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

Instruction Leaflet
I.L. 41-498.12B

Effective: March 1989
Supersedes I.L. 41-498.12A, Dated March 1972

✪ Denotes Change From Superseded Issue

# Type KD-5 Directional Comparison Blocking Systems

## 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 operate the relay to check the settings and electrical connections.

## 1. APPLICATION

The type KD-5 relay (Figure 1), is a polyphase compensator type relay which provides a single zone of phase protection for all three phases. It provides instantaneous tripping for all combinations of phase-to-phase, two phase-to-ground faults, and three-phase faults.

The type KD-5 relay is available with indicating contactor switches with either a 1 ampere or a 0.2/2.0 ampere 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.

Refer to I.L. 41-911 for a description of how KD-5 relays are used in directional comparison blocking systems.

For time-distance applications the KD-5 relay is used with either the TD-2 ac current operated timer, or with the TD-4 or TD-5 dc transistorized timer. See Figs. 12 and 13 for the external schematics for 3 zone protection, using the TD-2 and TD-4 relays, respectively. For further discussion see "External Connections."

* Fault detectors are used to supervise the trip circuit for those applications where the line side potentials are used or loss-of-potential supervision is desired. Otherwise, undesired tripping may occur on line oscillations or loss-of-potential. The cylinder type KC-2 or KC-4 relay (2-8 amperes) is recommended. The plunger or other magnetic attraction type relay (e.g. a three unit SC relay or a three unit ITH relay) may be used if the fault detector contacts carry trip coil current rather than auxiliary relay (e.g. auxiliary trip unit, timer, etc.) current.

The SC or ITH relay may also be used if a slow dropout contact (e.g. TX contact of TD-5 timer relay) is available to be connected around the fault detector contacts.

## 2. CONSTRUCTION

The type KD-5 relay consists of three single air gap transformers (compensators), three tapped auto-transformers, two cylinder type operating units, and an ICS indicating contactor switch.

### 2.1 Compensator

The compensators which are designated $T_{AB}$ and $T_{BC}$ are three-winding air-gap transformers (Fig. 2). There are two primary current windings each current winding has seven taps which terminate at the tap block. (Fig. 3). They are marked 0.23, 0.307, 0.383, 0.537, 0.690, 0.920 and 1.23. Current flowing through the primary coil provides an MMFwhich produces magnetic lines of flux in the core. Compensator designated T, has only one primary winding.

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

*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 this particular installation, operation or maintenance of this equipment, the local ABB Power T&D Company Inc. representative should be contacted.*

Printed in U.S.A.

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 phase 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 factory setting is for a maximum torque angle of 45° current lagging voltage for phase-to-phase unit and 35° for three phase unit.

## 2.2 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 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 (T = .23 to 1.23 ohms) by a multiplier of $\frac{S}{1 \quad M}$. Therefore, any relay ohm setting can be made within ±1.5 per cent from 0.2 ohms to 4.35 ohms by combining the compensator taps T, $T_{AB}$, and $T_{BC}$ with the auto-transformer taps S and M, $S_A$ and $M_A$, and $S_C$ and $M_C$.

## 2.3 Tripping 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 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 three basic components: a die-cast aluminum frame and 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 .020 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. Locating pins on the electromagnet 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 permanently secured to the frame and cannot be separated from the frame.

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.

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 the frame by two mounting screws. In addition to holding the upper pin bearing, the bridge is used for mounted 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.

### 2.4 Indicating contactor Switch Unit (ICS)

The indicating contactor switch is a small d-c operated clapper type device. A magnetic armature to which 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.

## 3. OPERATION

The KD-5 relay has two major components-compensators and tripping units. In the internal schematic of Fig. 4 the compensators are designated T, $T_{AB}$, and $T_{BC}$, the tripping units, Z ($3\phi$) & Z ($\phi\phi$). The phase to phase unit Z ($\phi\phi$) operates for all combinations of phase to phase faults (phase 1-2, 2-3, & 3-1). The 3-phase unit Z ($3\phi$) operates for 3-phase faults and for close-in-two phase-to-ground faults, although most two-phase-to-ground faults are cleared by operation of the phase-to-phase unit. Each of the tripping units and its associated compensator circuit are electrically separate, and will now be considered successively.

### 3.1 Three-Phase Unit

A single compensator T has its primary energized with ($I_1$ - $3I_0$) current Fig. 12. The current $I_1$ is the phase current; 3I0 is the residual current. There are three compensators shown-one for each of the three zones, one connection uses an auxiliary current transformer to insert the $3I_0$ component. The alternate connection supplies the compensator primaries with $-(I_2 + I_3)$. Since $I_1 + I_2 + I_3 = 3I_0$, $(I_1 - 3I_0 = (I_2 + I_3)$. Currents, $I_1$, $I_2$ and $I_3$ are phase currents. Accordingly, the alternate connection is equivalent to the first arrangement.

As shown on Fig. 4 the T-compensator secondary is connected to modify the phase 1-2 voltage. With a fault in the trip direction, the inducted voltage in the compensator bucks the phase 1-2 voltage. Vector diagrams on Fig. 5 illustrate the operation during the 3-phase fault at four locations. The system impedance is assumed to be at 60° and the compensator angle is assumed to be 90° for illustrative purposes only. Prefault voltages are depicted by the large triangle . The smaller dashed triangle in each case is the system voltages at the relay location during the fault. This triangle is modified by the compensator voltage, $1.73I1Z_C$, where $Z_C$ is the compensator mutual impedance.

The modified voltage triangle is designated by the X, Y, Z lettering. The $V_X$, $V_Y$, $V_Z$ voltages are applied to the tripping unit closes or strains depending on the phase sequence of these voltages.

The $V_X$, $V_Y$ and $V_Z$ voltages are derived as follows:

$V_X = V1 - 1.73I_1Z_C$ and

$V_Y = V_2$

$V_Z = V_3$

For a fault at A, beyond the relay operating zone the compensator voltage $- 1.73I_1Z_C$ modifies the phase 1 voltage forming a triangle of X,Y, Z rotation. Voltages of this phase rotation when applied to the tripping unit produce restraining torque.

For a fault at B, the current is larger than for a fault at A, so that $- 1.73I_1Z_C$ is larger. The point X is in line with points Y and Z. No torque is produced since the X, Y, Z triangle has a zero area.

For a fault in the operating zone, such as at C, point X is below the YZ-line. Now the rotation is X-Z-Y, which produces operating torque.

For a fault behind the relay at D, the fault is behind the relay, the current is of reversed polarity and compensator voltage, $-1.73I_1Z_C$ increases the area of the bus voltage triangle, 1-2-3. Modified voltage triangle has an X,Y,Z rotation which produces restraining torque.

A solid 3-phase fault at relay location tends to completely collapse the 1-2-3 voltage triangle. The area of the X,Y,Z triangle also tends to be zero under these conditions. A memory circuit in the KD-5 relay circuitry that consists of inductance $X_L$ and capacitor $C_{3C}$ provides momentary operating torque under these conditions for an internal fault.

The $R_{3A}$ and $C_{3A}$ parallel resistor-capacitor combination in the compensated phase corrects for a shift in the phase angle relation between the voltage across the left hand coils of Z(3$\phi$) and the voltage across the right hand coils of Z (3$\phi$) in internal schematic Dwg. 188A421. This phase shift is produced by capacitor $C_{3C}$. The $R_{3A}$-$C_{3A}$ combination also provides control of transients in the inductive coils of the cylinder unit.

### 3.2 Phase-to-Phase Unit

Compensator primaries of $T_{AB}$ and $T_{BC}$ are energized by $I_1$, $I_2$, and $I_3$ as shown in Fig. 11. Compensator secondaries are connected to modify their respective phase voltages (e.g., $T_{AB}$ modifies V12). With a fault in the trip direction, the induced voltages in the compensator secondaries buck the phase-phase voltages.

Vector diagrams in Fig. 6 illustrates the operation during phase 2-3 faults at four location. The system impedances and the compensator angle are assumed to be at 90° for illustrative purposes. Prefault voltages are depicted by the large triangles. The smaller light triangle in each case is the system voltages at the relay location during the fault. This triangle is modified by the compensator voltages $(I_1 - I_2)\,Z_C$ and $(I_2 - I_3)\,Z_C$ where $Z_C$ is the compensator mutual impedance. In this case $I_1 = 0$. The terminals of the tripping unit are designated: X, Y an Z. Tripping Unit voltages are for phase 2-3 fault:

$$V_{XY} = V_{12} - (I_1 - I_2)\,Z_C$$

Phase 2-3 tripping unit voltage is:

$$V_{YZ} = V_{23} - (I_2 - I_3)\,Z_C$$

For a fault at A, in Fig. 6, beyond the relay operating zone, the compensator voltages change the 1-2-3 voltage sequence to the identical X-Y-Z sequence. Voltages of this sequence applied to operating unit produce restraining torque.

For a fault at B, the currents are larger than for a fault at A, so that the compensator voltages are larger. Points Y & Z coincide now and the area of the X-Y-Z triangle is zero. No torque is produced.

For a fault in the operating zone, such as at C, the compensator voltages reverse the rotation of tripping unit voltages to X-Y-Z sequence. Voltages of this sequence applied to operating unit produce operating torque.

For a fault behind the relay at D, restraining torque is produced. Since the fault is behind the relay, the current is of reversed polarity and tripping unit voltage has an X-Y-Z rotation. This rotation produces restraining torque.

Note that this unit does not require memory action, since the sound-phase voltage reacts with the compensator voltages to produce a strong restraining or a strong operating torque, depending upon the fault location. This is true even for a complete collapse of the faulted phase-to-phase voltage.

Similar vector diagrams apply for a fault between phases 1 & 2 or between phases 3 & 1. Each of the three phase-to-phase fault combinations subjects the cylinder unit to a different but similar set of conditions.

## 4. CHARACTERISTICS

### 4.1 Distance Characteristic - Phase-to-Phase Unit

This unit responds to all phase-to-phase faults and most two phase-to-ground faults. It does not respond to load current, synchronizing surges, or out-of-step conditions. While a characteristic circle can be plotted for this unit on the R-X diagram as shown in Fig. 7, such a characteristics circle has no significance except in the first quadrant where resistance and reactance values are positive. A small portion of the fourth quadrant, involving positive resistance values and negative reactance values, could have some significance in the event that the transmission line includes a series capacitor. The portion of the circle in the first quadrant is of interest because it describes what the relay will do when arc resistance is involved in the fault. The phase-to-phase unit operating on an actual transmission system is inherently directional and no separate directional unit is required.

An inspection of Fig. 7 indicates that the circle of the phase-to-phase unit is dependent on source impedance $Z_S$. However, the circle always goes through the line balance point impedance. The reach at the compensator (and line) angle is constant, regardless of the system source impedance. The broadening of the characteristics circle with a relatively high source impedance gives the phase-to-phase unit the advantageous characteristics that for short lines, it makes a greater allowance for resistance in the fault. Stated another way, the characteristics approach that of a reactance relay more and more closely as the line being protected becomes shorter and shorter with respect to the source impedance back of the relaying location.

### 4.2 Sensitivity: Phase-to-Phase Unit

A plot of relay reach, in per cent of tap block setting, versus relay terminal voltage is shown in Fig. 8. The unit will operate with the correct directional sense for zero voltage phase-to-phase faults. For this condition the fault current must not be less than 0.030 relay amperes with an ohm setting of 1.23 with rated voltage on the unfaulted phase. Pick up current is proportionally higher in S = 2 and S = 3 taps.

The KD-5 relay may be set without regard to possible overreach due to d-c transients. Compensators basically are insensitive to d-c transients which attend faults on high-angle systems. The long time-constant of a high-angle system provides a minimum rate of change in flux-producing transient current with respect to time, and therefore induces a minimum of uni-directional voltage in the secondary. Asymmetrical currents resulting from faults on low-angle systems having a short time constant can induce considerable voltage in the secondary, but for the first half cycle, the transient derived voltage subtracts from the steady-state value. This transient decays so rapidly that it is insignificant during the second half cycle when it adds to the steady-state value.

### 4.3 Distance Characteristics - 3 Phase Unit

The three phase unit has a characteristics circle which passes through the origin as shown in Figure 9. This circle is independent of source impedance. The three-phase unit is also inherently directional and does not require a separate directional unit.

If a solid three-phase fault occurs right at the relay location, the entire voltage triangle collapses to zero to give a balance point condition, as shown by the relay characteristic in Figure 9 which passes through the origin. However, since all three voltages drop to zero, the relay would be unable to determine whether an internal or external fault existed. To correct this condition, a "memory" circuit is added. The "memory" circuit in the 3 phase unit is energized with voltage equal to $V_{pol.} = V_{30} - 1/2\ (V_{10} + V_{20})$. This voltage is chosen for 3-$\phi$ unit polarization so that it provides a natural 60° maximum torque angle characteristics, with the additional phase shift down to 35° maximum torque angle provided by the compensator phase shift winding. The resonant circuit is energized by this voltage which allows the polarity voltage to collapse gradually, thus giving a reference voltage to determine whether the fault is inside the protected line section or behind the relay. The maximum torque angle of this unit is set for less than the maximum torque angle of the phase-to-phase unit in order to accommodate more arc resistance. The factory setting is 35° (45° for phase-to-phase unit). The angle may be readjusted as needed up or down.

### 4.4 Sensitivity - KD-5, 3-Phase Unit

The impedance curve for the KD-5 three phase unit is shown in Figure 8.

The unit will operate with the correct directional sense for zero voltage three-phase faults when normal voltage exists at the relay terminals prior to the fault. This operation occurs due to memory action as described above. The unit will have zero torque or perhaps a slight opening torque if there is aero voltage at the relay prior to the fault or after the memory action has subsided. With an impedance setting of 1.23 ohms the three-phase unit will directionally operate for faults which produce .5 volts line to line and 2.7 ampere at the relay terminals.

Sensitivity with .75 volts line-to-line for any tap is defined by the following equation:

$$1 = \frac{3.4}{T} \text{ amperes}$$

where T = Compensator Tap Value

The KD-5 relay may be set without regard to possible overreach due to d-c transients.

### 4.5 General Characteristics

Impedance settings in ohms reach can be made for any value from .2 ohms to 4.35 ohms in steps of 3 per cent. The maximum torque angle which is set for 45 degrees at the factory for $\phi$-$\phi$ unit, and 35 degrees for 3$\phi$ may be set for any value from 35° to 60° for phase-to-phase unit and from 30° to 60° for 3-phase unit. 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 ($P_3$, $R_{2A}$ 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, IT, $IT_{AB}$ or $IT_{BC}$. Thus the net voltage, V, is phase-shifted to change the compensator maximum torque angle. As a result of this phase shift magnitude of V is reduced, as shown in Fig. 2. Tap markings in Fig. 3 are based on 45° for phase-to-phase unit and on a 35° compensator angle setting for three phase unit. If the resistors R3 and $R_{2C}$, A are adjusted for some other maximum torque angle the nominal reach is different than indicated by the taps. The reach, $Z\theta$ varies with the maximum torque angle $\theta$, as follows:

For $\phi$–$\phi$ unit $Z\theta = \dfrac{TS \sin\theta}{(1+M)\sin 45^\circ}$

For $3\phi$ unit $Z\theta = \dfrac{TS \sin(\theta + 30^\circ)}{(1+M)\sin 65^\circ}$

### 4.5.1 Tap Plate Markings

| (T, $T_A$, $T_B$, and $T_C$ |
|---|
| .23, .307, .383, .537, .690, .920, 1.23 |

| (S, $S_A$, $S_C$) |
|---|
| 1 2 3 |

| (M, $M_A$, $M_C$) |
|---|
| .03 .06 .06 |

### 4.5.2 Time Curves and Burden Data

Operating Time

The speed of operation for the KD-5 relay three-phase and phase-to-phase units is shown by the time curves in Figure 10. The curves indicates 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.

TABLE 1

Current Circuit Rating in Amperes

| TAP SETTING | CONTINUOUS S=1 | S=2 | S=3 | 1 SECOND |
|---|---|---|---|---|
| 1.23 | 10.0 | 10.0 | 10.0 | 240 |
| .920 | 10.0 | 15. | 15. | 240 |
| .690 | 10.0 | 15. | 15. | 240 |
| .537 | 15. | 15. | 15. | 240 |
| .383 | 15. | 15. | 15. | 240 |
| .307 | 15. | 15. | 15. | 240 |
| .230 | 15. | 15. | 15. | 240 |

Burden

The burden which the relays impose upon potential and current transformers in each phase is shown by Fig. 11 for the KD-5 relay. The potential and burden phase angle are based on 69 volts line-to-neutral applied to the relay terminals.

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 |

## 5. SETTING CALCULATIONS

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

| (T, $T_A$, $T_B$, and $T_C$ |
|---|
| .23, .307, .383, .537, .690, .920, 1.23 |

| (S, $S_A$, $S_C$) |
|---|
| 1 2 3 |

| (M, $M_A$, $M_C$) |
|---|
| .03 .06 .06 |

($\pm$ values between taps)

Maximum torque angle is set for 45° (current lagging voltage) for phase to phase unit and for 35° for three phase unit. For line angles below 45° set the phase-to-phase unit for the actual line angle by adjusting $R_{2A}$ and $R_{2C}$ without changing the 3-phase unit adjustment. Set zone 1 reach to be 90% of the line (85% for line angles of less than 30°).

Calculations for setting the KD-5 relays are straightforward and apply familiar principles. Assume a desired balance point which is 90% of the total length of line. The general formula for setting the ohms reach of the relays is:

For phase-to-phase unit

$$Z\theta = Z_{pri} \frac{0.9 R_C}{R_V}$$

For three phase unit

$$Z\theta = Z_{pri} \frac{0.9 R_C}{R_V}$$

The terms used in this formula are defined as follows:

$Z\theta$ = the desired ohmic reach of the relay in secondary ohms.

$Z = \dfrac{TS}{1 \quad M}$ = the tap plate setting

T = compensator tap value

S = auto-transformer primary tap value

$\theta$ = maximum torque angle setting of the relay

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 total line section

0.9 = the portion of the total line for which the relay is set.

$R_c$ = current transformer ratio

$R_v$ = potential transformer ratio

The following procedures should be followed in order to obtain an optimum tap plate setting of the relay, Z.

1a Establish $Z\theta$

1b Established Z - relay tap plate settings. If the desired maximum torque is different from the factory setting ($Z \neq Z\theta$) multiply $Z\theta$ -- value by factor $\frac{\sin 45^\circ}{\sin \theta}$ for phase to phase unit, and by

factor $\frac{\sin 65^\circ}{\sin (30 + \theta)}$ for three phase unit.

Now refer to the Table 6.

Table 6 lists optimum relay settings for relay range from .2 to 4.35 ohms.

a) Locate a table value for relay reach nearest to the desired value Z (it will always be within 1.5% or less off the desired value.)

b) Read off the table "S, T," and "M" settings. "M" column includes additional information for "L" and "R" leads setting for the specified "M" value.

c) Recheck the obtained S, T, M - settings by using equation.

$$Z = \frac{S\,T}{1 + M}$$

For example, assume the desired reach $Z\theta$, is 1.71 ohms at 40°. Making correction for maximum torque angle of the line (40°) that is different from factory setting of 45° the relay setting, Z should be Z = 1.71 x 1.11 = 1.89 ohms.

The phase-to-phase unit setting is found as follows:

a) The nearest reading is 1.90 ohms that is $\frac{1.90}{1.89} \times 100 = 100.5\%$ of the desired reach.

b) From the Table 6 read off S = 2
T = .920
M = .03

and "R" lead should be connected over "L" - lead with "L" connected to "0" tap and "R" - lead to ".03" tap.

c) Recheck settings

$$Z = \frac{S\,T}{1\ M} = \frac{2 \times .920}{1 - .03} = 1.897$$

$$\text{or } Z_\theta = Z_{40^\circ} = \frac{Z \sin 40^\circ}{\sin 45^\circ} = 1.897 \times .909 = 1.72 \text{ ohms}$$

Three phase unit setting is found as follows:

Since the line impedance angle is 40° the recommended maximum torque angle setting for three phase unit will be 35°, or the factory setting. Now $Z\theta$ = Z = 1.72

a) The nearest table value is 1.69

b) From the Table 6 read off

S = 2
T = .920
M = + .09

"L" lead should be over "R" with "L" lead, connected to lower .06 tap and "R" lead connected to "O" tap.

c) Recheck settings

$$Z = \frac{S\,T}{1 + M} = \frac{2 \times .920}{1 + .09} = 1.688$$

or 99% of desired setting.

SETTING THE RELAY

The KD-5 relay settings for each of the three compensators (T, $T_{AB}$, and $T_{BC}$), each of the auto-transformers, primaries (S, $S_A$, and $S_C$) an secondaries (M, $M_A$, and $M_C$). All of these settings are made with taps on the tap plate which is located between the operating units. Fig. 3 shows the tap plate.

### 5.1 Compensator (T, $T_{AB}$ and $T_{BC}$)

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 plate with two connector screws one in the common and one in the tap. There are two $T_B$ settings to be made since phase B current is passed through two compensators. 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.

### 5.2 Auto-Transformer Primary (S, $S_A$, 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 or above the taps and is held in place on the tap by connector screw. (Figure 3).

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

### 5.3 Auto-Transformer Secondary (M, $M_A$, 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 be 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.

See Table 6 for tabulated "M" settings.

### 5.4 Line Angle Adjustment

Maximum torque angle is set for phase-to-phase unit for 45° (current lagging voltage) and for 35° for three phase unit in factory. For line angles from 45° to 60° KD-5 relay maximum torque angel adjustment need not be disturbed. For line angles below 45°, set phase-to-phase unit for the required line angle, adjusting the compensator loading resistors $R_{2A}$ and $R_{2C}$, and leave the three phase unit undisturbed Refer to Repair Calibration parts 1 and 4, when a change in maximum torque angle is desired.

### 5.5 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- volts 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.

## 6. INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration and heat. Mount the relay vertically by means of the four mounting holes on the flange for 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.

### 6.1 External Connections

Fig. 12 shows the connections for 3 zone protection utilizing the TD-2 timer. Fig. 13 is similar to Fig. 12 except that the TD-4 timer is used instead of the TD-2. Fig 13 does not show the use of the 5/5 auxiliary current transformer so that the CT neutral may be formed elsewhere; however, this connection is equally applicable whether the TD-2 or TD-4 timer is employed .

A-C connections for additional applications are shown in Fig 14, 15 and 16. These connections apply when the transmission line is terminated in a power transformer, and when low side voltage and current are used to energize the relays. In calculating the reach settings, the bank impedance must be added to the line impedance.

For the case to a wye-delta bank (Fig. 15 and 16) the voltages and currents are phase-shifted by 30°; however, this fact should be ignored, as the KD relays are affected by this phase shift.

Fig. 14 through 16 show the TD-3 relays; however, the TD-4 is equally applicable. In the case of Figs. 15 and 16 the two S#234A240G07 auxiliary CT's are not required if the TD-4 is used.

### 6.2 Switchboard Testing with KD-5 Relay

Immediately prior to placing the relays in service, the external wiring can be checked my manipulating the current and voltage applied to the relay.

### 6.3 Receiving Acceptance

KD-5 relays have very a small number of moving parts and mechanical devices which might become inoperative. Acceptance tests in general consist of:

6.3.1 A visual inspection to make sure there are no loose connections, broken resistors, or broken resistor wires.

6.3.2 An electrical test to make certain that the relay measures the balance point impedance accurately.

### 6.4 Distance Units

Check the electrical response of the relay by using the test connections Figure 17. Set T, $T_A$, both $T_B$ & $T_C$ for 1.23; S, $S_A$, & $S_C$ for 1; M, $M_A$ & $M_C$ for 0.00.

6.4.1 Use connections for Test No. 1 and adjust the voltages $V_{1F2F}$ and $V_{2F3F}$ for 30 volts each.

6.4.2 The current required to make the contacts close for the three phase (bottom) unit should be between 13.8 and 14.4 amperes at the maximum torque angle 35° current lag. (Set phase shifter for 65° lag in Fig. 17).

6.4.3 Use connection for Test No. 4

6.4.4 Adjust the voltage between PH.1 and 1F and between PH.2 for 45 volts each so that the resultant voltage $V_{1F2F}$ equals 30 volts (120-45-45 = 30V).

6.4.5 The current required to make the contacts close for the phase-to-phase (top) unit should be between 11.9 and 12.5 amperes at an angle of 45° current lag.

6.4.6 Repeat E 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 3% of the smallest value.

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

### 6.5 Indicating Contact 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 not 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.

## 7. 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 periodically cleaned. A contact burnisher #182A386H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended because of the danger of embedding small particles in the face of the soft silver and thus impairing the contact.

### 7.1 Distance Units

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

Use the connections for tests 1, 4, 5 and 6 of Fig. 17 to check the reach of the relay, or use a K-DAR Test Unit for this purpose. When using test 1 of Fig. 17 the phase angle meter must be set of 30° more than the maximum torque angle. Note that the impedance measured by the 3-phase unit in test 1 is $Z_R = \frac{V_{L-L}}{3 I_L}$ where phase-to-phase voltage and $I_L$ is the phase current; similarly, in test 4, 5, and 6 of Fig. 17 the phase-to-phase unit measures $Z_R = \frac{V_{L-L}}{2I_L}$.

### 7.2 Indicating Contactor Switch (ICS)

Close the main relay contacts and pass sufficient d-c current through the circuit to close the contacts of the ICS. This value of current should be not less than 1.0 ampere not 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.

## 8. REPAIR CALIBRATION

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

Connect the relay for testing as shown in Figure 17. The four-pole-double-throw switch in the test circuit selects the type of voltage condition, for a phase-to-phase or a three-phase fault, that will be applied to the relay voltage terminals. The rotary switch switches the fault voltage to various terminals and thereby simulates any combination of phase-to-phase faults without the tester having to change connections or readjust the phase shifter and variable auto-transformer.

### 8.1 Tripping Units

With the stationary contacts 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.

### 8.2 Auto-Transformer Check

Auto-transformer may be checked for turns ratio and polarity by using the No. 1 test connection of Fig. 17 and the procedure outlined below.

Set S, $S_A$ and $S_C$ on tap number 3. Set the "R" leads of M, $M_A$ and $M_C$ all on 0.0 and disconnect all 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 and $S_A$. It should be 30 volts. From 8 to the #2 tap of S and $S_A$ 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, $S_A$, and $S_C$ on 1 and adjust $V_{1F2F}$ for 100 volts. Measure the voltage drop from terminal 8 to each of the M and 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 damaged and should be replaced.

Then apply 100 volts a-c to terminal 7 and 8 and measure voltage from terminal 8 to terminal 6, and from terminal 7 to terminal 6. Both voltages should measure 50 volts within 1 volt.

### 8.3 Distance Unit Calibration

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

T, $T_A$, $T_B$, and $T_C$ set on 1.23 (Tap $T_B$ is set twice).

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

"L" for M, $M_A$, and $M_C$ set on 0.0

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

1. Three Phase Unit (Lower Unit)

### 8.4 Core and $R_{3A}$ Resistor Adjustments

Set $R_3$ resistor for 145 ohms. Adjustable part of $R_{3A}$ should be connected for full resistance.

Preheat relay for at least one hour by energizing it with rated voltage, then proceed as follows:

8.4.1 Connect terminals 7-8 together, apply rated voltage between terminals 9 and 6 and adjust core by turning it slightly with a screwdriver until the contact arm restains very slightly.

8.4.2 Connect relay for Test #6. Set $V_{1F2F}$ = 2 volts. Set phase shifter so that voltage leads current by the angle (30° + $\theta$), where $\theta$° is the maximum torque angle of the 30 unit (35° for standard unit). Make sure that applied voltage is of correct phase sequence. Adjust resistor $R_{3A}$ so that 3$\phi$ unit trips at 2.25-2.35 ampere.

8.4.3 Connect relay for Test #5 except connect current leads 23 to 17 and 22 to 13. Otherwise similar voltage and phase condition, as above, check pickup. It should be between 1.2-1.6 amperes. If not, repeat parts 1 and 2 above.

8.4.4 Connect relay for Test 34. Otherwise same voltage and phase conditions as above. Check pickup, it should be between 1.1 - 1.5 amperes.

### 8.5 Maximum Torque Angle Adjustment

8.5.1 Use the No. 1 test switch positions and lead connections as tabulated in Fig. 17.

8.5.2 Adjust the voltages $V_{1F2F}$ and $V_{2F3F}$ for 20 volts with Brush No. 1 and Brush No. 2 respectively.

8.5.3 Adjust current for 15 amperes and rotate phase shifter to find the two angles, $\theta$ and $\theta_2$, at which the bottom unit contacts just close.

The maximum torque angle should be $\left(\frac{\theta + \theta_2}{2} - 30\right)$ degrees.

This angle should be between 33° and 37°.

If necessary, readjust $R_3$ resistor for correct angle. If $R_3$ adjustment is changed from its original setting, repeat core and $R_{3A}$ resistor adjustment.

8.5.4 A smaller angle $\theta$ may be obtained by reducing $R_3$, in this case the test current should be equal to $15 \frac{\sin(35° + 30°)}{\sin(\theta + 30)}$ amperes. The angle may be increased by increasing $R_3$. If $\theta$ of 60° is desired, open circuit $R_3$ resistor.

### 8.6 Contact Adjustment

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

Spring Restraint: Reconnect for a three-phase fault, Test No. 1, and set the phase shifter so that the current lags voltage by the maximum - torque angle, (65° in Fig. 17). Adjust the spring so that the current required to close the left hand contact is as follows:

Voltages $V_{1F2F}$ and $V_{2F3F}$ = 2.5 volts

Current to trip KD-5 = 1.46 amps

Phase-to-Phase Unit:

Core and $R_{AC}$ - Adjustment

A) Set $R_{AC}$ - resistor so that the adjustable band is in the center of the resistor.

B) Connect terminals 7 & 8 together and apply rated a-c voltage between terminals 89. Adjust core until contact arm floats in the middle of the gap. Use a screwdriver with insulated blade to avoid accidental contact with tap plate inserts.

C) Connect terminals 8 & 9 together and apply rated a-c voltage between terminals 7 & 8. The contact arm should float. If not, readjust core. Only slight readjustment should be required to do that. If this is not possible, rotate core 180° and adjust. Then recheck part B and see if contact is floating.

D) Connect terminals 7 & 9 together. Apply rated a-c voltage to terminals 7 & 8. Adjust resistor $R_{AC}$ until contact arm floats.

### 8.7 Maximum Torque Angle Adjustment (Fig. 17)

8.7.1 Use the No. 2 test switch position and lead connections. This connection is for checking and adjusting the maximum torque angle of the $T_{AB}$ compensator.

8.7.2 Adjust the voltage $V_{1F3F}$ and $V_{2F3F}$ for 10 volts with Brush No. 1 and Brush No. 2 respectively.

8.7.3 Adjust the current to 15 amperes and rotate the phase shifter to find angles $\theta_1$ and $\theta_2$, at which the top unit contacts just close. The maximum torque angle $\theta$ for the phase-to-phase unit then is $\frac{(\theta_1 + \theta_2)}{2} - 30°$.

This angle should be 43° - 47°. This angle $\theta$ can be changed by adjusting $R_{2A}$.

In this case, the test current should be equal to $\frac{15 \sin 45°}{\sin \theta}$ amperes.

A lower value of resistance gives a smaller angle and a higher resistance value gives a greater angle.

8.7.4 Use the No. 3 test connections and repeat the above procedure to check and adjust the angle of the $T_{BC}$ compensator. This adjustment is made with $R_{2C}$.

## 8.8 Spring Restraint

8.8.1 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 No. 2 is connected to 1F.

8.8.2 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.

## 8.9 Contact Adjustment

The procedure for contact adjustment for the phase-to-phase unit is identical to that described for three-phase unit.

The phase-to-phase unit is now calibrated and should be accurate to within $\pm$ 2% of the corrected tap value setting over the range of fault voltages from 2.5 $V_{L-L}$ to 120 $V_{L-L}$. The corrected tap value is actual relay reach at a given maximum torque angle $\theta$ and is equal to $Z_\theta = \frac{TS \sin \theta}{(1 + M)(\sin 45°)}$. The relay is now calibrated and ready for service.

## 8.10 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 below.

8.10.1 Set T, $T_A$, $T_B$, and $T_C$ on the 1.23 tap.

8.10.2 Disconnect the "L" leads of sections M, $M_A$, and $M_C$ and the brush leads of $R_3$, $R_{2A}$, $R_{2A}$, and $R_{2C}$ without disturbing the brush setting. (With resistor loading removed $\theta = 90°$.)

8.10.3 Connect terminals 12 to 14, 15 to 17, 16 to 18 and pass 20 amperes a-c current in terminal 19 and out of terminal 13.

8.10.4 Measure the compensator voltage $V_C$ with a high resistance voltmeter 5,000 ohm/volt as tabulated in Table 2. Refer to Fig. 1. for the location of $R_3$, $R_{2A}$, and $R_{2C}$.

8.10.5 Any compensator that has an output which is 1 volt more or less than the nominal values given above should be replaced.

## 8.11 Overall Check

After the calibration procedure has been completed, perform the following check:

8.11.1 Three-Phase Unit

Connect the relay for a three-phase fault. Test No. 1 of Figure 17 and set the phase shifter so that the phase angle meter indicates 30° more than the maximum torque angle. The current required to trip the relay should be within the limits specified for each of the voltages in Table 3. Note that for the three-phase unit the impedance measured by the relay is $Z_R = \frac{V_{L-L}}{3I_L}$ where $V_{L-L}$ is phase-to-phase fault voltage and $I_L$ is phase current.

To determine the limits of current when $\theta$ is not equal to 35° multiply the nominal values tabulated above the ratio $\frac{\sin (35 + 30°)}{\sin (\theta + 30°)}$ phase angle meter set for $\theta + 30°$.

8.11.2 Phase-to-Phase Unit

Using the connections for Tests Nos. 4, 5 and 6 set the phase shifter so that the current lags voltage by Θ. The current required to trip the phase-to-phase unit should be within the limits specified for each of the voltages in Table 4. Note that for the phase-to-phase unit the impedance measured by the relay is $Z_R = \frac{V_{L-L}}{2I_L}$ where $V_{L-L}$ is phase-to-phase fault voltage and $I_L$ is phase current.

To determine the limits of current when 0 is not equal to 45, multiply the nominal values tabulated above by the ratio $\frac{\sin 45^o}{\sin \theta}$

*If test 4 and 5 produce different results, rotate core about 1-2 degrees until 4 and 5 are within limits above. For best results trip current for parts 4 and 5 should be within 2%.

If test #6 is out limits readjust $R_{AC}$ resistor until current limits are met.

If substantial core or resistor changes are made, re-check parts A, B, C, D or core and $R_{AC}$ adjustment in Section 8.6.

TABLE 2

| Measure $V_C$ | | |
|---|---|---|
| From Terminal | To Fixed End of | Voltmeter Reading |
| "L" of M | $R_3$ | $V_C$ = 46.8 volts = 1.73 IT ($\theta$ = 60°) |
| "L" of $M_A$ | $R_{2A}$ | $V_C = 21T\left(\frac{\sin \theta}{\sin 45^o}\right)$ |
| "L" of $M_C$ | $R_{2C}$ | = 69.5 volts ($\theta$ = 90°) |

**8.12 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 0.2-2.0 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 ampere unit, between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

**9. 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.

TABLE 3

| Volts | | Amperes ($\theta$ = 35°) |
|---|---|---|
| $V_{1F2F}$ $V_{2F3F}$ | $I_{min}$ | $I_{max}$ |
| 2.5 | | 1.46 |
| 10 | 4.6 | 4.8 |
| 30 | 13.6 | 14.4 |

TABLE 4

| Test No. | VOLTS | AMPERES ($\theta = 45^o$) | |
|---|---|---|---|
| | $V_{1F2F}$ | $I_{min}$ | $I_{max}$ |
| 4, 5, & 6 | 2.5<br>5.0<br>30.0<br>70.0 | .98<br>1.99<br>11.9<br>28.0 | 1.08<br>2.10<br>12.5<br>29. |

TABLE 5

NOMENCLATURE FOR RELAY TYPE KD-5

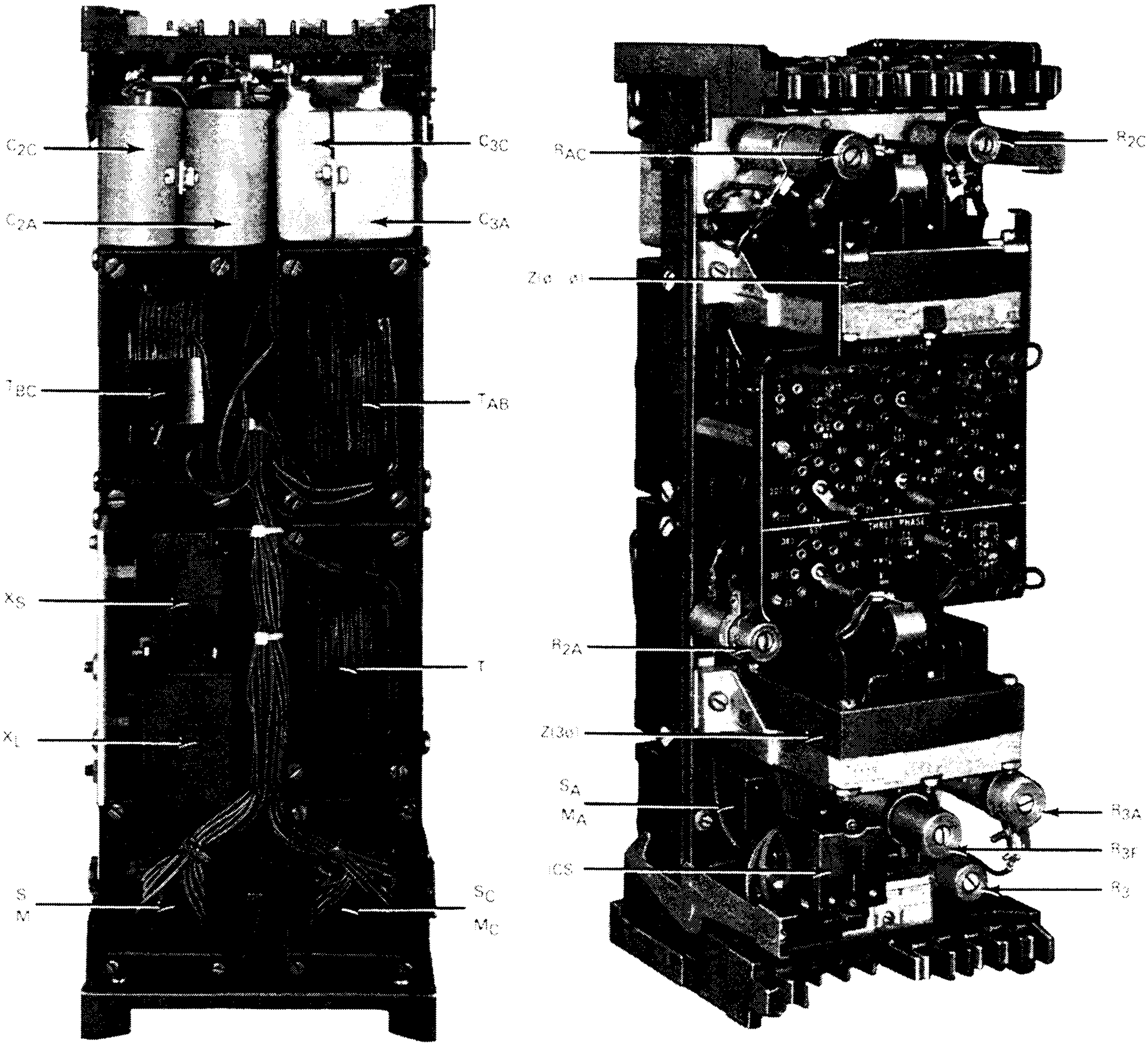
| UNIT | ITEM | DESCRIPTION |
|---|---|---|
| | Z (3$\phi$ ) | Two Element-Coils; Total d-c Resistance = 125 to 155 ohms |
| | Z (3$\phi$ ) | Two Element-Coils; Total d-c Resistance = 360 to 440 ohms |
| THREE- | *$R_{3A}$, $R_{3F}$ | 2 of 3-1/2 inch Resistors, Total Resistance 2250 ohms (one adjustable) |
| PHASE | $R_3$ | 2 inch Resistor 300 ohms adjustable |
| | $C_{3A}$ | 2.0 MFD Capacitor |
| | *$C_{3C}$ | 0.50 MFD Capacitor |
| | T | Compensator (Primary Taps - .23; .307; .383; .537; .690; .920; 1.23) |
| | S | Auto-Transformer Primary (Taps - 1; 2; 3) |
| | M | Auto-Transforemr Secondary (Between Taps - 0.0; .03; .06; .06) |
| | $X_{I1}$,$X_S$ | Reactors |
| PHASE- | Z ($\phi\phi$) | Two Element-Coils; Total d-c Resistance = 180 to 220 ohms |
| TO- | *$R_{AC}$ | 3-1/2 inch Resistor 750 ohms Adjustable |
| PHASE | $R_{2A}$ | 2 inch Resistor 100 ohms Adjustable |
| | *$C_{2A}$, $C_{2C}$ | 1.35 MFD Capacitor |
| | $T_{AB}$ $T_{BC}$ | Compensator Same as T |
| | $S_A$ $S_C$ | Same as S |
| | $M_A$ $M_C$ | Same as M |

TABLE 6

RELAY SETTINGS FOR KD-5 RELAY (.2 - 4.35 OHMS)

| | S = 1 | | | | | | | S = 2 | | | S = 3 | | | | LEAD CONNECTION | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * T | 230 | .307 | .383 | .537 | 690 | .920 | 1.23 | .690 | .920 | 1.23 | .920 | 1.23 | +M | -M | "L"LEAD | "R"LEAD | "L" |
| | .200 | .267 | .333 | .467 | .600 | .800 | 1.070 | - | 1.60 | 2.14 | - | 3.21 | +.15 | | Upper.06 | 0 | over |
| | .205 | .274 | .342 | .479 | .616 | .821 | 1.100 | - | 1.64 | 2.20 | - | 3.29 | +.12 | | Upper.06 | .03 | "R" |
| | .211 | .282 | .351 | .493 | .633 | .844 | 1.13 | - | 1.69 | 2.26 | - | 3.38 | +.09 | | Lower.06 | 0 | |
| | .217 | .290 | .361 | .507 | .651 | .868 | 1.160 | - | 1.74 | 2.32 | - | 3.48 | .06 | | Upper.06 | Lower.06 | |
| | .223 | .298 | .372 | .521 | .670 | .893 | 1.194 | - | 1.78 | 2.39 | - | 3.58 | +.03 | | .03 | 0 | |
| | .230 | .307 | .383 | .537 | .690 | .920 | 1.23 | - | 1.84 | 2.46 | - | 3.69 | 0 | -0 | 0 | 0 | |
| | .237 | .317 | .395 | .554 | .711 | .949 | 1.27 | - | 1.90 | 2.54 | - | 3.80 | | -.03 | 0 | .03 | |
| | .245 | .327 | .407 | .571 | .734 | .980 | 1.31 | 1.47 | 1.96 | 2.62 | 2.94 | 3.93 | | -.06 | Lower.06 | Upper.06 | "R" |
| | .253 | - | .421 | .590 | .758 | 1.01 | 1.35 | 1.52 | 2.02 | 2.70 | 3.03 | 4.05 | | -.09 | 0 | Lower.06 | over |
| | .261 | - | .435 | - | .784 | 1.05 | 1.398 | 1.57 | 2.09 | 2.80 | 3.14 | 4.19 | | -.12 | .03 | Upper.06 | "L" |
| | .271 | - | .450 | - | - | - | 1.45 | - | - | 2.89 | - | 4.34 | | -.15 | 0 | Upper.06 | |

* "T" tap plate value refers to standard maximum torque angle adjustment which is 35° for three phase unit and 45° for the phase-to-phase unit.




(Rear View)

(Front View)

*Fig. 1. Type KD-5 Relay Without Case*

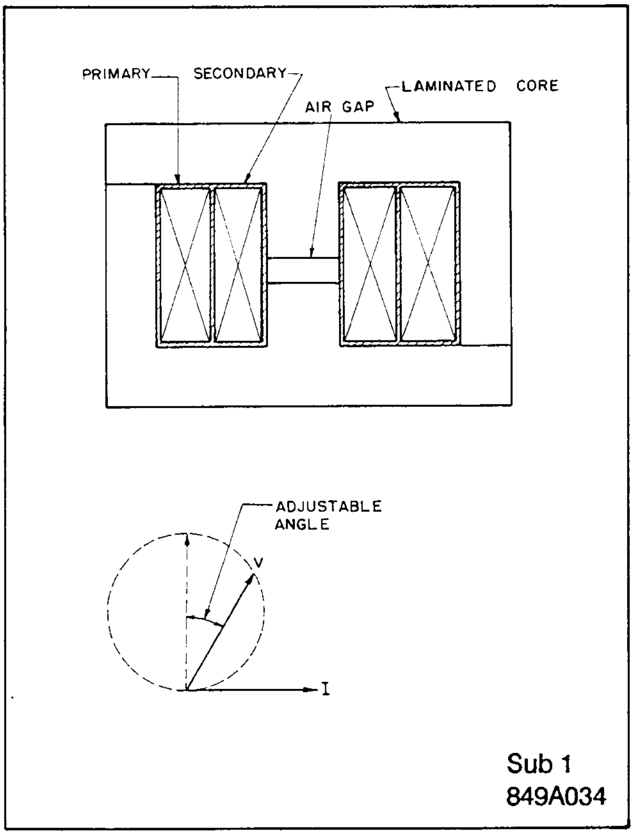



*Fig. 2. Compensator Construction*

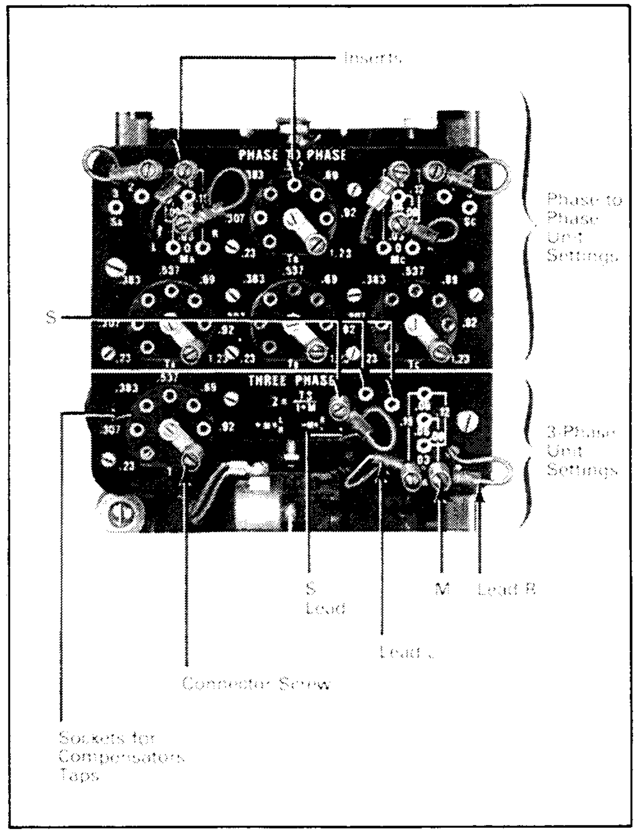



*Fig. 3. Tap Plate*

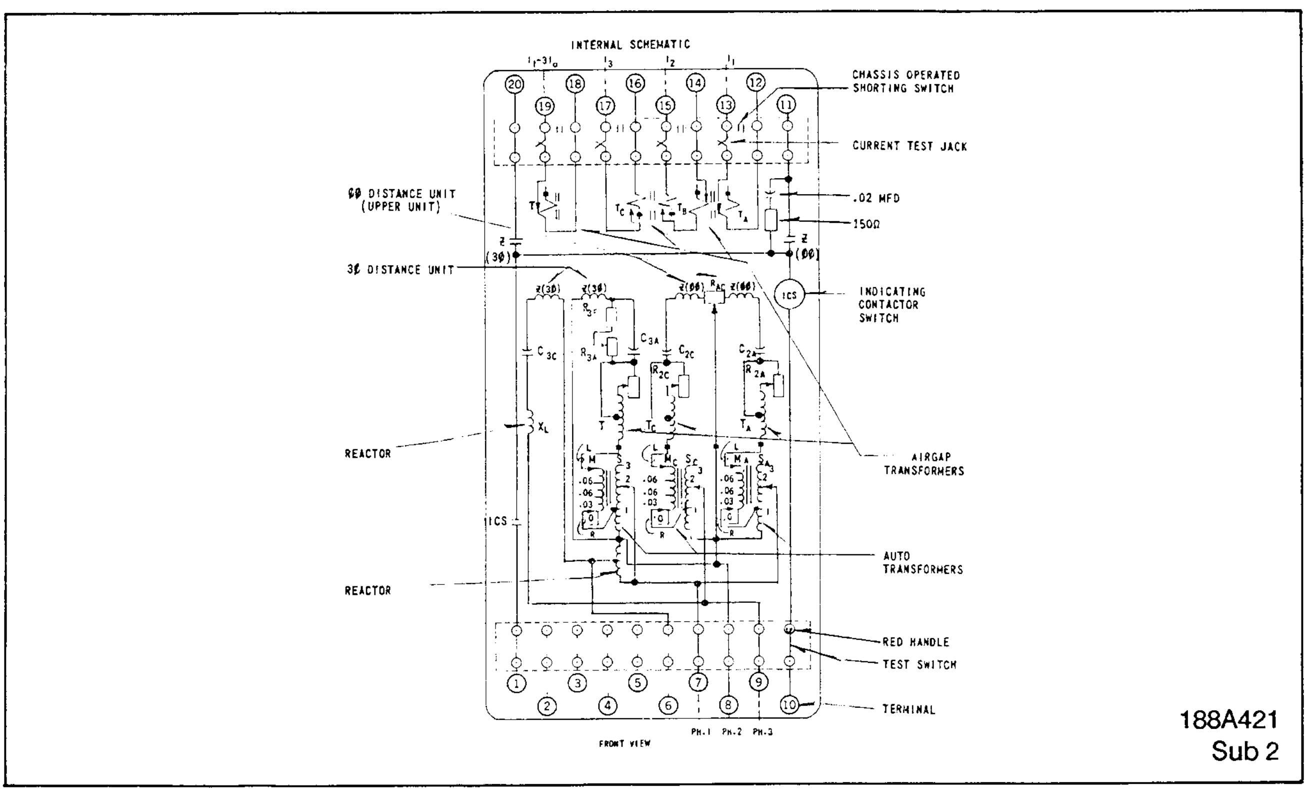



*Fig. 4 Internal Schematic of Type KD5 Relay(Prior to 1975) with 1.0 ampere ICS in the type FT42 case. (Relay with 0.2/2.0 ampere ICS unit has identical wiring except that the ICS coil is tapped on terminal 10 (188A426)*

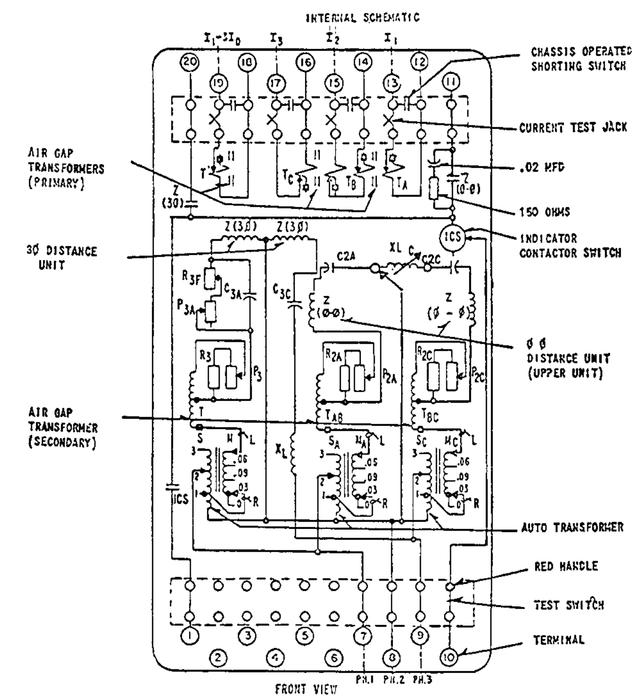



*Fig. 4a Internal Schematic of Type KD5 Relay(After 1975) with 1.0 ampere ICS in the type FT42 case. (Relay with 0.2/2.0 ampere ICS unit has identical wiring except that the ICS coil is tapped on terminal 10 (188A426)*

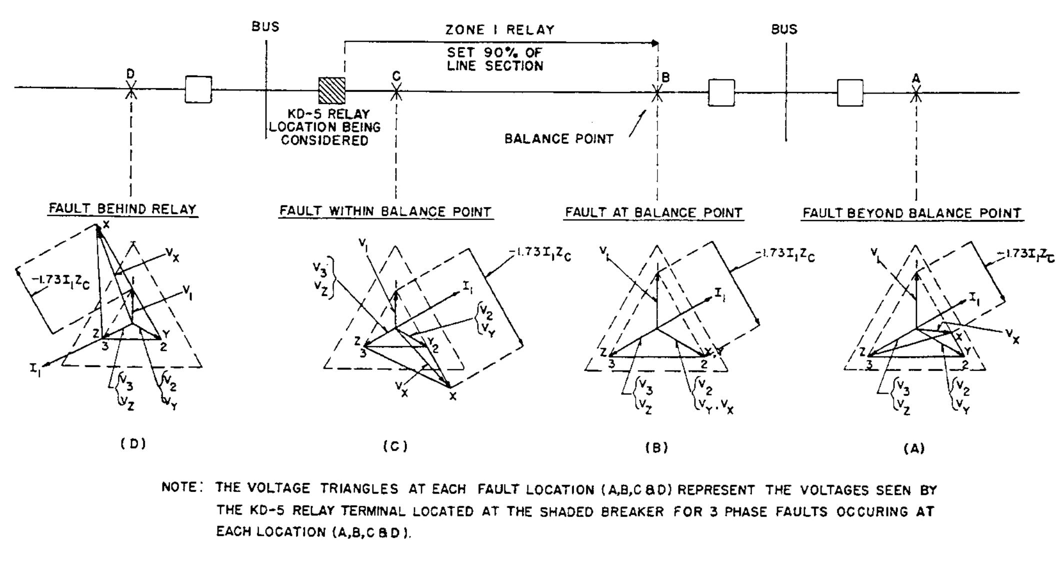
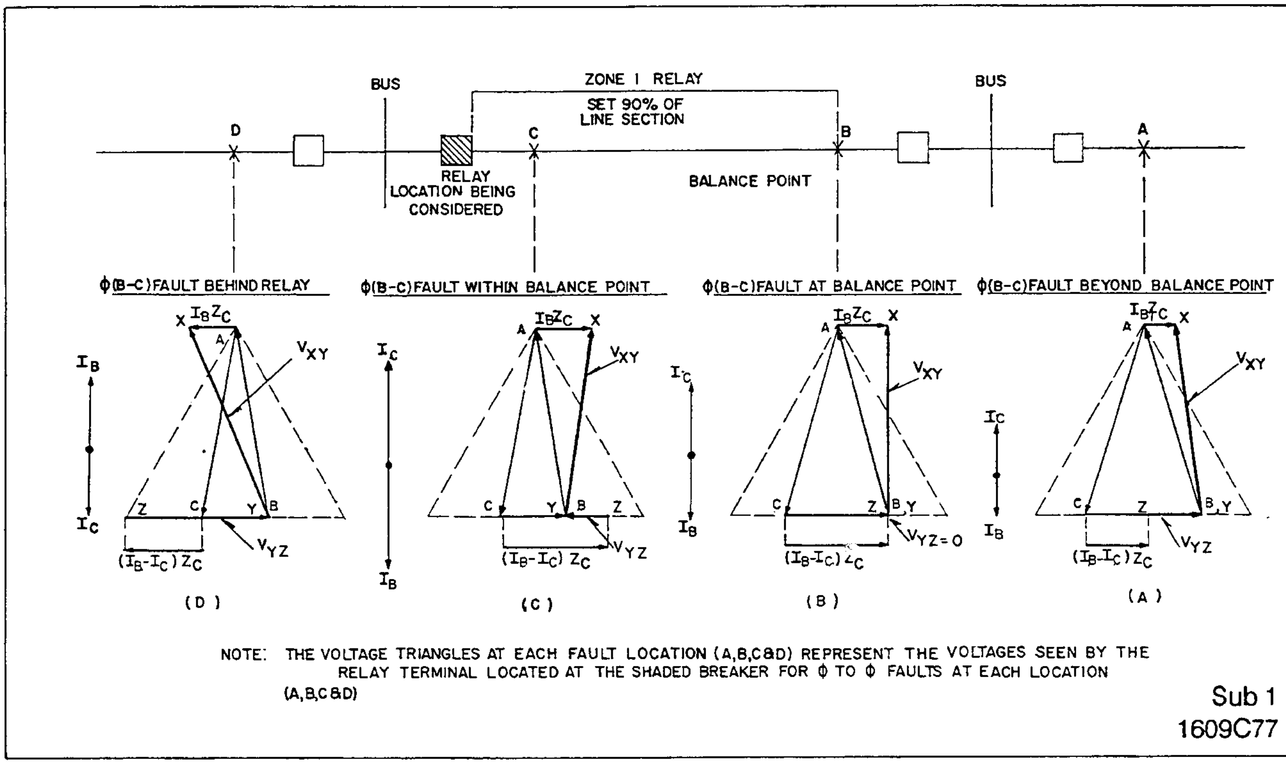



*Fig. 5. Voltage and Current Conditions for the Three-Phase Unit at the Shaded Breaker for Three-Phase Faults at Various Locations.*




* *Fig. 6. Voltage and Current Conditions for the Phase-to-Phase Unit at the Shaded Breaker for ϕ(2-3) Faults at various Locations.*

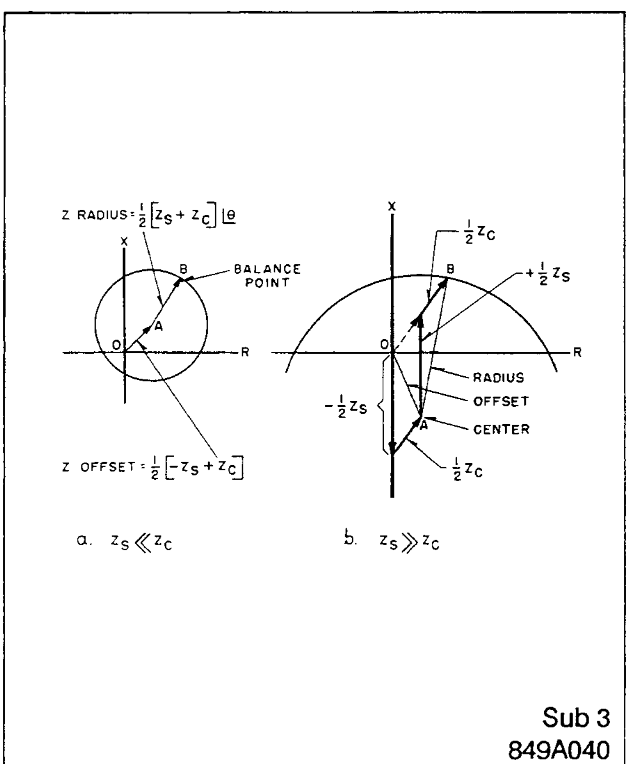



*Fig. 7. Impedance Circles for Phase-to-Phase Unit in the Type KD-5 Relay.*

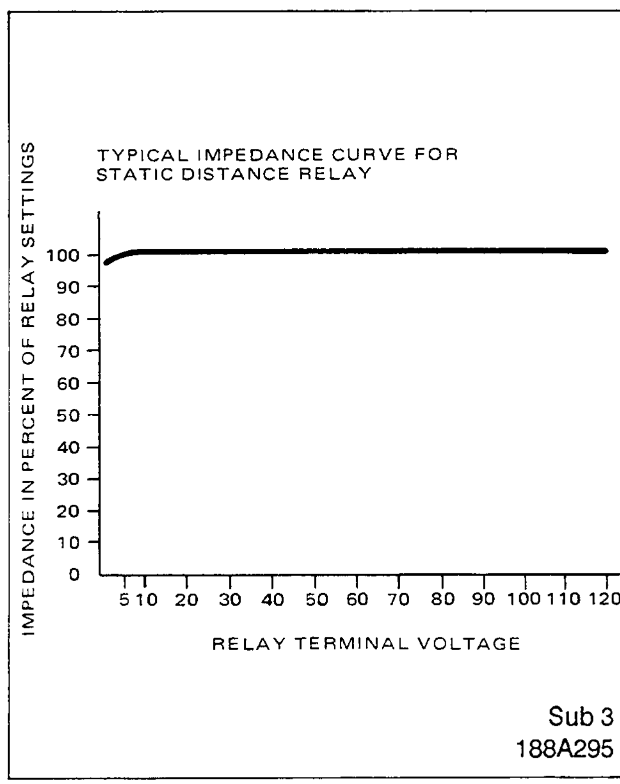



*Fig. 8. Impedance Curves for Type KD-5 Relay.*

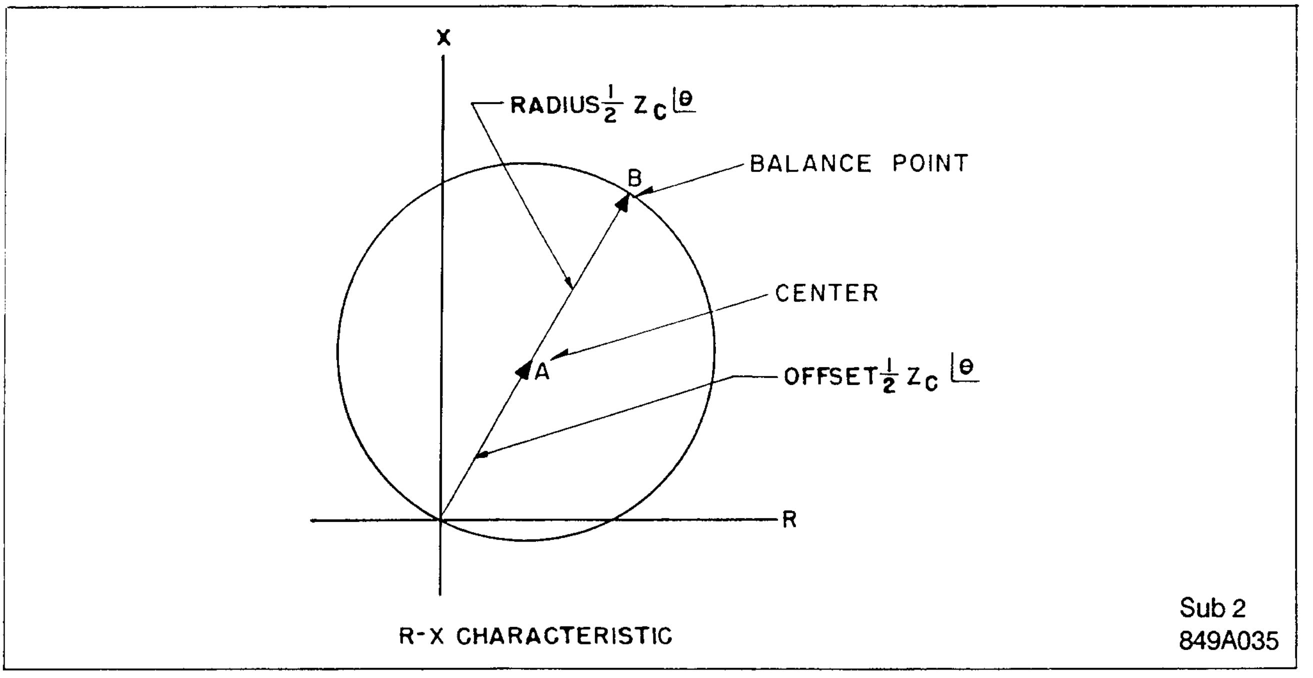
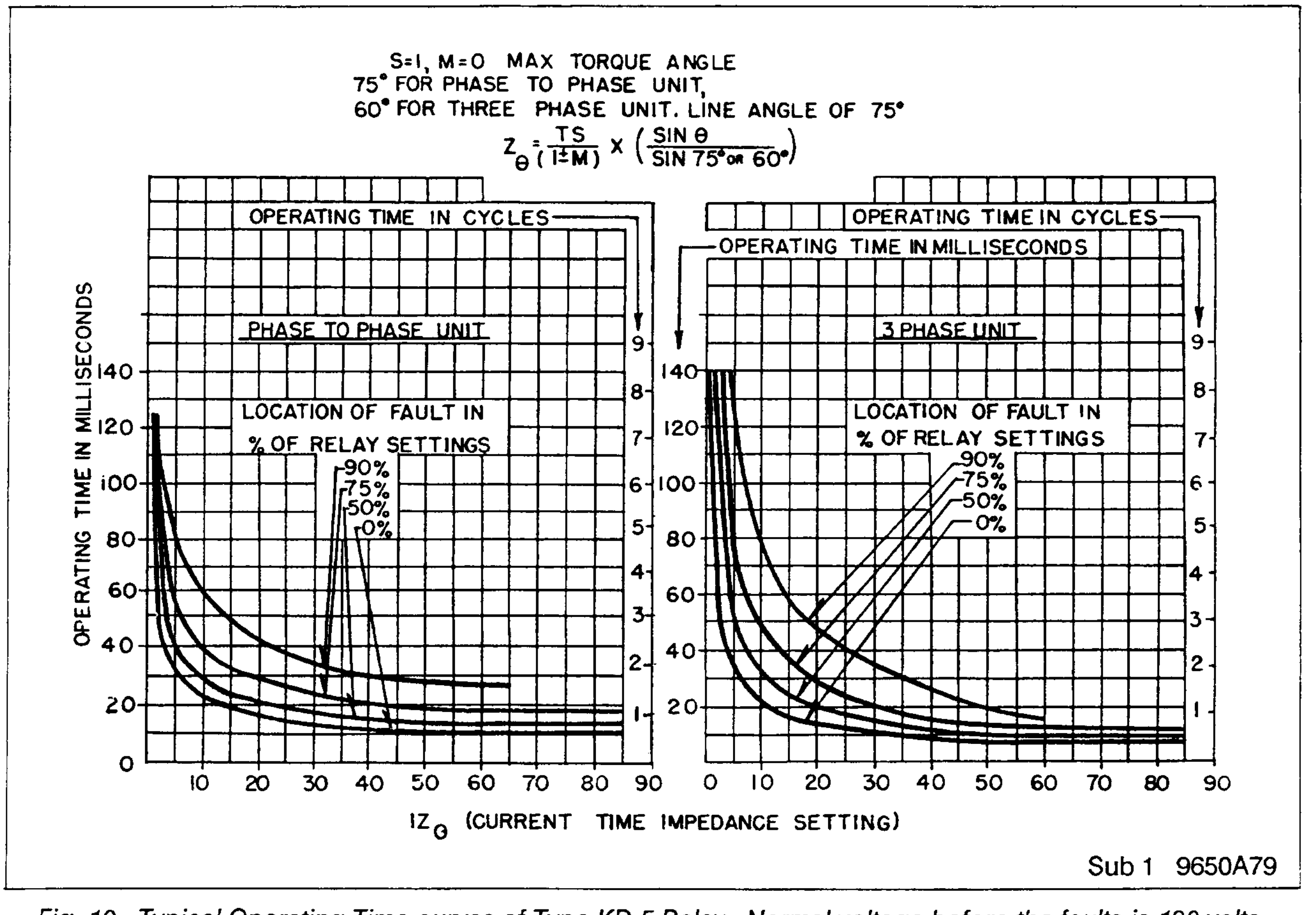
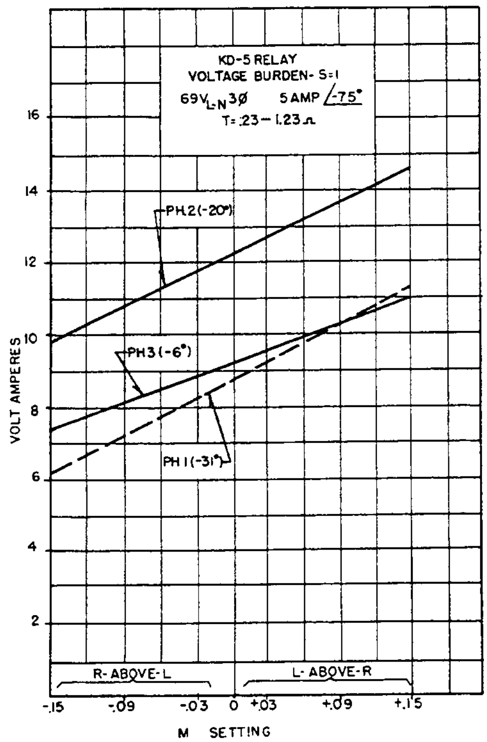
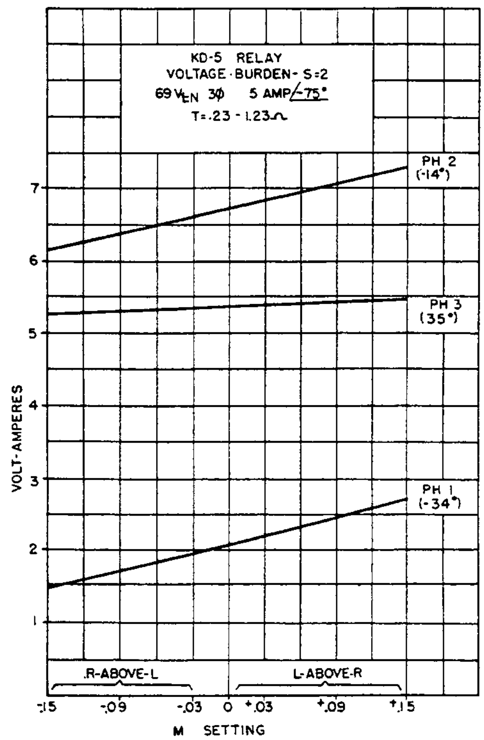


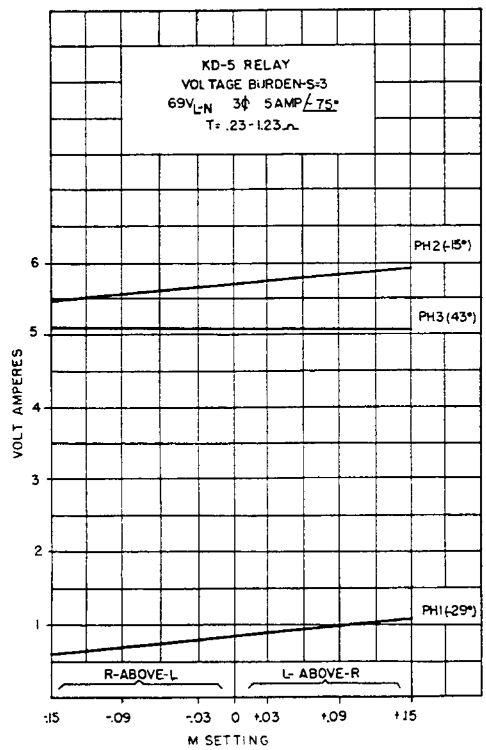

*Fig. 9. Impedance Circle for Three-Phase Unit in Type KD-5 Relay.*




* *Fig. 10. Typical Operating Time curves of Type KD-5 Relay. Normal voltage before the faults is 120 volts.*




CURRENT BURDEN TABLE
POTENTIAL CIRCUIT 69$V_{L-N}$ S=1
THREE PHASE CURRENT= 5 /-75° AMPS.

| TAP SETTING | PHASE 1 VA | PHASE 1 VARS | PHASE 1 WATTS | PHASE 2 VA | PHASE 2 VARS | PHASE 2 WATTS | PHASE 3 VA | PHASE 3 VARS | PHASE 3 WATTS |
|---|---|---|---|---|---|---|---|---|---|
| 23 | 1.05 | .306 | 1.01 | .650 | .157 | .63 | .200 | .062 | .190 |
| .307 | 1.25 | .605 | 1.09 | .700 | .240 | .660 | .350 | .126 | .327 |
| .383 | 1.45 | .852 | 1.17 | .802 | .354 | .722 | .600 | .262 | .54 |
| .537 | 1.65 | 1.16 | 1.16 | 1.000 | .615 | .788 | .850 | .488 | .696 |
| .690 | 1.85 | 1.41 | 1.19 | 1.400 | 1.00 | .980 | .950 | .600 | .74 |
| .920 | 2.25 | 1.92 | 1.19 | 2.100 | 1.74 | 1.18 | 1.35 | .94 | .97 |
| 1.23 | 3.2 | 2.98 | 1.19 | 3.350 | 3.02 | 1.47 | 2.20 | 1.55 | 1.55 |

Sub 1
9650A83

** Fig. 11. Type KD-5 Relay Burden Data.*

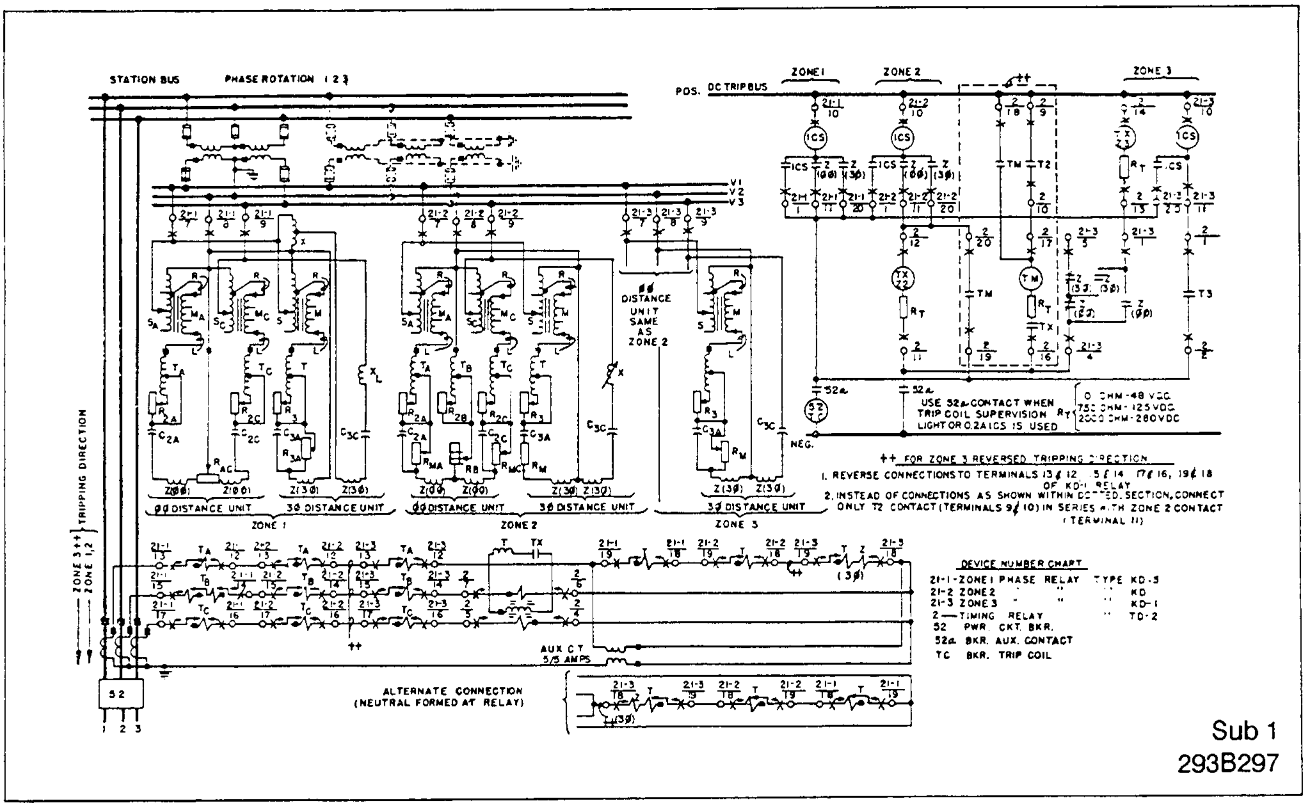



*Fig. 12. External Schematic of Type KD-5, KD and KD-1 Relays with Type TD-2 Timing Relay.*

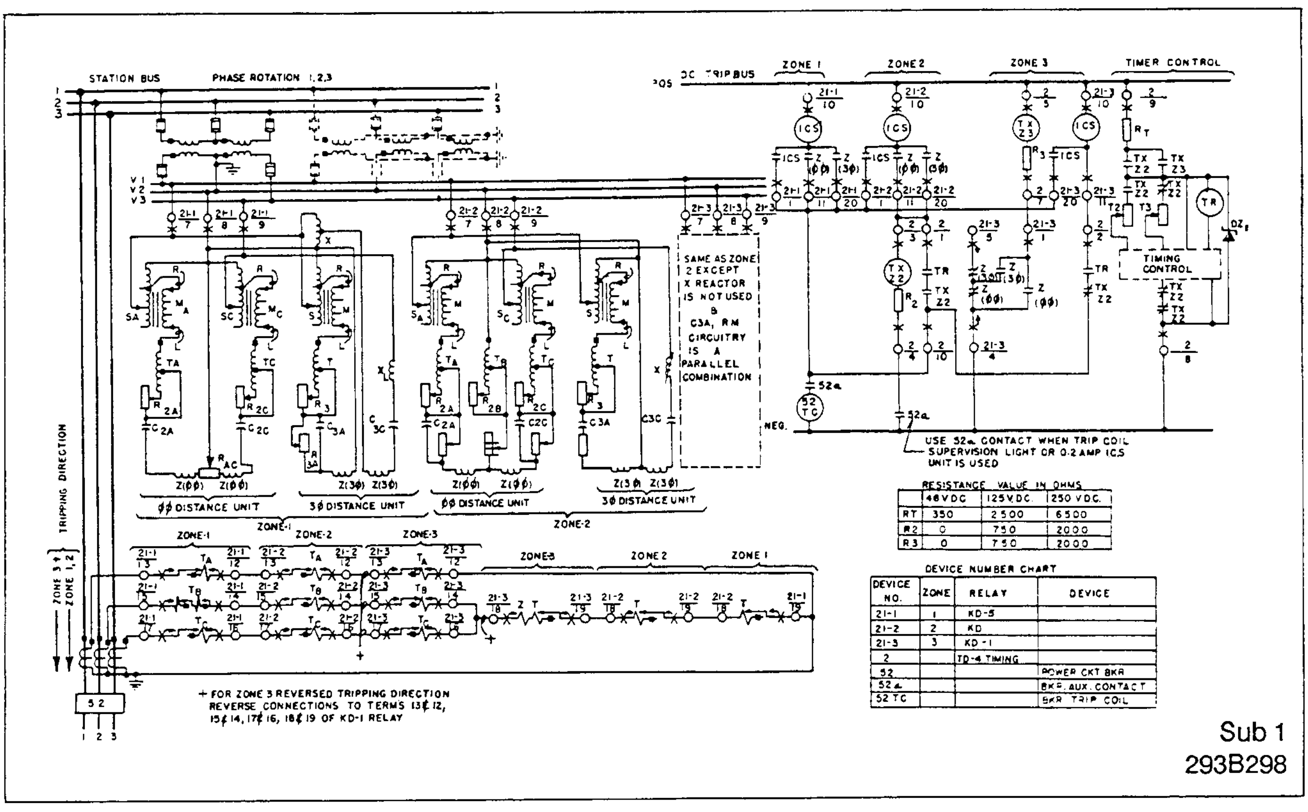
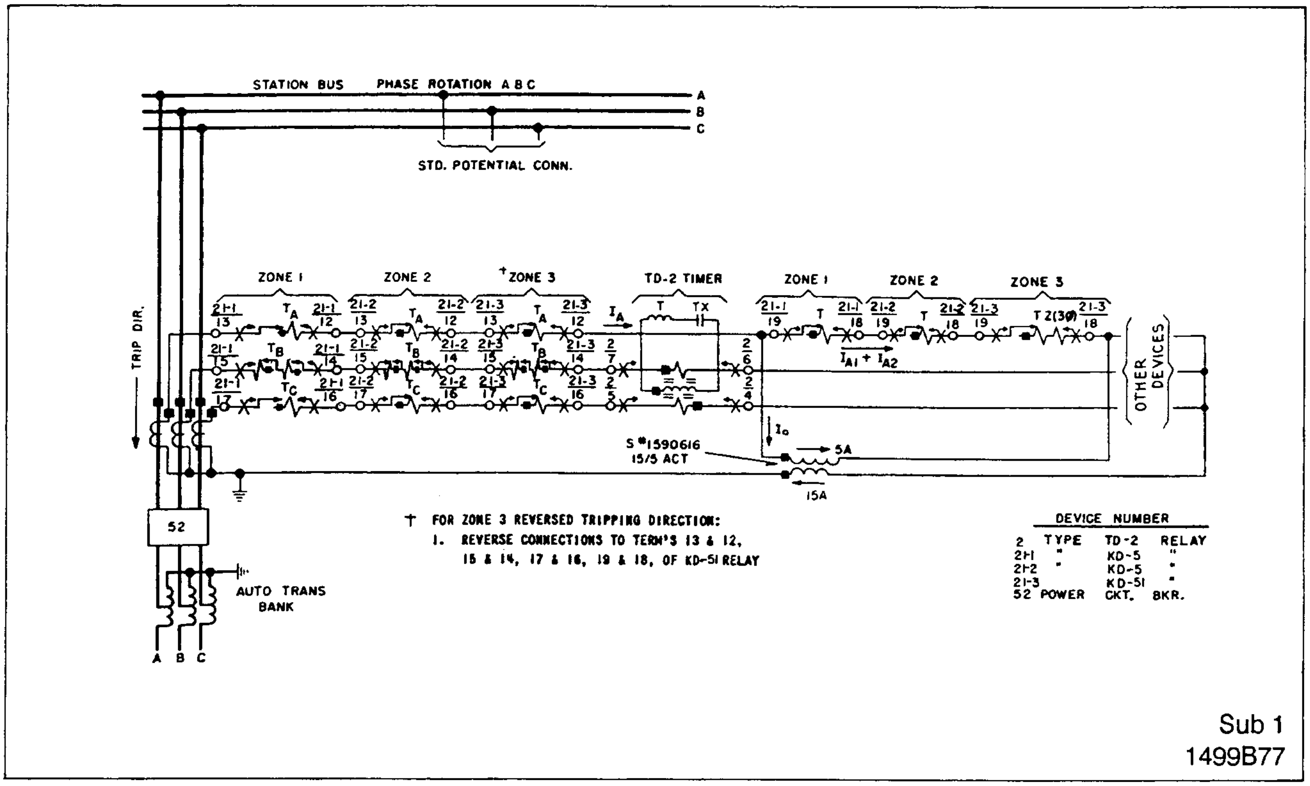
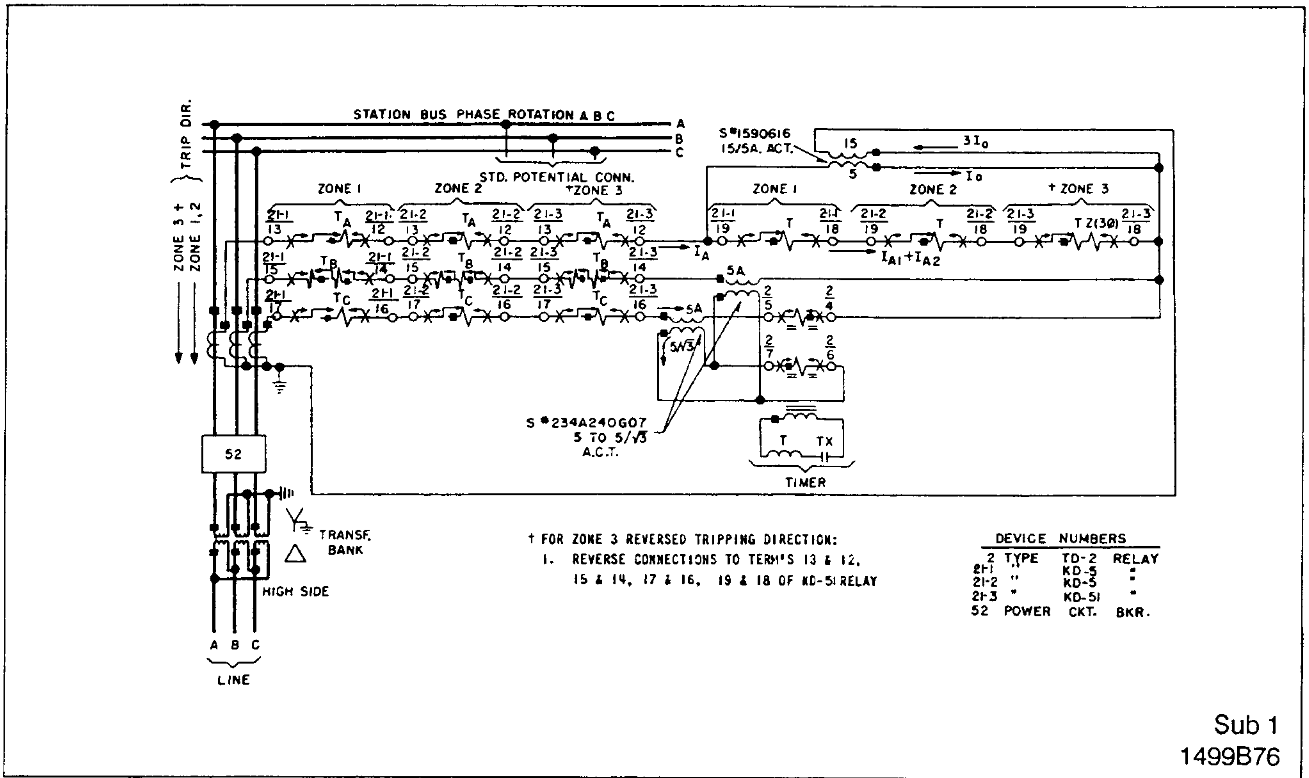


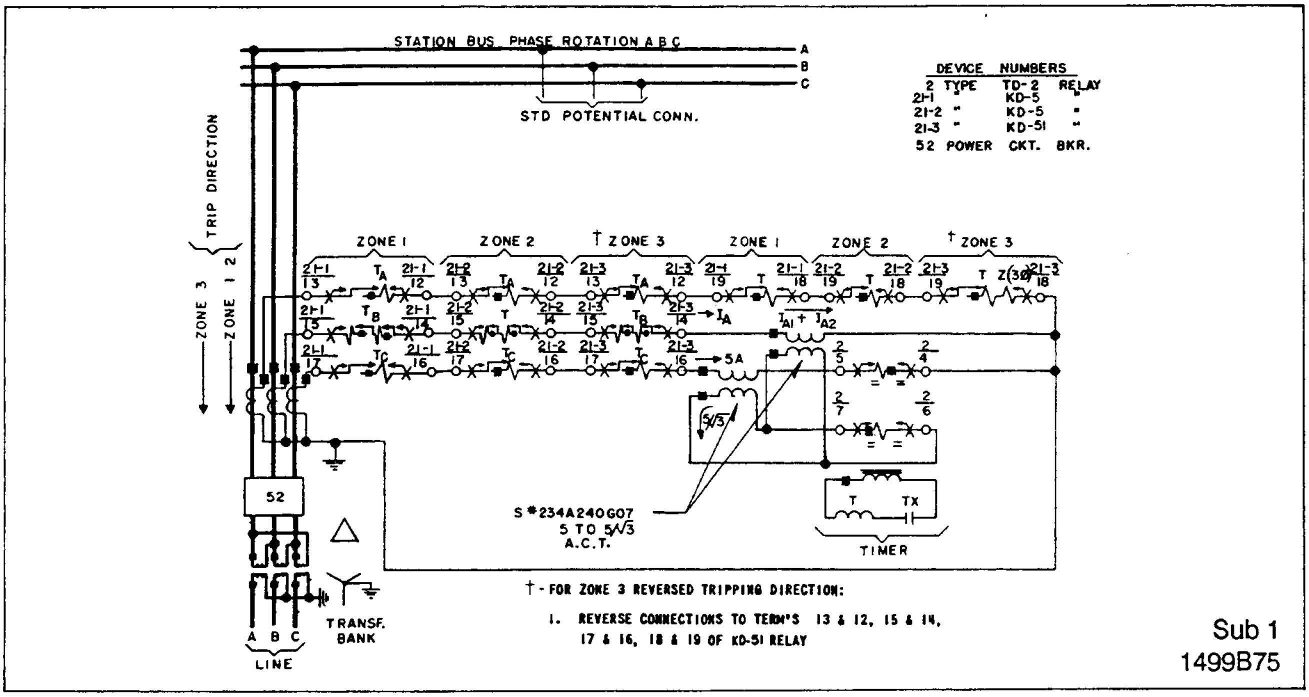

*Fig. 13. External Schematic of Type KD-5, KD and KD-1 Relays with Type TD-4 Timing Relay.*



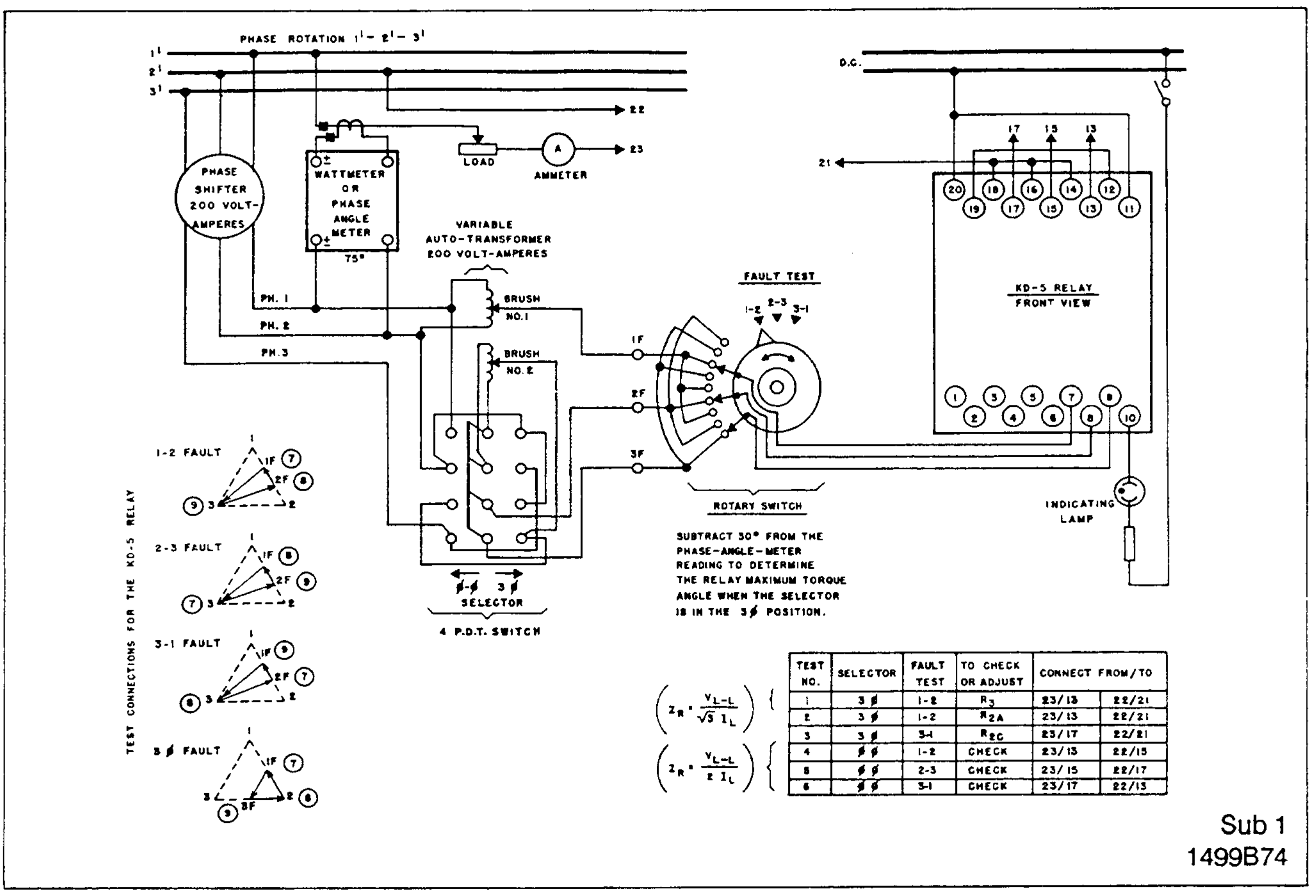

* *Fig. 14. A.C. External Schematic of Type KD-5 KD and KD-1 Relays with Type TD-2 Timing Relay-Auto-transformer Termination.*




* *Fig. 15. A.C. External Schematic of Type KD-5 KD and KD-1 Relays with Type TD-2 Relay-Wye Delta Bank Termination with Grounded Wye on Relay Side.*



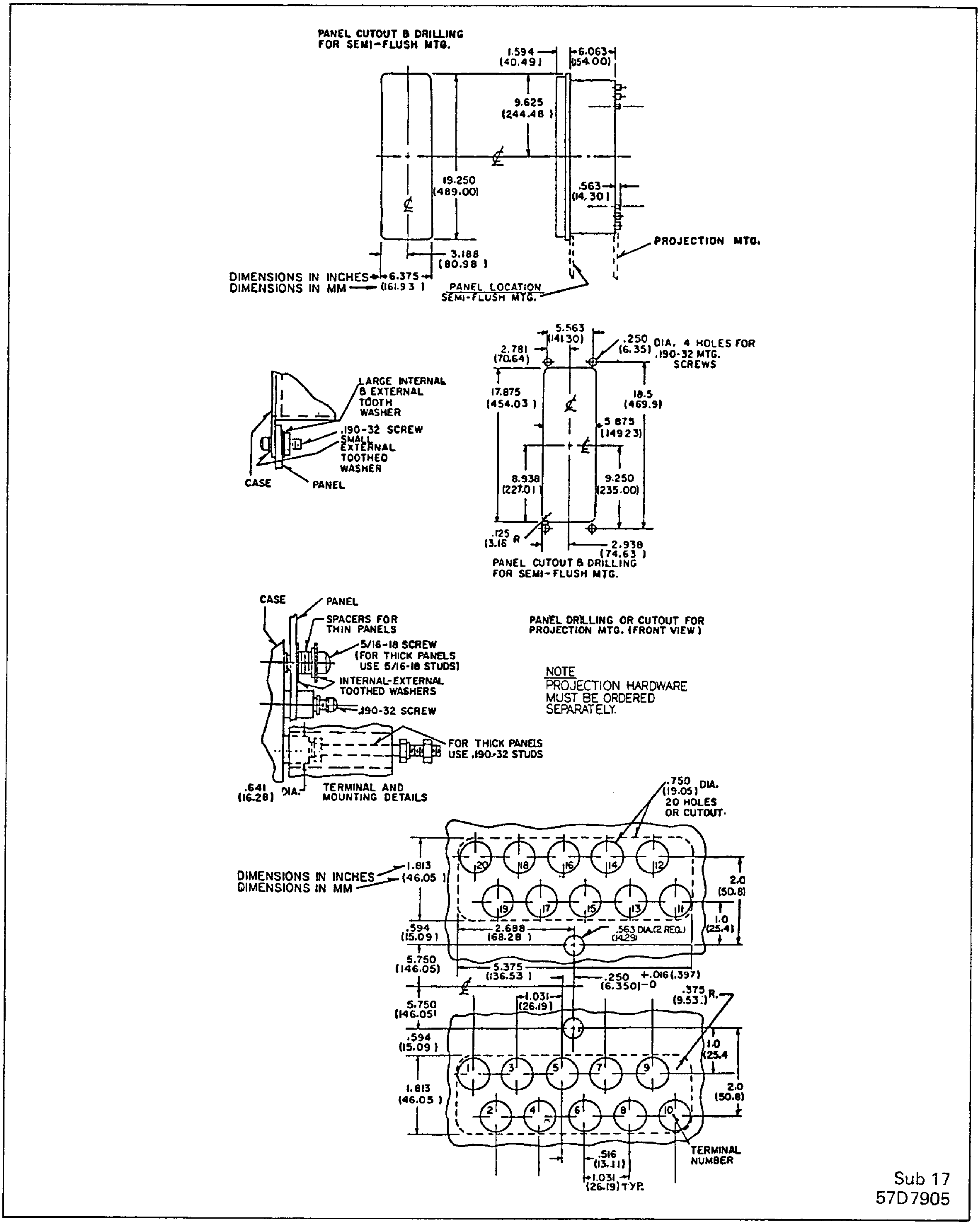

* *Fig. 16. A.C. External Schematic of Type KD-5 KD and KD-1 Relays with Type TD-2 Timing Relay-Wye-Delta Bank Termination with Delta on Relay Side.*




$\left(Z_R = \frac{V_{L-L}}{\sqrt{3}\, I_L}\right)$ — tests 1–3; $\left(Z_R = \frac{V_{L-L}}{2\, I_L}\right)$ — tests 4–6

| TEST NO. | SELECTOR | FAULT TEST | TO CHECK OR ADJUST | CONNECT FROM/TO | |
|---|---|---|---|---|---|
| 1 | 3 ∅ | 1-2 | $R_3$ | 23/13 | 22/21 |
| 2 | 3 ∅ | 1-2 | $R_{2A}$ | 23/13 | 22/21 |
| 3 | 3 ∅ | 3-1 | $R_{2C}$ | 23/17 | 22/21 |
| 4 | ∅ ∅ | 1-2 | CHECK | 23/13 | 22/15 |
| 5 | ∅ ∅ | 2-3 | CHECK | 23/15 | 22/17 |
| 6 | ∅ ∅ | 3-1 | CHECK | 23/17 | 22/13 |

* *Fig. 17. Test Connections for Type KD-5 Relay.*




* *Fig. 18. Outline and Drilling Plan for Type KD-5 Relay in the Type FT42 case.*