Instruction Leaflet
41-498B

Type KD-3
Distance Relay

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★ Denotes Changed Since Previous Issue

CAUTION

Before putting protective relays into service make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The KD-3 relay (Figure 1) is a single phase impedance type relay connected to receive phase-to-neutral voltage and phase current and may be applied as a supplement to conventional two-zone or three-zone distance relaying. It has provisions for a completely offset circle characteristic with both the long reach and the short reach adjustable.

In KD relay applications where a normal second zone or third zone setting of the three-phase unit might cause tripping because of possible load conditions, the conventional relay settings must be shortened to exclude load. The KD-3 displaced circle characteristic may be added to the KD relay three-phase unit shortened circle characteristic to provide the desired total reach at the line angle without danger of tripping on load. The KD phase-to-phase unit does not respond to balanced three phase conditions and therefore can be set for any distance without fear of tripping on load or swing conditions.

The KD-3 relay is available with either a 1 ampere or a 0.2/2.0 ampere indicating contactor switch rating. The 1 ampere rating is recommended for all directional comparison applications and for most distance relaying applications. The 0.2/2.0 ampere rating is recommended for distance relaying where a lockout relay is energized or where a high impedance auxiliary tripping relay is utilized.

CONSTRUCTION

The type KD-3 relay consists of two single air gap transformers (compensators), two tapped auto-transformers, a cylinder type operating unit, an adjustable reactor and an ICS indicating contactor switch.

Compensator

Compensators, which are designated as T_A 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 (Figure 3). T_A is the "long reach" compensator, T_B is the "short reach" compensator and tap markings for the respective units are as follows:

T_A = 1.3, 1.74, 2.4, 3.3, 4.5, 6.3, and 8.7.

T_B = .87, 1.16, 1.6, 2.2, 3.0, 4.2, and 5.8.

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° 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 per cent in steps of 3 per cent.

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 settings 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 $\pm$ 1.5 per cent from 1.13 ohms to 30 ohms, for a long reach setting, and from 0.75 ohms to 20 ohms, for a short reach setting, by combining the compensator taps T_A

and T_C with the auto-transformer taps S_A and M_A, and S_C and M_C.

Tripping Unit

The device which acts to initiate tripping is a four-pole cylinder unit which is connected so that one pole-pair voltage leads the other by 90° and operates as a two-phase induction motor. Contact-closing torque is produced by the unit when the voltage applied to its terminals has a negative-phase sequence. Closing torque for the relay forces the moving contact to the left hand side as viewed from the front of the relay. Contact-opening torque is produced when positive-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 spring and snap ring. This is an adjustable core which has a .025 inch flat on one side and is held in its adjusted position by the clamping action of two compressed springs. The bearing can be replaced, if necessary without having to remove the magnetic core from the frame.

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

The moving element assembly consists of a spiral spring, contact carrying member, and an aluminum cylinder assembled to a molded hub which holds the shaft. The hub to which the moving contact arm is clamped has a wedge-and-cam construction, to provide low-bounce contact action. A casual inspection of the assembly might lead one to think that the contact arm bracket does not clamp on the hub as tightly as it should. However, this adjustment is accurately made at the factory and is locked in place with a lock nut and should not be changed.

Optimum contact action is obtained when a force of 4 to 10 grams pressure applied to the face of the moving contact will make the arm slip one-fourth of its total free travel. Free travel is the angle through which the hub will slip from the condition of reset to the point where the clamp projection begins to ride up on the wedge. The free travel can vary between 15° to 20°.

The shaft has removable top and bottom jewel bearing. 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 an air gap formed by the electromagnet and the magnetic core.

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. This stationary contact has .002 to .006 inch follow which is set at the factory by means of the adjusting screw. After the adjustment is made the screw is sealed in position with a material which flows around the threads and then solidifies. 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 contacts close, the electrical connection is made through the stationary contact housing clamp, to the moving contact, through the spiral spring and out to the spring adjuster clamp.

Indicating Contactor Switch Unit (ICS)

The indicating contactor switch is a small d-c operated clapper type device. A magnetic armature, to which the leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from outside of the case by a push rod located at the bottom of the cover.

The front spring, in addition to holding the target, provides restraint for the armature and thus controls the pickup value of the switch.

OPERATION

Type KD-3 relays have two major components, the compensators and the tripping unit. In the internal schematic of Fig. 4 compensators designated T_A and T_C are shown connected so as to modify the voltage applied to the long-reach coils (Z_{LR}) and the short-reach coils (Z_{SR}) respectively.

Operation of the KD-3 relay can be explained by referring to Fig. 5. In this figure the addition of voltage vectors, at various fault locations, results in a set of vectors indicating predominantly positive sequence voltages for restraining the tripping unit or indicating predominantely negative sequence voltages for closing the tripping unit.

In Fig. 5 the short reach setting (Z_C) is about one third of the long reach setting (Z_A) and is in the same direction. This produces the solid line offset circle characteristic which excludes the origin when plotted on an R-X diagram. Note that if Z_C had been set with reverse polarity, by reversing the external current connections, the broken line circle characteristic which includes the origin would have resulted. Terms and symbols used in the diagrams are defined as follows:

- V_{SM} = Output voltage from the autotransformers which receive phase to neutral voltage.
- Z_A = Mutual impedance setting of the long reach compensator.
- Z_C = Mutual impedance setting of the short reach compensator.
- I = Phase Current.
- XY = Z(LR) tripping unit coil voltage.
- ZY = Z(SR) tripping unit coil voltage.
- X-Y-Z = Positive Sequence (restraining) phase rotation.
- X-Z-Y = Negative Sequence (closing) phase rotation.

Consider a fault at location "A" which is beyond the long reach setting. For the sake of simplicity, assume both the line angle and the relay maximum torque angle to be 90°. Compensator Z_A modifies voltage V_{SM} by adding the mutual impedance drop IZ_A which leaves voltage XY across the Z(LR) coils. Compensator Z_C modifies its voltage V_{SM} by adding IZ_C to produce Z'Y. This voltage is then advanced 90°, by the phase shifting action of capacitor C_{CS}, to provide voltage ZY across the Z(SR) coils. The resulting diagram has an X-Y-Z (positive sequence) phase rotation which restrains the unit for this fault beyond the protected zone.

Using the same method of analysis for a fault at location "B", the long reach setting Z_A, it is shown that X, Y, and Z lie in a straight line indicating equal positive and negative sequence voltages which provides a balance point. Within the protected zone, for a fault at location "C", the XY voltage is reversed by compensator action and negative sequence voltage X-Z-Y produces closing torque in the tripping unit. At location "D", the short reach setting, another balance point is encountered as positive sequence and negative sequence voltages become equal again with X, Y, and Z in line.

A fault at location "E" which is between the relay and the protected zone causes both XY and ZY to be reversed. This provides a restraining X-Y-Z phase rotation. A fault at location "F", behind the relay, causes a current reversal in both compensators and a modifying voltage is produced which increases the restraining voltage V_{SM} to a large value with X-Y-Z phase rotation.

The combination of series resistor R_A and parallel capacitor C_{AP} shown in Figure 4 controls transients in the $Z_{(LR)}$ circuit and also provides a small amount of phase shift. In the $Z_{(SR)}$ circuit, capacitor C_{CS} provides memory action to improve the operating characteristics for faults near the relay location. C_{CS} also provides the major phase shifting effect which makes the voltage across $Z_{(SR)}$ lead the voltage across $Z_{(LR)}$ by 90° when only voltage is applied to the relay. The most efficient phase relation between pole pairs for the cylinder type tripping unit is 90° which can be accurately set using the variable X adjustment. Reactor X is a small adjustable unit which is used to compensate for variations in other components.

CHARACTERISTICS

The KD-3 relay is designed to respond primarily to three phase faults. Since it receives phase-to-neutral voltage and phase current, it responds accurately to any three phase condition and to phase-to-ground faults on one particular phase. It has a limited response to phase-to-phase and double-phase-to-ground faults.

Distance Characteristic

A characteristic circle is established by setting two points on the circle, diametrically opposite one another, by means of the Long Reach and the Short Reach compensators. As shown in Figure 6, the Short Reach setting, Z_{SR}, may be positive or negative with respect to Z_{LR}, or it may be zero depending upon the current circuit connections to the Short Reach compensator T_C. The external schematic Figure 7 shows positive polarity current connections to both T_A and T_C.

Solid line characteristics of Figure 6 are typical for a positive Z_{SR}. Memory action in the tripping unit circuitry provides the light-line dynamic characteristic when normal voltage exists at the relay terminals prior to the fault. The heavy-line static characteristic dominates for load and swing conditions or if there is zero voltage at the relay prior to the fault.

The broken-line characteristic passing through the origin is obtained by by-passing the current terminals of the T_C compensator to make Z_{SR} equal to zero. The dashed-line characteristic which includes the origin is obtained by making reverse polarity connections to current terminals of the T_C compensator.

The relay is inherently directional when Z_{SR} is either zero or is of positive polarity. If T_C has a negative polarity connection to the current terminals, Z_{SR} is reversed with respect to Z_{LR} and the circle characteristic then includes the origin and loses its sense of direction.

Sensitivity

..re 8 is an impedance curve which demonstrates the relay sensitivity to faults at the balance point for various values of voltage at the relay terminals.

Zero voltage sensitivity for characteristics which include the origin is graphically illustrated in Figure 9.

General Characteristic

Impedance settings in ohms reach can be made for any value from 1.13 ohms to 30 ohms for Z_{IR} and from .75 ohms to 20 ohms for Z_{SR} in steps of 3 per cent. The maximum torque angle, which is set for 75 degrees at the factory, may be set for any value from 60 degrees to 80 degrees. A change in maximum torque angle will produce a slight change in reach for any given setting of the relay. Referring to Figure 2 note that the compensator secondary voltage output V, is largest when V leads the primary current, I, by 90°. This 90° relationship is approached, if the compensator loading resistor (R_{2A} 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, V, is phase-shifted to change the compensator maximum torque angle. As a result of this phase shift the magnitude of V is reduced, as shown in Figure 2.

Tap markings in Figure 3 are based upon a 75° compensator angle setting. If the resistors R_{2A} 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						
1.3	1.74	2.4	3.3	4.5	6.3	8.7

T_C						
.87	1.16	1.6	2.2	3.0	4.2	5.8

S_C & S_C		
1	2	3

± Values between taps

M_A & M_C		
.03	.06	.06

TIME CURVES AND BURDEN DATA

Operating Time

The speed of operation for the KD-3 relay is shown by the time curves in Figure 10. The curves indicate the time in milliseconds required for the relay to close its contacts for tripping after the inception of a fault at any point on a line within the relay setting.

Current Circuit Rating in Amperes

Tap Setting	Continuous S=1	Continuous S 2	Continuous S=3	1 Second
5.8	5.0	8.5	8.5	240
4.2	6.0	10.	10.	240
3.0	8.0	10.	10.	240
2.2	10.	10.	10.	240
1.6	10.	10.	10.	240
1.16	10.	10.	10.	240
0.87	10.	10.	10.	240

Burden

The burden which the relay imposes upon potential and current transformers is shown by Figure 11.

Trip Circuit Constants

1 ampere rating:	0.1 ohms d.c. resistance
0.2/2.0 ampere rating:	0.2 tap -- 6.5 ohms
	2 tap -- 0.15 ohms

SETTING CALCULATIONS

Relay reach is set on the tap plate shown in Fig. 3. The tap markings are:

T_A						
1.3	1.74	2.4	3.3	4.5	6.3	8.7

T_C						
.87	1.16	1.6	2.2	3.0	4.2	5.8

S_A and S_C		
1	2	3

M_A and M_C		
.03	.06	.06

(Values between taps)

Maximum torque angle is set for 75° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angles of 65° or higher. For line angles below 65°, set for a 60° maximum torque angle, by adjusting R_{2A} and R_{2C}.

The general formula for setting the ohms reach of the relay is:

$$Z_\theta = Z \frac{(\text{Sin } \theta)}{(\text{Sin } 75°)} = Z_{pri} \frac{R_C}{R_V}$$

The terms used in this formula are defined as follows:

Z_θ = the desired ohmic reach of the relay and relates equally to Long Reach ($Z_{\theta LR}$) and Short Reach ($Z_{\theta SR}$).

$Z = \frac{TS}{1 \pm M}$ = the tap plate setting.

T = compensator tap value.

S = Auto-transformer primary tap value.

θ = Maximum torque angle setting of the relay.

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

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).

Z_{pri} - ohms per phase of the line section to be protected.

R_c = current transformer ratio.

R_V = potential transformer ratio.

The following procedure should be followed in order to obtain an optimum setting of the relay. Relate the general equation to Long Reach or Short Reach by sub letters "A" and "C" respectively.

* 1. Select the lowest tap S which gives a product of 10.3 S_A and 6.9 S_C greater than Z where $Z = Z_\theta \frac{(\sin 75°)}{(\sin \theta)}$

2. Select a value for T that is nearest the value $\frac{Z}{S}$.

3. Determine the value of M that will most nearly make $M = \frac{TS}{Z} - 1$. 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 reach, $Z_{\theta LR}$ of the relay is 10.8 ohms at 60 degrees. Then $Z_{LR} = 10.8 \times 1.11 = 12$ ohms.

1. The lowest tap S for 10.3 S_A greater than 12 is S = 2. Set S_A in tap 2.
2. T_A nearest to $\frac{12}{2} = 6.0$ is 6.3 ohms. Set T_A in tap 6.3
3. $M = \left(\frac{12.6}{12} - 1\right) = (1.05-1) = 0.05$ (Use M = .06)
   Set M_A for + .06
4. Then $Z_{LR} = \frac{6.3 \times 2}{1 + .06} = 11.9$
5. $Z_{\theta LR} = Z_{LR} \frac{(\sin \theta)}{(\sin 75°)} = 1.07$ relay ohms at a maximum torque angle setting of 60 degrees. This is 99% of the desired value.
6. Set R_{2A} for a 60° maximum torque angle.
7. Use the same six steps described above to calculate settings for T_C, S_C, and M_C when $Z_{\theta SR}$ is any value other than zero. If $Z_{\theta SR}$ is to be zero, set S_C on 1, M_C for 0.0, and by-pass the current terminals of T_C.

SETTING THE RELAY

The KD-3 relay requires settings for each of the two compensators (T_A and T_C), each of the two auto-transformer primaries (S_A and S_C), and for the two auto-transformer secondaries (M_A and M_C). All of these settings are made with taps on the tap plate which is located above the operating unit. Figure 3 shows the tap plate.

Compensator (T_A 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 3).

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 negative (-) if the R lead is higher.

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

Tabulated Settings

$Z75°$	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

Line Angle Adjustment

Maximum torque angle is set for 75° (current lagging voltage) in the factory. This adjustment need not be disturbed for line angles of

65° or higher. For line angles below 65°, set for a 60° maximum torque angle by adjusting the compensator loading resistors R_{2A} and R_{2C}. Refer to repair calibration when a change in maximum torque angle is desired.

Indicating Contactor Switch (ICS)

No setting is required for relays with a 1.0 ampere unit. For relays with a 0.2/2.0 ampere unit, connect the lead located in front of the tap block to the desired setting by means of the connecting screw. When the relay energizes a 125- or 250-volt d-c type WL relay switch, or equivalent, use the 0.2 ampere tap; for 48-volt d-c applications set the unit in a tap 2 and use a Type WL relay with a S#304C209G01 coil, or equivalent.

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.

ACCEPTANCE TESTS

KD-3 relays have a very small number of moving parts and mechanical devices which might become inoperative. Acceptance tests in general consists 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.

Distance Unit

Check the electrical response of the relay by using the test connections for Test No. 6 shown in Figure 12. Set T_A for 8.7, T_C for 3.0, S_A and S_C for 1, and M_A and M_C for + 0.15 (L in top position and R in bottom position).

A. Adjust the voltage V_1 to 30 volts.

B. The current required to make the contacts close for the long-reach balance point should be between 3.89 and 4.05 amperes at the maximum-torque angle of 75° current lag.

C. The current required to make the contacts reset at the short-reach balance point should be between 11.1 and 11.6 amperes at 75° current lag.

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

Indicating Contactor Switch (ICS)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be less than 1.0 ampere nor greater than 1.2 amperes for the 1 ampere ICS. The current should not be greater than the particular ICS tap setting being used for the 0.2-2.0 ampere ICS. The operation indicator target should drop freely.

The contact gap should be approximately 0.047" for the 0.2/2.0 ampere unit and 0.070" for the 1.0 ampere unit between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

ROUTINE MAINTENANCE

The 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.

CAUTION: Before making "hi-pot" tests, jumper the contacts together to avoid destroying arc-suppressor capacitors.

When performing routine maintenance, the distance unit and the ICS can be checked by using the same procedure as outlined in Acceptance Tests. The balance point impedance measured by the relay is

$$Z_R = \frac{V_{L-N}}{I_L}$$

where V_{L-N} is the phase-to-neutral voltage applied to the relay terminals and I_L is the phase current.

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 12. 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 per cent of the warm relay.

Distance Unit Calibration

With the stationary contact open so that the moving contact cannot touch, 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 upper pin bearing should be screwed down until there is approximately .025 inch (one complete turn of the screw) between it and the top of the shaft bearing. The upper pin bearing should then be securely locked in position with the lock nut. The lower bearing position is fixed and cannot be adjusted.

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

T_A set on 8.7 and T_C set on 5.8

S_A and S_C set on 1.

"R" for M_A and M_C set on 0.0

"L" for M_A and M_C hangs free.

Resistors R2A and R2C open circuited by adjustable bands not making contact.

A. Compensator Angle Adjustment:

1. Long Reach Compensator T_A.

   a. Connect the relay as per Figure 12. Test No. 1.

   b. Adjust voltage V_1 to 90 volts, set the phase shifter so that current lags voltage by 90°, and increase the current to the value which produces a null (within three volts) reading on null detector N_A (requires about 10 amperes).
   Note the Exact Value of Current.

   c. Change voltage V_1 to 87 volts, swing phase shifter to 75° current lagging, and adjust R_{2A} to reach a null on N_A when the current is at the null value of 1.b. noted above.

2. Short Reach Compensator T_C

   a. With the relay connected as per Figure 12, test No. 2, adjust V_1 to 60 volts, set phase shifter for current lagging voltage by 90°, increase the current to the value which produces a null (within 3 volts) reading on null detector N_C (requires about 10 amperes). Note the Exact Value of Current.

b. Change V_1 to 58 volts, swing the phase shifter to 75° current lagging, and adjust R_{2C} to read a null on N_C when the current is at the null value of 2.a. noted above.

B. Auto-transformer Check:

Auto-transformers may be checked for turns ratio and polarity by using the No. 3 test connections of Figure 12, and the procedure outlined below.

1. Set S_A and S_C on tap number 3. Apply 90 volts between terminals 8 and 9. Measure the voltage from terminal 9 to tap No. 1 of S_A and S_C. It should be 1/3 the applied voltage = 30 volts. From terminal 9 to tap No. 2 of S_A and S_C the voltage should be 2/3 the applied value = 60 volts.

2. Set S_A and S_C on tap number 1 and apply 100 volts between terminals 8 and 9. Measure the voltage drop from terminal 9 to each of the M_A and M_C 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.

Transformers which have an output different from nominal by more than 1.0 volt probably have been damaged and should be replaced.

C. Tripping Unit Core Adjustment: The adjustable core is set at the factory to bias the contacts open on current-only. This adjustment can be checked or made according to the following procedure.

Use test connections of Test No. 4 and set "L" for M_A and M_C in the top position (.03 + .06 + .06 = .15 between L and R). Supply 5 amperes to the relay and set the adjustable core so that the contacts just open. Increase the current in steps of about 10 amperes up to 65 amperes. It may be necessary to readjust the core in order to make sure that the contacts never close on current only.

The reactor X adjustment should be checked after any change in the core adjustment.

D. Reactor X Adjustment: The reactor adjustment is provided to permit setting the impedance angle of its own circuit to a proper relation with the impedance angle of the $Z_{(LR)}$ circuit. Use connections of Test No. 5 to check or make the reactor adjustments.

1. Set the voltage, V_1, for 50 volts and the current, A, for 7.5 amperes. Adjust the Reactor X for a maximum torque angle of 75° ± 2°. Rotate the phase shifter to find the two angles, θ_1 and θ_2, at which the contacts just close. The maximum torque angle is:

$$\left(\frac{\theta_1+\theta_2}{2} \right) \text{degrees}$$

This angle should be between 73° and 77° for a nominal 75° adjustment.

A smaller angle may be obtained by drawing the reactor core out. The angle may be increased by screwing the core in.

2. Check to see if the Tripping Unit Core Adjustment is changed as a result of a change in the X adjustment.

E. Contact Adjustment:

With the moving-contact arm against the right-hand backstop, screw the stationary contact in until it just touches the moving contact. Then back the stationary contact out two-thirds (2/3) of one turn to give 0.020-inch gap between contacts.

F. Spring Restraint and Impedance Curve:

1. Connect for Test No. 6 of Figure 12. Set T_A = 8.7 and T_C = 3.0; S_A and S_C = 1; "R" for M_A and M_C set 0.0; "L" for M_A and M_C should be in the top positions.

Set V_1 = 5.0 volts

A = 0.88 amp. lagging voltage by 75°.

Then adjust the restraint spring so that the contacts just close. This should provide the restraint torque necessary to reset the contacts when the relay is deenergized.

2. Increase the voltage to 30 volts and check that current for the two balance point settings fall within the limits stated below:

Settings	Volts	Amperes (θ = 75°) ≁	
		I_{min}	I_{max}
Z_{IR} = 7.56	30	3.89	4.05
Z_{SR} = 2.64	30	11.1	11.06

/ To determine the limits of current when θ is not equal to 75° multiply the nominal values tabulated above by the ratio

$$\frac{\sin 75°}{\sin \theta}$$

Indicating Contactor Switch (ICS)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should be not less than 1.0 ampere nor greater than 1.2 amperes for the 1 ampere ICS. The current should not be greater than the particular ICS tap setting being used for the 0.2-2. ampere ICS. The operation indicator target should drop freely.

The contact gap should be approximately 0.047" for the 0.2/2.0 ampere unit and 0.070" for the 1 ampere unit, between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to the customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

NOMENCLATURE FOR RELAY TYPE KD-3

ITEM	DESCRIPTION
Z_{LR}	Two Element-Coils in Long Reach Circuit; Total d.c. resistance = 127 ohms.
Z_{SR}	Two Element-Coils in Short Reach Circuit; Total d.c. resistance = 219 ohms.
R_A	2 Inch Resistor 355 Ohms Fixed.
R_{2A} & R_{2C}	2 Inch Resistor 600 Ohms Adjustable.
C_{AP}	4 MFD Capacitor Parallel Connected.
C_{CS}	1.8 MFD Capacitor Series Connected.
X	Variable Reactor.
T_A	Compensator (Primary Taps -1.3; 1.74; 2.4; 3.3; 4.5; 6.3; 8.7).
T_C	Compensator (Primary Taps - .87; 1.16; 1.6; 2.2; 3.0; 4.2; 5.8).
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).

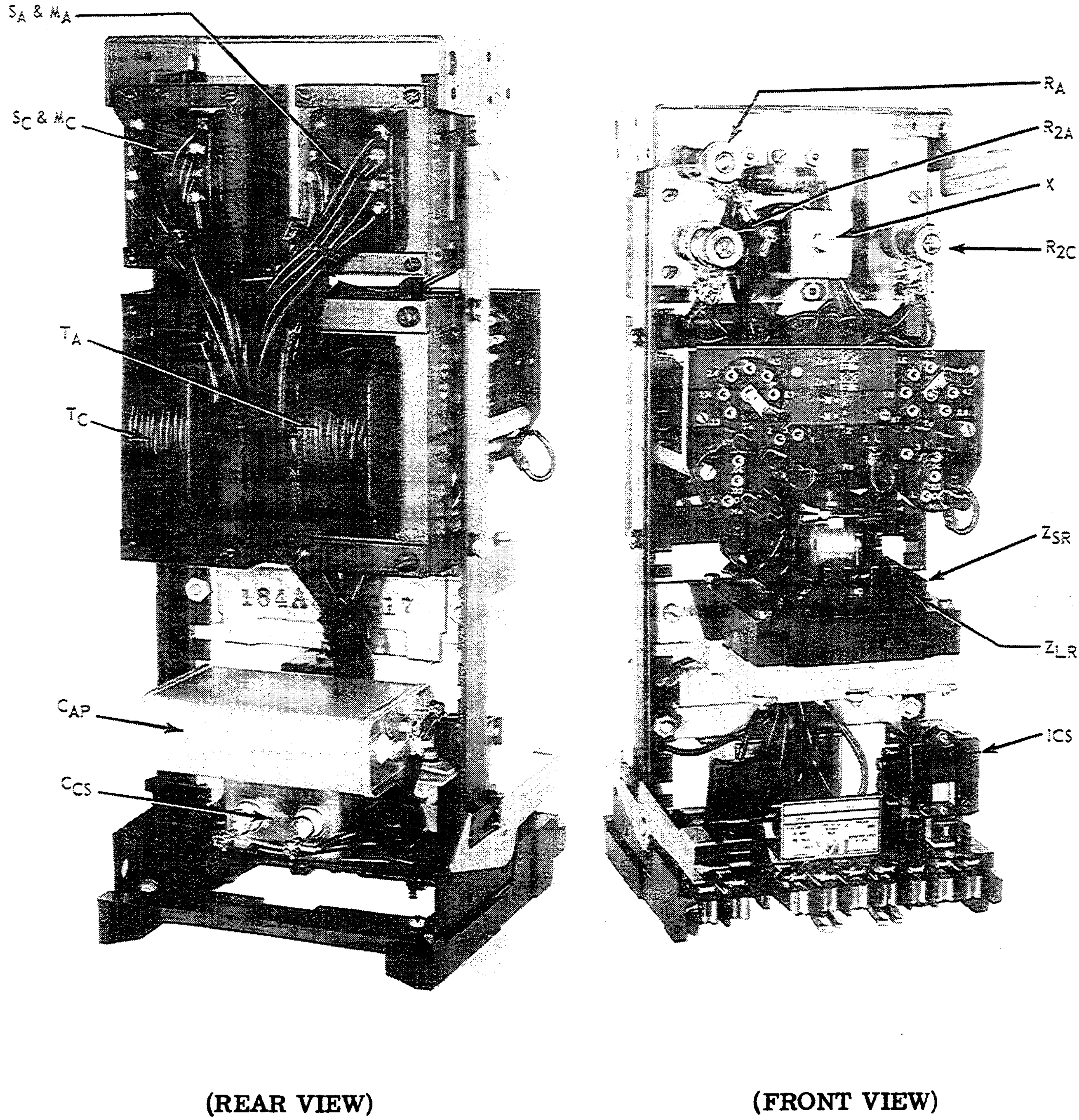


Fig. 1 Type KD-3 Relay Without Case

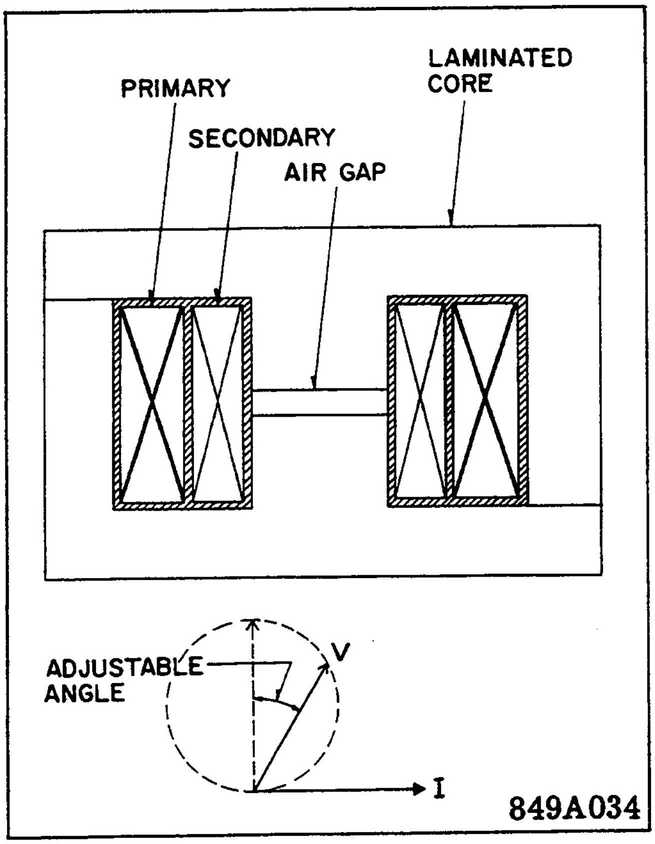


Fig. 2 Compensator Construction

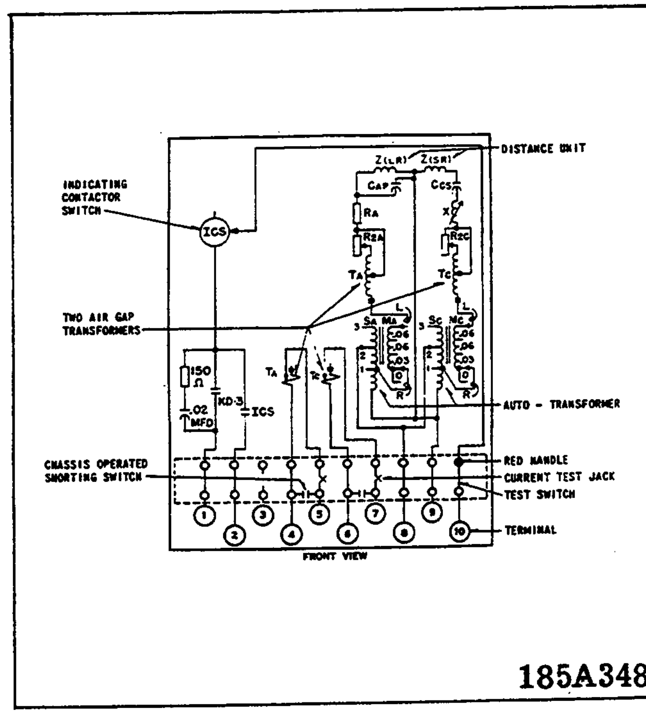


Fig. 4 Internal Schematic of Type FT31 case. (ICS Coil Not Tapped for Relays with 1 Amp I. C. S.)

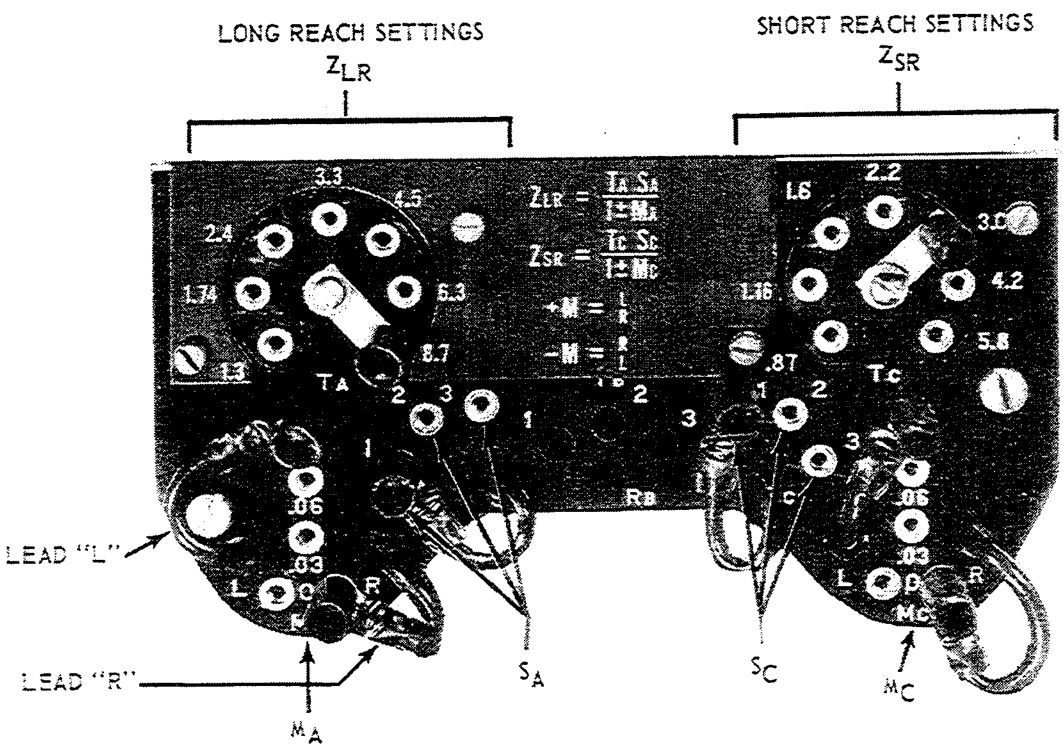


Fig. 3 Tap Plate

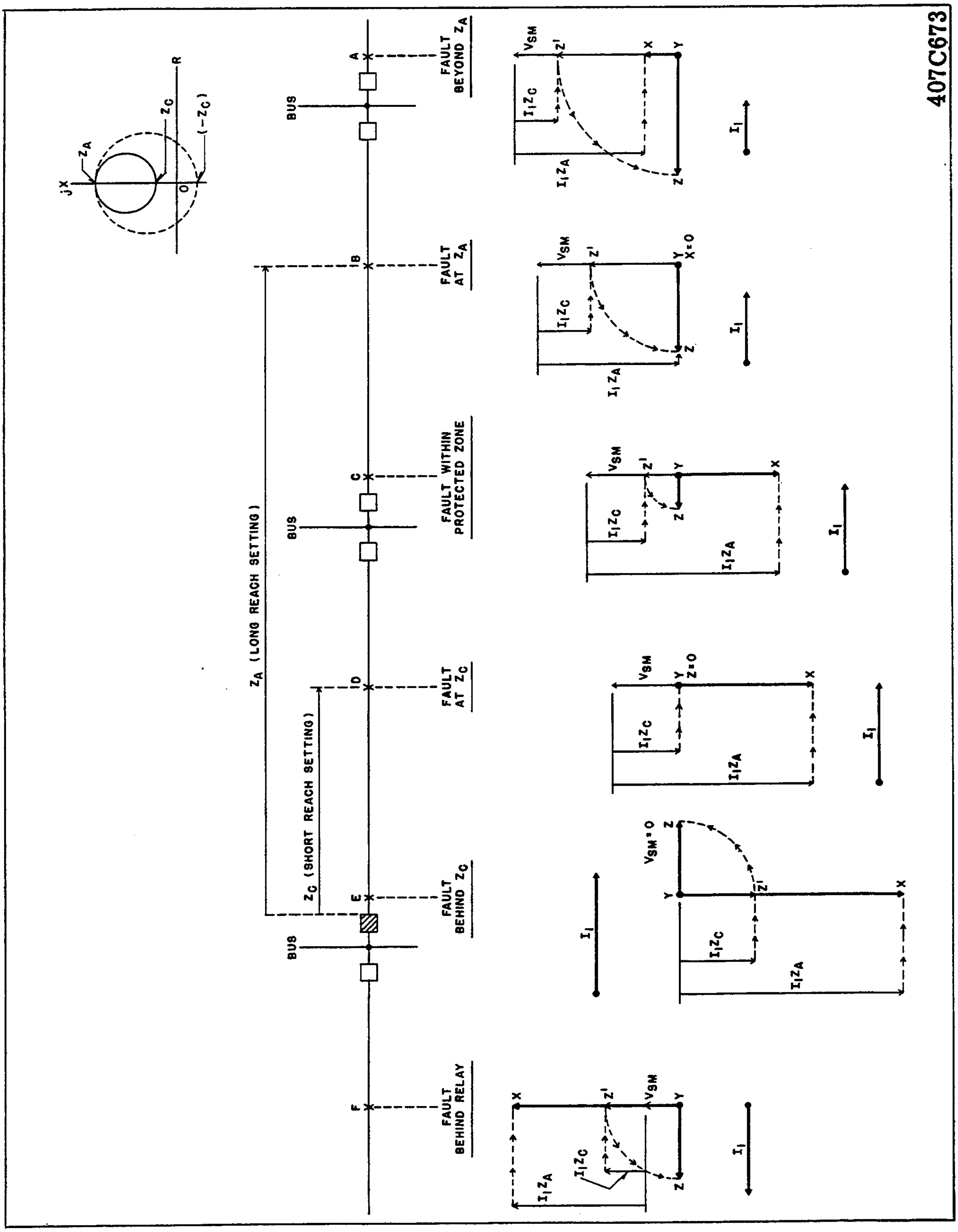


Fig. 5 Voltage and Current Conditions for the Type KD-3 Relay for Faults at Various Locations.

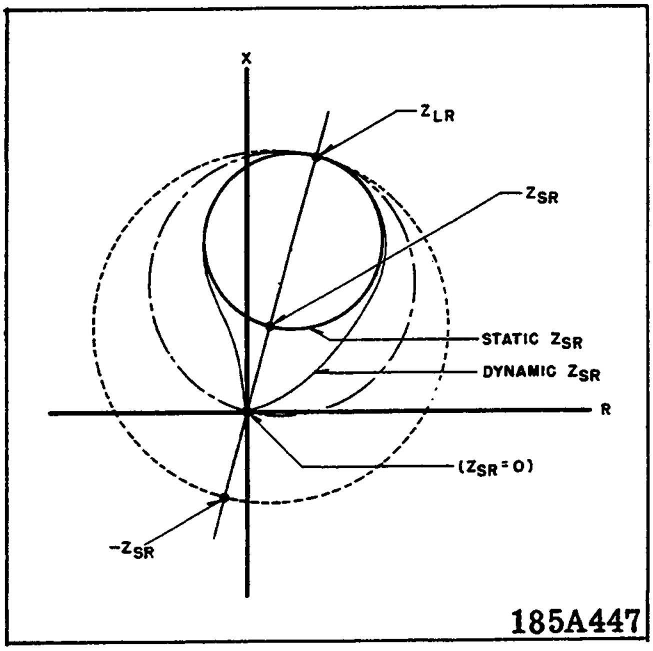


Fig. 6 Impedance Circle for the Type KD-3 Relay

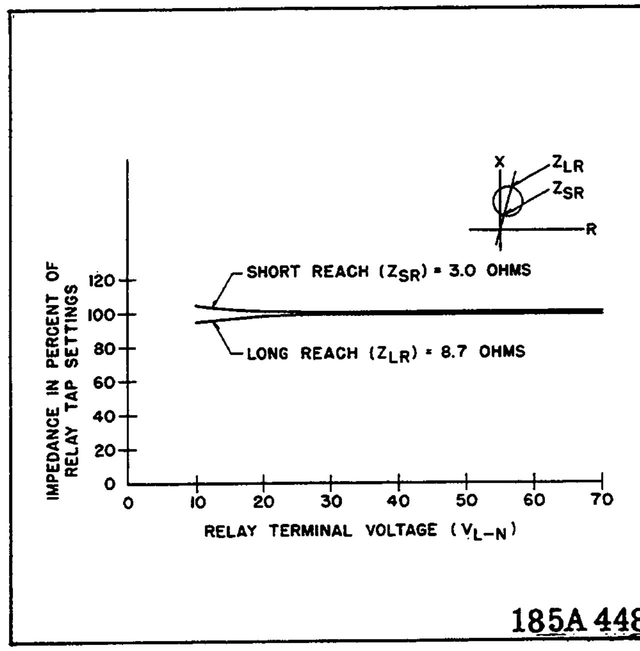
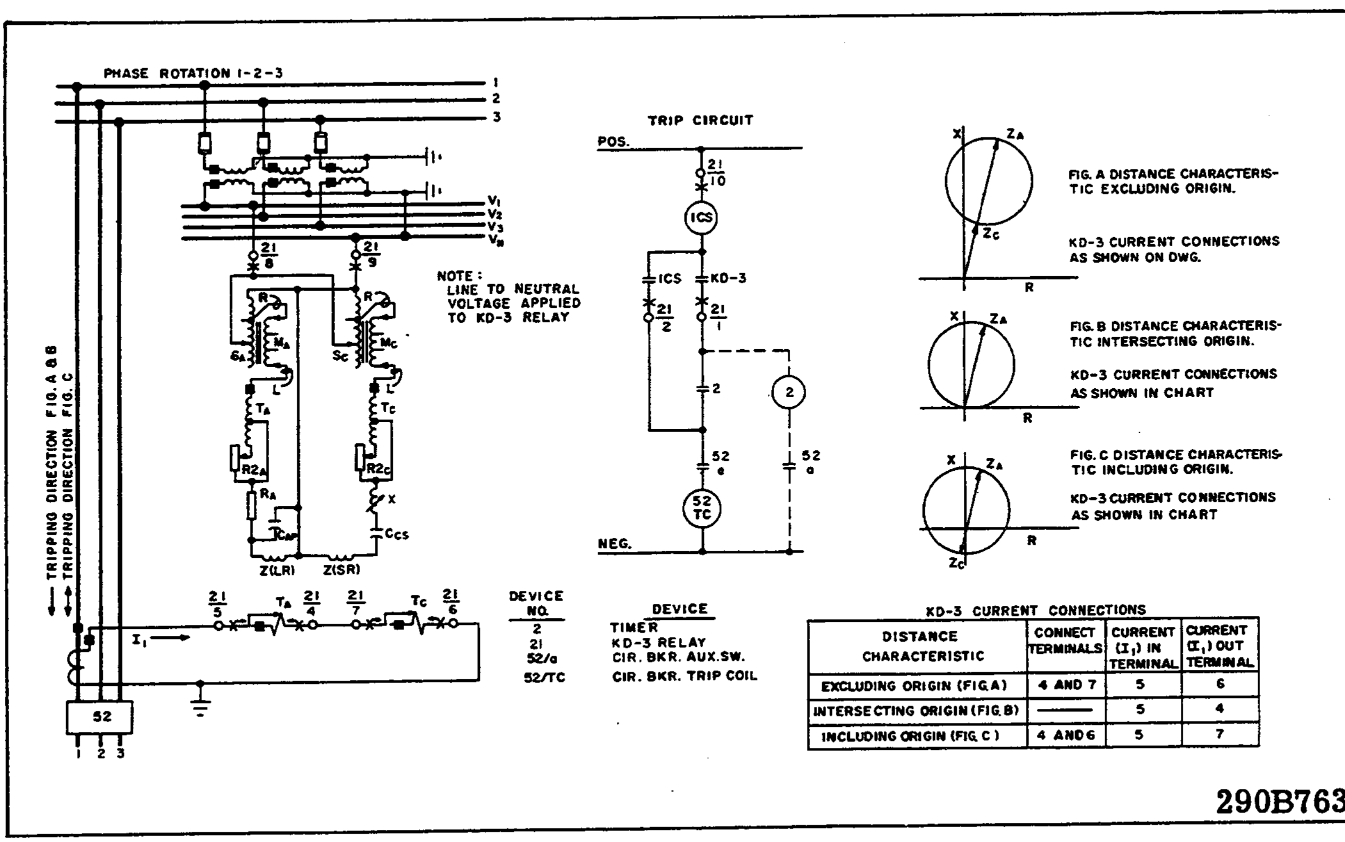


Fig. 8 Impedance Curves for the Type KD-3 Relay



KD-3 CURRENT CONNECTIONS

DISTANCE CHARACTERISTIC	CONNECT TERMINALS	CURRENT (I_1) IN TERMINAL	CURRENT (I_1) OUT TERMINAL
EXCLUDING ORIGIN (FIG. A)	4 AND 7	5	6
INTERSECTING ORIGIN (FIG. B)	———	5	4
INCLUDING ORIGIN (FIG. C)	4 AND 6	5	7

Fig. 7 External Schematic for the Type KD-3 Relay

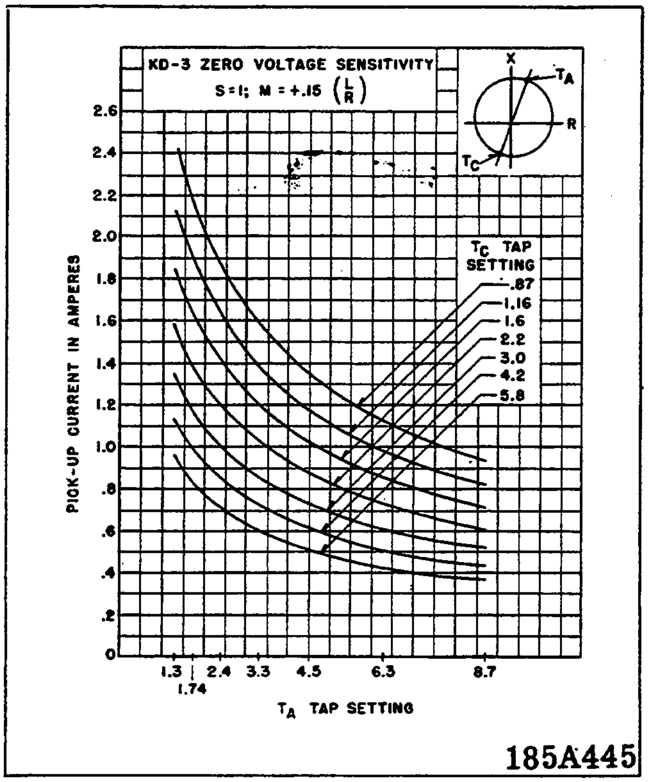


Fig. 9 Zero Voltage Sensitivity Curves for Type KD-3 Relay

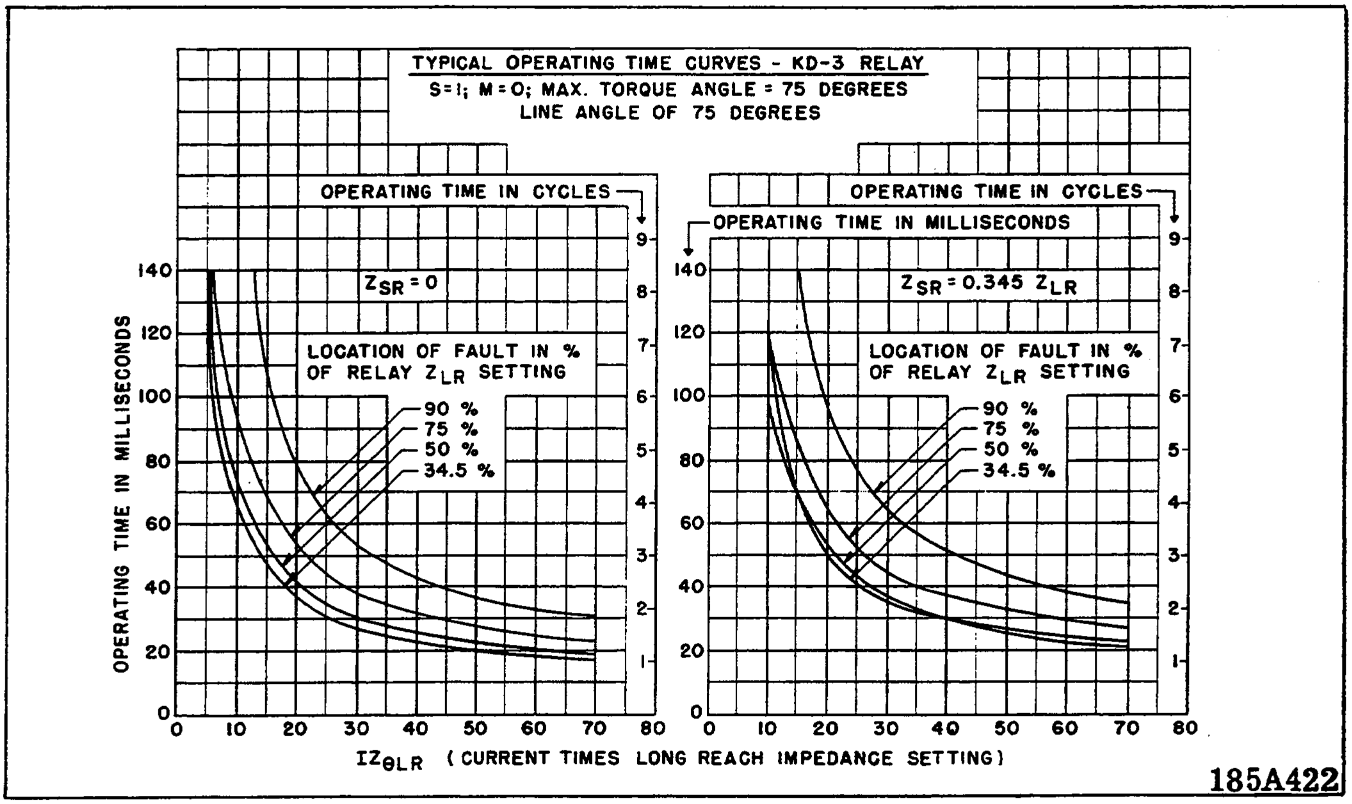


Fig. 10 Typical Operating Time Curves of the Type KD-3 Relay. Normal Voltage before Fault is 70 volts.

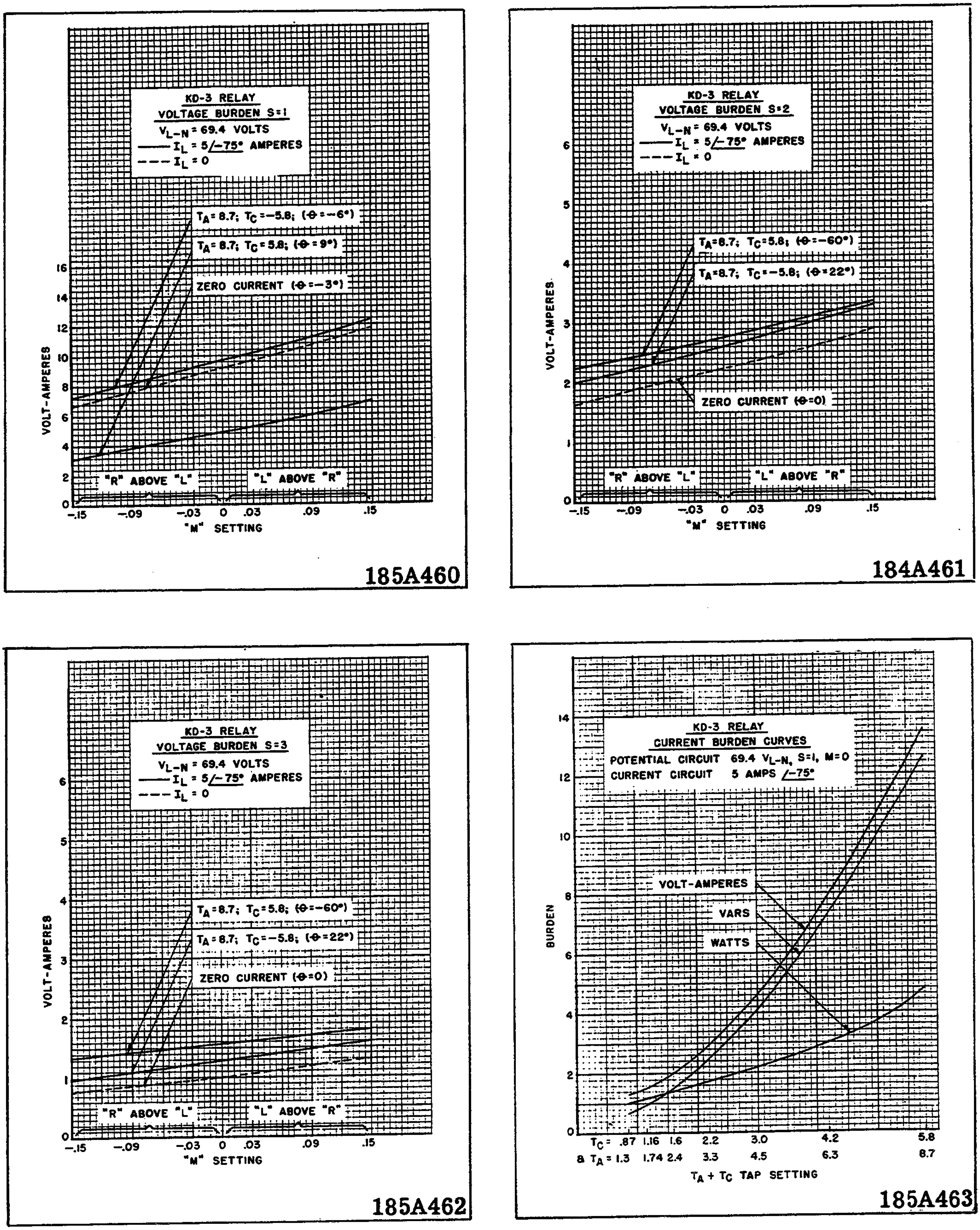
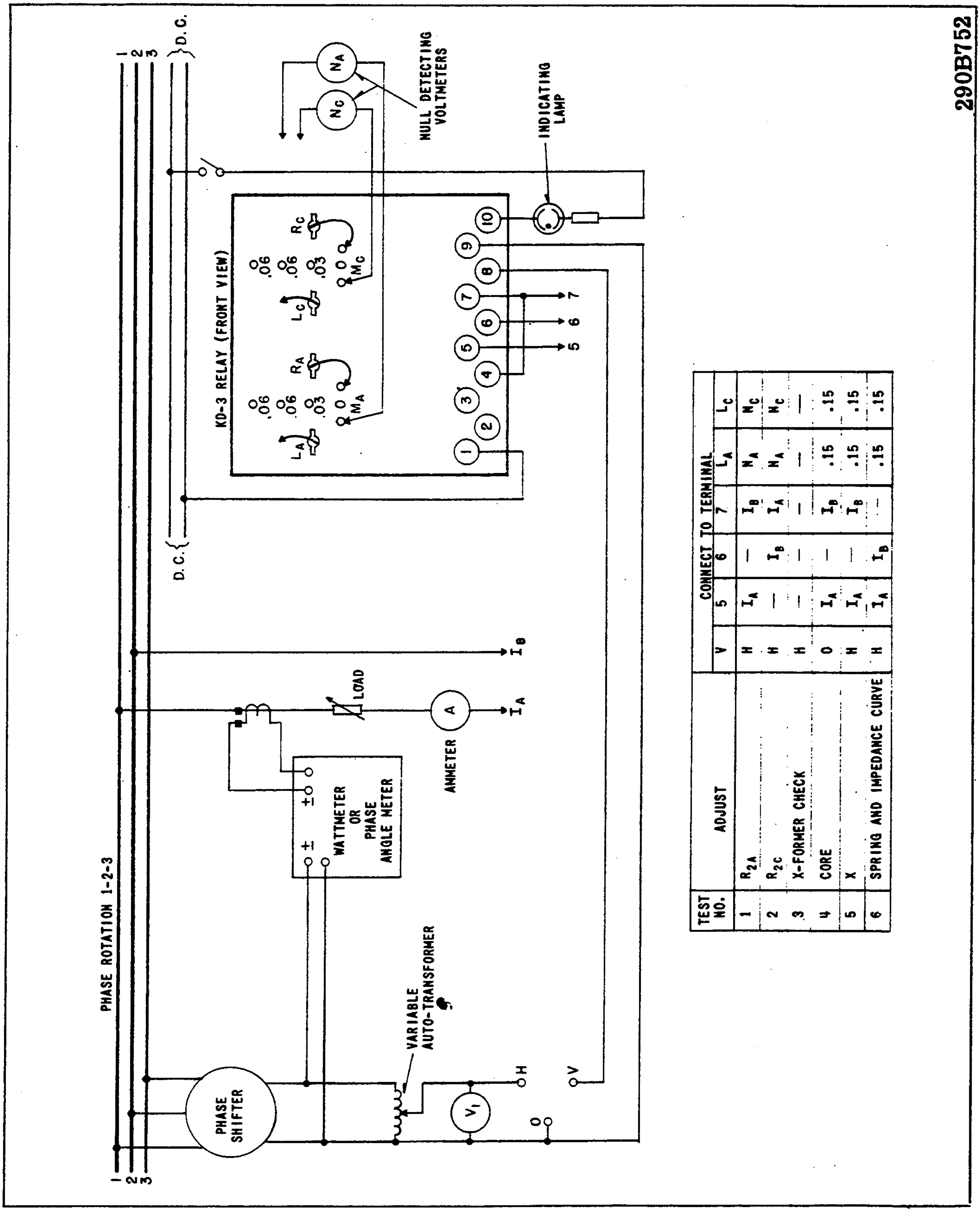


Fig. 11 Type KD-3 Relay Burden Data



TEST NO.	ADJUST	V	CONNECT TO TERMINAL 5	6	7	L_A	L_C
1	R_{2A}	H	I_A	—	I_B	N_A	N_C
2	R_{2C}	H	—	I_B	I_A	N_A	N_C
3	X-FORMER CHECK	H	—	—	—	—	—
4	CORE	O	I_A	—	I_B	.15	.15
5	X	H	I_A	—	I_B	.15	.15
6	SPRING AND IMPEDANCE CURVE	H	I_A	I_B	—	.15	.15

Fig. 12 Test Connections For Type KD-3 Relay

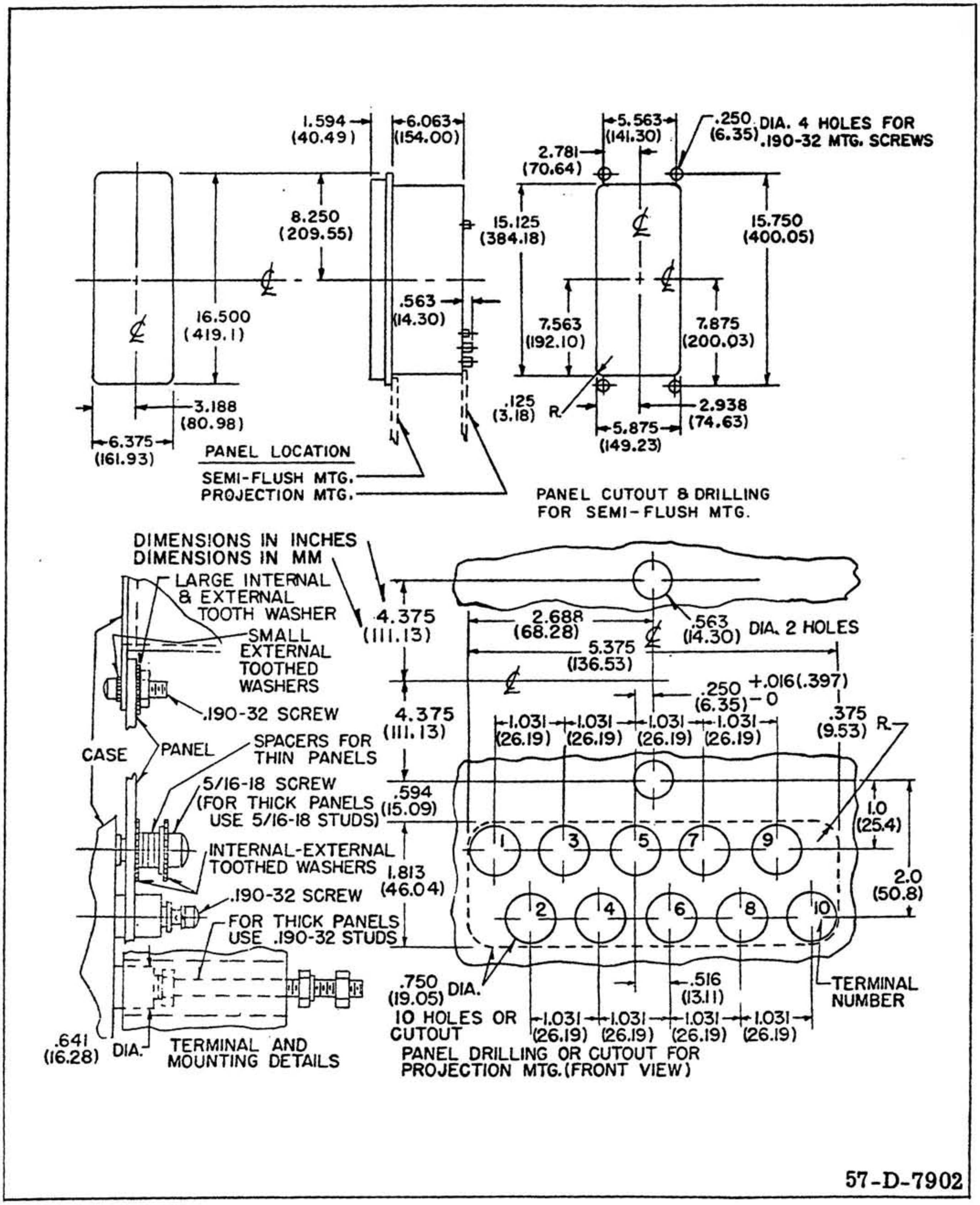


Fig. 13 Outline-Drilling Plan for Type KD-3 Relay in FT 31 Case.

THIS PAGE RESERVED FOR NOTES

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ABB Inc.

4300 Coral Ridge Drive
Coral Springs, Florida 33065

Telephone: +1 954-752-6700
Fax: +1 954-345-5329

www.abb.com/substation automation