
	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ
−.15	4.4	4.0	1.81	6.8	4.0	5.5	3.4	1.0	3.25
−.12	4.6	4.2	1.81	6.9	4.15	5.4	3.5	1.08	3.33
−.09	4.8	4.3	1.8	7.1	4.35	5.6	3.6	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

TAP SETTING	VOLTAGE BURDEN — I = 0 — $V_{AN} = V_{BN} = V_{CN} = 69$ Volts — 3 ϕ — S = 2								
	ϕA			ϕB			ϕC		
	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	1.55	1.21	.97	.59	.306	.505
−.06	1.17	1.15	.217	1.65	1.29	1.01	.61	.322	.52
−.03	1.24	1.22	.222	1.70	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	.375	.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

TAP SETTING	VOLTAGE BURDEN — I = 0 — $V_{AN} = V_{BN} = V_{CN} = 69$ Volts — 3 ϕ — S = 3								
	ϕA			ϕB			ϕC		
	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	.260
−.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

CURRENT BURDEN

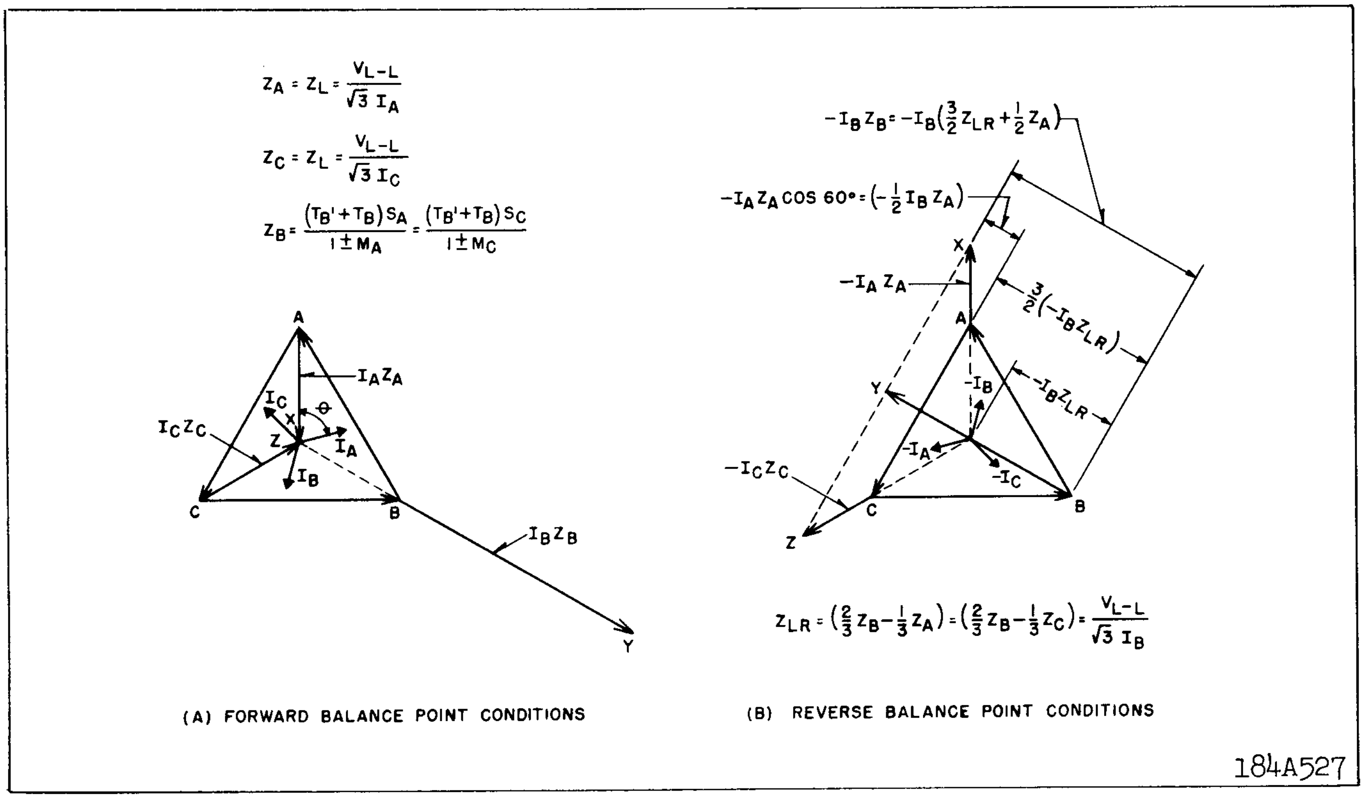
3ϕI = 5 AMP /0 3ϕV = 69V$_{L-N}$ M = 0 S = 1

TAP T_A	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.0030	0.0 +2.85	.115	.097	.063	.87	.026	.025	.005
1.16	.044	.042	.011	.15+2.85	.14	.116	.08	1.16	.03	.026	.014
1.6	.064	.060	.021	.3 +2.85	.165	.13	.10	1.6	.036	.27	.024
2.2	.074	.062	.04	.45+3.9	.19	.15	.12	2.2	.052	.030	.043
3.0	.12	.083	.088	.6 +3.9	.2	.13	.15	3.0	.068	.029	.062
4.2	.21	.114	.177	.75+3.9	.22	.14	.17	4.2	.11	.034	.105
5.8	.32	.115	.30	.9 +4.95	.3	.16	.25	5.8	.2	.052	.19

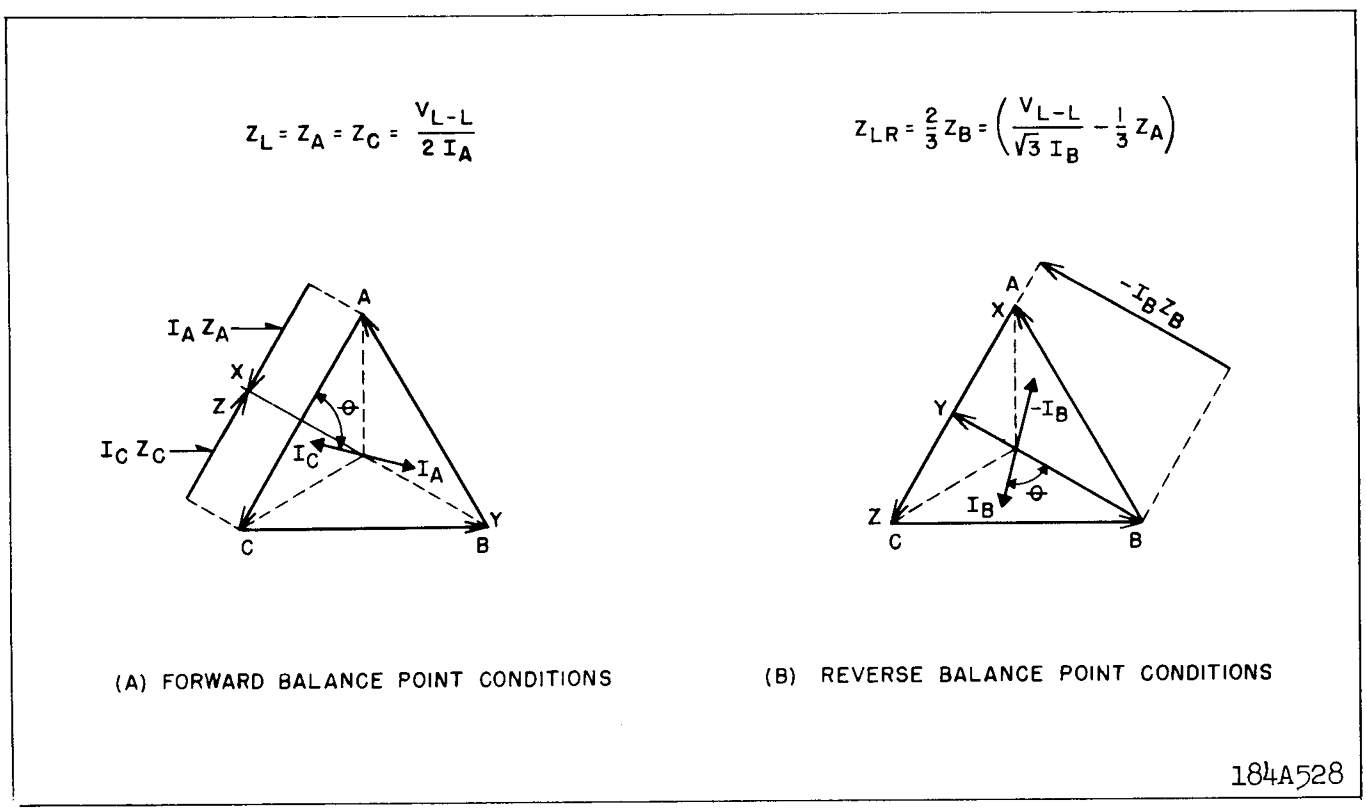
CURRENT BURDEN

3ϕI = 50 AMP /0 3ϕV = 120V$_{L-L}$ M = 0 S = 1

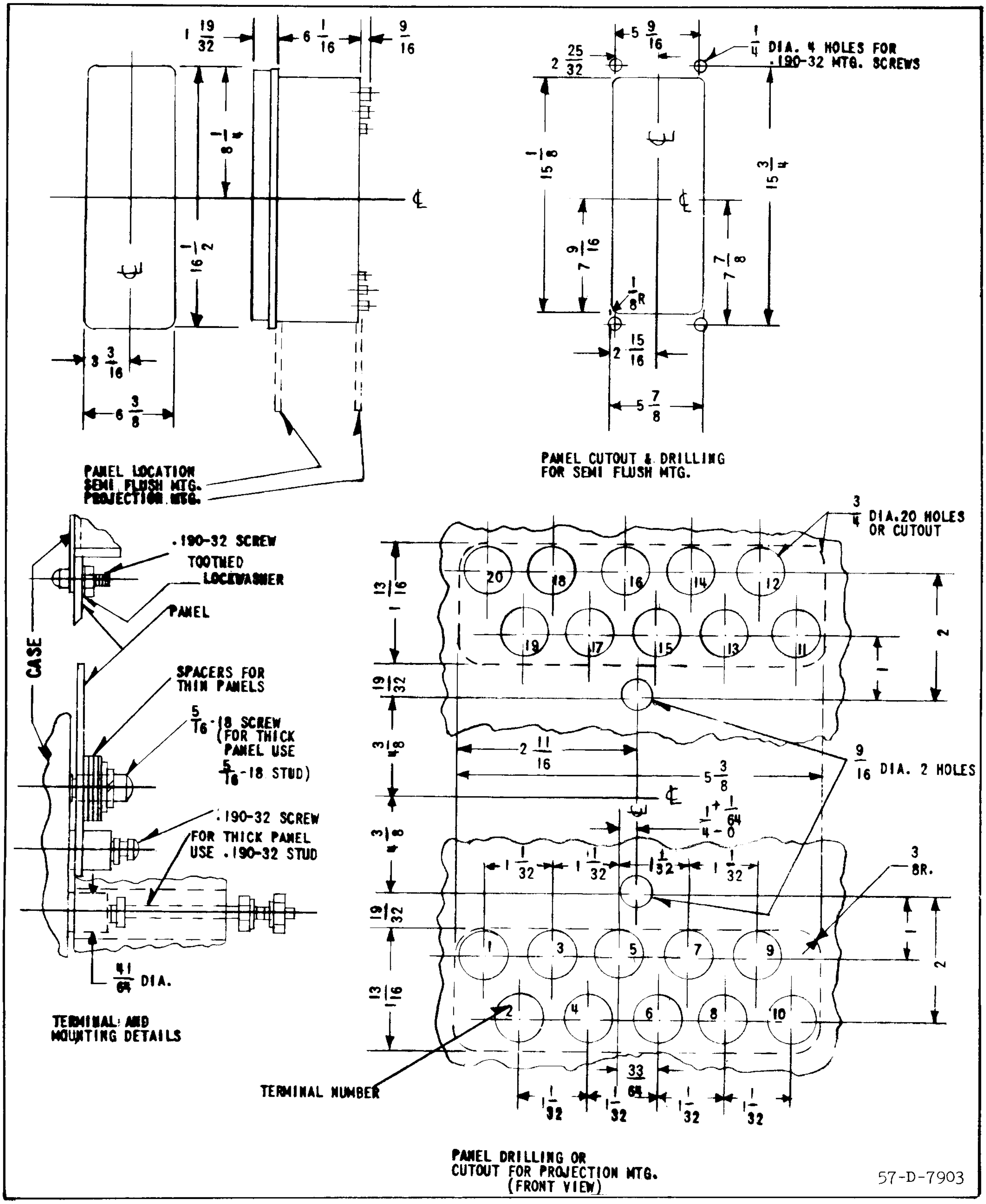
TAP T_A	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.003	0.0 +2.85	.088	.070	.053	.87	.034	.034	.004
1.16	.034	.033	.008	.15+2.85	.092	.073	.056	1.16	.038	.037	.007
1.6	.05	.047	.016	.3 +2.85	.10	.078	.063	1.6	.046	.043	.060
2.2	.06	.051	.032	.45+3.9	.154	.105	.11	2.2	.066	.073	.059
3.0	.098	.075	.063	.6 +3.9	.16	.107	.12	3.0	.094		
4.2	15	.096	.115	.75+3.9	.17	.11	.13	4.2	.144		
5.8	.24	.14	.195	.9 +4.95	.24	.15	.19	5.8	.23		



* *Fig. 8. Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.*



* *Fig. 9. Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.*



* *Fig. 10. Outline-Drilling Plan for the Type KS Relay in the FT32 Case.*

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION **NEWARK, N. J.**

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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 on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps 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 .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 ±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.

SUPERSEDES I.L. 41-492E
*Denotes change from superseded issue

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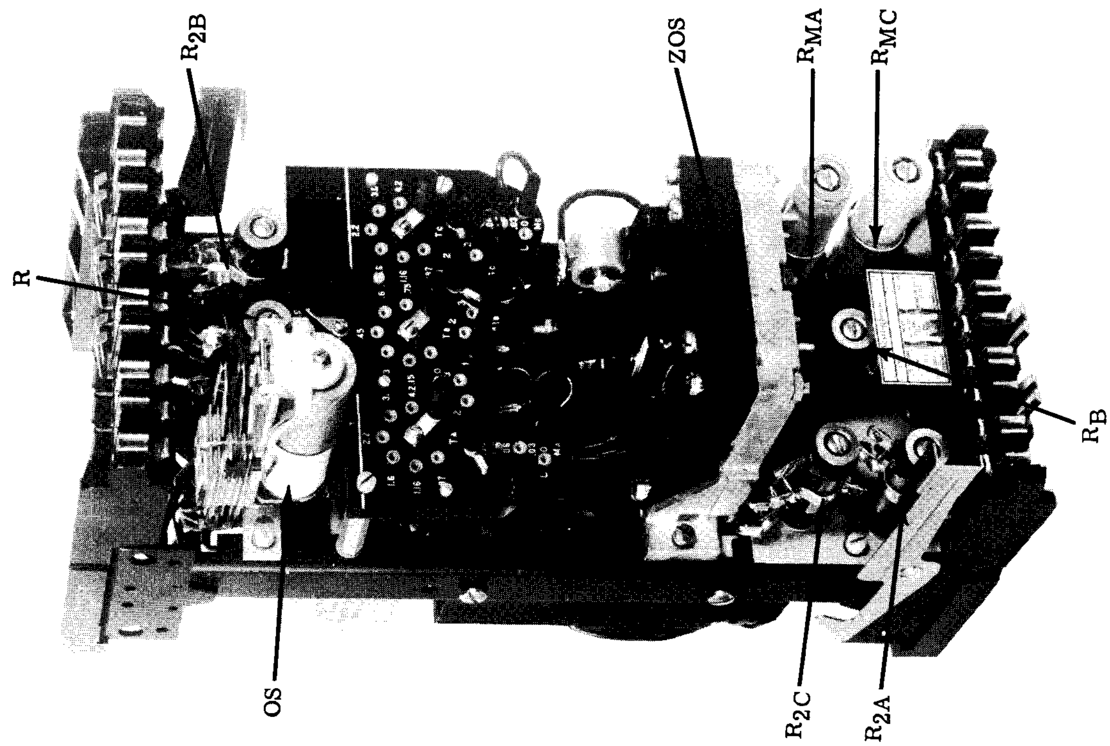


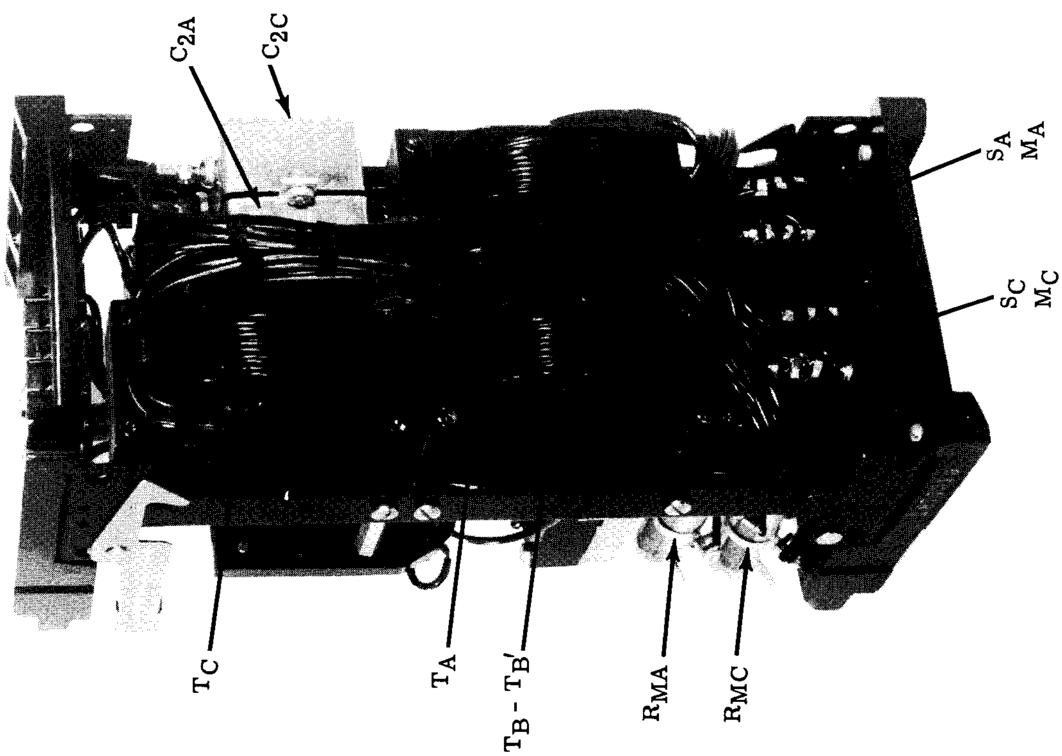


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

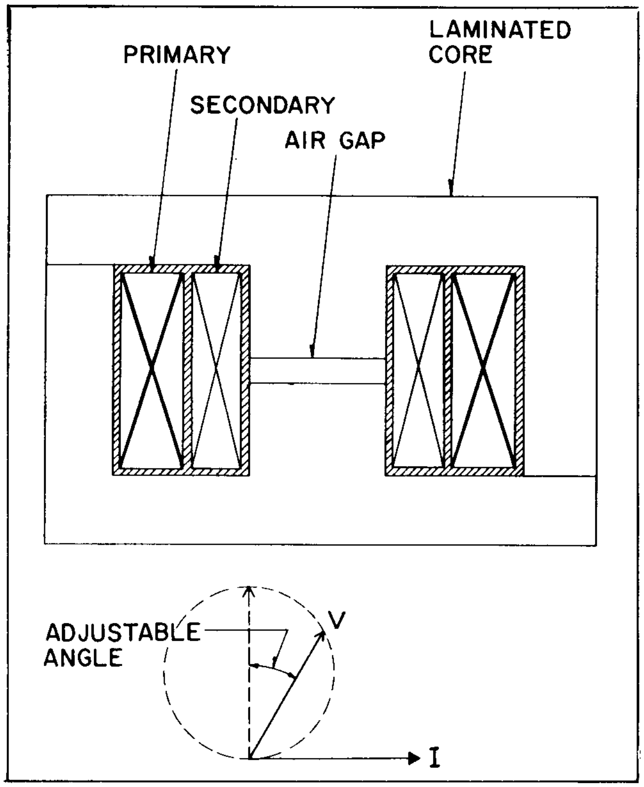
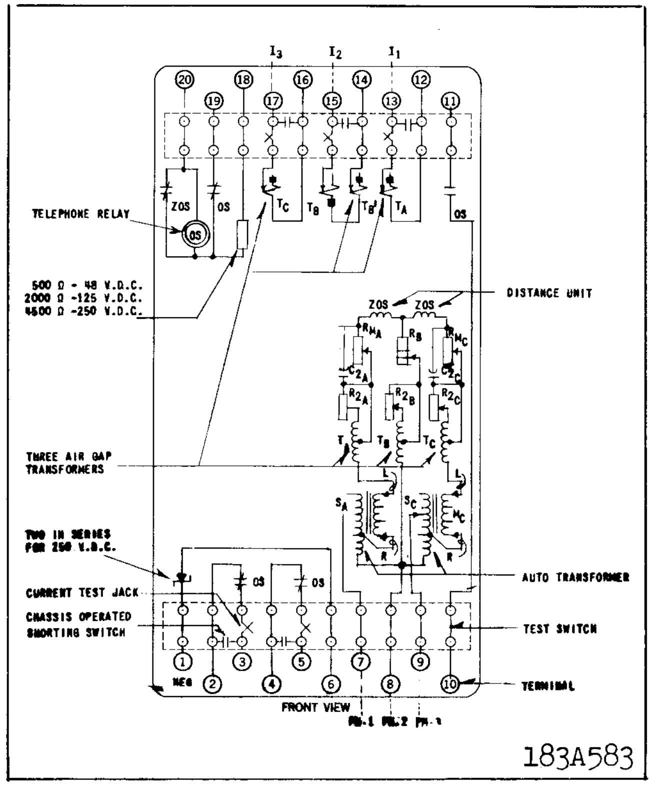


Fig. 2. Compensator Construction.



✻ *Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.*

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

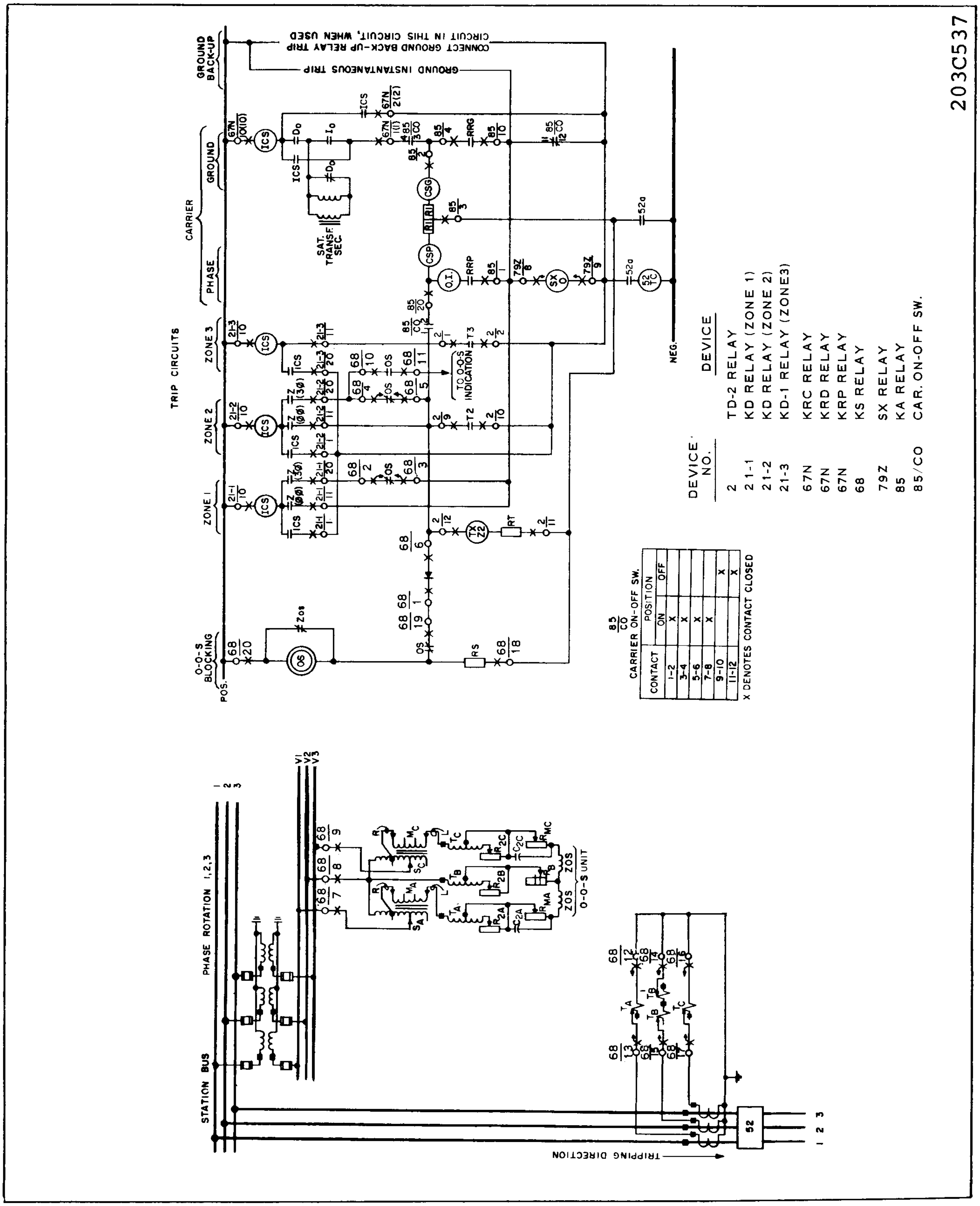
Mechanically, the cylinder unit is composed of four basic components: a die-cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge.

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 sprial 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 adjusted 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.



* *Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.*

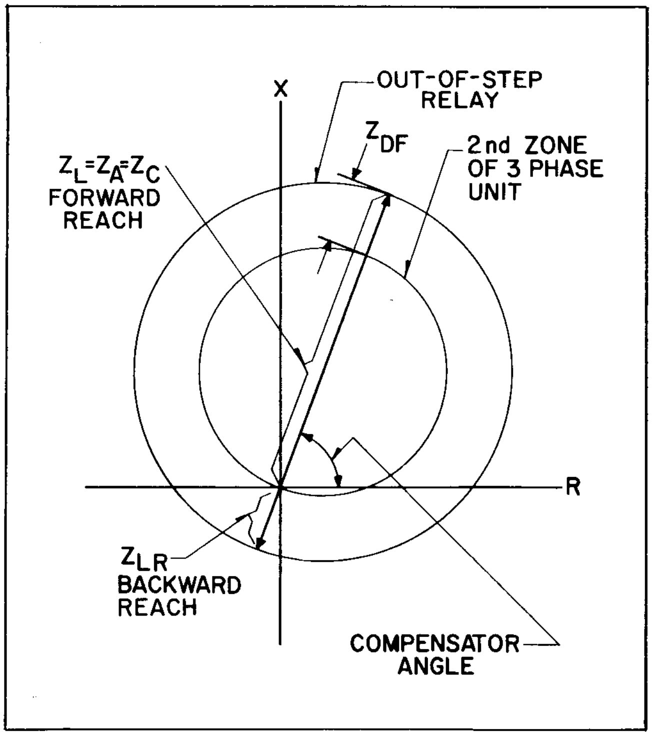


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figure 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles. its OS contacts located between the $\frac{68}{4}$ and $\frac{68}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 6 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)

.87 1.16 1.6 2.2 3.0 4.2 5.8

(T_B)

0 .15 .3 .45 .6 .75 .9

T_B'

2.85 3.9 4.95

(S_A, S_C, R_B)

1 2 3

(M_A, M_C)

± Values between taps .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 on page 14 and 15.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay three-phase unit with a 2 ohm margin. The angle of maximum torque should be the same as that of the KD

relay. The forward-looking reach Z_L is equal to the setting Z_A and Z_C.

$$Z_L = Z_A = Z_C = \frac{TS}{(1 \pm M)}$$

(Sub-letters refer to the T_A and T_C compensators.) The backward reach Z_{LR} is a function of both Z_B and Z_L where

$$Z_B = \frac{(T'_B + T_B)\,S}{(1 \pm M).}$$

When the proper value of Z_{LR} is determined (usually 2 ohms) then the setting for Z_B can be calculated.

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

The S & M settings of the auto-transformer are determined in the setting of the forward reach.

At the line angle in the forward direction, the ohmic difference, Z_{DF} will generally be set for two ohms. When the two circles are concentric, the backward reach, Z_{LR}, is equal to Z_{DF}. The forward reach, Z_L, can be set up to 20 ohms. The reverse reach, Z_{LR}, can be set at most any practical value with the best coverage at two ohms.

Calculations for setting the KS relay are straightforward and apply familiar principles. Assume a desired balance point which is 2 (relay) ohms greater than the second-zone impedance-relay setting. The general formula for setting the ohms forward reach of the relay is:

$$Z_{L\theta} = Z_L \frac{(\sin \theta)}{(\sin 75^o)} = (Z_{Zone\ 2} + 2 \text{ ohms})$$

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

S = Auto-transformer primary tap value

θ = Maximum torque angle setting of the relay

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

M = Auto-transformer secondary tap value.
(This is a Per Unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\ Z_{B\theta} - 1/3\ Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\sin \theta)}{(\sin 75^o)}$$

$$Z_B = \frac{(T'_B + T_B)\,S}{1 \pm M}$$

$T'_B + T_B$ = compensator tap value

$Z_{L\theta}$, S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{zone\ 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{zone\ 2}$.

2. Select the lowest tap, S, which gives a product of 6.9S greater than Z_L where

   $$Z_L = Z_{L\theta} \frac{(\sin 75^o)}{(\sin \theta)}$$

3. Select a value for T that is nearest the value $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.

4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms

2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta}\frac{(\text{Sin } 75^o)}{(\text{Sin } \theta)}$

   $Z_{B\theta} = 1/2\, Z_{L\theta} + 3/2\, Z_{LR\theta}$

2. Solve for $(T_B' + T_B)$ where $(T_B' + T_B) = \frac{Z_B (1 \pm M)}{S}$

3. Select the highest possible value for T_B' and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

1. Then $Z_B = (\frac{9}{2} + \frac{3 \times 2}{2}) \times \frac{0.966}{0.866}$

   $= 7.5 \times 1.11 = 8.36$ ohms

2. $(T_B' + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T_B' = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35\,(\frac{.866}{.966}) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, T_B-T_B, and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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 – 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 insert 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.

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 8).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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_{75^0}	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 75^0 current lagging voltage and the tap values are based on this angle. Generally speaking, the 75^0 setting can be applied on lines with angles from 65^0 to 90^0 and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between 60^0 and 80^0 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 stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 7. 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 open should be between 2.95 and 3.05 amperes at an angle of 75^0 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 close 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 7 set the phase shifter so that the current lags voltage by θ^{0}. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L-L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is

$Z_{LR} = \frac{V_{L-L}}{\sqrt{3}\, I_L} - 1/3\ Z_L$. Here V_{L-L} is phase-to-phase voltage and I_L is phase current.

Test No.	Volts	Amperes (θ= 75°) & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
8	30	2.95	3.05
	70	6.90	7.10
9	30	5.06 ††	5.24 ††
	70	11.8	12.2

†† Phase Angle Meter Set for $\theta + 30^{0}$

† To determine the limits of current when θ is not equal to 75^{0}, multiply the nominal values tabulated above by the ratio $\frac{\sin 75^{0}}{\sin \theta}$

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 8, 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 9 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 7 Figure 7, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L-L}}{\sqrt{3}\, I_L}$ 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 9. 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 checked for turns ratio and polarity by using the No. 1 test connections of Figure 7, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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'-T_B for 5.85

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 center than the end.

1. Using connections for test #1 of Figure 7 adjust brush #1 so that $V_{1F2F} = V_{78} = 0$. Adjust brush #2 for rated voltage across terminals 8 & 9. Adjust R_B so that the contact floats or has a minimum of torque. This is a rough adjustment for making the impedance angle of phase 1 to be equal to impedance of phase 2.

2. Using test #1 to Figure 7, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.

2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.

3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73° and 76° 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.

6. 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 7. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
3. Adjust the phase shifter for θ degrees between load current and $V_{PH.1\text{-}PH.2}$.
4. With load current set for 0.51 amperes, adjust R_{MA} so that the cylinder unit contacts just open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. Check the current required to close the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 $V_{L\text{-}L}$ to 120 $V_{L\text{-}L}$. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS}{(1 \pm M)}\frac{\sin \theta}{(\sin 75^o)}$.

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 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'-T_B on 5.85 tap.

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

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

The relay is now calibrated and ready for service.

TABLE I

NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors – 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; .06; .06)
OS	Telephone Type Relay – D.C. Resistance = 475 to 525 ohms

TAP SETTING	VOLTAGE BURDEN								
	I = 0 $V_{AN} = V_{BN} = V_{CN}$ = 69 Volts 3 ϕ S = 1								
	ϕ A			ϕ B			ϕ 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	4.0	1.81	6.8	4.0	5.5	3.4	1.0	3.25
−.12	4.6	4.2	1.81	6.9	4.15	5.4	3.5	1.08	3.33
−.09	4.8	4.3	1.8	7.1	4.35	5.6	3.6	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

TAP SETTING	VOLTAGE BURDEN								
	I = 0 $V_{AN} = V_{BN} = V_{CN}$ = 69 Volts 3 ϕ S = 2								
	ϕ A			ϕ B			ϕ 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	1.55	1.21	.97	.59	.306	.505
−.06	1.17	1.15	.217	1.65	1.29	1.01	.61	.322	.52
−.03	1.24	1.22	.222	1.70	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	.375	.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

TAP SETTING	VOLTAGE BURDEN								
	I = 0 $V_{AN} = V_{BN} = V_{CN}$ = 69 Volts 3 ϕ S = 3								
	ϕ A			ϕ B			ϕ 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	.260
−.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

CURRENT BURDEN											
	$3\phi I = 5$ AMP $\angle 0$ $3\phi V = 69V_{L-N}$ M = 0 S = 1										
TAP T_A	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.0030	0.0 +2.85	.115	.097	.063	.87	.026	.025	.005
1.16	.044	.042	.011	.15+2.85	.14	.116	.08	1.16	.03	.026	.014
1.6	.064	.060	.021	.3 +2.85	.165	.13	.10	1.6	.036	.27	.024
2.2	.074	.062	.04	.45+3.9	.19	.15	.12	2.2	.052	.030	.043
3.0	.12	.083	.088	.6 +3.9	.2	.13	.15	3.0	.068	.029	.062
4.2	.21	.114	.177	.75+3.9	.22	.14	.17	4.2	.11	.034	.105
5.8	.32	.115	.30	.9 +4.95	.3	.16	.25	5.8	.2	.052	.19

CURRENT BURDEN											
	$3\phi I = 50$ AMP $\angle 0$ $3\phi V = 120V_{L-L}$ M = 0 S = 1										
TAP T_A	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.003	0.0 +2.85	.088	.070	.053	.87	.034	.034	.004
1.16	.034	.033	.008	.15+2.85	.092	.073	.056	1.16	.038	.037	.007
1.6	.05	.047	.016	.3 +2.85	.10	.078	.063	1.6	.046	.043	.060
2.2	.06	.051	.032	.45+3.9	.154	.105	.11	2.2	.066	.073	.059
3.0	.098	.075	.063	.6 +3.9	.16	.107	.12	3.0	.094		
4.2	15	.096	.115	.75+3.9	.17	.11	.13	4.2	.144		
5.8	.24	.14	.195	.9 +4.95	.24	.15	.19	5.8	.23		

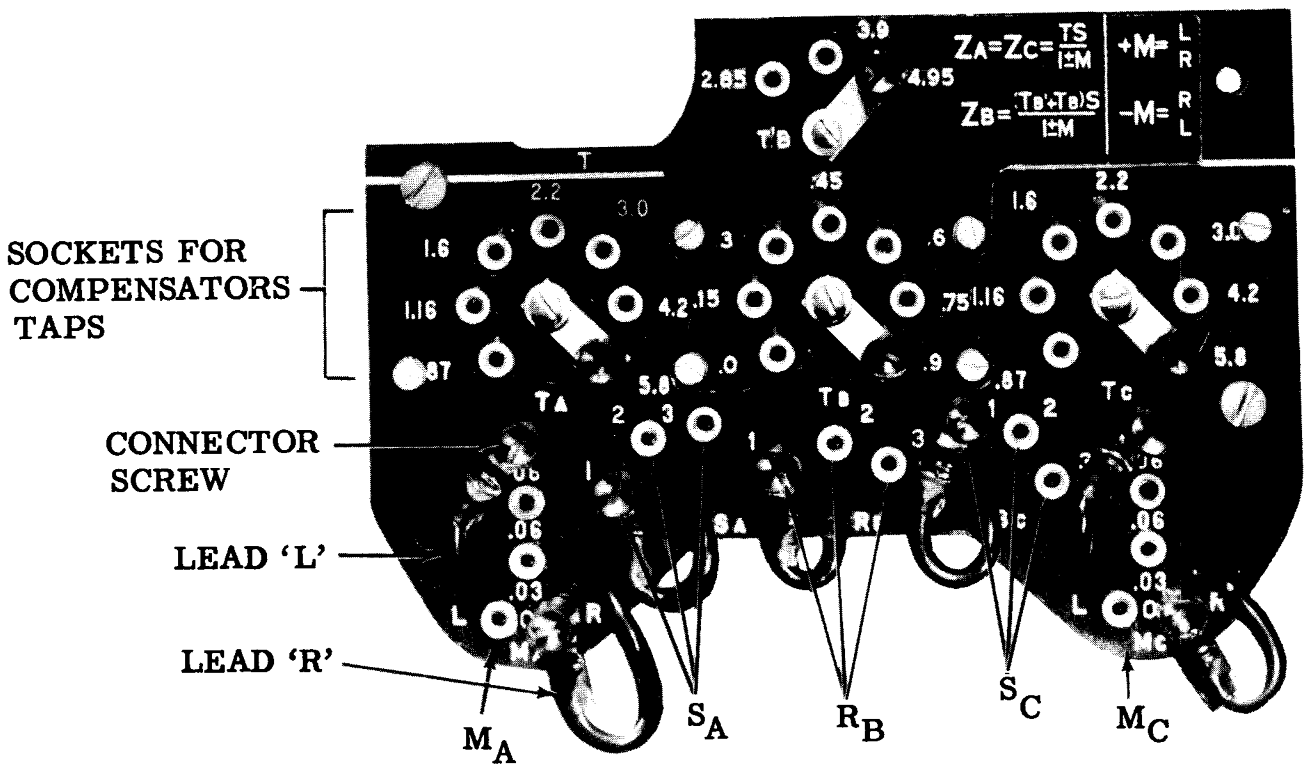
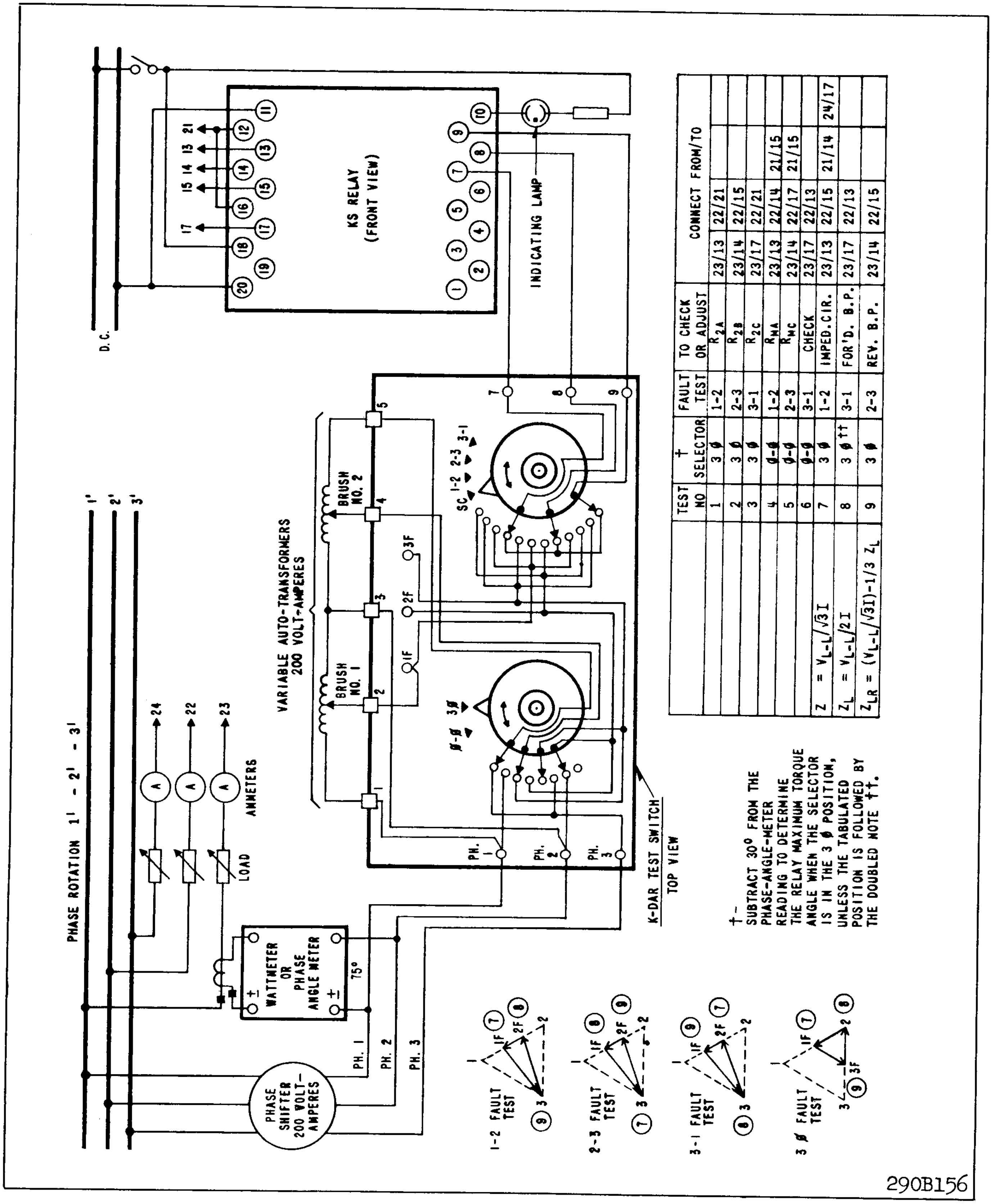


Fig. 6. Tap Plate.



	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		

Fig. 7. Test Connections for Type KS Relays.

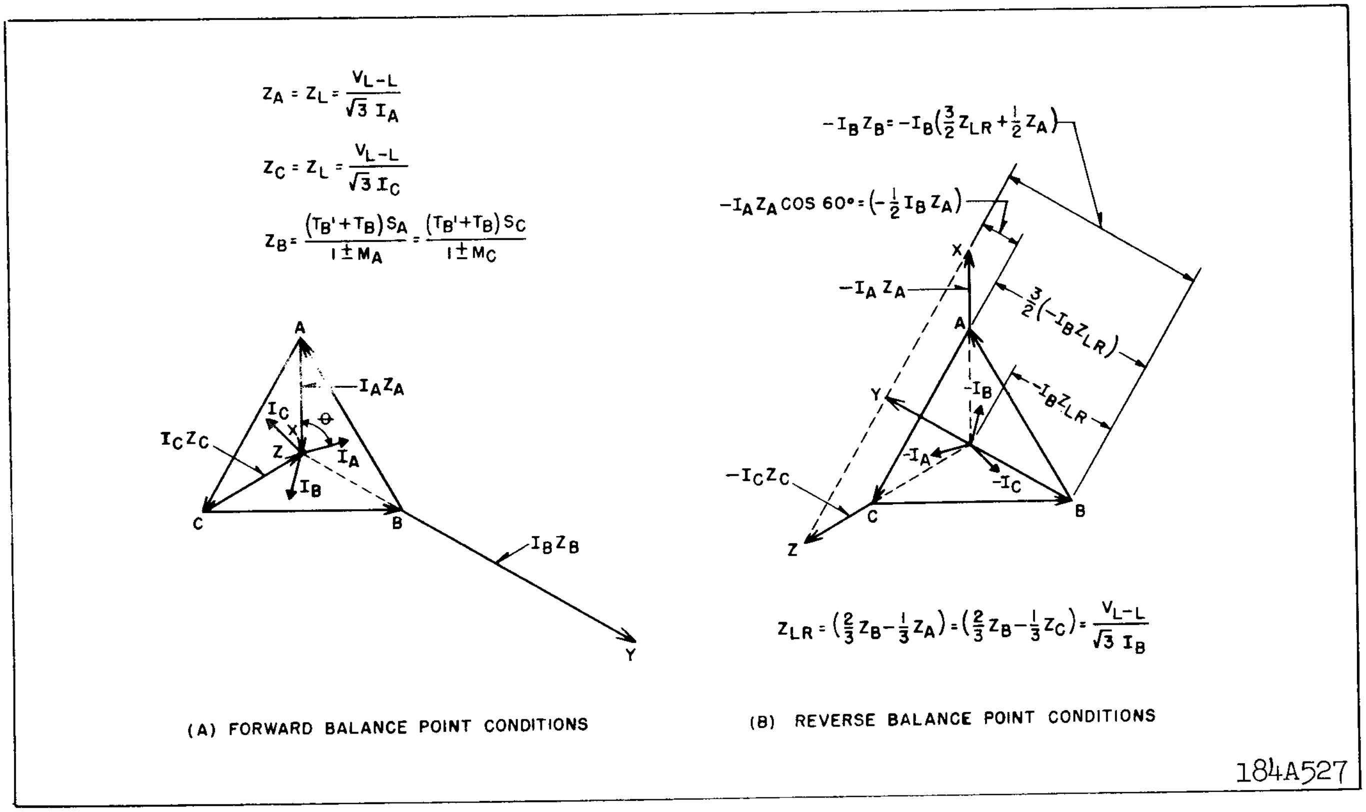


Fig. 8. Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.

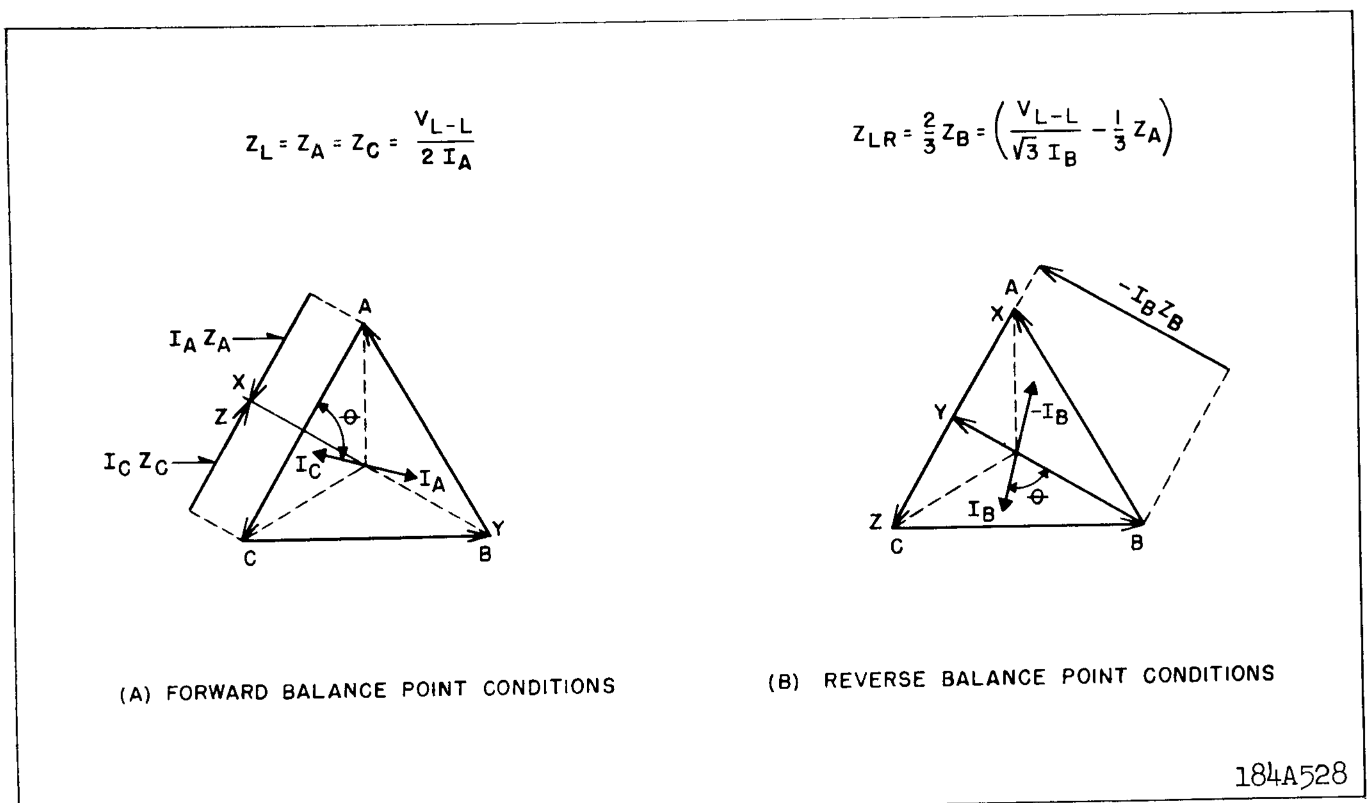


Fig. 9. Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.

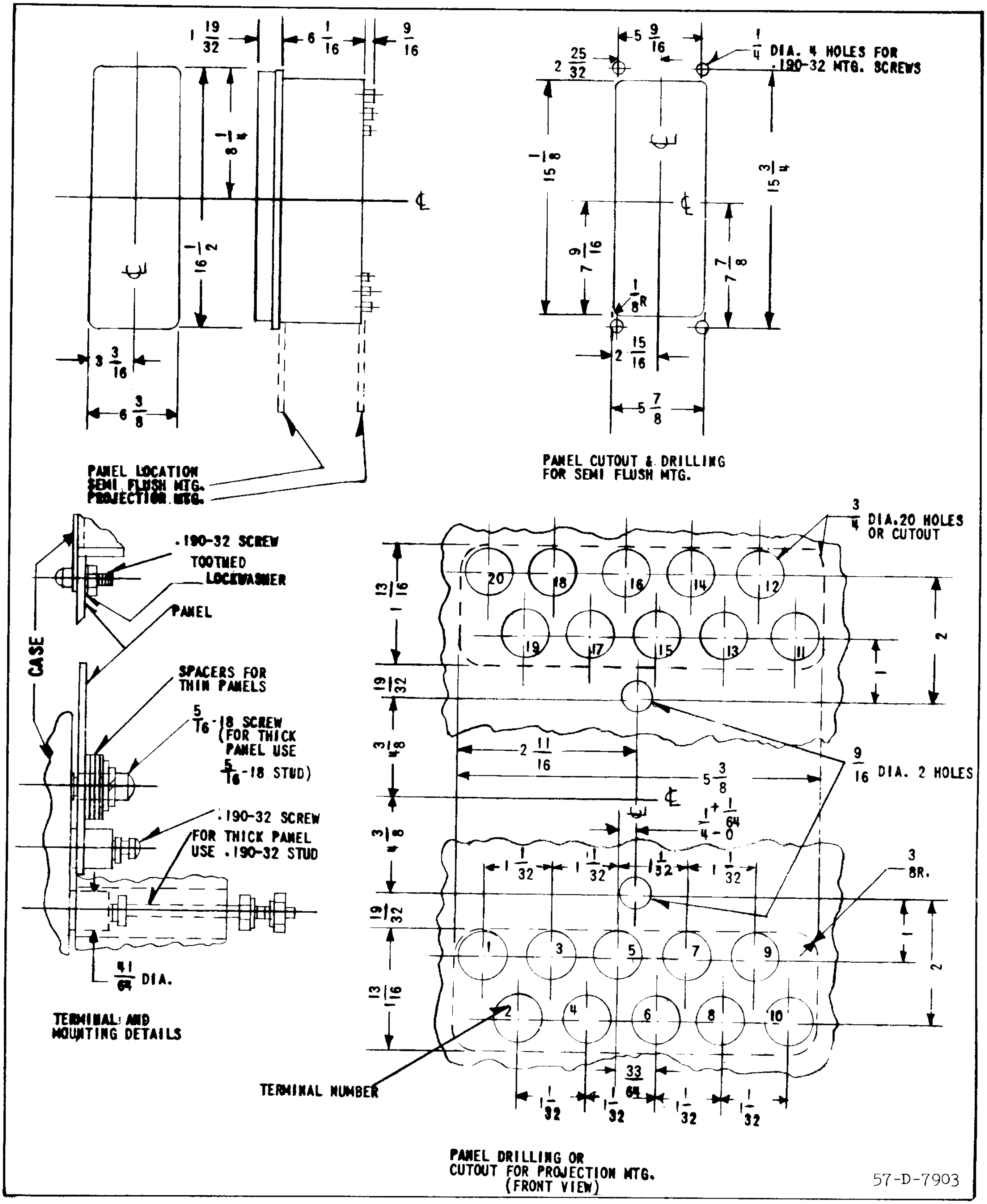


Fig. 10. *Outline-Drilling Plan for the Type KS Relay in the FT32 Case.*

WESTINGHOUSE ELECTRIC CORPORATION
RELAY-INSTRUMENT DIVISION **NEWARK, N. J.**
Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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^o and 80^o 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 on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps 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 .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 ±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.

SUPERSEDES I.L. 41-492F
*Denotes change from superseded issue

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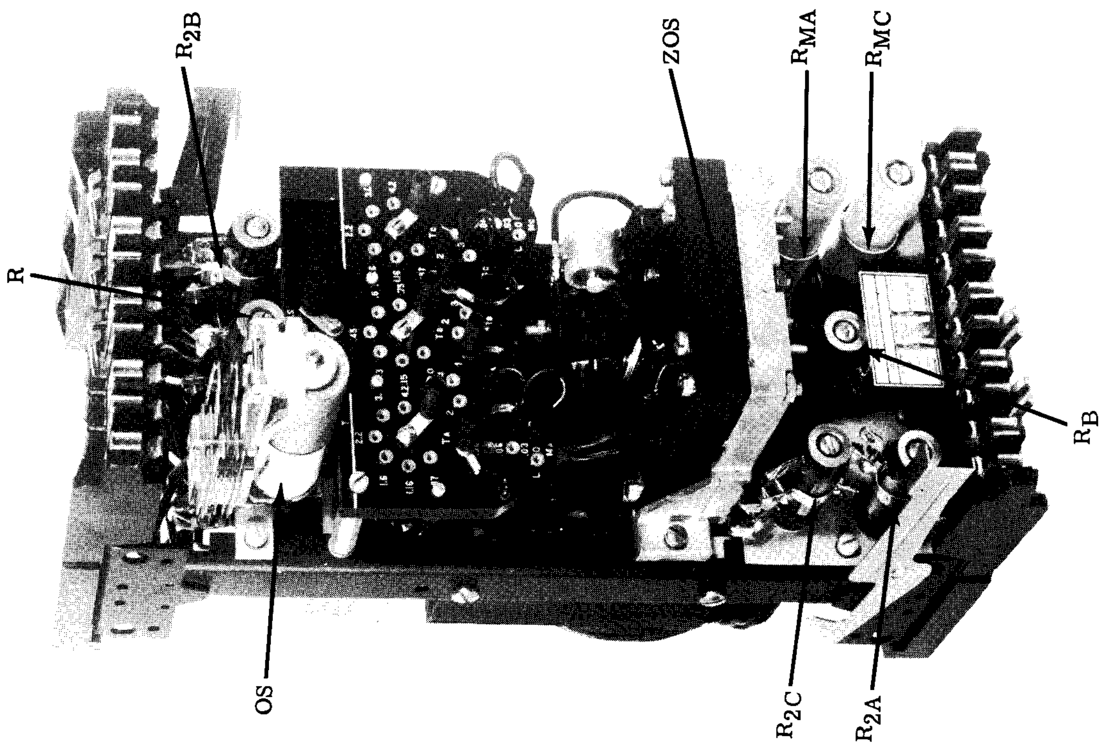


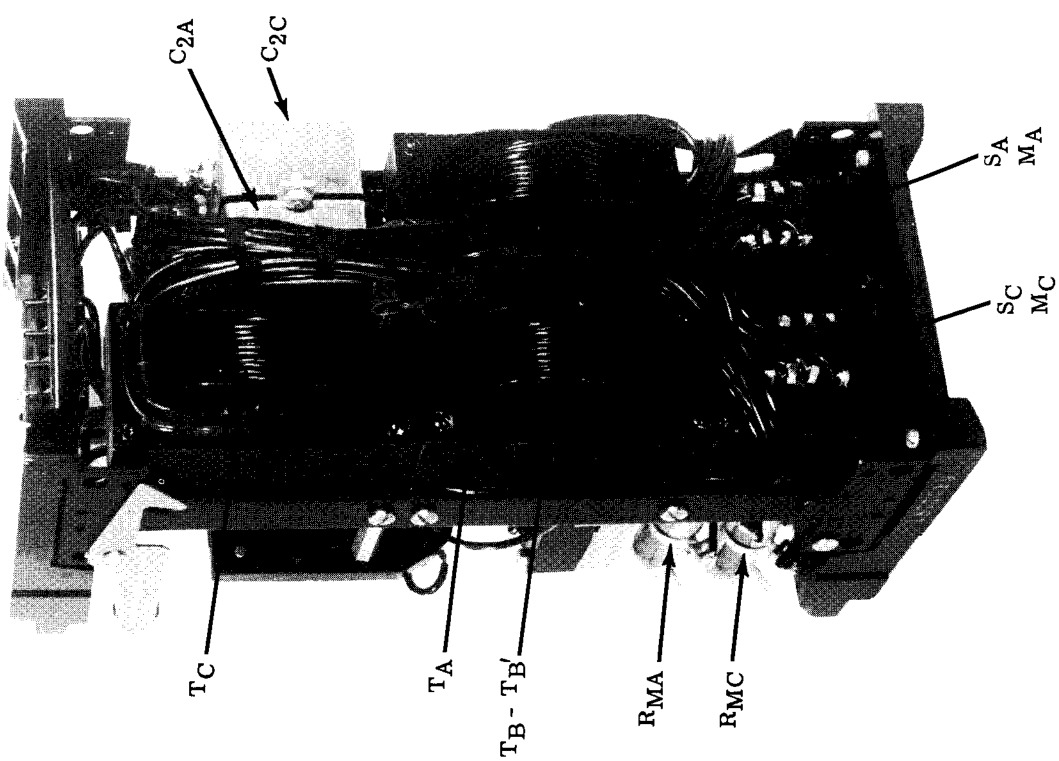


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

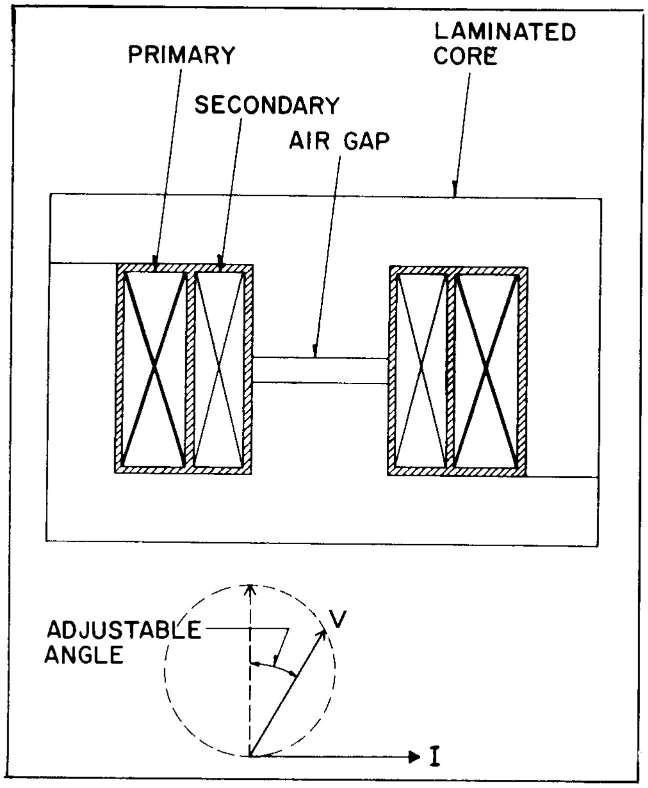


Fig. 2. Compensator Construction.

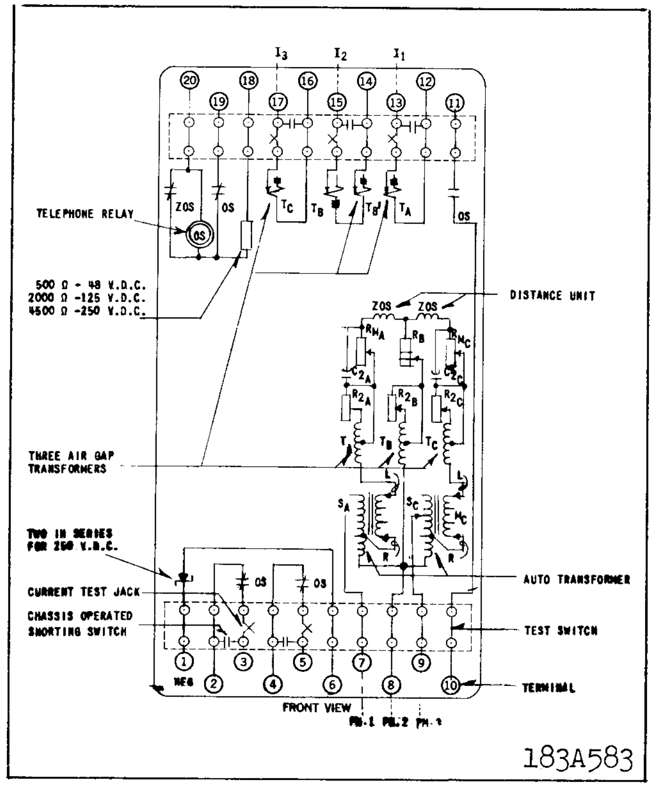


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 sprial 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 adjusted 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.

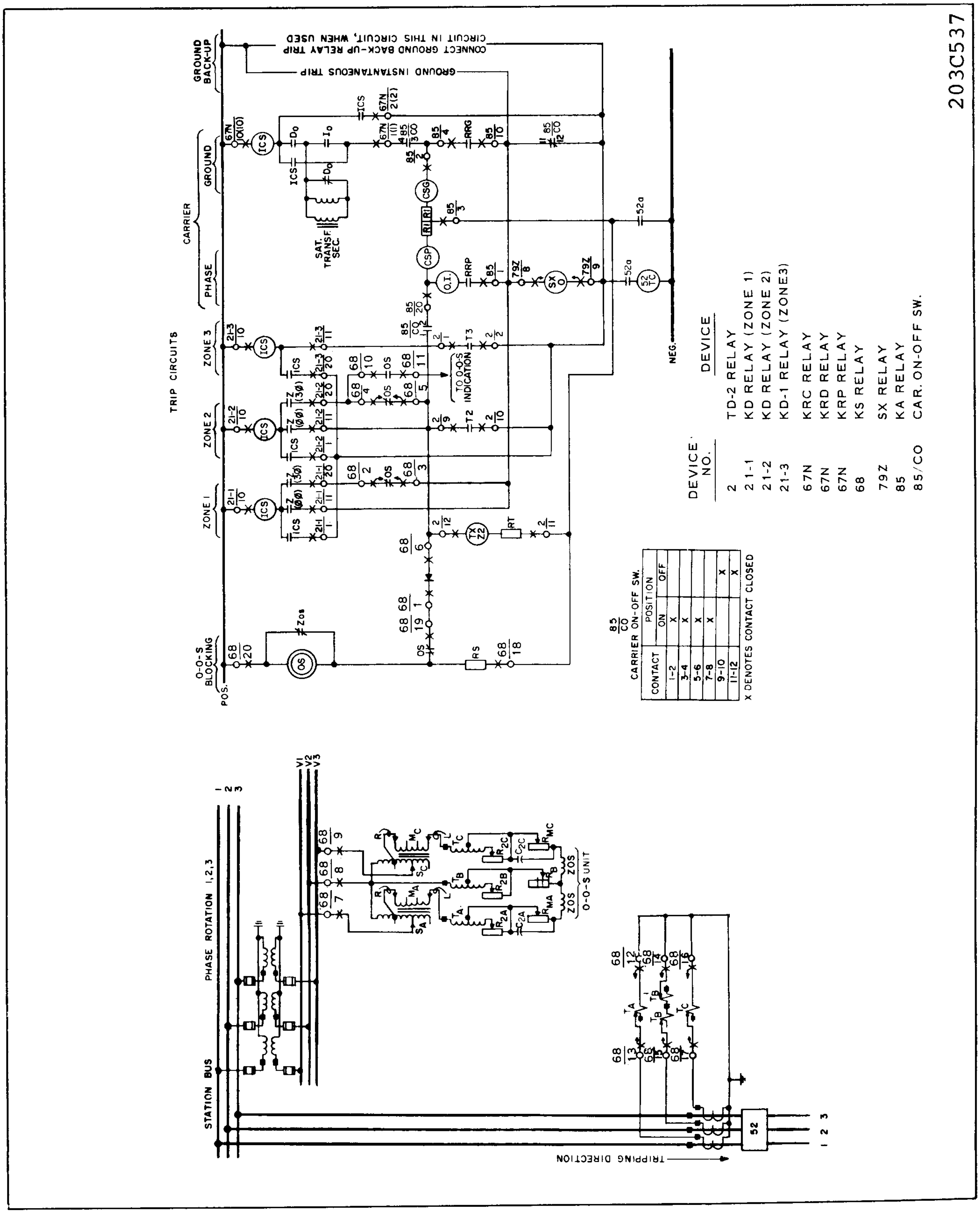


Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.

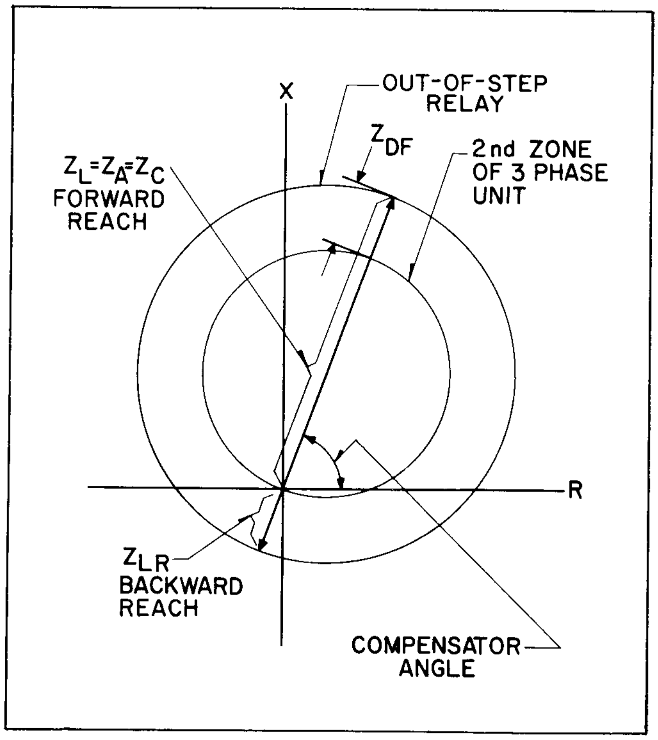


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figure 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles. its OS contacts located between the $\frac{68}{4}$ and $\frac{68}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 6 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)

.87 1.16 1.6 2.2 3.0 4.2 5.8

(T_B)

0 .15 .3 .45 .6 .75 .9

T_B'

2.85 3.9 4.95

(S_A, S_C, R_B)

1 2 3

(M_A, M_C)

± Values between taps .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 on page 14 and 15.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay three-phase unit with a 2 ohm margin. The angle of maximum torque should be the same as that of the KD

relay. The forward-looking reach Z_L is equal to the setting Z_A and Z_C.

$$Z_L = Z_A = Z_C = \frac{TS}{(1 \pm M)}$$

(Sub-letters refer to the T_A and T_C compensators.) The backward reach Z_{LR} is a function of both Z_B and Z_L where

$$Z_B = \frac{(T'_B + T_B)\, S}{(1 \pm M).}$$

When the proper value of Z_{LR} is determined (usually 2 ohms) then the setting for Z_B can be calculated.

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

The S & M settings of the auto-transformer are determined in the setting of the forward reach.

At the line angle in the forward direction, the ohmic difference, Z_{DF} will generally be set for two ohms. When the two circles are concentric, the backward reach, Z_{LR}, is equal to Z_{DF}. The forward reach, Z_L, can be set up to 20 ohms. The reverse reach, Z_{LR}, can be set at most any practical value with the best coverage at two ohms.

Calculations for setting the KS relay are straightforward and apply familiar principles. Assume a desired balance point which is 2 (relay) ohms greater than the second-zone impedance-relay setting. The general formula for setting the ohms forward reach of the relay is:

$$Z_{L\theta} = Z_L \frac{(\text{Sin } \theta)}{(\text{Sin } 75^o)} = (Z_{Zone\ 2} + 2 \text{ ohms})$$

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

S = Auto-transformer primary tap value

θ = Maximum torque angle setting of the relay

(For a factory setting of 75^o then $\frac{\text{Sin } \theta}{\text{Sin } 75^o} = 1$.)

M = Auto-transformer secondary tap value. (This is a Per Unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\, Z_{B\theta} - 1/3\, Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\text{Sin } \theta)}{(\text{Sin } 75^o)}$$

$$Z_B = \frac{(T'_B + T_B)\, S}{1 \pm M}$$

$T'_B + T_B$ = compensator tap value

$Z_{L\theta}$, S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{zone\ 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{zone\ 2}$.
2. Select the lowest tap, S,which gives a product of 6.9S greater than Z_L where
$$Z_L = Z_{L\theta} \frac{(\text{Sin } 75^o)}{(\text{Sin } \theta)}$$
3. Select a value for T that is nearest the value $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.
4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms
2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta} \frac{(\text{Sin } 75^0)}{(\text{Sin } \theta)}$

   $Z_{B\theta} = 1/2\ Z_{L\theta} + 3/2\ Z_{LR\theta}$

2. Solve for $(T_B' + T_B)$ where $(T_B' + T_B) = \frac{Z_B (1 \pm M)}{S}$

3. Select the highest possible value for T_B' and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

1. Then $Z_B = (\frac{9}{2} + \frac{3 \times 2}{2}) \times \frac{0.966}{0.866}$

   $= 7.5 \times 1.11 = 8.36$ ohms

2. $(T_B' + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T_B' = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35 \left(\frac{.866}{.966}\right) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, T_B-T_B, and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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 – 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 insert 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.

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 8).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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^o}	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^o current lagging voltage and the tap values are based on this angle. Generally speaking, the 75^o setting can be applied on lines with angles from 65^o to 90^o and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between 60^o and 80^o 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 stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 7. 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 open should be between 2.95 and 3.05 amperes at an angle of 75^o 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 close 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 7 set the phase shifter so that the current lags voltage by θ^{o}. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L-L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is

$Z_{LR} = \frac{V_{L-L}}{\sqrt{3}\, I_L} - 1/3\ Z_L$. Here V_{L-L} is phase-to-phase

* voltage and I_L is phase current and $Z_L = \frac{V_{LL}}{2\, I_{L_1}}$ where I_{L_1} is the current found in test #8.

Test No.	Volts V_{1F2F} & V_{2F3F}	Amperes ($\theta = 75°$) & † I_{min}	I_{max}
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 $\theta + 30^{o}$

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

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 8, 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 9 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 7 Figure 7, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L-L}}{\sqrt{3}\, I_L}$ 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 9. 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 checked for turns ratio and polarity by using the No. 1 test connections of Figure 7, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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'-T_B for 5.85

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 center than the end.

1. Using connections for test #1 of Figure 7 adjust brush #1 so that $V_{1F2F} = V_{78} = 0$. Adjust brush #2 for rated voltage across terminals 8 & 9. Adjust R_B so that the contact floats or has a minimum of torque. This is a rough adjustment for making the impedance angle of phase 1 to be equal to impedance of phase 2.

2. Using test #1 to Figure 7, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.

2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.

3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73^0 and 76^0 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.

6. 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 7. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
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 open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. Check the current required to close the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 V_{L-L} to 120 V_{L-L}. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS}{(1 \pm M)} \frac{\sin \theta}{(\sin 75^o)}$.

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 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'-T_B on 5.85 tap.

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

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

The relay is now calibrated and ready for service.

TABLE I

NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors – 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; .06; .06)
OS	Telephone Type Relay – D.C. Resistance = 475 to 525 ohms

TAP SETTING	VOLTAGE BURDEN								
	I = 0	$V_{AN} = V_{BN} = V_{CN}$ = 69 Volts				3 φ	S = 1		
	φA			φB			φC		
	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ
−.15	4.4	4.0	1.81	6.8	4.0	5.5	3.4	1.0	3.25
−.12	4.6	4.2	1.81	6.9	4.15	5.4	3.5	1.08	3.33
−.09	4.8	4.3	1.8	7.1	4.35	5.6	3.6	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

TAP SETTING	VOLTAGE BURDEN								
	I = 0	$V_{AN} = V_{BN} = V_{CN}$ = 69 Volts				3 φ	S = 2		
	φA			φB			φC		
	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	1.55	1.21	.97	.59	.306	.505
−.06	1.17	1.15	.217	1.65	1.29	1.01	.61	.322	.52
−.03	1.24	1.22	.222	1.70	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	.375	.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

TAP SETTING	VOLTAGE BURDEN								
	I = 0	$V_{AN} = V_{BN} = V_{CN}$ = 69 Volts				3 φ	S = 3		
	φA			φB			φC		
	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	.260
−.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

TAP T_A	CURRENT BURDEN: $3\phi I = 5$ AMP $\underline{/0}$ $3\phi V = 69V_{L-N}$ M = 0 S = 1										
	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.0030	0.0 +2.85	.115	.097	.063	.87	.026	.025	.005
1.16	.044	.042	.011	.15+2.85	.14	.116	.08	1.16	.03	.026	.014
1.6	.064	.060	.021	.3 +2.85	.165	.13	.10	1.6	.036	.27	.024
2.2	.074	.062	.04	.45+3.9	.19	.15	.12	2.2	.052	.030	.043
3.0	.12	.083	.088	.6 +3.9	.2	.13	.15	3.0	.068	.029	.062
4.2	.21	.114	.177	.75+3.9	.22	.14	.17	4.2	.11	.034	.105
5.8	.32	.115	.30	.9 +4.95	.3	.16	.25	5.8	.2	.052	.19

TAP T_A	CURRENT BURDEN: $3\phi I = 50$ AMP $\underline{/0}$ $3\phi V = 120V_{L-L}$ M = 0 S = 1										
	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.003	0.0 +2.85	.088	.070	.053	.87	.034	.034	.004
1.16	.034	.033	.008	.15+2.85	.092	.073	.056	1.16	.038	.037	.007
1.6	.05	.047	.016	.3 +2.85	.10	.078	.063	1.6	.046	.043	.060
2.2	.06	.051	.032	.45+3.9	.154	.105	.11	2.2	.066	.073	.059
3.0	.098	.075	.063	.6 +3.9	.16	.107	.12	3.0	.094		
4.2	15	.096	.115	.75+3.9	.17	.11	.13	4.2	.144		
5.8	.24	.14	.195	.9 +4.95	.24	.15	.19	5.8	.23		

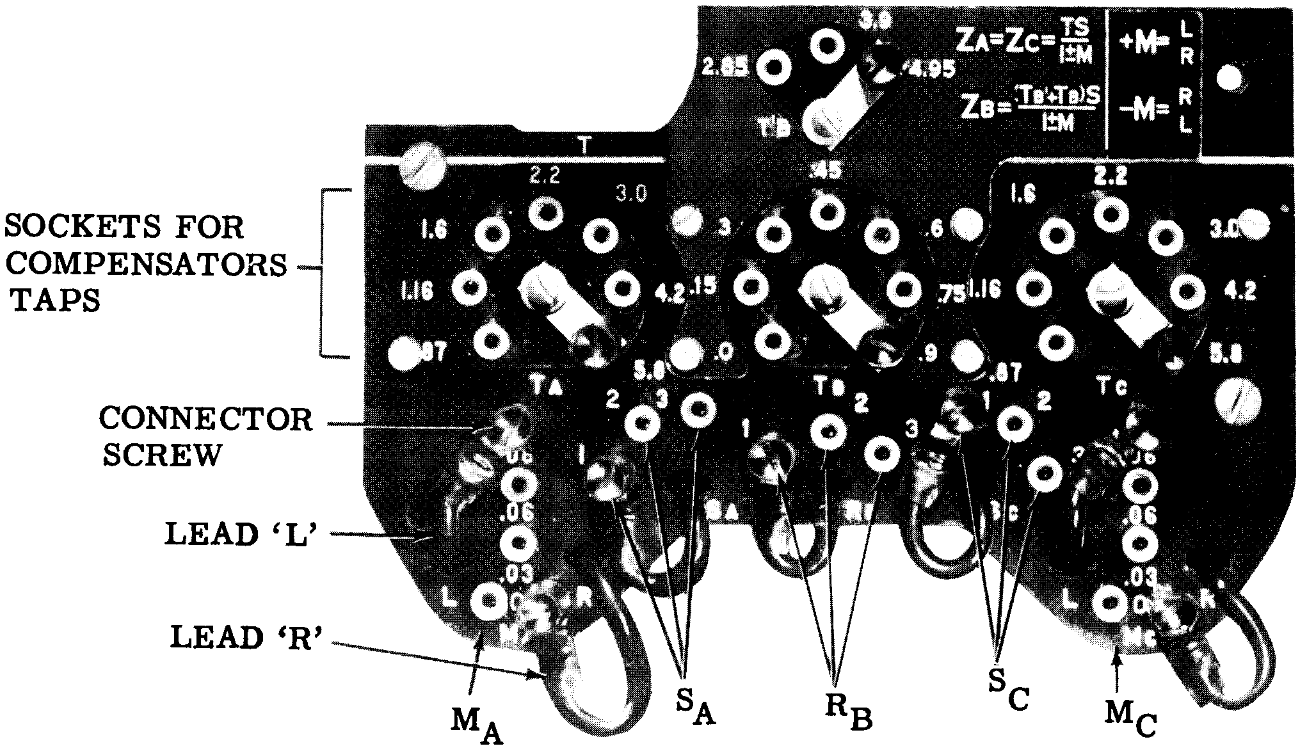
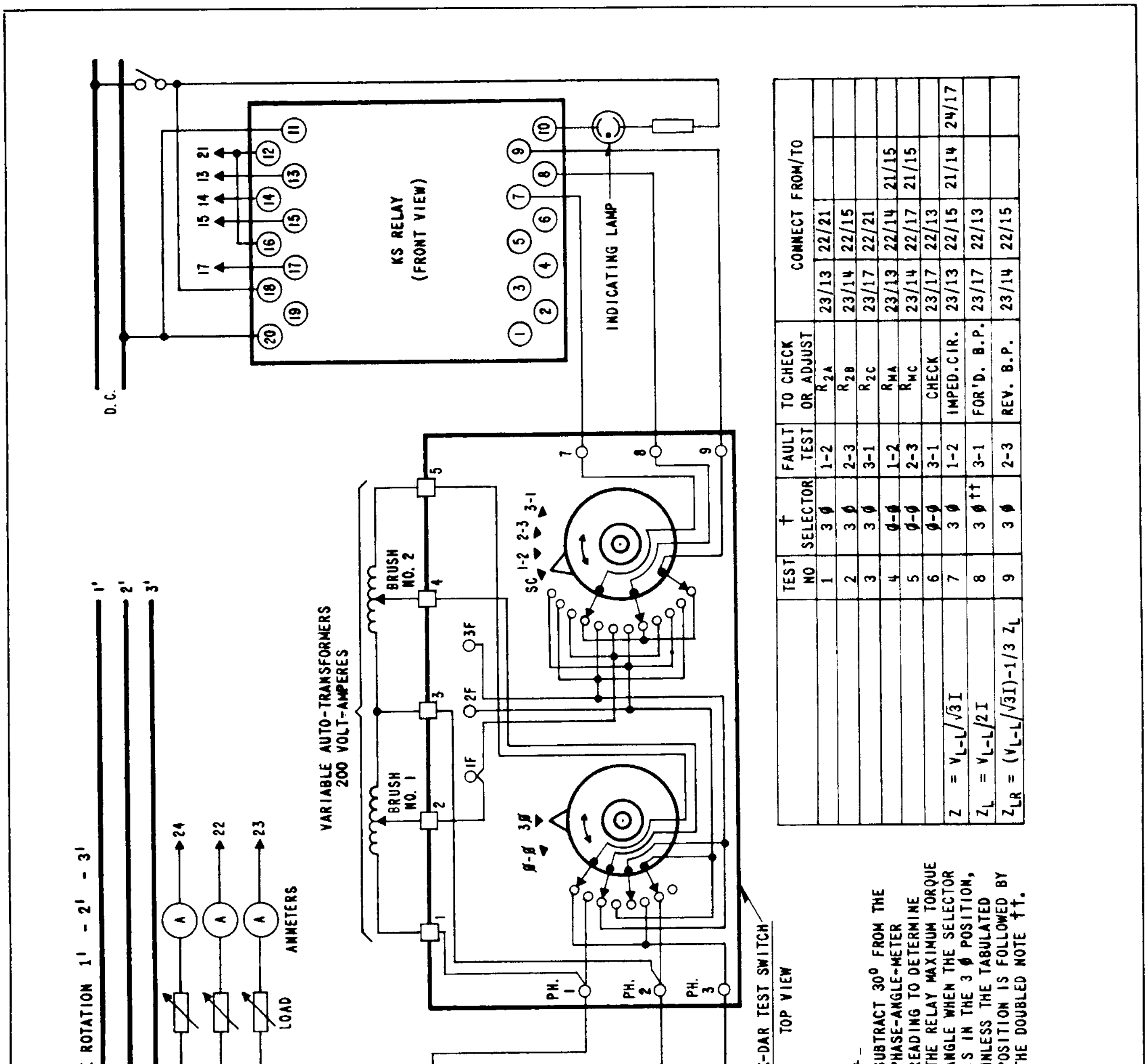


Fig. 6. Tap Plate.



	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 3 ø POSITION, UNLESS THE TABULATED POSITION IS FOLLOWED BY THE DOUBLED NOTE ††.

Fig. 7. Test Connections for Type KS Relays.

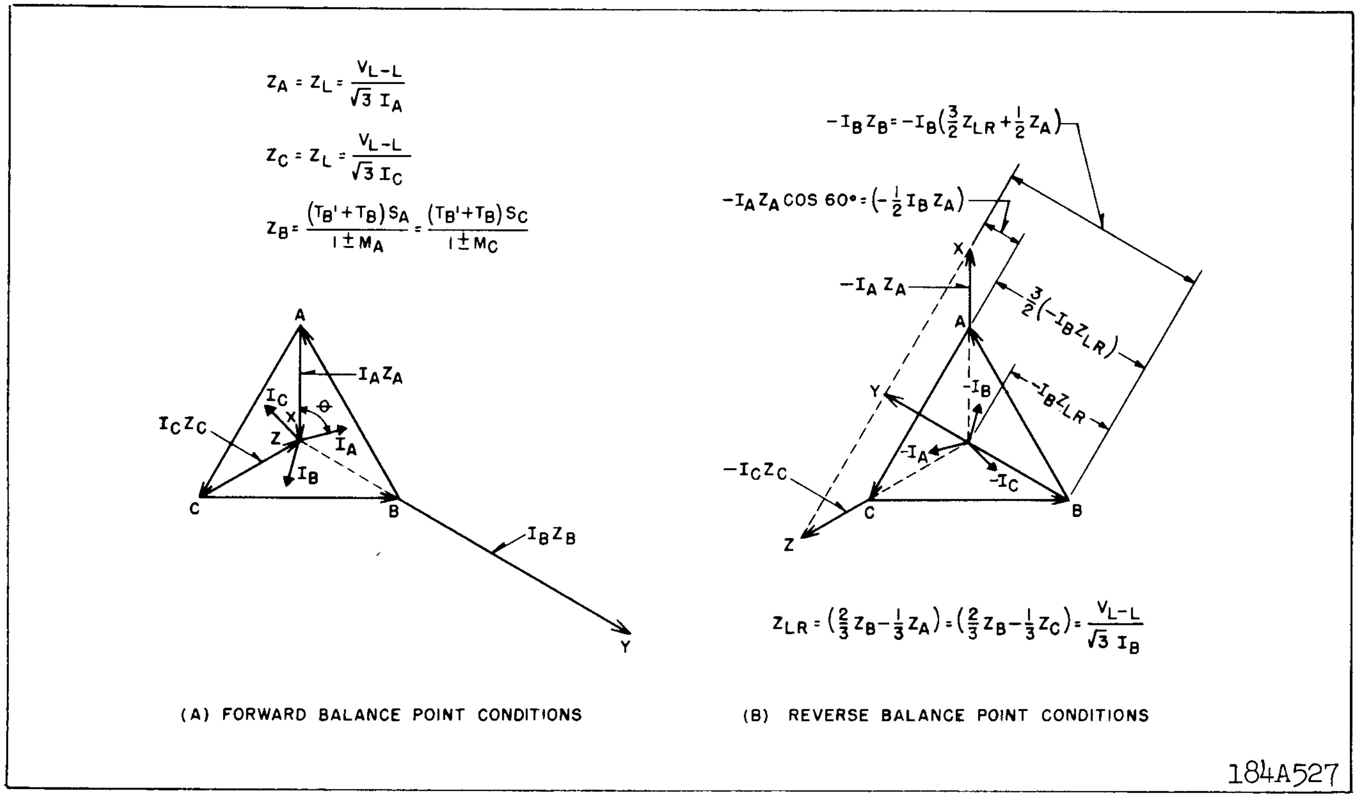


Fig. 8. ***Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.***

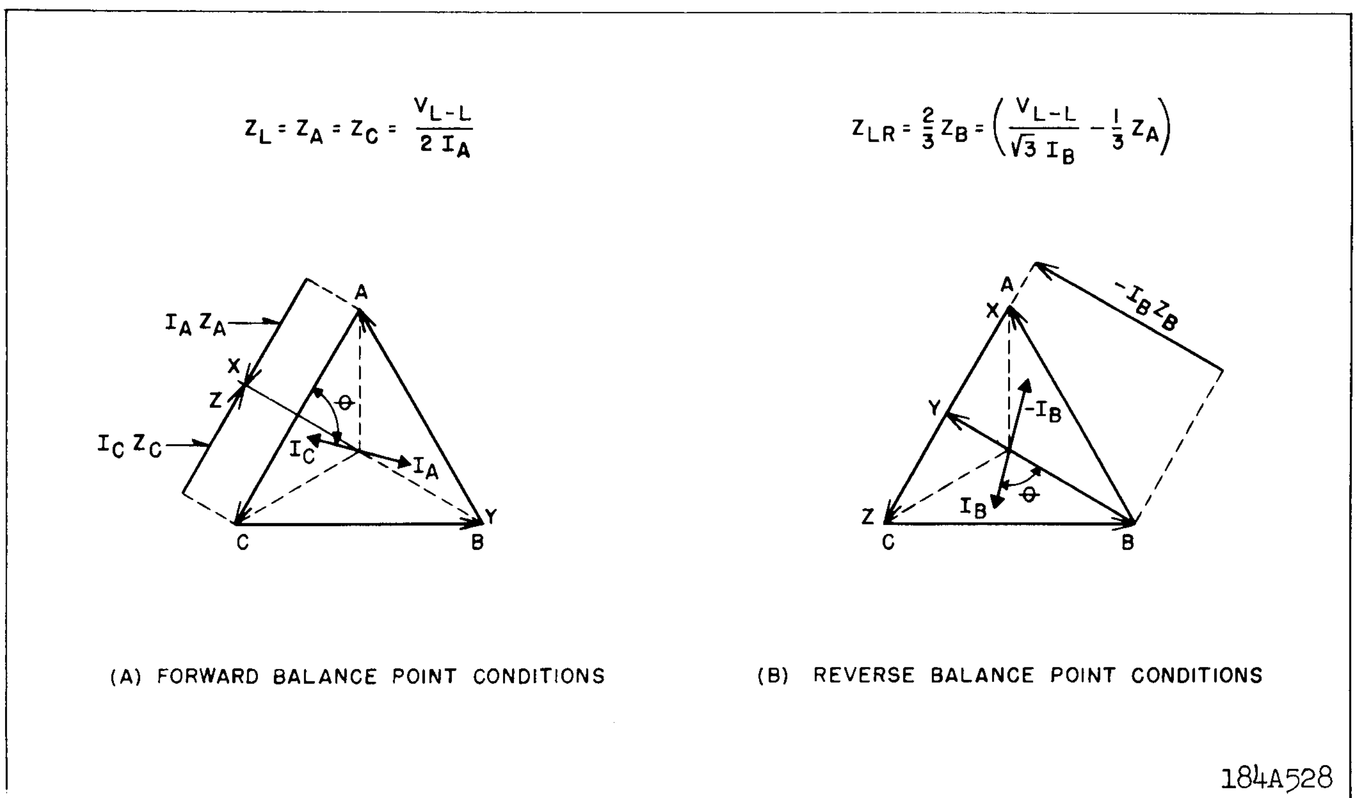


Fig. 9. ***Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.***

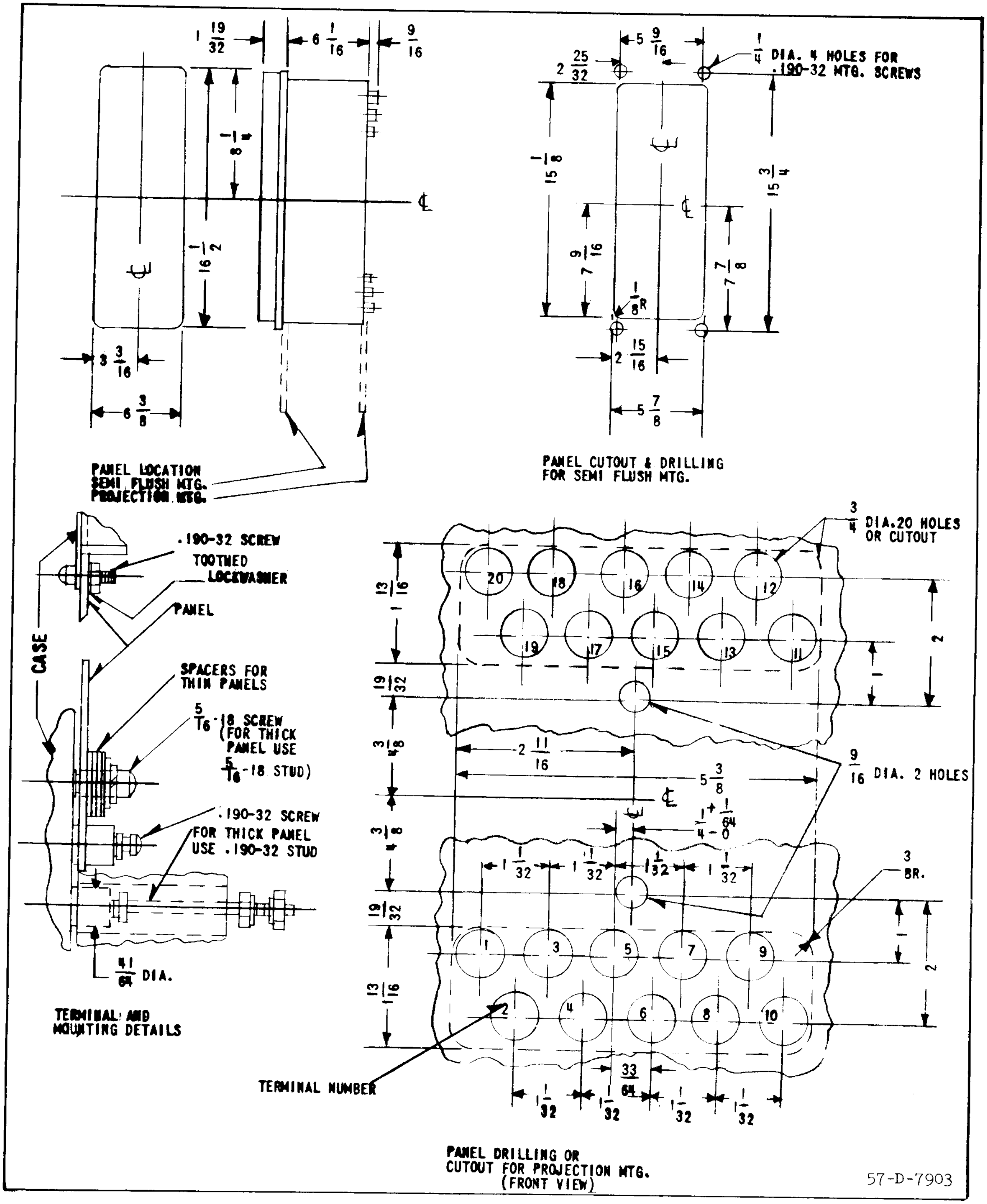


Fig. 10. *Outline-Drilling Plan for the Type KS Relay in the FT32 Case.*

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION

NEWARK, N. J.

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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 on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps 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 .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 ±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.

SUPERSEDES I.L. 41-492G
*Denotes change from superseded issue.

EFFECTIVE APRIL 1972.

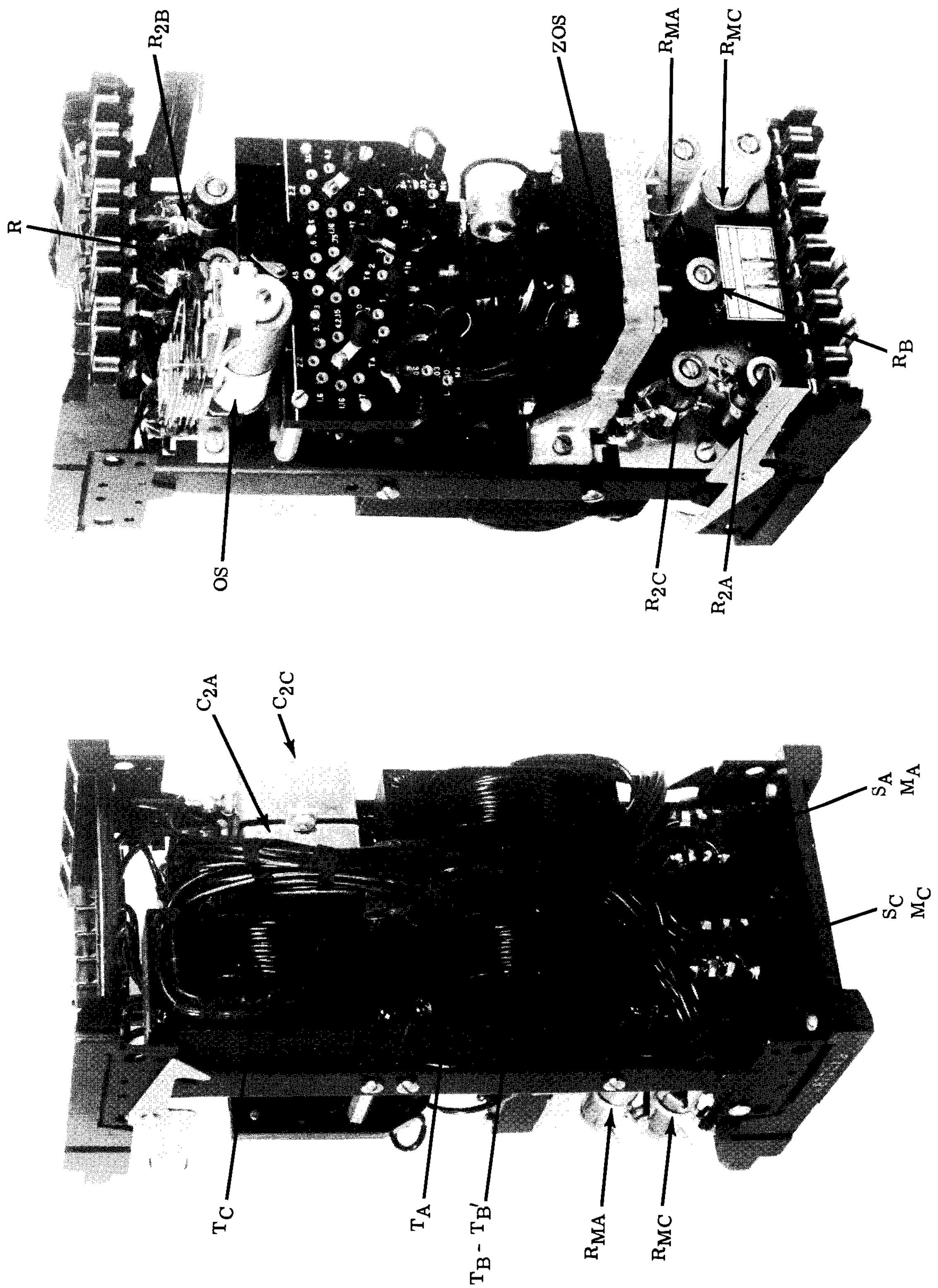


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

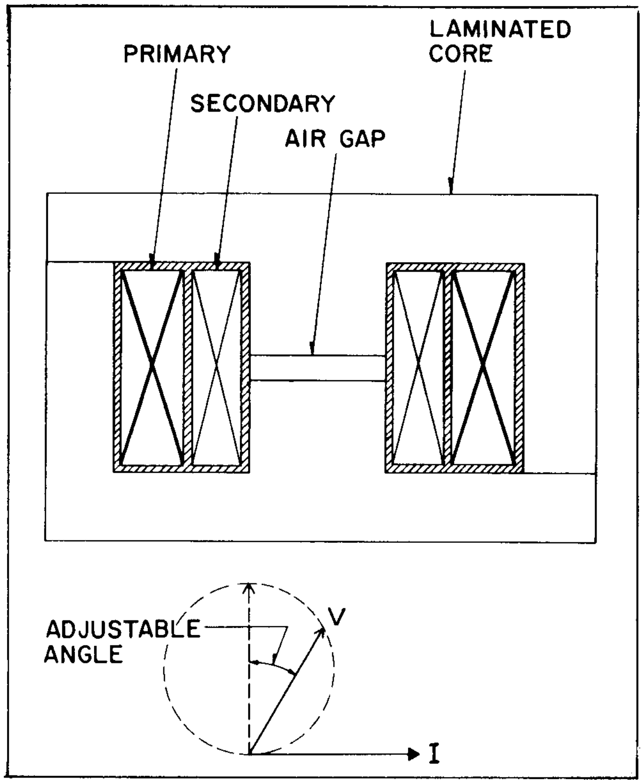


Fig. 2. Compensator Construction.

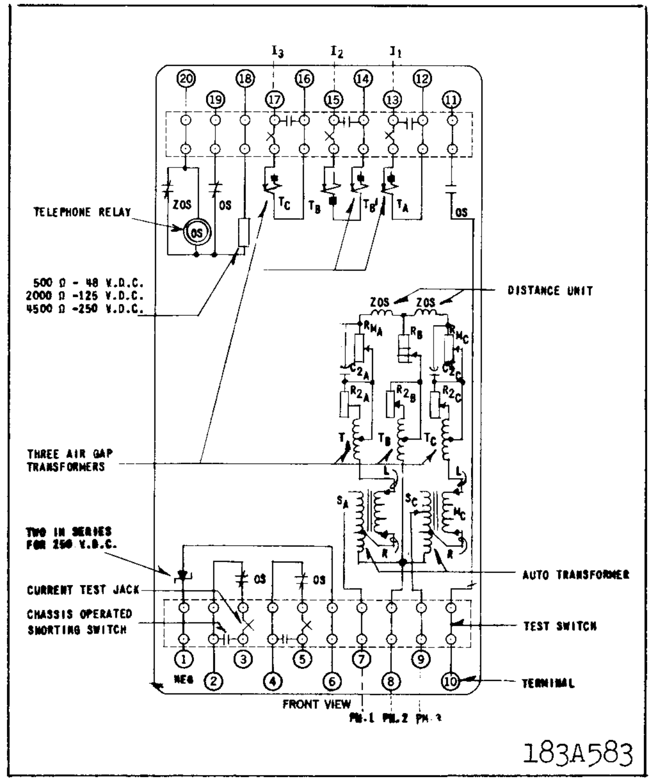


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 sprial 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 adjusted 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.

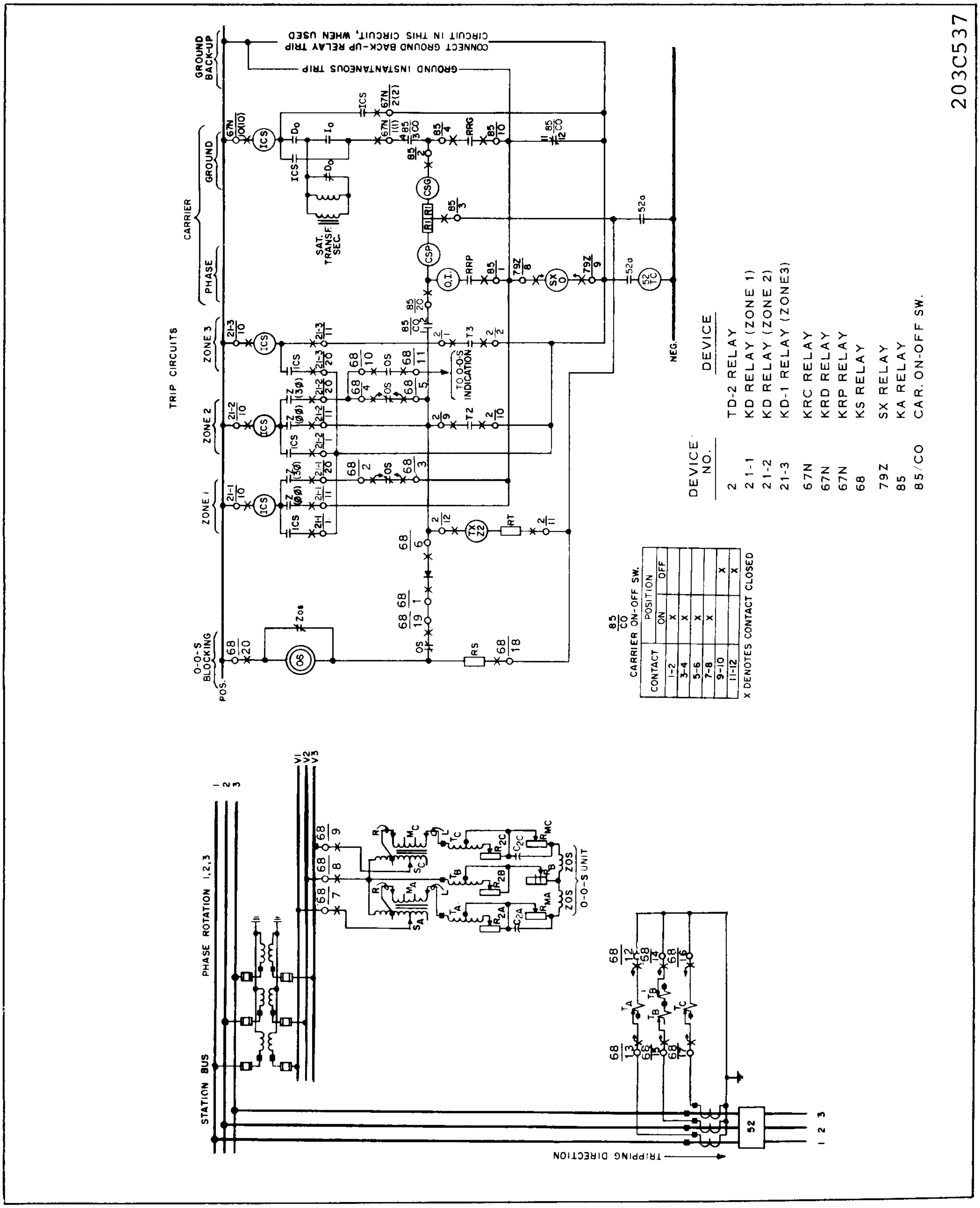


Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.

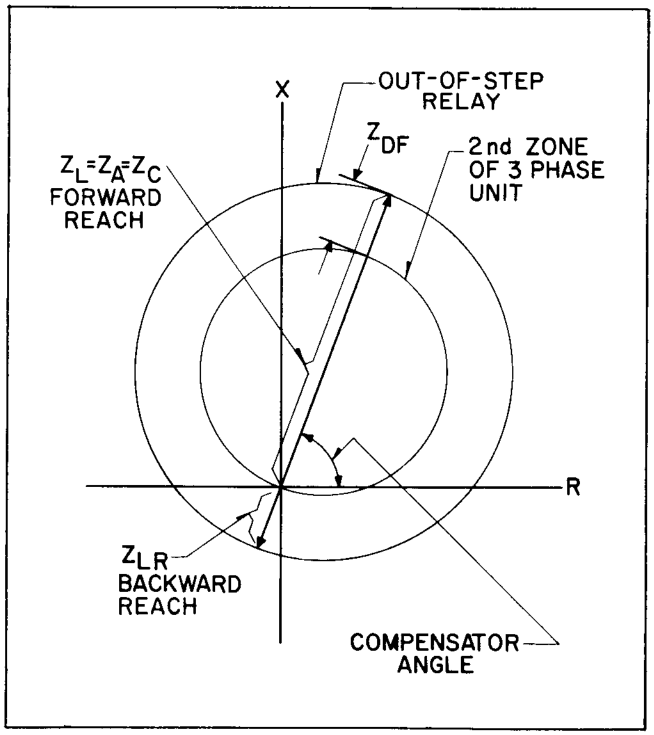


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figure 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles, its OS contacts located between the $\frac{68}{4}$ and $\frac{68}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 6 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)

.87 1.16 1.6 2.2 3.0 4.2 5.8

(T_B)

0 .15 .3 .45 .6 .75 .9

T_B'

2.85 3.9 4.95

(S_A, S_C, R_B)

1 2 3

(M_A, M_C)

± Values between taps .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 on page 14 and 15.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay three-phase unit with a 2 ohm margin. The angle of maximum torque should be the same as that of the KD

relay. The forward-looking reach Z_L is equal to the setting Z_A and Z_C.

$$Z_L = Z_A = Z_C = \frac{TS}{(1 \pm M)}$$

(Sub-letters refer to the T_A and T_C compensators.) The backward reach Z_{LR} is a function of both Z_B and Z_L where

$$Z_B = \frac{(T'_B + T_B)\,S}{(1 \pm M)}.$$

When the proper value of Z_{LR} is determined (usually 2 ohms) then the setting for Z_B can be calculated.

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

The S & M settings of the auto-transformer are determined in the setting of the forward reach.

At the line angle in the forward direction, the ohmic difference, Z_{DF} will generally be set for two ohms. When the two circles are concentric, the backward reach, Z_{LR}, is equal to Z_{DF}. The forward reach, Z_L, can be set up to 20 ohms. The reverse reach, Z_{LR}, can be set at most any practical value with the best coverage at two ohms.

Calculations for setting the KS relay are straightforward and apply familiar principles. Assume a desired balance point which is 2 (relay) ohms greater than the second-zone impedance-relay setting. The general formula for setting the ohms forward reach of the relay is:

$$Z_{L\theta} = Z_L \frac{(\text{Sin } \theta)}{(\text{Sin } 75^0)} = (Z_{\text{Zone } 2} + 2 \text{ ohms})$$

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

S = Auto-transformer primary tap value

θ = Maximum torque angle setting of the relay

(For a factory setting of 75^0 then $\frac{\text{Sin } \theta}{\text{Sin } 75^0} = 1$.)

M = Auto-transformer secondary tap value.
(This is a Per Unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\ Z_{B\theta} - 1/3\ Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\text{Sin } \theta)}{(\text{Sin } 75^0)}$$

$$Z_B = \frac{(T'_B + T_B)\,S}{1 \pm M}$$

$T'_B + T_B$ = compensator tap value

$Z_{L\theta}$, S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{\text{zone } 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{\text{zone } 2}$.

2. Select the lowest tap, S,which gives a product of 6.9S greater than Z_L where

   $$Z_L = Z_{L\theta} \frac{(\text{Sin } 75^0)}{(\text{Sin } \theta)}$$

3. Select a value for T that is nearest the value $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.

4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms

2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta}\frac{(\sin 75^o)}{(\sin \theta)}$

   $Z_{B\theta} = 1/2\, Z_{L\theta} + 3/2\, Z_{LR\theta}$

2. Solve for $(T_B' + T_B)$ where $(T_B' + T_B) = \frac{Z_B (1 \pm M)}{S}$

3. Select the highest possible value for T_B' and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

1. Then $Z_B = (\frac{9}{2} + \frac{3 \times 2}{2}) \times \frac{0.966}{0.866}$

   $= 7.5 \times 1.11 = 8.36$ ohms

2. $(T_B' + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T_B' = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35 (\frac{.866}{.966}) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, T_B -T_B, and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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 – 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 insert 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.

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 8).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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^o}	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^o current lagging voltage and the tap values are based on this angle. Generally speaking, the 75^o setting can be applied on lines with angles from 65^o to 90^o and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between 60^o and 80^o 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 stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 7. 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 open should be between 2.95 and 3.05 amperes at an angle of 75^o 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 close 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 7 set the phase shifter so that the current lags voltage by θ^{o}. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L-L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is $Z_{LR} = \frac{V_{L-L}}{\sqrt{3} I_L} - 1/3\ Z_L$. Here V_{L-L} is phase-to-phase voltage and I_L is phase current and $Z_L = \frac{V_{LL}}{2 I_{L_1}}$ where I_{L_1} is the current found in test #8.

Test No.	Volts	Amperes (θ= 75°) & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
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 $\theta + 30^{o}$

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

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 8, 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 9 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 7 Figure 7, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L-L}}{\sqrt{3}\ I_L}$ 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
* 7. 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 checked for turns ratio and polarity by using the No. 1 test connections of Figure 7, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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'-T_B for 5.85

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 center than the end.

1. Using connections for test #1 of Figure 7 adjust brush #1 so that $V_{1F2F} = V_{78} = 0$. Adjust brush #2 for rated voltage across terminals 8 & 9. Adjust R_B so that the contact floats or has a minimum of torque. This is a rough adjustment for making the impedance angle of phase 1 to be equal to impedance of phase 2.

2. Using test #1 to Figure 7, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.

2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.

3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73^o and 76^o 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.

6. 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 7. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
3. Adjust the phase shifter for θ degrees between load current and $V_{PH.1\text{-}PH.2}$.
4. With load current set for 0.51 amperes, adjust R_{MA} so that the cylinder unit contacts just open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. Check the current required to close the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 $V_{L\text{-}L}$ to 120 $V_{L\text{-}L}$. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS \quad \sin\theta}{(1 \pm M)\,(\sin 75^\circ)}$.

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 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'-T_B on 5.85 tap.

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

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

The relay is now calibrated and ready for service.

TABLE I

NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors – 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; .06; .06)
OS	Telephone Type Relay – D.C. Resistance = 475 to 525 ohms

VOLTAGE BURDEN

I = 0 $V_{AN} = V_{BN} = V_{CN}$ = 69 Volts 3 ϕ S = 1

TAP SETTING	ϕA			ϕB			ϕC		
	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ
−.15	4.4	4.0	1.81	6.8	4.0	5.5	3.4	1.0	3.25
−.12	4.6	4.2	1.81	6.9	4.15	5.4	3.5	1.08	3.33
−.09	4.8	4.3	1.8	7.1	4.35	5.6	3.6	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

I = 0 $V_{AN} = V_{BN} = V_{CN}$ = 69 Volts 3 ϕ S = 2

TAP SETTING	ϕA			ϕB			ϕC		
	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	1.55	1.21	.97	.59	.306	.505
−.06	1.17	1.15	.217	1.65	1.29	1.01	.61	.322	.52
−.03	1.24	1.22	.222	1.70	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	.375	.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

I = 0 $V_{AN} = V_{BN} = V_{CN}$ = 69 Volts 3 ϕ S = 3

TAP SETTING	ϕA			ϕB			ϕC		
	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	.260
−.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

CURRENT BURDEN												
TAP T_A	$3\phi I = 5$ AMP $\angle 0$ $3\phi V = 69V_{L-N}$ M = 0 S = 1											
	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC			
	Z	R	jX		Z	R	jX		Z	R	jX	
.87	.032	.031	.0030	0.0 +2.85	.115	.097	.063	.87	.026	.025	.005	
1.16	.044	.042	.011	.15+2.85	.14	.116	.08	1.16	.03	.026	.014	
1.6	.064	.060	.021	.3 +2.85	.165	.13	.10	1.6	.036	.27	.024	
2.2	.074	.062	.04	.45+3.9	.19	.15	.12	2.2	.052	.030	.043	
3.0	.12	.083	.088	.6 +3.9	.2	.13	.15	3.0	.068	.029	.062	
4.2	.21	.114	.177	.75+3.9	.22	.14	.17	4.2	.11	.034	.105	
5.8	.32	.115	.30	.9 +4.95	.3	.16	.25	5.8	.2	.052	.19	

CURRENT BURDEN												
TAP T_A	$3\phi I = 50$ AMP $\angle 0$ $3\phi V = 120V_{L-L}$ M = 0 S = 1											
	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC			
	Z	R	jX		Z	R	jX		Z	R	jX	
.87	.032	.031	.003	0.0 +2.85	.088	.070	.053	.87	.034	.034	.004	
1.16	.034	.033	.008	.15+2.85	.092	.073	.056	1.16	.038	.037	.007	
1.6	.05	.047	.016	.3 +2.85	.10	.078	.063	1.6	.046	.043	.060	
2.2	.06	.051	.032	.45+3.9	.154	.105	.11	2.2	.066	.073	.059	
3.0	.098	.075	.063	.6 +3.9	.16	.107	.12	3.0	.094			
4.2	15	.096	.115	.75+3.9	.17	.11	.13	4.2	.144			
5.8	.24	.14	.195	.9 +4.95	.24	.15	.19	5.8	.23			

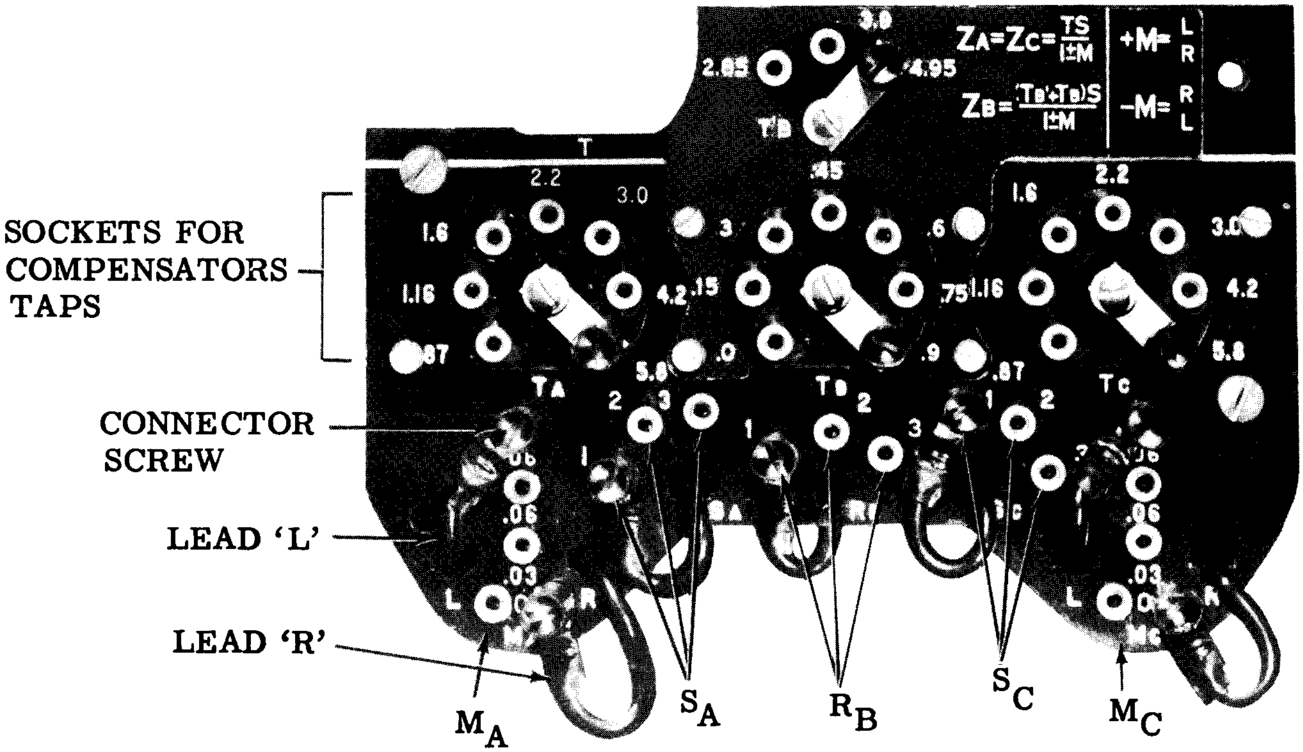
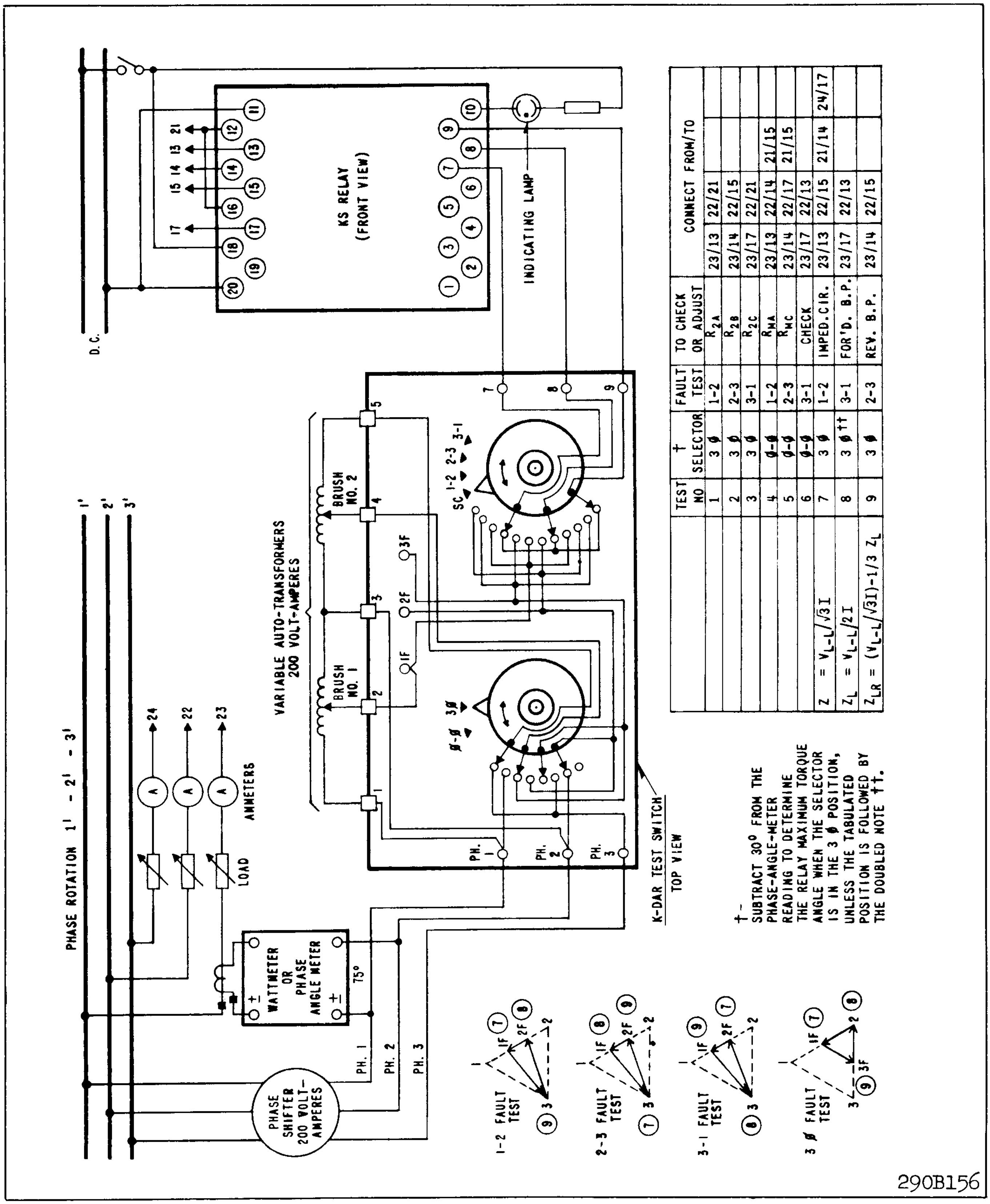
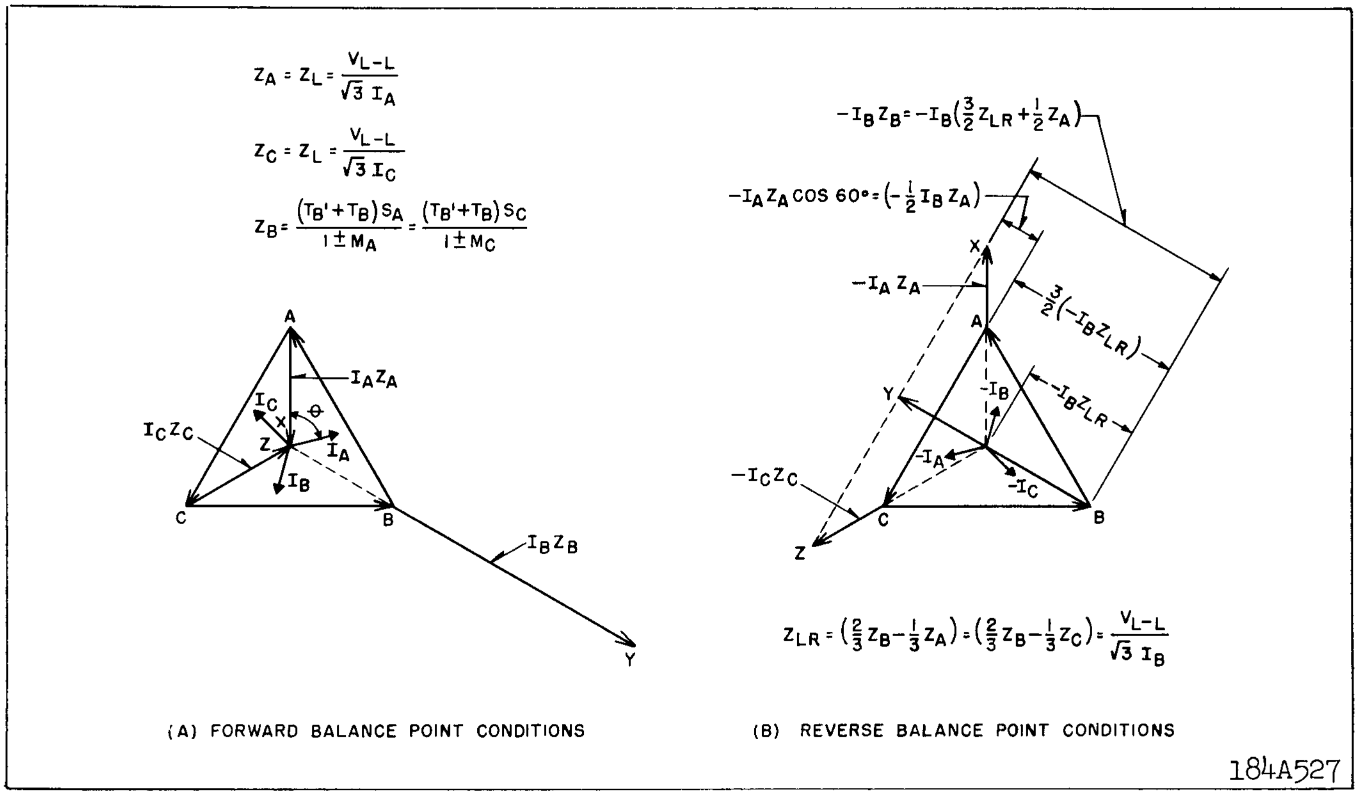


Fig. 6. Tap Plate.



	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		

Fig. 7. Test Connections for Type KS Relays.



* *Fig. 8. Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.*

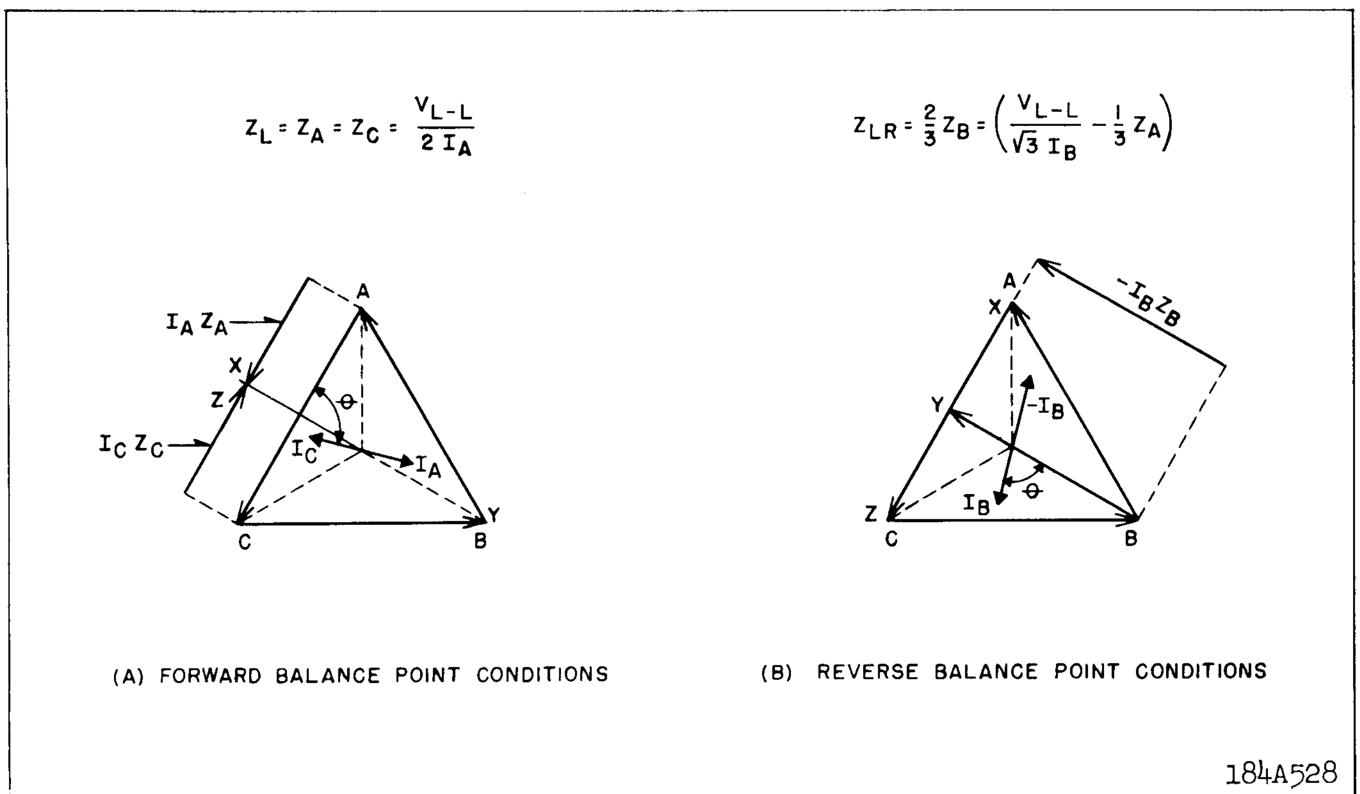


Fig. 9. Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.

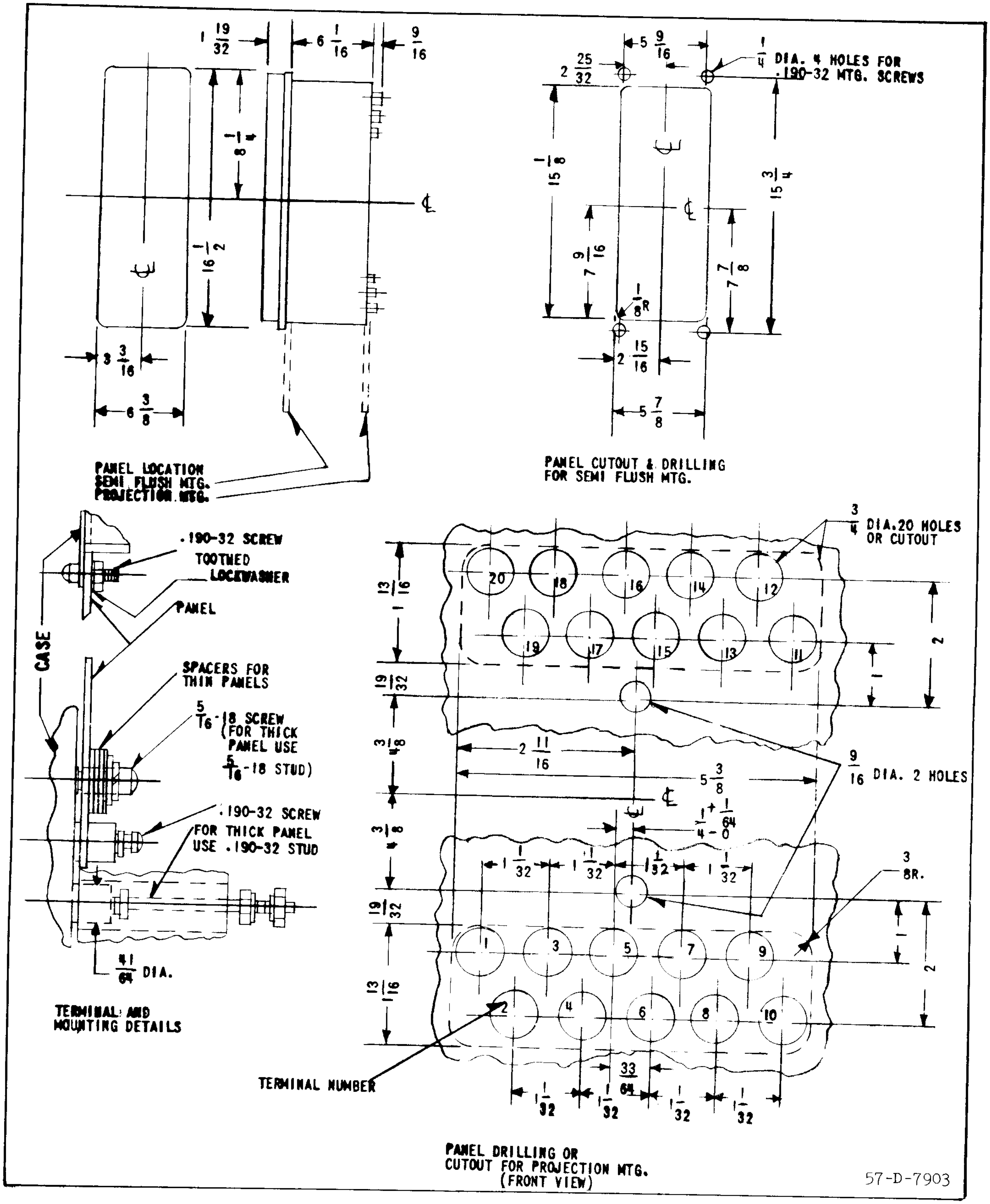


Fig. 10. Outline-Drilling Plan for the Type KS Relay in the FT32 Case.

WESTINGHOUSE ELECTRIC CORPORATION
RELAY-INSTRUMENT DIVISION
NEWARK, N. J.
Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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 on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps 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 .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 ±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.

SUPERSEDES I.L. 41-492H
*Denotes change from superseded issue.

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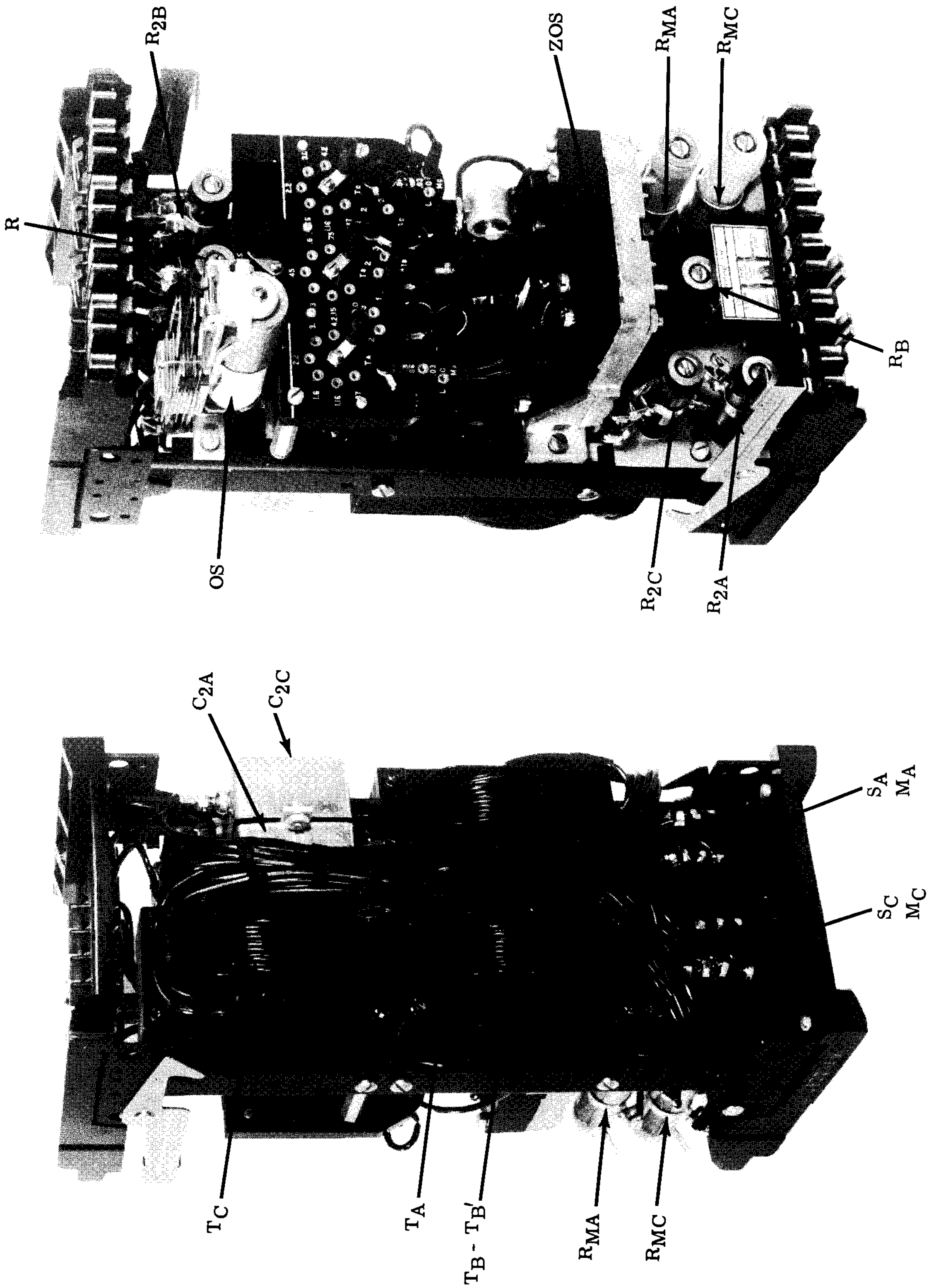


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

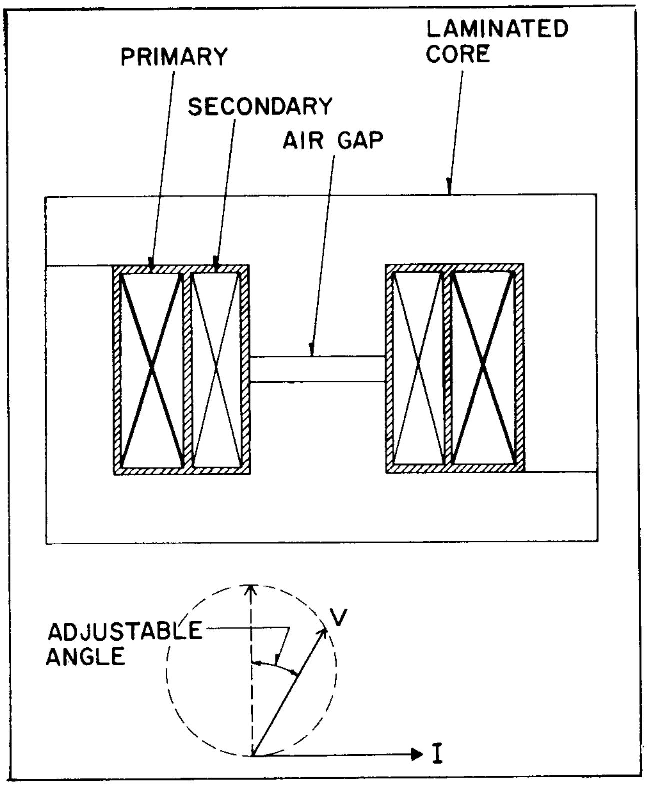


Fig. 2. Compensator Construction.

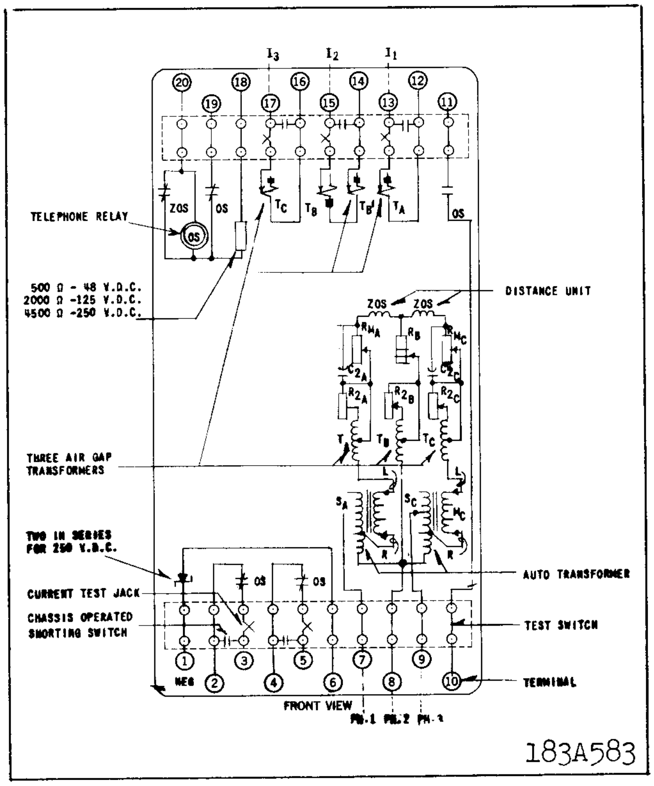


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 sprial 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 adjusted 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.

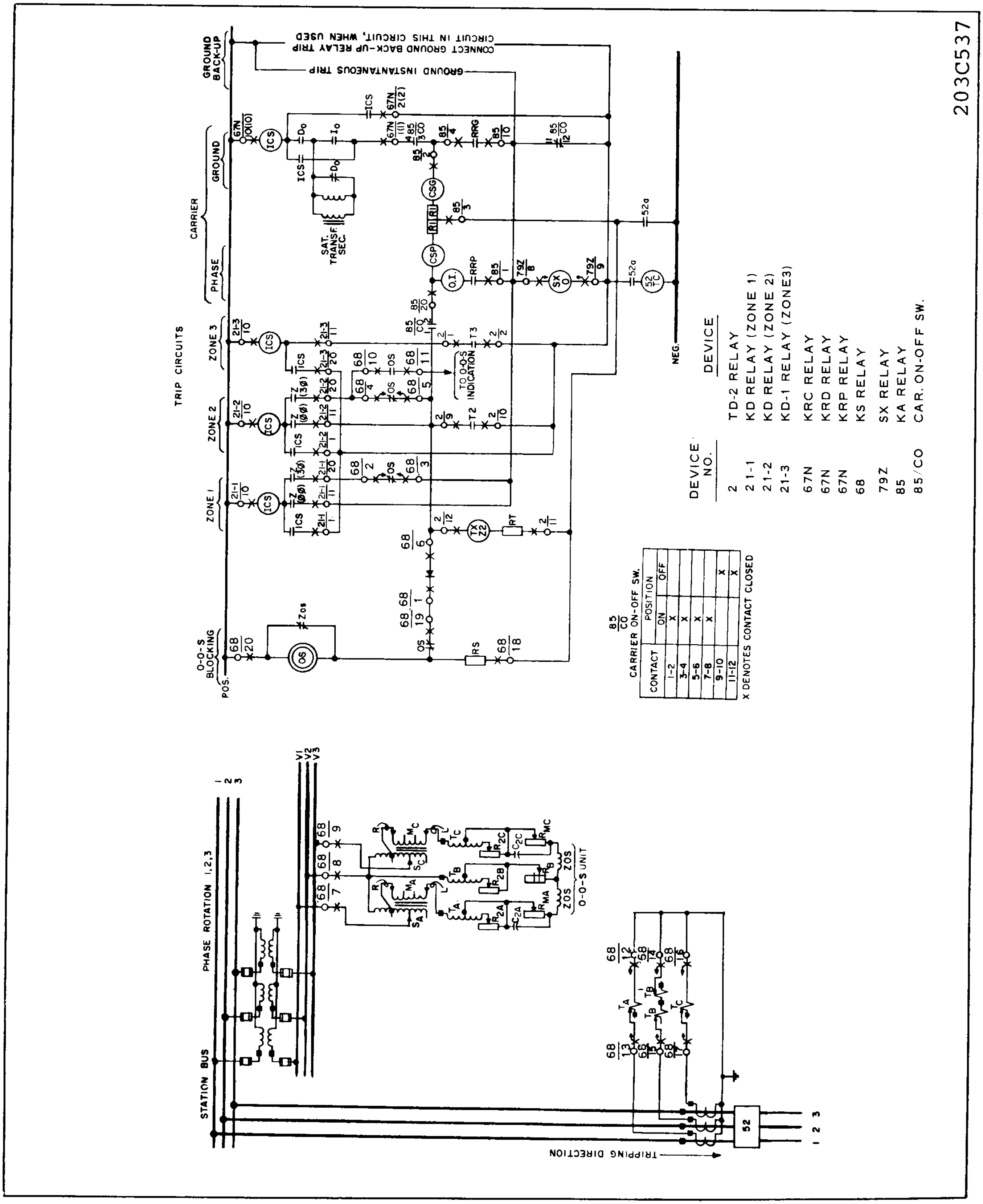


Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.

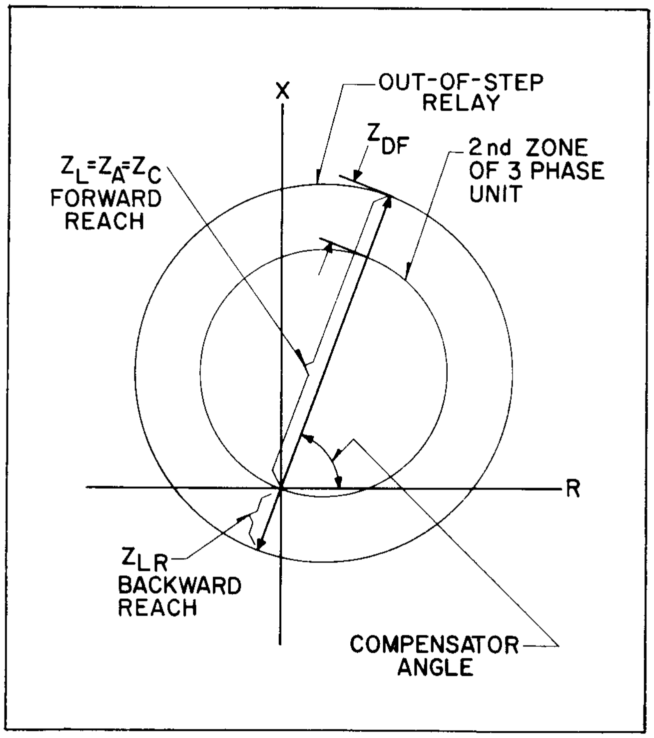


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figure 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles. its OS contacts located between the $\frac{68}{4}$ and $\frac{68}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 6 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)						
.87	1.16	1.6	2.2	3.0	4.2	5.8

(T_B)						
0	.15	.3	.45	.6	.75	.9

T_B'		
2.85	3.9	4.95

(S_A, S_C, R_B)		
1	2	3

	(M_A, M_C)		
± Values between taps	.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 on page 14 and 15.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay three-phase unit with a 2 ohm margin. The angle of maximum torque should be the same as that of the KD

relay. The forward-looking reach Z_L is equal to the setting Z_A and Z_C.

$$Z_L = Z_A = Z_C = \frac{TS}{(1 \pm M)}$$

(Sub-letters refer to the T_A and T_C compensators.) The backward reach Z_{LR} is a function of both Z_B and Z_L where

$$Z_B = \frac{(T'_B + T_B)\,S}{(1 \pm M).}$$

When the proper value of Z_{LR} is determined (usually 2 ohms) then the setting for Z_B can be calculated.

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

The S & M settings of the auto-transformer are determined in the setting of the forward reach.

At the line angle in the forward direction, the ohmic difference, Z_{DF} will generally be set for two ohms. When the two circles are concentric, the backward reach, Z_{LR}, is equal to Z_{DF}. The forward reach, Z_L, can be set up to 20 ohms. The reverse reach, Z_{LR}, can be set at most any practical value with the best coverage at two ohms.

Calculations for setting the KS relay are straightforward and apply familiar principles. Assume a desired balance point which is 2 (relay) ohms greater than the second-zone impedance-relay setting. The general formula for setting the ohms forward reach of the relay is:

$$Z_{L\theta} = Z_L \frac{(\text{Sin } \theta)}{(\text{Sin } 75^o)} = (Z_{Zone\ 2} + 2 \text{ ohms})$$

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

S = Auto-transformer primary tap value

θ = Maximum torque angle setting of the relay

(For a factory setting of 75^o then $\frac{\text{Sin } \theta}{\text{Sin } 75^o} = 1$.)

M = Auto-transformer secondary tap value.
(This is a Per Unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\ Z_{B\theta} - 1/3\ Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\text{Sin } \theta)}{(\text{Sin } 75^o)}$$

$$Z_B = \frac{(T'_B + T_B)\,S}{1 \pm M}$$

$T'_B + T_B$ = compensator tap value

$Z_{L\theta}$ S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{zone\ 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{zone\ 2}$.

2. Select the lowest tap, S, which gives a product of 6.9S greater than Z_L where
$$Z_L = Z_{L\theta} \frac{(\text{Sin } 75^o)}{(\text{Sin } \theta)}$$

3. Select a value for T that is nearest the value $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.

4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms

2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta} \frac{(\text{Sin } 75^o)}{(\text{Sin } \theta)}$

   $Z_{B\theta} = 1/2\, Z_{L\theta} + 3/2\, Z_{LR\theta}$

2. Solve for $(T_B' + T_B)$ where $(T_B' + T_B) = \frac{Z_B (1 \pm M)}{S}$

3. Select the highest possible value for T_B' and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

* 1. Then $Z_B = (\frac{9}{2} + \frac{3 \times 2}{2}) \times \frac{0.966}{0.866}$
   $= 7.5 \times 1.11 = 8.36$ ohms

2. $(T_B' + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T_B' = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35 (\frac{.866}{.966}) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, T_B -T_B, and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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 – 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 insert 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.

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 8).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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^o}	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^o current lagging voltage and the tap values are based on this angle. Generally speaking, the 75^o setting can be applied on lines with angles from 65^o to 90^o and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between 60^o and 80^o 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 stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 7. 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 open should be between 2.95 and 3.05 amperes at an angle of 75^o 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 close 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 7 set the phase shifter so that the current lags voltage by θ^{o}. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L-L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is

$Z_{LR} = \frac{V_{L-L}}{\sqrt{3}\, I_L} - 1/3\ Z_L$. Here V_{L-L} is phase-to-phase voltage and I_L is phase current and $Z_L = \frac{V_{LL}}{2\, I_{L_1}}$ where I_{L_1} is the current found in test #8.

Test No.	Volts	Amperes (θ= 75°) & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
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 $\theta + 30^{o}$

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

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 8, 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 9 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 7 Figure 7, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L-L}}{\sqrt{3}\, I_L}$ 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 7. 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 checked for turns ratio and polarity by using the No. 1 test connections of Figure 7, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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'-T_B for 5.85

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 center than the end.

1. Using connections for test #1 of Figure 7 adjust brush #1 so that $V_{1F2F} = V_{78} = 0$. Adjust brush #2 for rated voltage across terminals 8 & 9. Adjust R_B so that the contact floats or has a minimum of torque. This is a rough adjustment for making the impedance angle of phase 1 to be equal to impedance of phase 2.

2. Using test #1 to Figure 7, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.

2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.

3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73° and 76° 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.

6. 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 7. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
3. Adjust the phase shifter for θ degrees between load current and $V_{PH.1\text{-}PH.2}$.
4. With load current set for 0.51 amperes, adjust R_{MA} so that the cylinder unit contacts just open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. Check the current required to close the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 $V_{L\text{-}L}$ to 120 $V_{L\text{-}L}$. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS \quad \sin\theta}{(1 \pm M)\ (\sin 75^o)}$.

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 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'-T_B on 5.85 tap.

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

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

The relay is now calibrated and ready for service.

TABLE I

NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors – 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; .06; .06)
OS	Telephone Type Relay – D.C. Resistance = 475 to 525 ohms

TAP SETTING	VOLTAGE BURDEN								
	I = 0 $V_{AN} = V_{BN} = V_{CN}$ = 69 Volts 3 φ S = 1								
	φA			φB			φC		
	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ
−.15	4.4	4.0	1.81	6.8	4.0	5.5	3.4	1.0	3.25
−.12	4.6	4.2	1.81	6.9	4.15	5.4	3.5	1.08	3.33
−.09	4.8	4.3	1.8	7.1	4.35	5.6	3.6	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

TAP SETTING	VOLTAGE BURDEN								
	I = 0 $V_{AN} = V_{BN} = V_{CN}$ = 69 Volts 3 φ S = 2								
	φA			φB			φC		
	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	1.55	1.21	.97	.59	.306	.505
−.06	1.17	1.15	.217	1.65	1.29	1.01	.61	.322	.52
−.03	1.24	1.22	.222	1.70	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	.375	.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

TAP SETTING	VOLTAGE BURDEN								
	I = 0 $V_{AN} = V_{BN} = V_{CN}$ = 69 Volts 3 φ S = 3								
	φA			φB			φC		
	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	.260
−.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

CURRENT BURDEN											
TAP T_A	$3\phi I = 5$ AMP $\angle 0$	$3\phi V = 69V_{L-N}$		M = 0		S = 1					
	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.0030	0.0 +2.85	.115	.097	.063	.87	.026	.025	.005
1.16	.044	.042	.011	.15+2.85	.14	.116	.08	1.16	.03	.026	.014
1.6	.064	.060	.021	.3 +2.85	.165	.13	.10	1.6	.036	.27	.024
2.2	.074	.062	.04	.45+3.9	.19	.15	.12	2.2	.052	.030	.043
3.0	.12	.083	.088	.6 +3.9	.2	.13	.15	3.0	.068	.029	.062
4.2	.21	.114	.177	.75+3.9	.22	.14	.17	4.2	.11	.034	.105
5.8	.32	.115	.30	.9 +4.95	.3	.16	.25	5.8	.2	.052	.19

CURRENT BURDEN											
TAP T_A	$3\phi I = 50$ AMP $\angle 0$	$3\phi V = 120V_{L-L}$		M = 0		S = 1					
	ϕA			$T_B + T'_B$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.003	0.0 +2.85	.088	.070	.053	.87	.034	.034	.004
1.16	.034	.033	.008	.15+2.85	.092	.073	.056	1.16	.038	.037	.007
1.6	.05	.047	.016	.3 +2.85	.10	.078	.063	1.6	.046	.043	.060
2.2	.06	.051	.032	.45+3.9	.154	.105	.11	2.2	.066	.073	.059
3.0	.098	.075	.063	.6 +3.9	.16	.107	.12	3.0	.094		
4.2	15	.096	.115	.75+3.9	.17	.11	.13	4.2	.144		
5.8	.24	.14	.195	.9 +4.95	.24	.15	.19	5.8	.23		

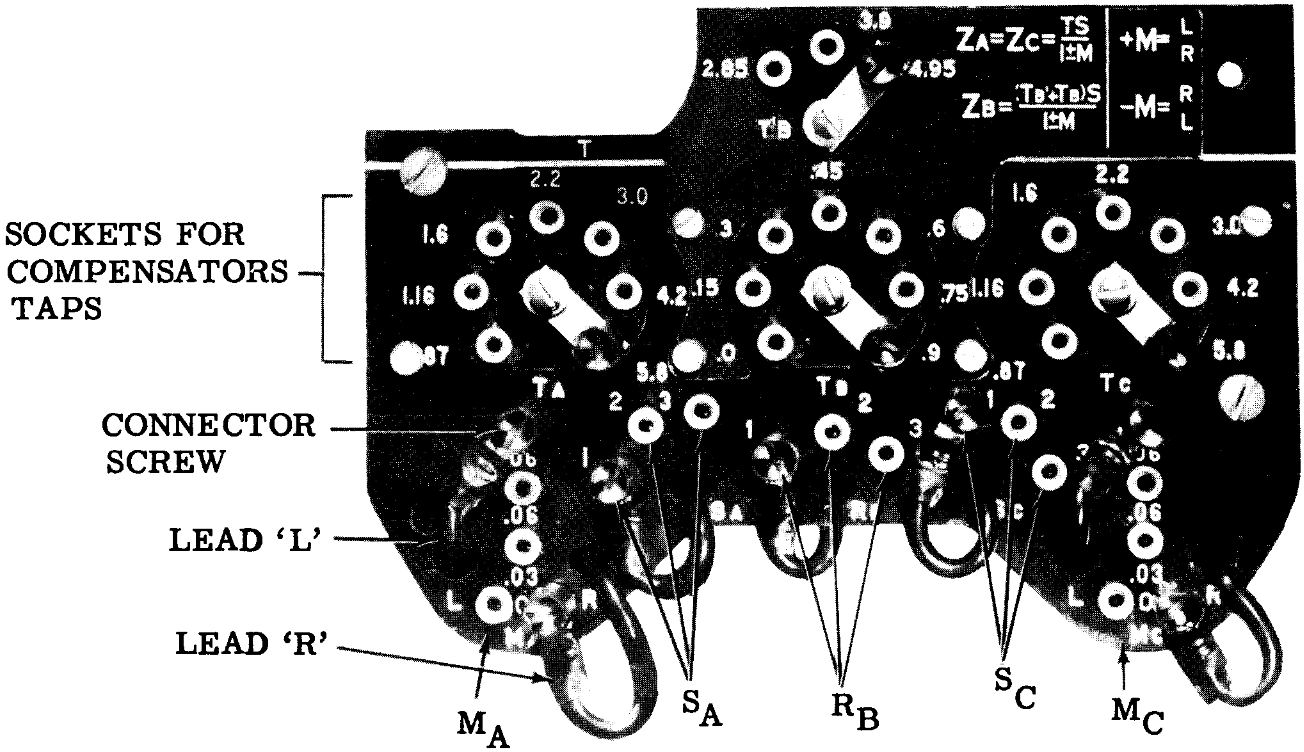
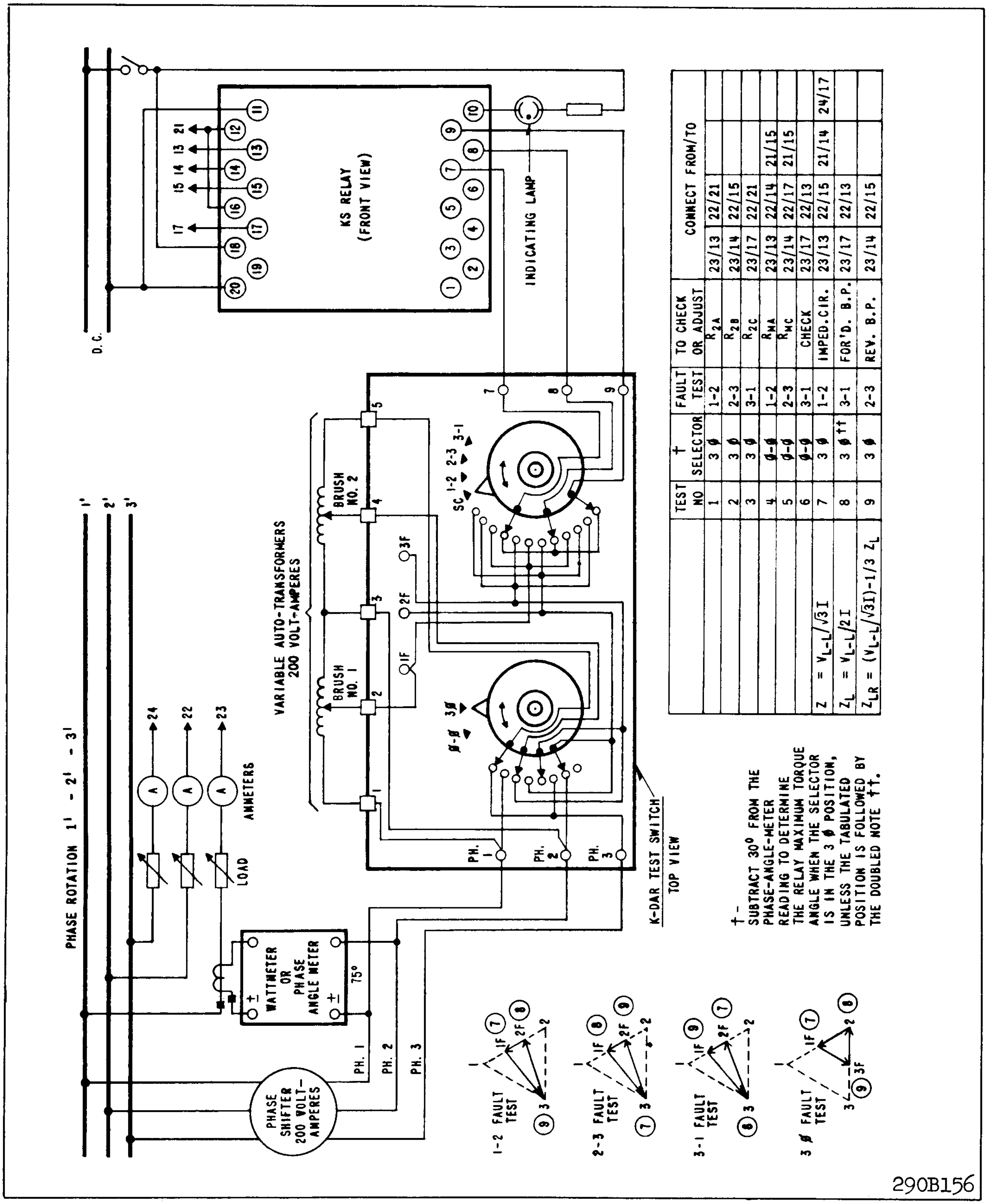
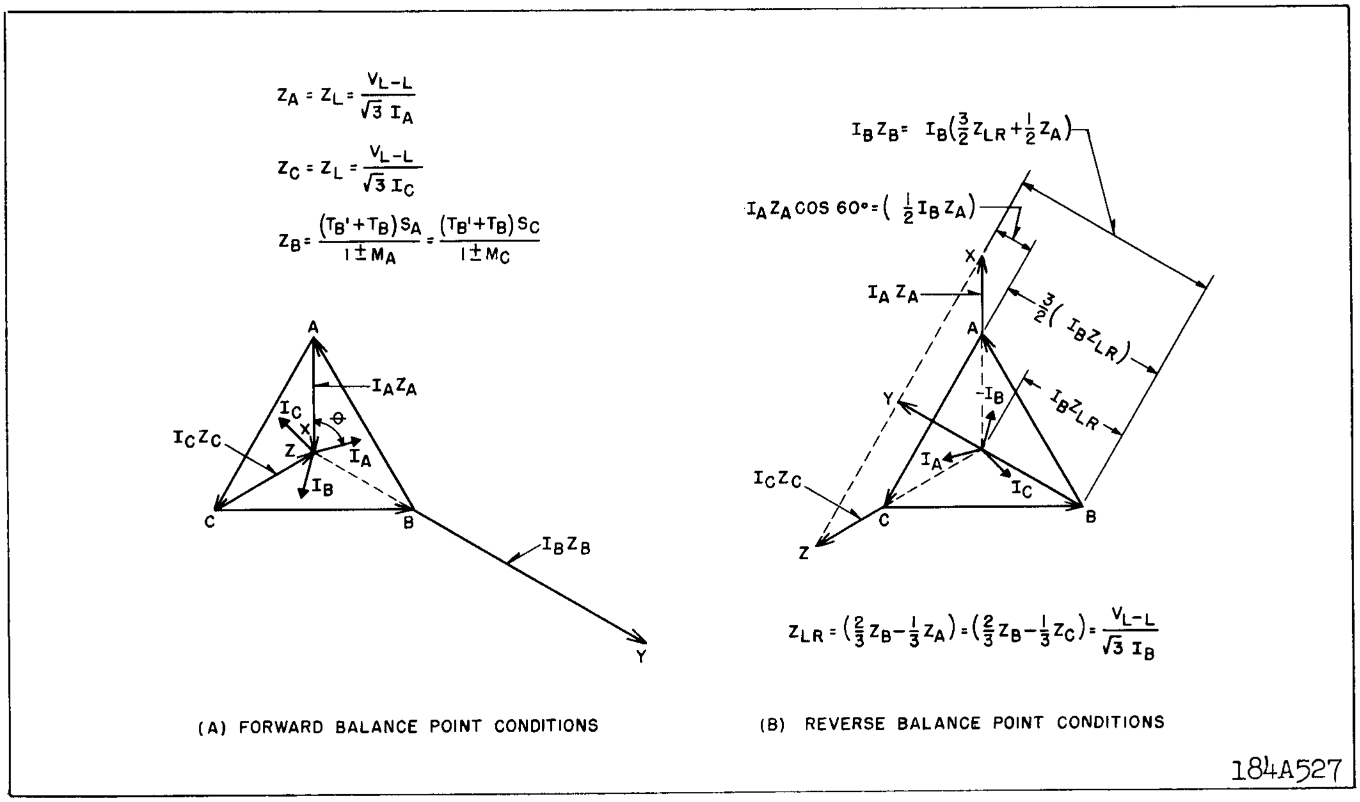


Fig. 6. Tap Plate.

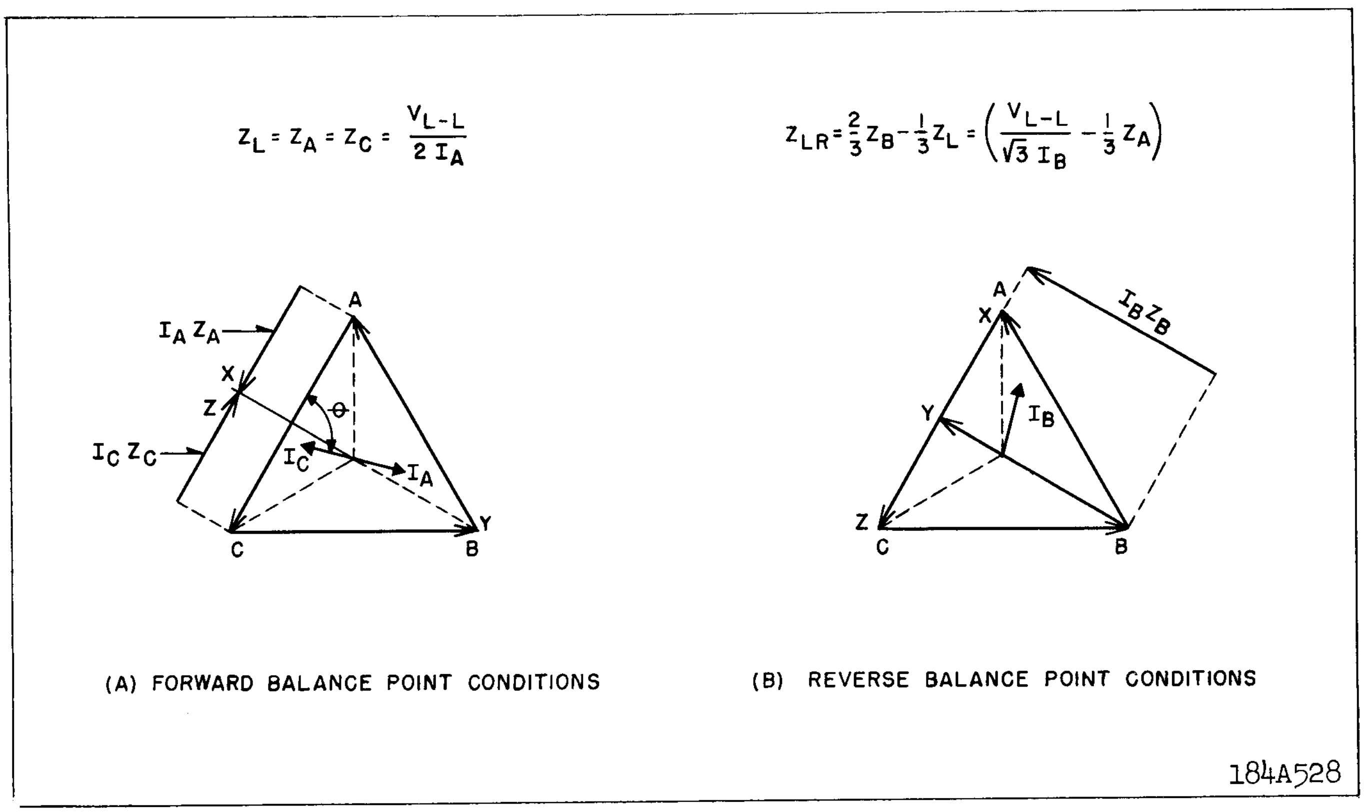


	TEST NO	† SELECTOR	FAULT TEST	TO CHECK OR ADJUST	CONNECT FROM/TO			
	1	3 Ø	1-2	R_{2A}	23/13	22/21		
	2	3 Ø	2-3	R_{2B}	23/14	22/15		
	3	3 Ø	3-1	R_{2C}	23/17	22/21		
	4	Ø-Ø	1-2	R_{MA}	23/13	22/14	21/15	
	5	Ø-Ø	2-3	R_{MC}	23/14	22/17	21/15	
	6	Ø-Ø	3-1	CHECK	23/17	22/13		
$Z = V_{L-L}/\sqrt{3}I$	7	3 Ø	1-2	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		

Fig. 7. Test Connections for Type KS Relays.



* *Fig. 8. Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.*



* *Fig. 9. Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.*

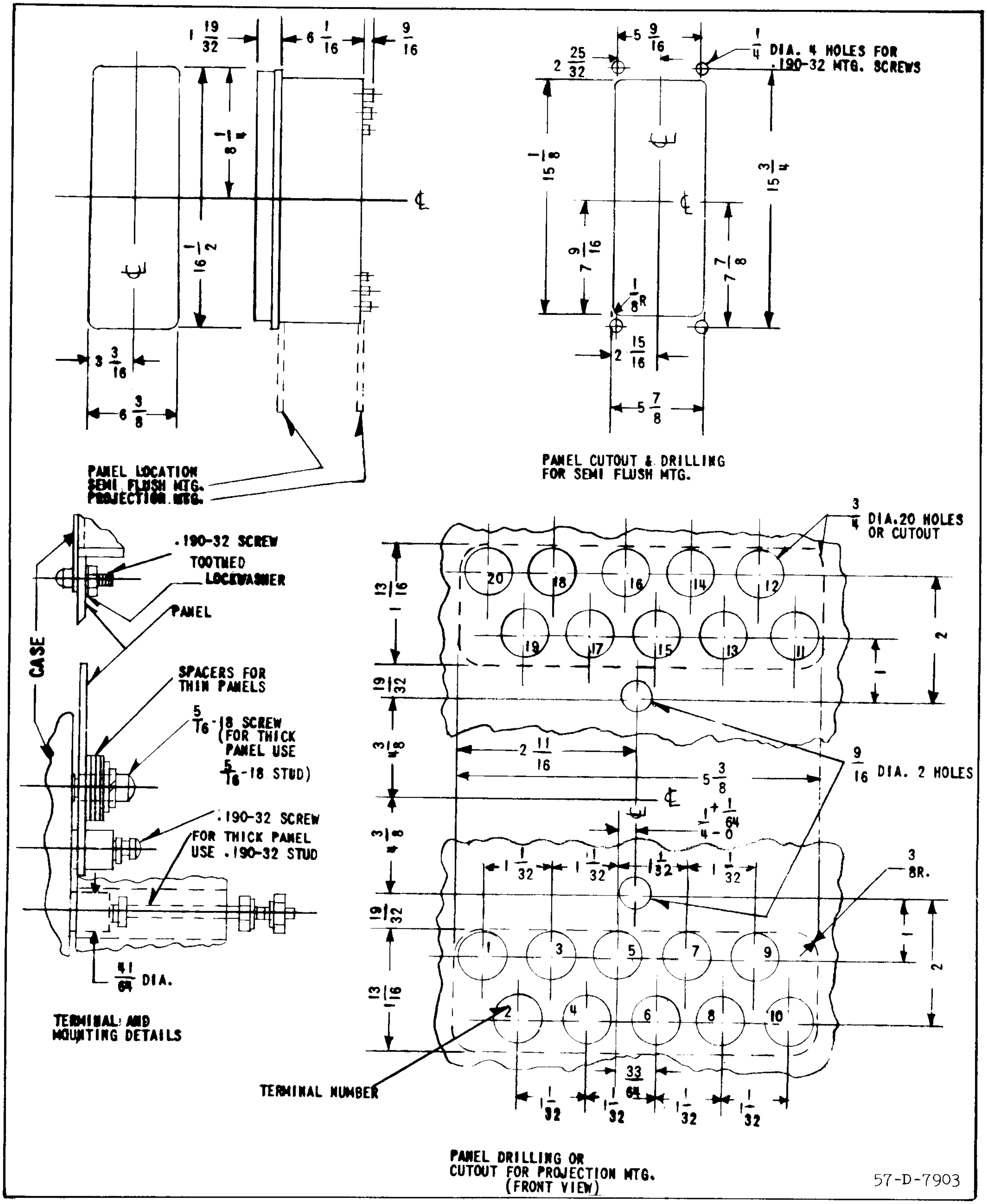


Fig. 10. Outline-Drilling Plan for the Type KS Relay in the FT32 Case.

WESTINGHOUSE ELECTRIC CORPORATION
RELAY-INSTRUMENT DIVISION **NEWARK, N. J.**
Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING 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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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^o and 80^o 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 on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps 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 .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 ±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.

SUPERSEDES I.L. 41-492J
*Denotes change from superseded issue.

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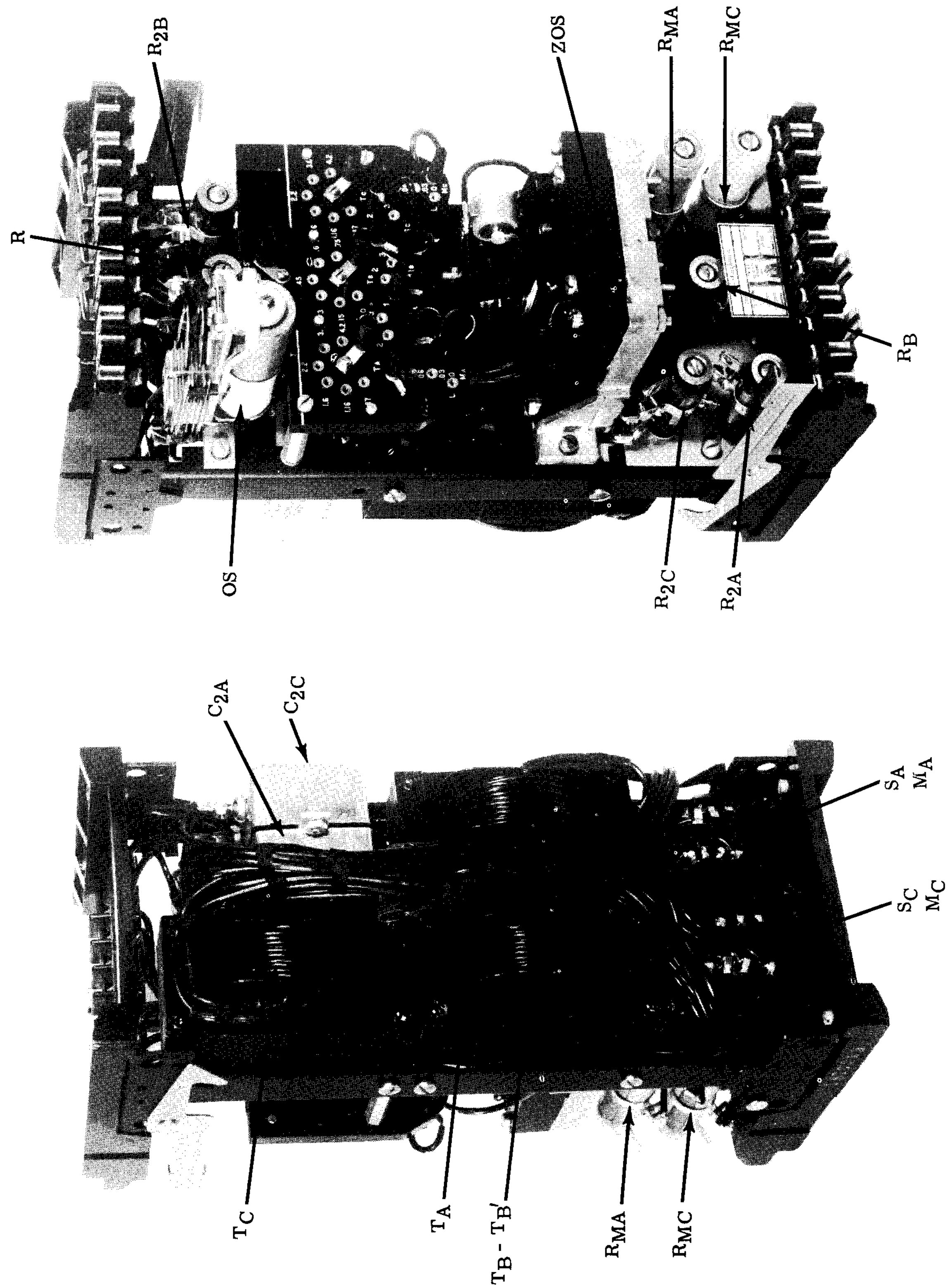


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

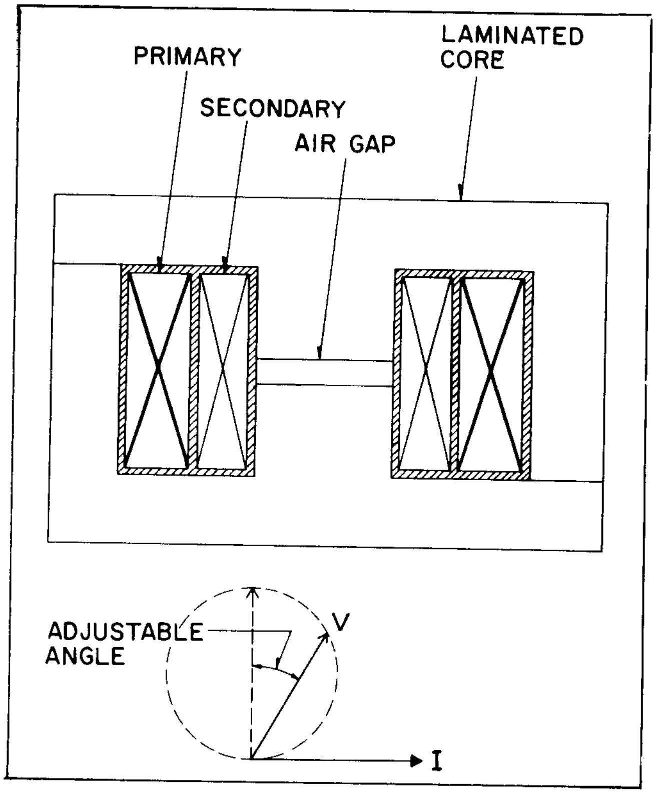


Fig. 2. Compensator Construction.

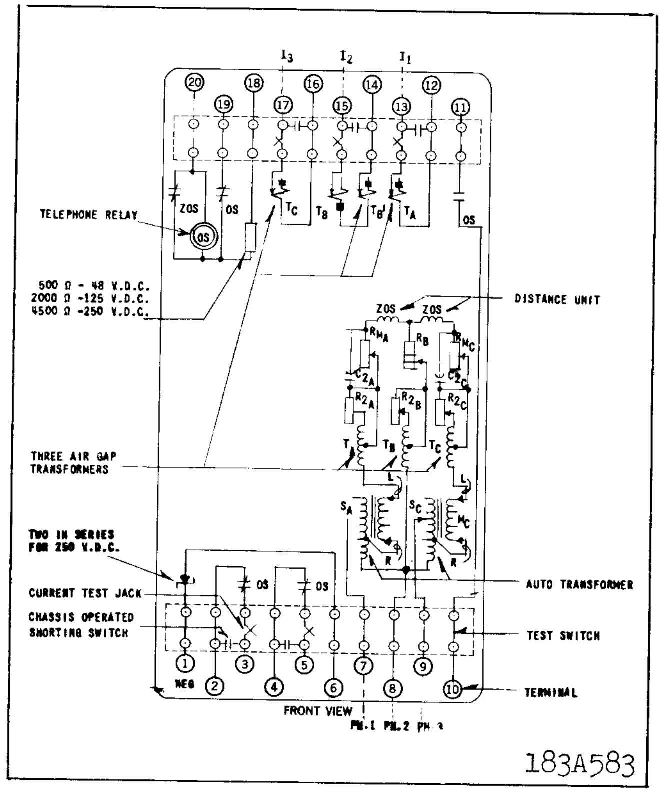


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 sprial 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 adjusted 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.

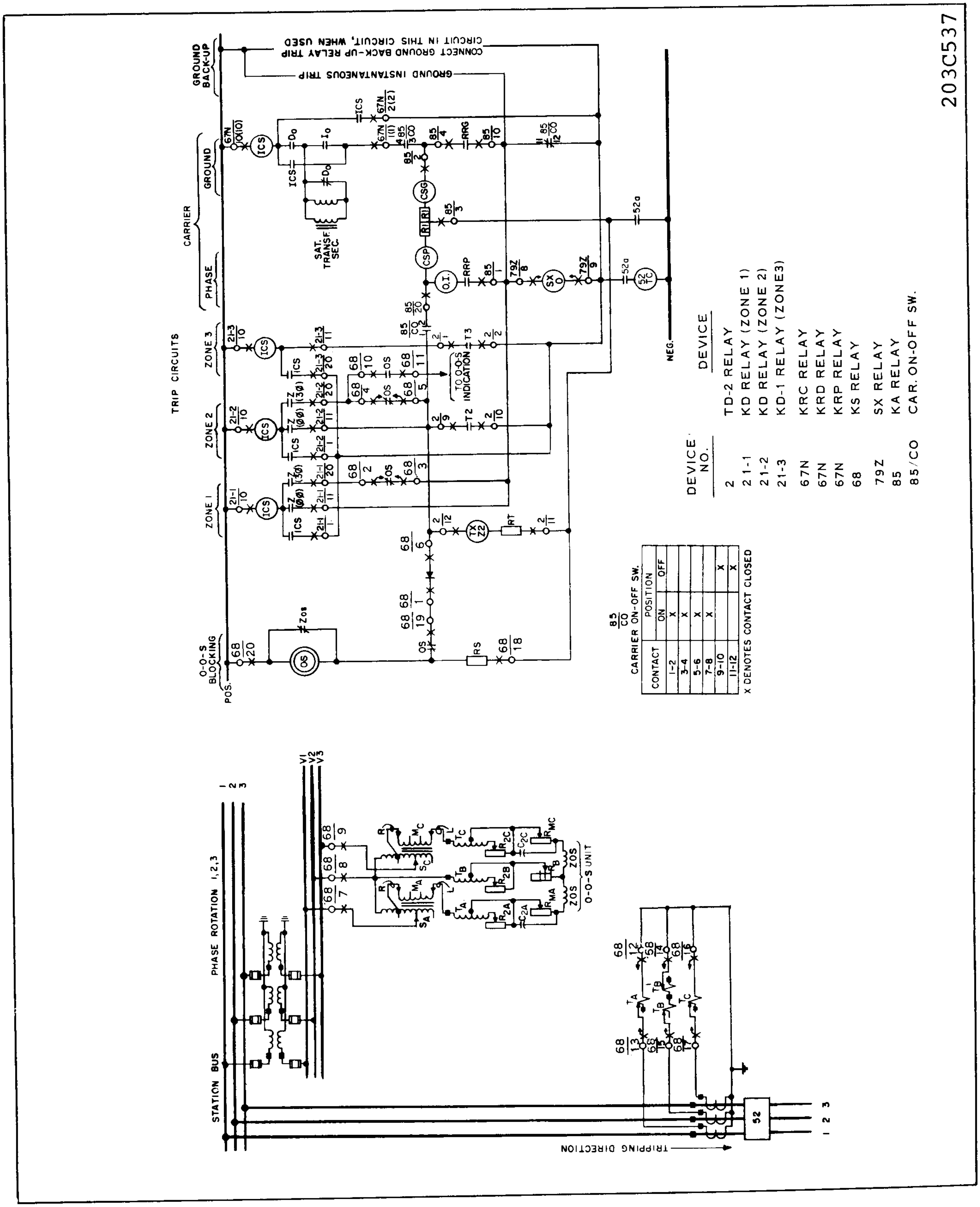


Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.

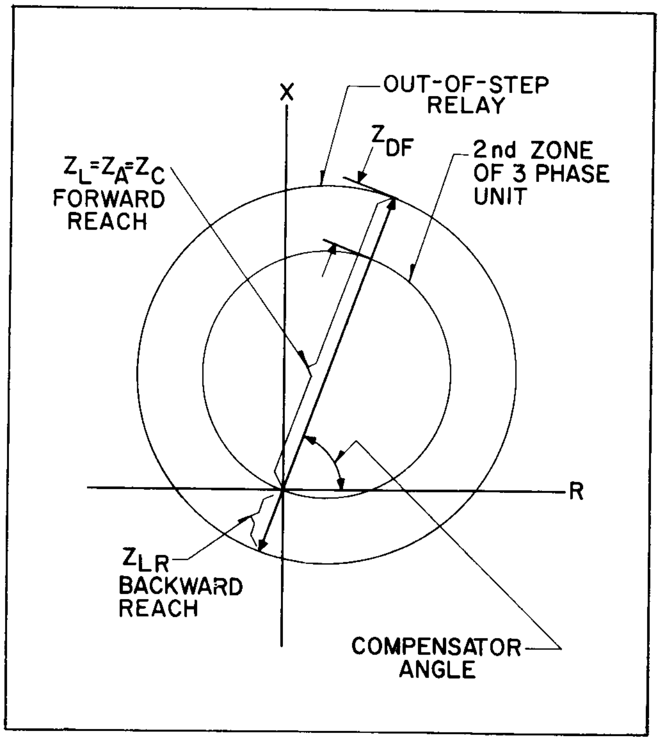


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figure 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles, its OS contacts located between the $\frac{68}{4}$ and $\frac{68}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 6 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)

.87 1.16 1.6 2.2 3.0 4.2 5.8

(T_B)

0 .15 .3 .45 .6 .75 .9

T_B'

2.85 3.9 4.95

(S_A, S_C, R_B)

1 2 3

(M_A, M_C)

± Values between taps .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 on page 14 and 15.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay * three-phase 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 described 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:

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

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°.

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

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

(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 values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\, Z_{B\theta} - 1/3\, Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\sin \theta)}{(\sin 75°)}$$

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

$T_B' + T_B$ = compensator tap value

$Z_{L\theta}$ S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{zone\ 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{zone\ 2}$.

2. Select the lowest tap, S which gives a product of 6.9S greater than Z_L where

$$Z_L = Z_{L\theta} \frac{(\sin 75°)}{(\sin \theta)}$$

3. Select a value for T that is nearest the value $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.

4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms

2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta} \frac{(\text{Sin } 75^o)}{(\text{Sin } \theta)}$

$$Z_{B\theta} = 1/2\, Z_{L\theta} + 3/2\, Z_{LR\theta}$$

2. Solve for $(T_B' + T_B)$ where $(T_B' + T_B) = \frac{Z_B (1 \pm M)}{S}$

3. Select the highest possible value for T_B' and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

* 1. Then $Z_B = \left(\frac{9}{2} + \frac{3 \times 2}{2}\right) \times \frac{0.966}{0.866}$

$= 7.5 \times 1.11 = 8.36$ ohms

2. $(T_B' + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T_B' = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35 \left(\frac{.866}{.966}\right) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, T_B-T_B', and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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 – 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 insert 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.

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 8).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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^o}	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^o current lagging voltage and the tap values are based on this angle. Generally speaking, the 75^o setting can be applied on lines with angles from 65^o to 90^o and the maximum error in relay reach will not exceed 4%. However, the angle can be set to any value between 60^o and 80^o 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 stud for the type FT projection case or by means of the four mounting holes on the flange for the semi-flush type FT case. Either the stud or the mounting screws may be utilized for grounding the relay. The electrical connections may be made directly to the terminals by means of screws for steel panel mounting or to the terminal stud furnished with the relay for thick panel mounting. The terminal stud may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 7. 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 open should be between 2.95 and 3.05 amperes at an angle of 75^o 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 close 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 7 set the phase shifter so that the current lags voltage by θ^{0}. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L-L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is

$Z_{LR} = \frac{V_{L-L}}{\sqrt{3}\, I_L} - 1/3\ Z_L$. Here V_{L-L} is phase-to-phase voltage and I_L is phase current and $Z_L = \frac{V_{LL}}{2\, I_{L_1}}$ where I_{L_1} is the current found in test #8.

Test No.	Volts	Amperes (θ= 75°) & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
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 $\theta + 30^{0}$

† To determine the limits of current when θ is not equal to 75^{0}, multiply the nominal values tabulated above by the ratio $\frac{\sin 75^{0}}{\sin \theta}$

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 8, 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 9 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 7 Figure 7, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L-L}}{\sqrt{3}\, I_L}$ 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 7. 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 checked for turns ratio and polarity by using the No. 1 test connections of Figure 7, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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' + T_B for 5.85

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 center than the end.

1. Using connections for test #1 of Figure 7 adjust brush #1 so that $V_{1F2F} = V_{78} = 0$. Adjust brush #2 for rated voltage across terminals 8 & 9. Adjust R_B so that the contact floats or has a minimum of torque. This is a rough adjustment for making the impedance angle of phase 1 to be equal to impedance of phase 2.

2. Using test #1 to Figure 7, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.
2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.
3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73^o and 76^o 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.
6. 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 7. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
3. Adjust the phase shifter for θ degrees between load current and $V_{PH.1\text{-}PH.2}$.
4. With load current set for 0.51 amperes, adjust R_{MA} so that the cylinder unit contacts just open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. Check the current required to close the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 $V_{L\text{-}L}$ to 120 $V_{L\text{-}L}$. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS}{(1 \pm M)} \frac{\sin\theta}{(\sin 75^o)}$.

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 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'-T_B on 5.85 tap.

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

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

The relay is now calibrated and ready for service.

TABLE I

NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors — 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; .06; .06)
OS	Telephone Type Relay — D.C. Resistance = 475 to 525 ohms

TAP SETTING	VOLTAGE BURDEN								
	I = 0			$V_{AN} = V_{BN} = V_{CN} = 69$ Volts			3 ϕ	S = 1	
	ϕA			ϕB			ϕC		
	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ
−.15	4.4	4.0	1.81	6.8	4.0	5.5	3.4	1.0	3.25
−.12	4.6	4.2	1.81	6.9	4.15	5.4	3.5	1.08	3.33
−.09	4.8	4.3	1.8	7.1	4.35	5.6	3.6	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

TAP SETTING	VOLTAGE BURDEN								
	I = 0			$V_{AN} = V_{BN} = V_{CN} = 69$ Volts			3 ϕ	S = 2	
	ϕA			ϕB			ϕC		
	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	1.55	1.21	.97	.59	.306	.505
−.06	1.17	1.15	.217	1.65	1.29	1.01	.61	.322	.52
−.03	1.24	1.22	.222	1.70	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	.375	.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

TAP SETTING	VOLTAGE BURDEN								
	I = 0			$V_{AN} = V_{BN} = V_{CN} = 69$ Volts			3 ϕ	S = 3	
	ϕA			ϕB			ϕC		
	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	.260
−.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

CURRENT BURDEN

3φI = 5 AMP /0 3φV = 69V$_{L-N}$ M = 0 S = 1

TAP T_A	φA Z	φA R	φA jX	$T_B + T'_B$	φB Z	φB R	φB jX	T_C	φC Z	φC R	φC jX
.87	.032	.031	.0030	0.0 +2.85	.115	.097	.063	.87	.026	.025	.005
1.16	.044	.042	.011	.15+2.85	.14	.116	.08	1.16	.03	.026	.014
1.6	.064	.060	.021	.3 +2.85	.165	.13	.10	1.6	.036	.27	.024
2.2	.074	.062	.04	.45+3.9	.19	.15	.12	2.2	.052	.030	.043
3.0	.12	.083	.088	.6 +3.9	.2	.13	.15	3.0	.068	.029	.062
4.2	.21	.114	.177	.75+3.9	.22	.14	.17	4.2	.11	.034	.105
5.8	.32	.115	.30	.9 +4.95	.3	.16	.25	5.8	.2	.052	.19

CURRENT BURDEN

3φI = 50 AMP /0 3φV = 120V$_{L-L}$ M = 0 S = 1

TAP T_A	φA Z	φA R	φA jX	$T_B + T'_B$	φB Z	φB R	φB jX	T_C	φC Z	φC R	φC jX
.87	.032	.031	.003	0.0 +2.85	.088	.070	.053	.87	.034	.034	.004
1.16	.034	.033	.008	.15+2.85	.092	.073	.056	1.16	.038	.037	.007
1.6	.05	.047	.016	.3 +2.85	.10	.078	.063	1.6	.046	.043	.060
2.2	.06	.051	.032	.45+3.9	.154	.105	.11	2.2	.066	.073	.059
3.0	.098	.075	.063	.6 +3.9	.16	.107	.12	3.0	.094		
4.2	15	.096	.115	.75+3.9	.17	.11	.13	4.2	.144		
5.8	.24	.14	.195	.9 +4.95	.24	.15	.19	5.8	.23		

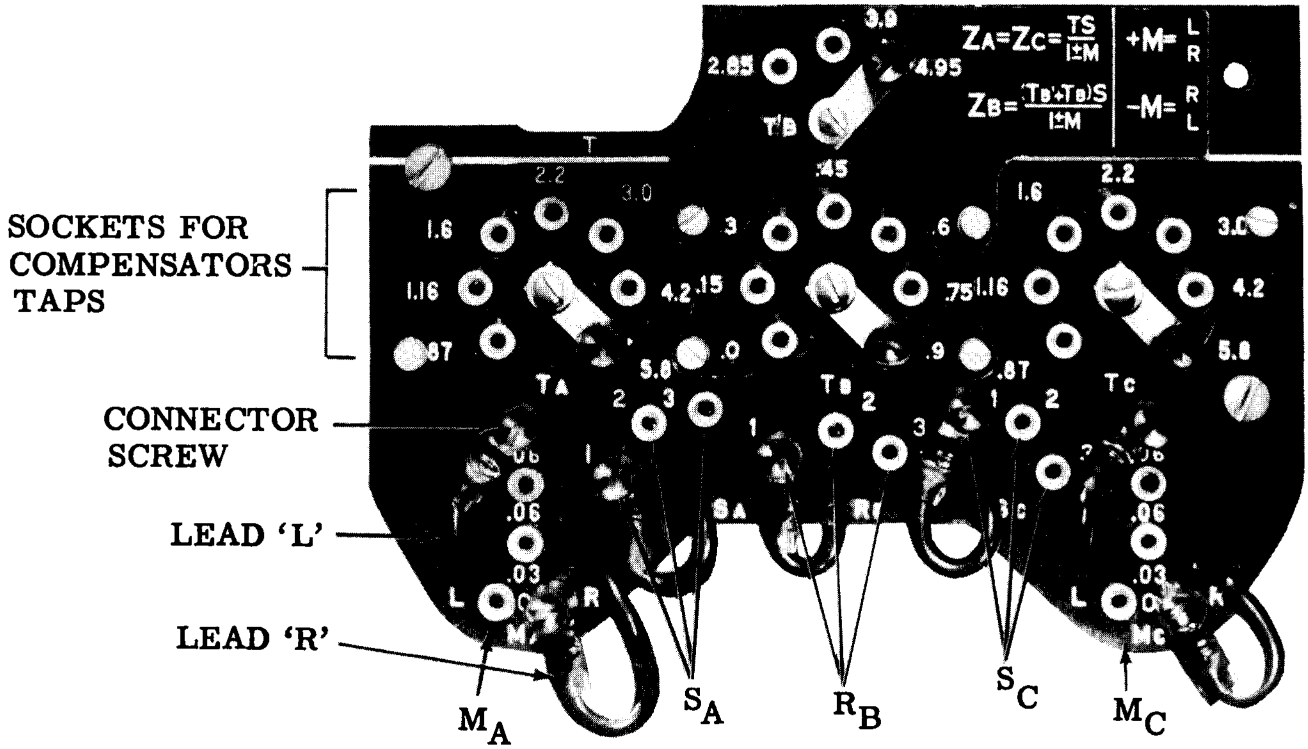
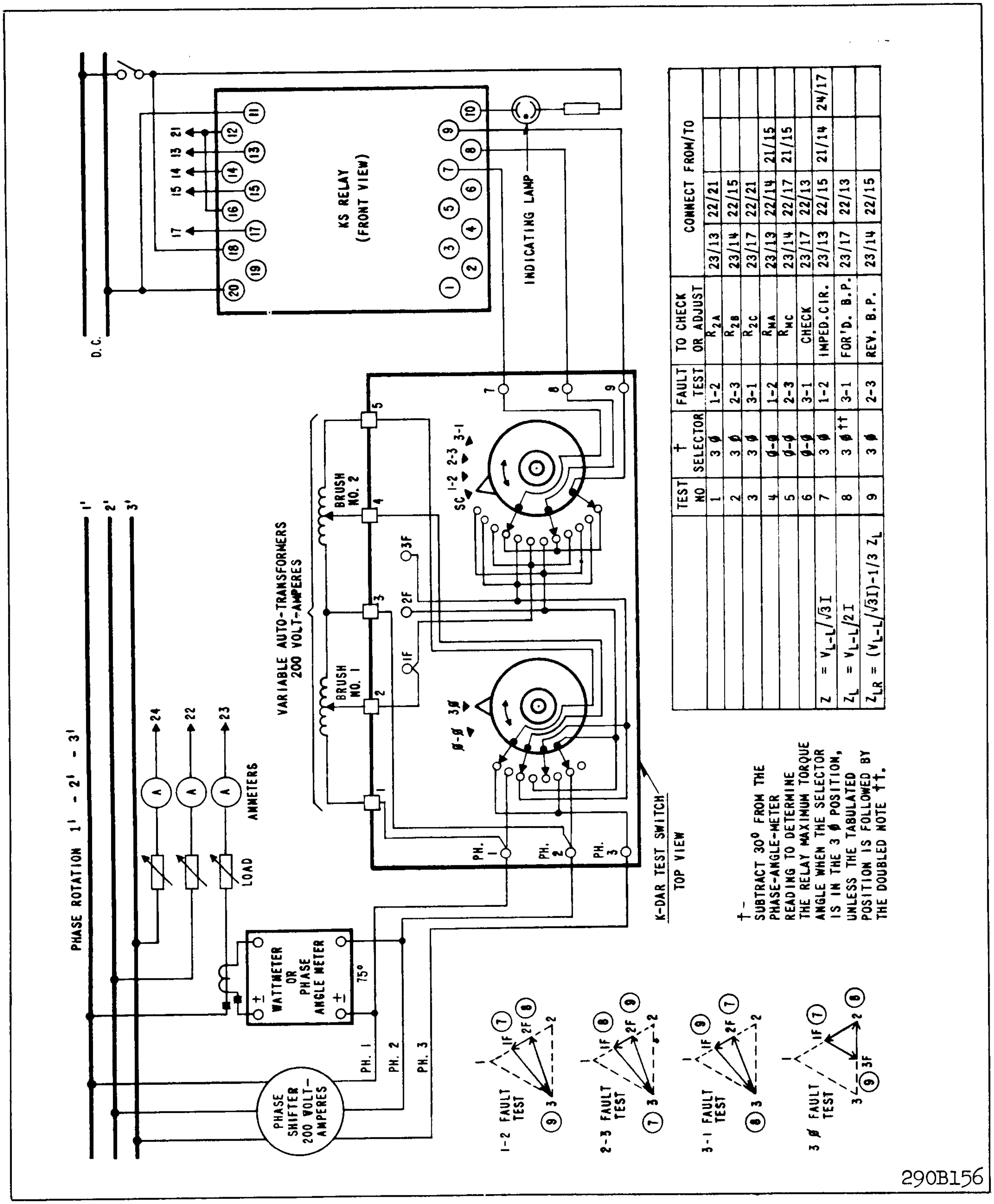


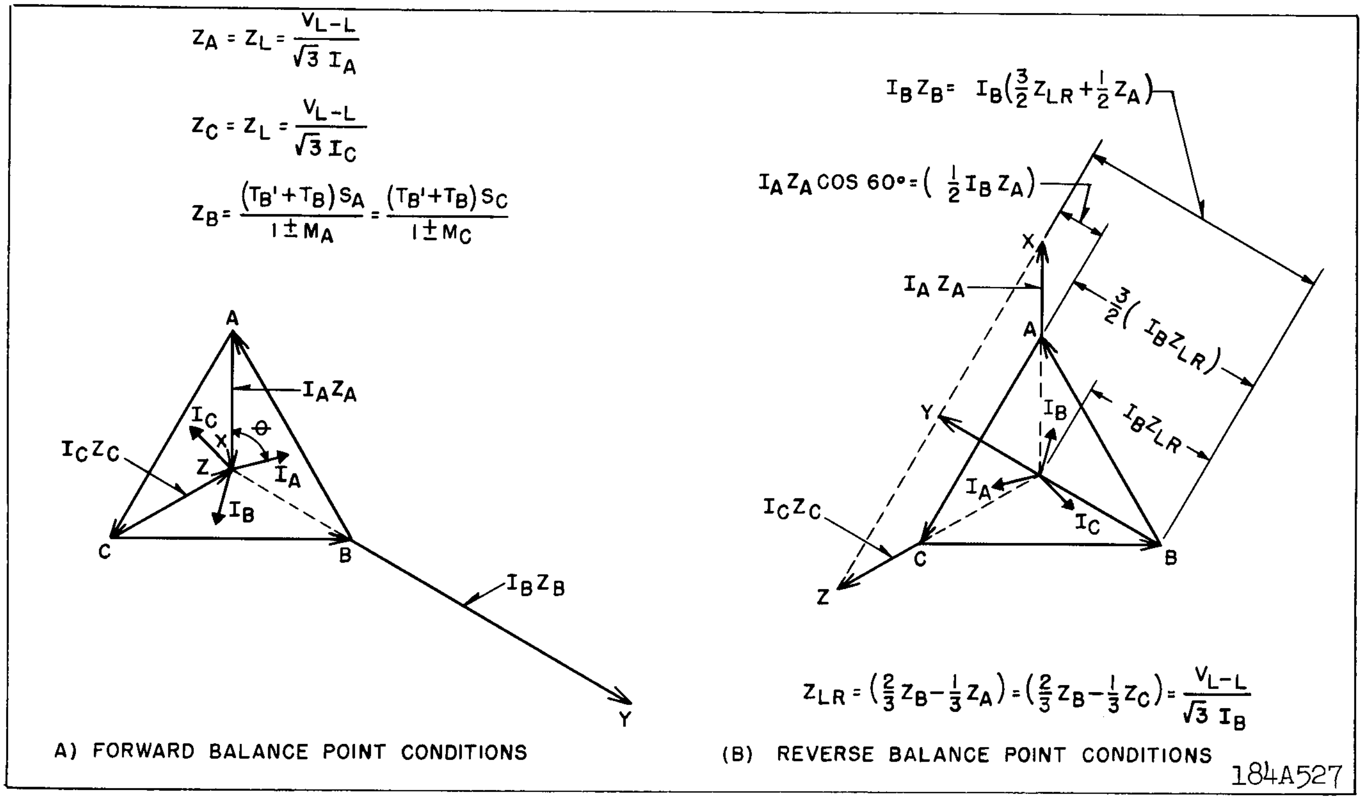
Fig. 6. Tap Plate.



	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 3 ø POSITION, UNLESS THE TABULATED POSITION IS FOLLOWED BY THE DOUBLED NOTE ††.

Fig. 7. Test Connections for Type KS Relays.



* *Fig. 8. Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.*

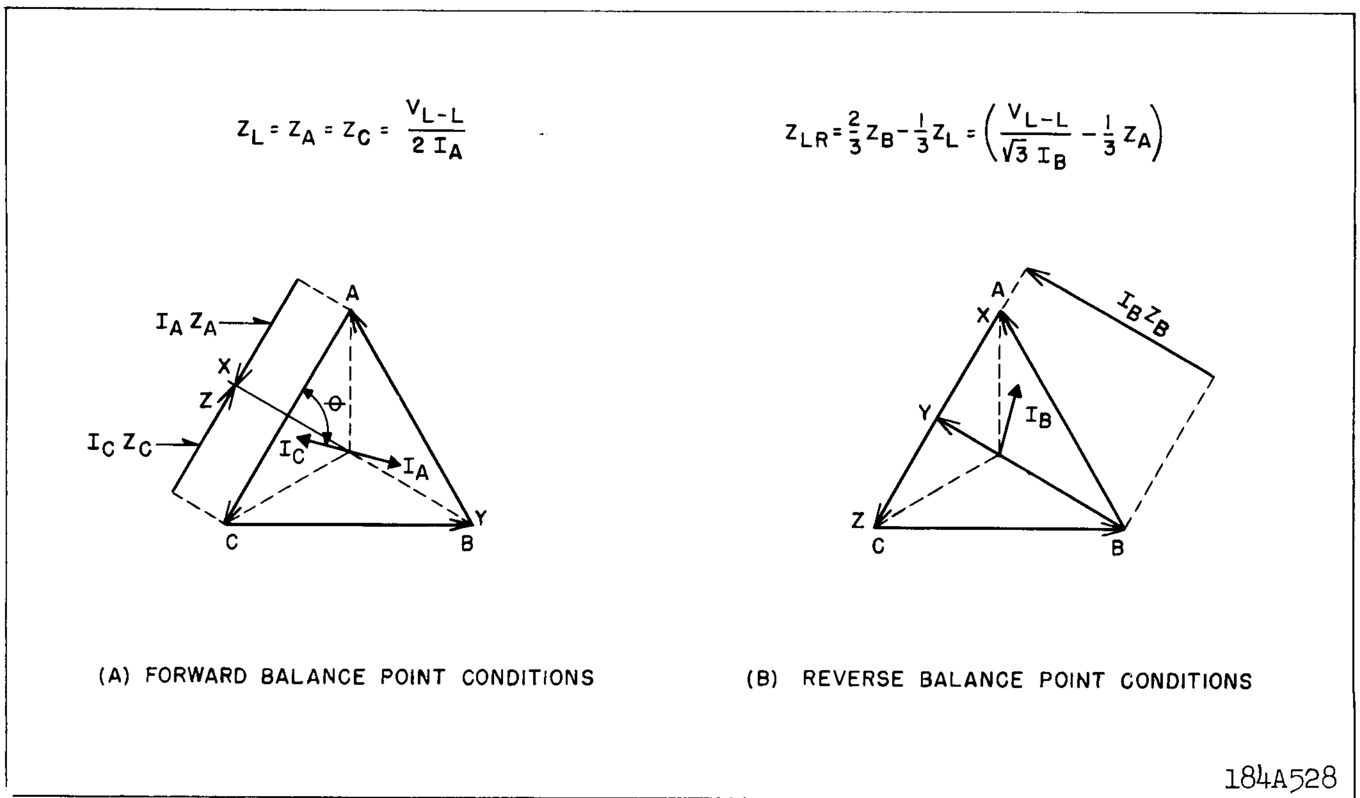


Fig. 9. Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.

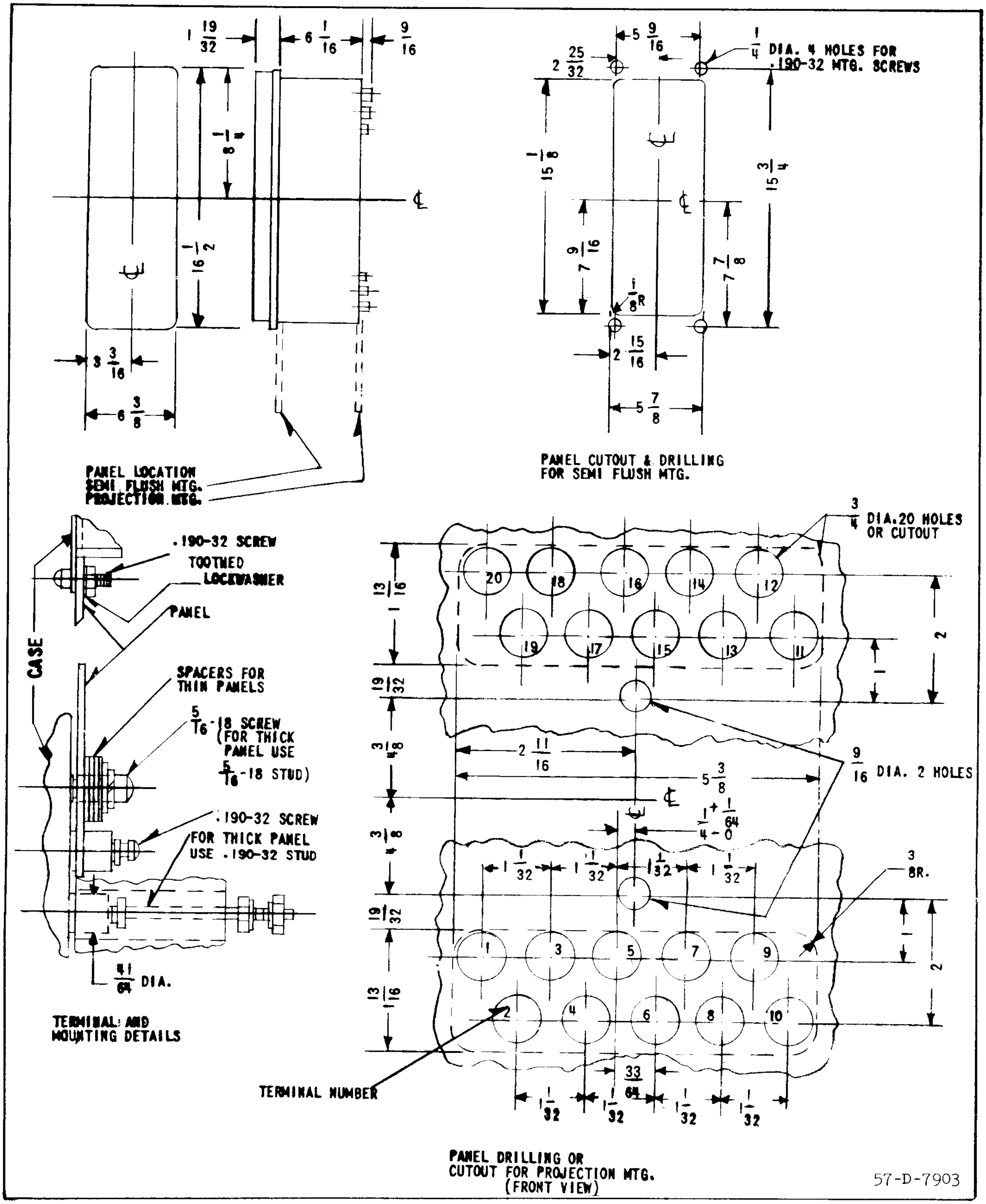


Fig. 10. Outline-Drilling Plan for the Type KS Relay in the FT32 Case.

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION NEWARK, N. J.

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KS OUT-OF-STEP BLOCKING RELAY
✪ 0.75-20 OHMS

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.

APPLICATION

The KS Relay (Figure 1) is a polyphase compensator distance type relay used with the type KD distance relay to prevent tripping while out-of-step or out-of-synchronism conditions exist on the system. It does not prevent or delay the type KD relay from tripping on phase-to-phase faults within its protective zone that occur during the out-of-step condition.

CONSTRUCTION

The type KS Blocking Relay consists of three air-gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, and a time-delay telephone type relay, all mounted in the type FT32 relay case.

Compensator

The compensators which are designated 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, 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

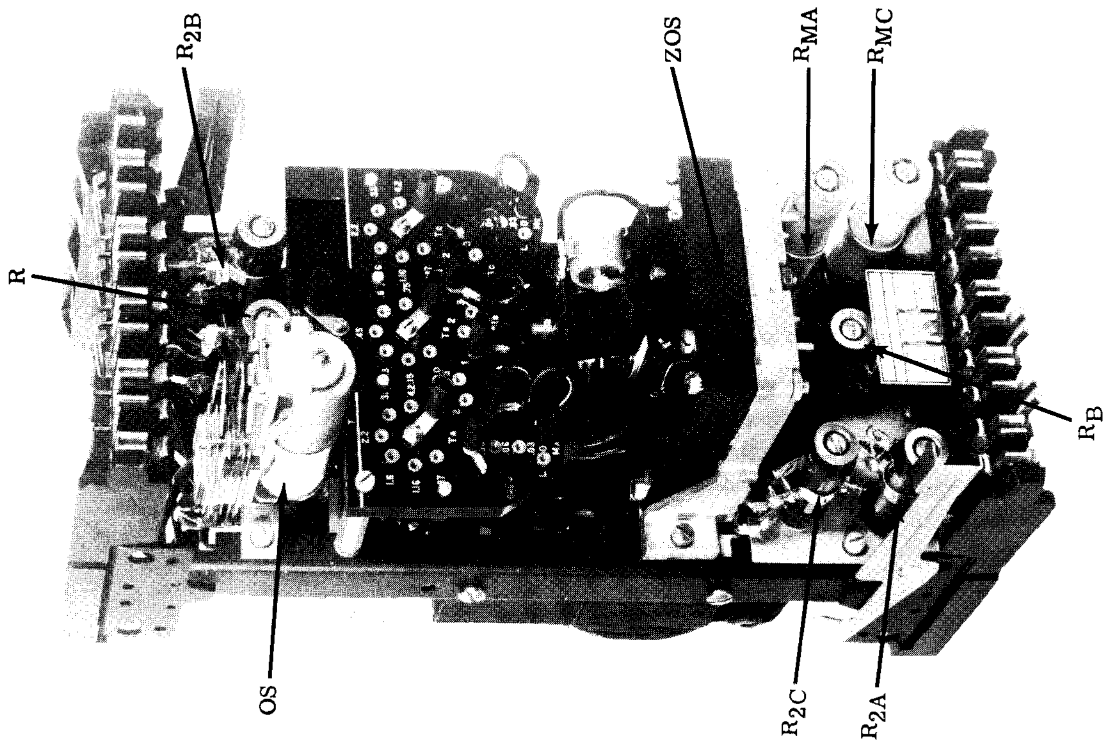
The auto-transformer has three taps on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps which may be connected additively, or subtractively to inversely modify the S setting by any value from -15 to +15 percent in steps of 3 percent.

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 .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 ±1.5 percent from 0.75 ohms to 20

All possible contingencies which may arise during installation, operation, or maintenance, and all details and variations of this equipment do not purport to be covered by these instructions. If further information is desired by purchaser regarding his particular installation, operation or maintenance of his equipment, the local Westinghouse Electric Corporation representative should be contacted.

SUPERSEDES I.L. 41-492K, dated August, 1975
✪ Denotes changed since previous issue.
EFFECTIVE MAY 1979



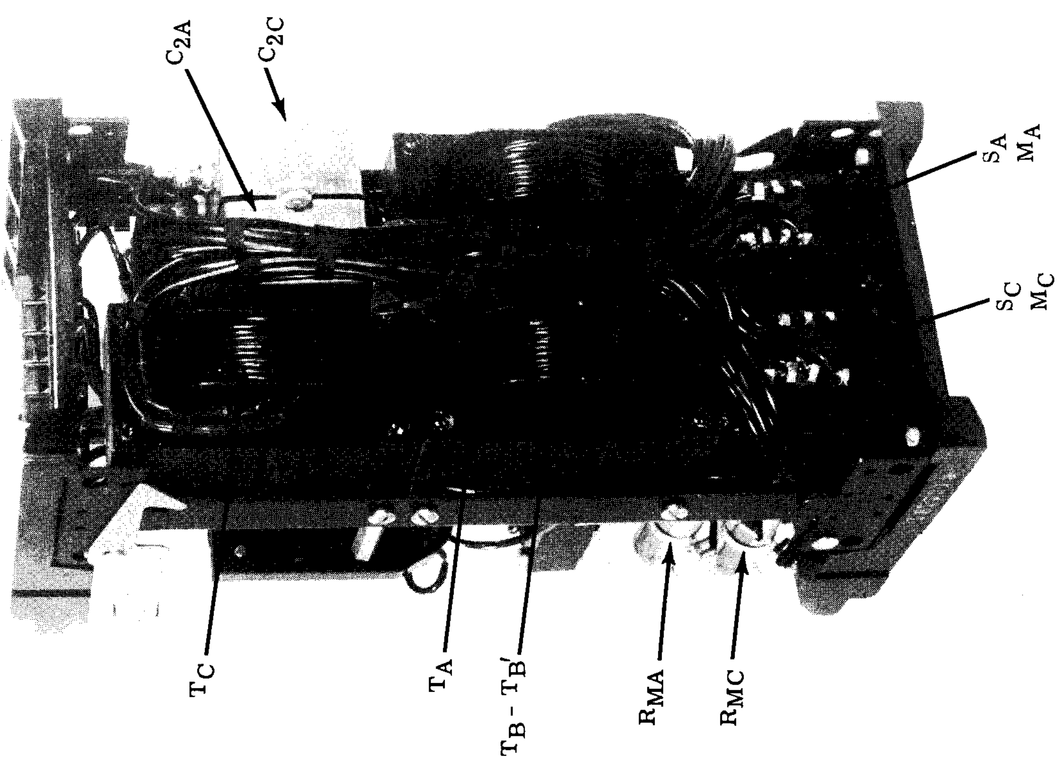


Fig. 1. Type KS Out-of-Step Blocking Relay without Case.

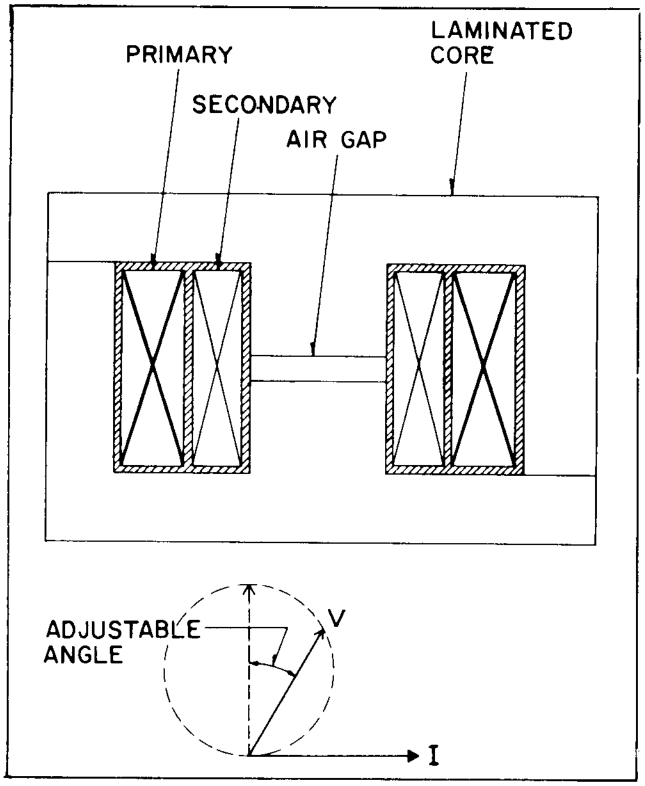


Fig. 2. Compensator Construction.

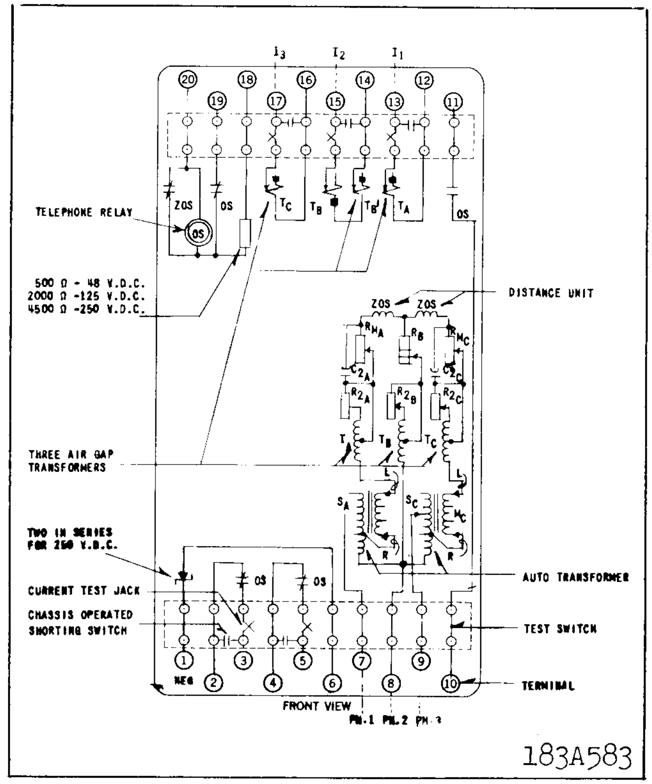


Fig. 3. Internal Schematic of the Type KS Relay in FT32 Case.

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. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 voltages applied to its terminals.

Mechanically, the cylinder unit is composed of four basic components: a die-cast 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 sprial 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 adjusted 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.

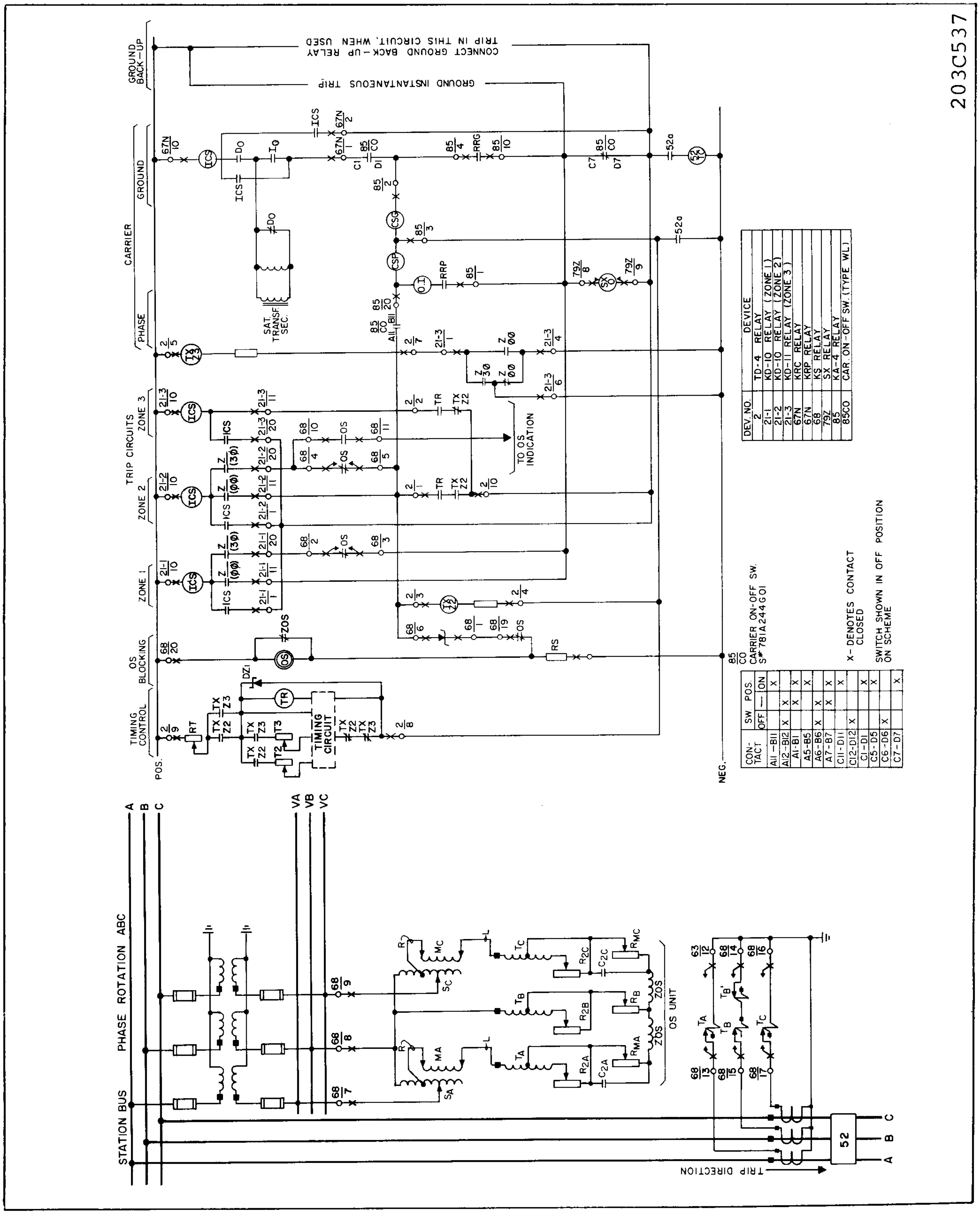


Fig. 4. External Schematic of the Type KS Relay with K-Dar Carrier Relaying.

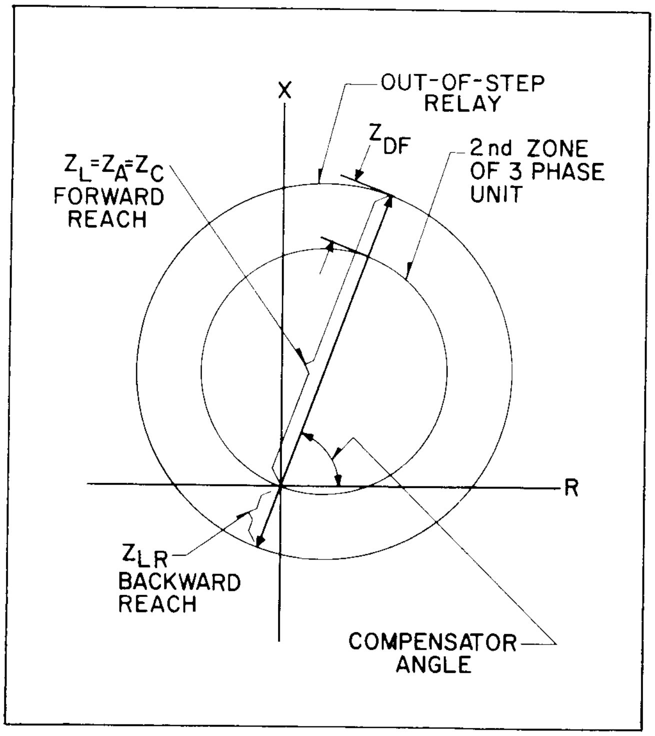


Fig. 5. Relay Characteristic on an R-X Diagram.

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 short-circuit the telephone type relay coil, OS. When operating torque causes the contacts to open, then the short-circuit is removed from across OS, permitting it to become energized.

Telephone Relay

The telephone-type relay unit, OS, is a slow-to-operate type. 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.

When the telephone-type relay is energized, by the opening of the cylinder unit contacts, it opens its several sets of contacts which are normally connected in series with the KD relay three-phase unit contacts, and thus prevents completing the trip circuit during an out-of-step condition (Figure 4).

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-opening 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 increase 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 KS relay takes advantage of the distinction between a fault and an out-of-step condition. Under out-of-step conditions, the KS relay will operate followed after a short time delay by zone 2 KD relay, as the apparent short circuit drifts toward the relay. In case of a fault, the KS as well as one or two zone relays may be operated but if more than the KS relay is to operate, the other will operate within a very short time, and will not follow the sequence described for an out-of-step condition.

Blocking Unit

The four-pole cylinder unit which acts to initiate blocking for an out-of-step condition is connected open delta and operates as a three-phase induction motor. Contact closing torque is produced by the unit when the voltage applied to its terminals has a positive-phase sequence. Contact-opening 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 ohm 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 torque is produced in the cylinder unit.

CHARACTERISTICS

Referring to Figure 5, the scheme of operation is described below. The impedance circle of the relay is set to encircle the second zone KD relay three-phase unit. The difference between the two circles provides a margin in ohms sufficient to give the telephone-type relay time to operate before the swing condition enters the characteristic circle of zone 2 after having entered the circle of the KS relay. The telephone-type relay will open, within 3 to 4 cycles. its OS contacts located between the $\frac{68}{4}$ and $\frac{68}{5}$ terminals shown in the trip circuits section of Figure 4. Thus all of the OS contacts operate to block tripping and also to prevent the short-circuiting and de-energizing of the OS coil as the zone 2 contacts close. When zone 2 operates before OS, as it does for a three-phase fault condition, a short-circuit across the coil, OS, is completed through the KD relay, and OS is not energized even though the ZOS contacts do open.

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°. This 90° 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, IT_A, IT_B or IT_C. 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. 6 are based upon a 75° 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_θ, varies with the maximum torque angle, θ, as follows:

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

TAP PLATE MARKINGS

(T_A and T_C)
.87 1.16 1.6 2.2 3.0 4.2 5.8

(T_B)
0 .15 .3 .45 .6 .75 .9

T_B'
2.85 3.9 4.95

(S_A, S_C, R_B)
1 2 3

(M_A, M_C)
± Values between taps .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 on page 14 and 15.

SETTING CALCULATIONS

The type KS relay requires an ohm setting high enough so that its impedance circle completely surrounds the impedance circle of the zone 2 KD relay three-phase 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 described 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:

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

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°.

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

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

(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 values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to Lower the Z setting. The sign is negative when "R" is above "L" and acts to Raise the Z setting).

Reverse reach is calculated by the formula:

$$Z_{LR\theta} = 2/3\ Z_{B\theta} - 1/3\ Z_{L\theta}$$

Terms used in this formula are defined as follows:

$Z_{LR\theta}$ = The desired ohmic reverse reach of the relay at θ degrees maximum torque angle setting

$$Z_{B\theta} = Z_B \frac{(\sin\theta)}{(\sin 75°)}$$

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

$T_B' + T_B$ = compensator tap value

$Z_{L\theta}$, S, & M = same as in forward reach formula

Sample Calculations

An optimum forward setting can be obtained by the following procedure.

1. Determine the desired forward reach, $Z_{L\theta}$, which is ($Z_{zone\ 2}$ + 2 ohms). Note that 2 ohms is a rule-of-thumb value selected as a safe margin for identifying a system swing and is not influenced by the magnitude of $Z_{zone\ 2}$.

2. Select the lowest tap, S which gives a product of 6.9S greater than Z_L where

$$Z_L = Z_{L\theta} \frac{(\sin 75°)}{(\sin\theta)}$$

3. Select a value for T that is nearest the value $\frac{Z_L}{S}$. This will be the setting for T_A and T_C.

4. Determine the value of M that will most nearly make $M = \frac{TS}{Z_L} - 1$. If the sign is negative, then the M taps are connected with the R lead above the L lead to Raise the setting.

For example, assume the desired value of $Z_{L\theta}$ to be (7 + 2) = 9 ohms at 60 degrees.

1. Then $Z_L = 9 \times \frac{(0.966)}{(0.866)} = 10.0$ ohms

2. The lowest tap S for 6.9 S greater than 10.0 is S = 2.

3. T nearest to $\frac{10}{2} = 5$ is 5.8 (The next lower tap might have been selected but the highest possible T tap is preferred).

4. $M = \frac{11.6}{10.0} - 1 = 0.16$ (Use M = .15)

Check the setting calculations.

$$Z_L = \frac{5.8 \times 2}{1 + .15} = 10.1 \text{ ohms}$$

$$Z_{L\theta} = 10.1 \frac{(.866)}{(.966)} = 9.05 \text{ relay ohms}$$

at a maximum torque angle setting of 60 degrees. This is 100.4% of the desired value.

An optimum reverse setting can be obtained by the following procedure.

1. Solve for Z_B where $Z_B = Z_{B\theta} \frac{(\text{Sin } 75^o)}{(\text{Sin } \theta)}$

   $$Z_{B\theta} = 1/2\, Z_{L\theta} + 3/2\, Z_{LR\theta}$$

2. Solve for $(T_B' + T_B)$ where $(T_B' + T_B) = \frac{Z_B\,(1 \pm M)}{S}$

3. Select the highest possible value for T_B' and set the remaining portion on the closest value of T_B.

For example assume the desired value of $Z_{LR\theta}$ to be 2 ohms at 60 degrees ($Z_{L\theta}$ has already been established as 9 ohms at 60 degrees).

1. Then $Z_B = (\frac{9}{2} + \frac{3 \times 2}{2}) \times \frac{0.966}{0.866}$
   $= 7.5 \times 1.11 = 8.36$ ohms

2. $(T_B' + T_B) = \frac{8.36 \times 1.15}{2} = 4.81$ ohms

3. Highest possible value for $T_B' = 3.9$ and $T_B = 4.81 - 3.9 = 0.91$ (Use $T_B = .9$)

$$Z_B = \frac{(3.9 + .9) \times 2}{1 + .15} = 8.35 \text{ ohms}$$

$$Z_{B\theta} = 8.35\,(\frac{.866}{.966}) = 7.5 \text{ ohms}$$

$$Z_{LR\theta} = \frac{2 \times 7.5}{3} - \frac{9.05}{3} = (5 - 3) = 2 \text{ ohms.}$$

SETTING THE RELAY

The KS relay requires settings for each of the three compensators (T_A, $T_B'+T_B$, and T_C), each of the two auto-transformers, primaries (S_A and S_C) and 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, $T_B - T_B'$, 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 insert 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.

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 6).

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. These leads come out of the tap plate each 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 nega-

tive (-) 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°	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° 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.

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

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

RECEIVING ACCEPTANCE

KS relays have a very small number of moving parts and machanical 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 resistor 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 7. 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 open 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 open 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 faulty or out of calibration.

Check the time-delay unit by applying rated D.C. voltage across terminals 18 and 20. Opening the cylinder unit contacts should cause the telephone type relay to pick up. It should drop out when the cylinder unit contacts close.

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 operating 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 7 set the phase shifter so that the current lags voltage by θ^{0}. The current required to open the contacts should be within the limits specified for each voltage. Note that for the forward reach, connection 8, the impedance measured by the relay is $Z_L = \frac{V_{L-L}}{2I_L}$. Reverse reach, connection 9, measured by the relay in this test is $Z_{LR} = \frac{V_{L-L}}{\sqrt{3}\, I_L} - 1/3\ Z_L$. Here V_{L-L} is phase-to-phase voltage and I_L is phase current and $Z_L = \frac{V_{LL}}{2\, I_{L_1}}$ where I_{L_1} is the current found in test #8.

Test No.	Volts	Amperes (θ= 75°) & †	
	V_{1F2F} & V_{2F3F}	I_{min}	I_{max}
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 $\theta + 30^{0}$

† To determine the limits of current when θ is not equal to 75^{0}, multiply the nominal values tabulated above by the ratio $\frac{\sin 75^{0}}{\sin \theta}$

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 8, 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 9 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 5 cannot be checked using a single phase current. A polyphase current is required, with test connections as per Test No. 7 Figure 7, to plot the characteristic circle. The reach of the relay for this connection is $Z = \frac{V_{L-L}}{\sqrt{3}\, I_L}$ 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 7. 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 checked for turns ratio and polarity by using the No. 1 test connections of Figure 7, and following the procedure outlined below.

Set S_A and S_C on tap number 3. Set the "R" leads 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 measured). 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; $T_B' + T_B$ for 5.85

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 center than the end.

1. Using connections for test #1 of Figure 7 adjust brush #1 so that $V_{1F2F} = V_{78} = 0$. Adjust brush #2 for rated voltage across terminals 8 & 9. Adjust R_B so that the contact floats or has a minimum of torque. This is a rough adjustment for making the impedance angle of phase 1 to be equal to impedance of phase 2.

2. Using test #1 to Figure 7, adjust brush #2 so that $V_{2F3F} = V_{89} = 0$. Adjust brush #1 for rated voltage across terminals 7 & 9. 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 resistors 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 R_B only.

1. 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.
2. Adjust the voltage V_{1F2F} and V_{2F3F} for 50 volts with Brush No. 1 and Brush No. 2 respectively.
3. 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 θ then is $(\frac{\theta 1 + \theta 2}{2} - 30)$ degrees.

This angle should be between 73^o and 76^o 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 No. 2 Test connections and repeat the procedures numbered 2, 3, and 4 to check and adjust the angle of the phase-2 compensator. Adjustments may be made by varying R_{2B}.
6. 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 7. Each value of current required to trip the top cy-

linder 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 No. 4.
2. 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).
3. Adjust the phase shifter for θ degrees between load current and $V_{PH.1\text{-}PH.2}$.
4. With load current set for 0.51 amperes, adjust R_{MA} so that the cylinder unit contacts just open.
5. Reconnect the relay for a 2-3 fault in Test No. 5 and adjust R_{MC} using procedures of steps 2, 3, and 4.
6. Determine the current value at which the contacts open 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.
7. Increase R_{MA} a slight amount and reduce R_{MC} an equal amount until the contacts just open for 0.51 amperes.
8. ✪ Check the current required to open the contacts for Tests Nos. 4, and 5. The values should be equal to each other and to Test No. 7 within ±3%,
9. If the currents are not equal ±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 the moving-contact arm against the left-hand side of the bridge, screw the right-hand contact in to just touch the moving-contact. Then back the contact out one (1) full turn to give approximately 0.032 inch gap.

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 $V_{L\text{-}L}$ to 120 $V_{L\text{-}L}$. The corrected tap value is the actual relay reach at a given maximum torque angle θ and is equal to $Z_\theta = \frac{TS}{(1 \pm M)} \frac{\sin\theta}{(\sin 75^o)}$.

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 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+T_B on 5.85 tap.

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

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

Telephone Relay

With the cylinder unit contacts open, energize the telephone relay through terminals 18 and 20 with rated D-C voltage and measure the time required for the contacts to open between terminals 4 and 5. This operating time should be between three and four cycles, (50 and 66 milliseconds). The operating time can be adjusted by bending the contact-springs located at the top left-hand side of the OS unit and by changing the armature gap.

The relay is now calibrated and ready for service.

TABLE I

NOMENCLATURE FOR TYPE KS RELAY

ITEM	DESCRIPTION
ZOS	Two Element-Coils; Total D.C. 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 Resistors — 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; .06; .06)
OS	Telephone Type Relay — D.C. Resistance = 475 to 525 ohms

VOLTAGE BURDEN

$I = 0$ $V_{AN} = V_{BN} = V_{CN} = 69$ Volts 3ϕ $S = 1$

TAP SETTING	ϕA			ϕB			ϕC		
	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ	VI	VI Cos θ	VI Sin θ
−.15	4.4	4.0	1.81	6.8	4.0	5.5	3.4	1.0	3.25
−.12	4.6	4.2	1.81	6.9	4.15	5.4	3.5	1.08	3.33
−.09	4.8	4.3	1.8	7.1	4.35	5.6	3.6	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

$I = 0$ $V_{AN} = V_{BN} = V_{CN} = 69$ Volts 3ϕ $S = 2$

TAP SETTING	ϕA			ϕB			ϕC		
	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	1.55	1.21	.97	.59	.306	.505
−.06	1.17	1.15	.217	1.65	1.29	1.01	.61	.322	.52
−.03	1.24	1.22	.222	1.70	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	.375	.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

$I = 0$ $V_{AN} = V_{BN} = V_{CN} = 69$ Volts 3ϕ $S = 3$

TAP SETTING	ϕA			ϕB			ϕC		
	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	.260
−.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

CURRENT BURDEN											
TAP T_A	$3\phi I = 5$ AMP $\angle 0$ $3\phi V = 69V_{L-N}$ M = 0 S = 1										
	ϕA			$T_B + T_B'$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.0030	0.0 +2.85	.115	.097	.063	.87	.026	.025	.005
1.16	.044	.042	.011	.15 + 2.85	.14	.116	.08	1.16	.03	.026	.014
1.6	.064	.060	.021	.3 +2.85	.165	.13	.10	1.6	.036	.27	.024
2.2	.074	.062	.04	.45 + 3.9	.19	.15	.12	2.2	.052	.030	.043
3.0	.12	.083	.088	.6 +3.9	.2	.13	.15	3.0	.068	.029	.062
4.2	.21	.114	.177	.75 + 3.9	.22	.14	.17	4.2	.11	.034	.105
5.8	.32	.115	.30	.9 +4.95	.3	.16	.25	5.8	.2	.052	.19

CURRENT BURDEN											
TAP T_A	$3\phi I = 50$ AMP $\angle 0$ $3\phi V = 120V_{L-L}$ M = 0 S = 1										
	ϕA			$T_B + T_B'$	ϕB			T_C	ϕC		
	Z	R	jX		Z	R	jX		Z	R	jX
.87	.032	.031	.003	0.0 +2.85	.088	.070	.053	.87	.034	.034	.004
1.16	.034	.033	.008	.15 + 2.85	.092	.073	.056	1.16	.038	.037	.007
1.6	.05	.047	.016	.3 +2.85	.10	.078	.063	1.6	.046	.043	.060
2.2	.06	.051	.032	.45 + 3.9	.154	.105	.11	2.2	.066	.073	.059
3.0	.098	.075	.063	.6 +3.9	.16	.107	.12	3.0	.094		
4.2	15	.096	.115	.75 + 3.9	.17	.11	.13	4.2	.144		
5.8	.24	.14	.195	.9 +4.95	.24	.15	.19	5.8	.23		

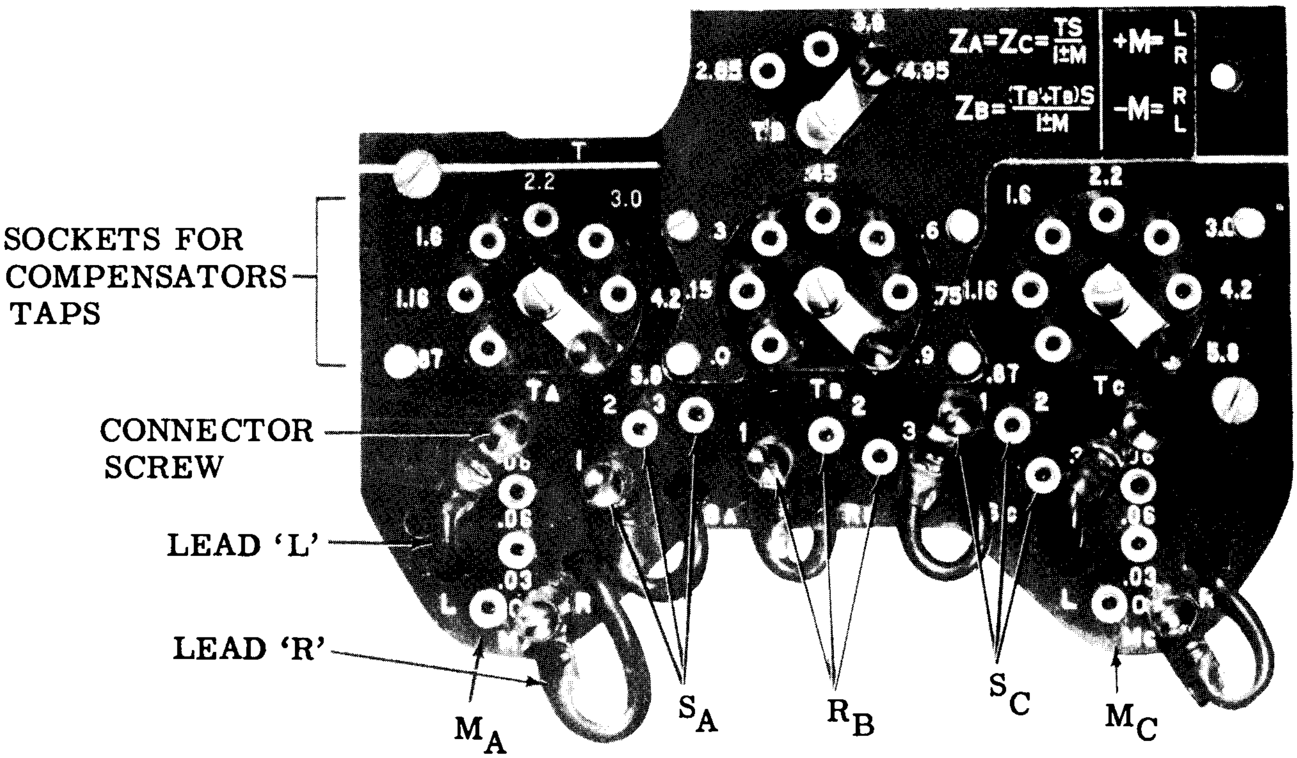
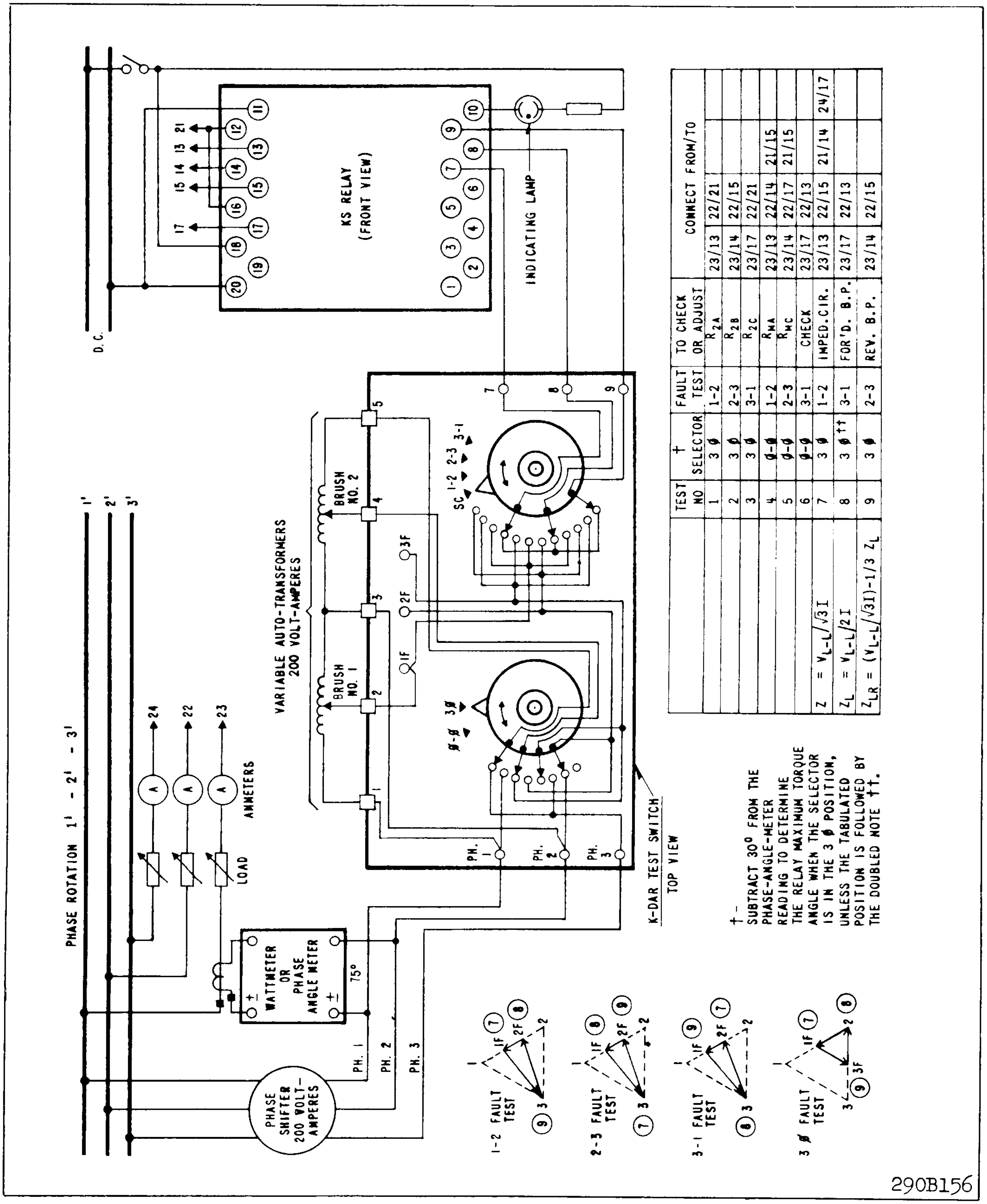


Fig. 6. Tap Plate.



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		
7	3 ø	1-2	IMPED.CIR.	23/13	22/15	21/14	24/17
8	3 ø††	3-1	FOR'D. B.P.	23/17	22/13		
9	3 ø	2-3	REV. B.P.	23/14	22/15		

$Z = V_{L-L}/\sqrt{3}I$

$Z_L = V_{L-L}/2I$

$Z_{LR} = (V_{L-L}/\sqrt{3}I) - 1/3\ Z_L$

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

Fig. 7. Test Connections for Type KS Relays.

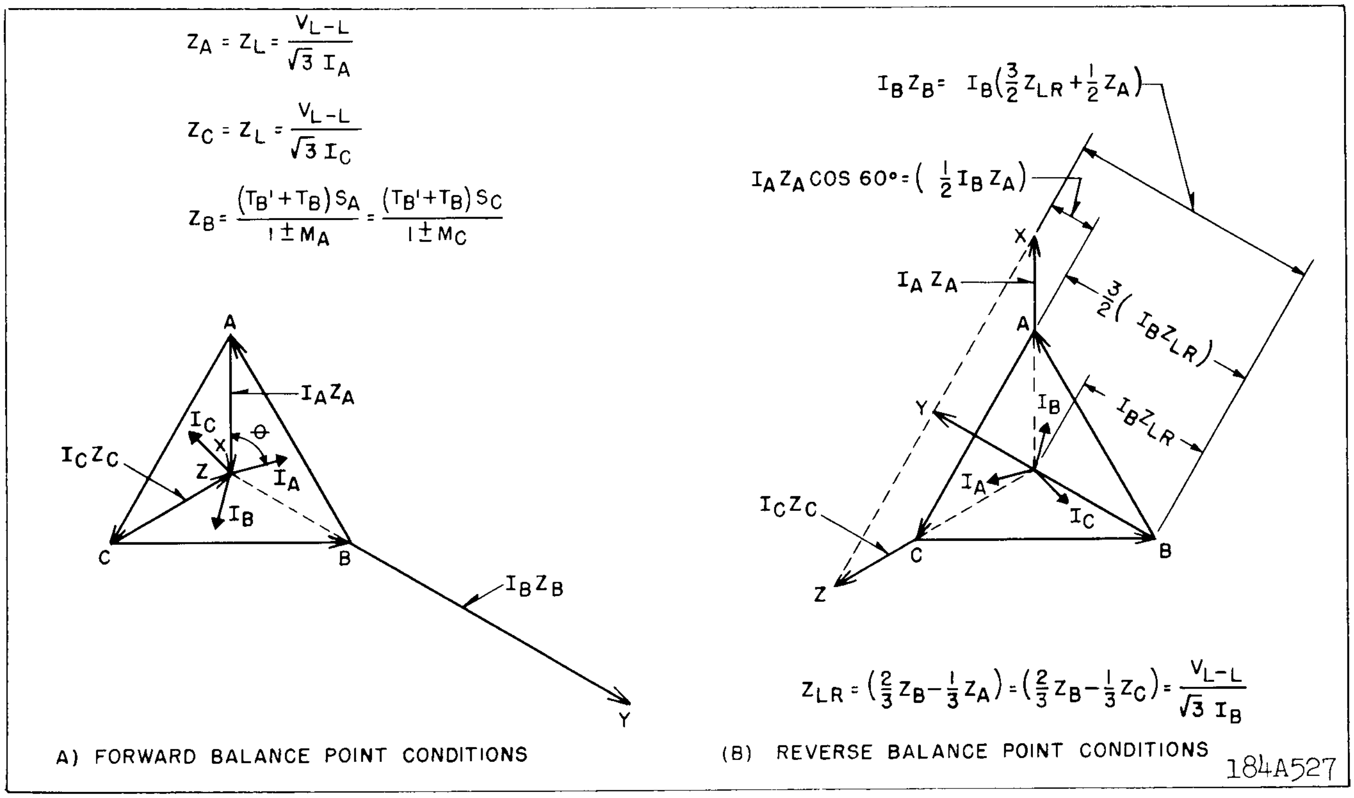


Fig. 8. Vector Diagrams of the Forward and Reverse Balance Point Conditions for Type KS Relay.

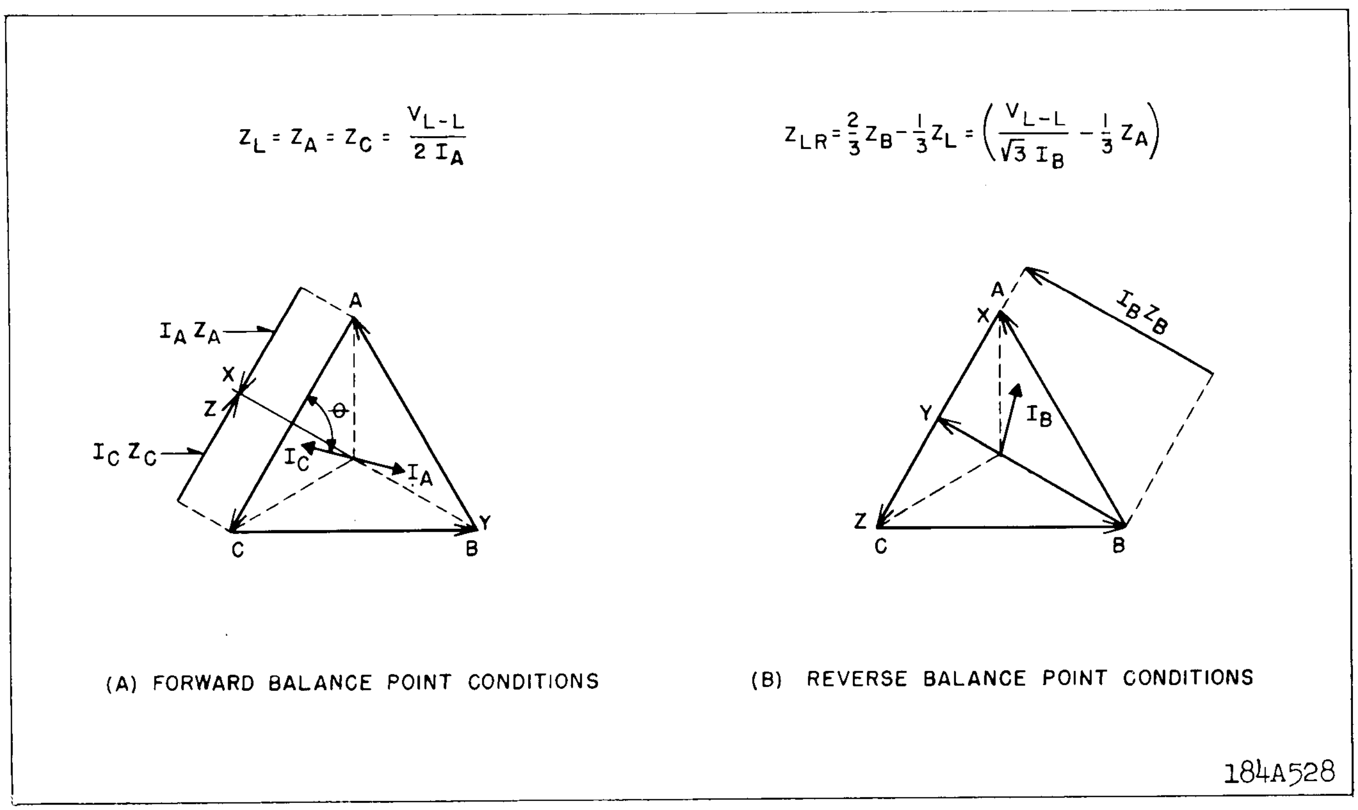


Fig. 9. Vector Diagrams of the Artificial Forward and Reverse Balance Point Conditions when testing with Single Phase Current for Type KS Relay.

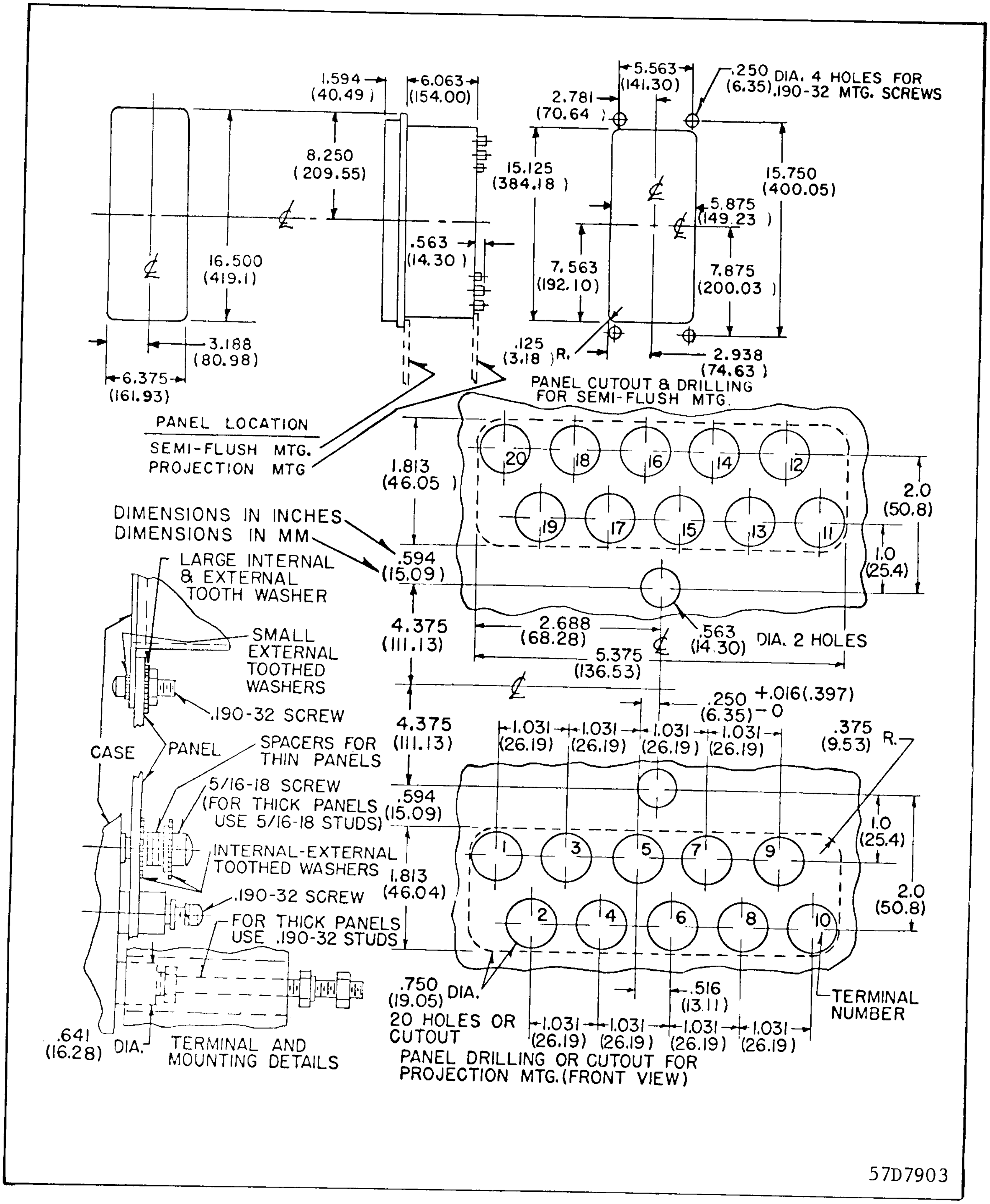


Fig. 10. ***Outline-Drilling Plan for the Type KS Relay in the FT32 Case.***

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