INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SD-2 COMPENSATOR TIME-DISTANCE RELAY

APPLICATION

The type SD-2 relay (Figure 1) is a compensator type semi-static distance relay which provides a single zone of phase protection for all three phases. Operating time of the relay is proportional to the distance the fault is from the relay. This makes it quite suitable for intermediate voltage circuits (19KV to 33KV) for second zone protection. First zone protection may be provided by an impedance relay such as the KD-4.

The type SD-2 relay provides time-proportional-to-distance tripping for all combinations of phase-to phase, two phase-to-ground, and three phase faults. It can be set to any value of reach from 0.8 ohms to 25.6 ohms. Time-proportional-to-distance delays of .5 to 5.0 seconds for faults at 75% of the relay setting can be set with the time scale in addition to fixed time delays of from .05 to .5 seconds.

CONSTRUCTION

The type SD-2 relay contains an ICS indicating contactor switch, a single output telephone type relay and a complete set of components for each of the three phases. Each set of components consists of an air-gap transformer (compensator), a coupling transformer, a voltage transformer, and a static sensing circuit with a transistor output which controls a timing circuit.

Compensator

Compensators are three winding air-gap transformers. The double wound primary, or current winding, has five taps per winding which terminate at the tap block. They are marked .8, 1.6, 3.2, 6.4, and 12.8 (Figure 2). Current flowing through each of the primary coils comes from different phases and produces magnetic lines of flux in the core which is proportional to delta current.

A voltage is induced in the secondary which is proportional to the primary tap settings and current magnitudes. This voltage is then applied to the coupling transformer which operates to compensate the voltage as well as provide an operate and a timing quantity.

Coupling Transformer

The coupling transformer is a three winding unit with a single primary and two secondaries. It is designed to saturate in the presence of high fault currents and thereby limit the magnitude of voltage applied to the static sensing and timing circuits. The two secondaries are equal. One is connected to the operate side of a sensing and timing network and permits the relay to start timing when the operate quantity exceeds the magnitude of the restraint quantity produced by compensated voltage. The other is connected subtractively in series with the voltage to provide compensation and thereby produces the restraint quantity.

Voltage Transformer

The voltage transformer is a three winding isolating transformer which reduces the applied restraint voltage to a level within the rating of the static sensing and timing circuit. Voltage of the restraint quantity in the distance measuring circuit is adjusted by means of a potentiometer designated as S_A, S_B, or S_C. The potentiometer shown in Figure 2 has a dial calibrated between the values of 1.0 and 2.0 and is used in setting the relay reach.

Timing Circuit

The timing circuit contains a potentiometer in series with a capacitor. Charging of the timing capacitor is accomplished by the operate quantity and is supervised by the sensing circuit. When voltage across the timing capacitor exceeds the voltage output of the potential transformer, a circuit is energized to operate the telephone relay.

The three potentiometers used for setting time delay are designated TD_A, TD_B, and TD_C. They have calibrated scales which are marked in major divisions of .5, 1.0, 2.0, 3.0, 4.0, and 5.0 seconds as shown

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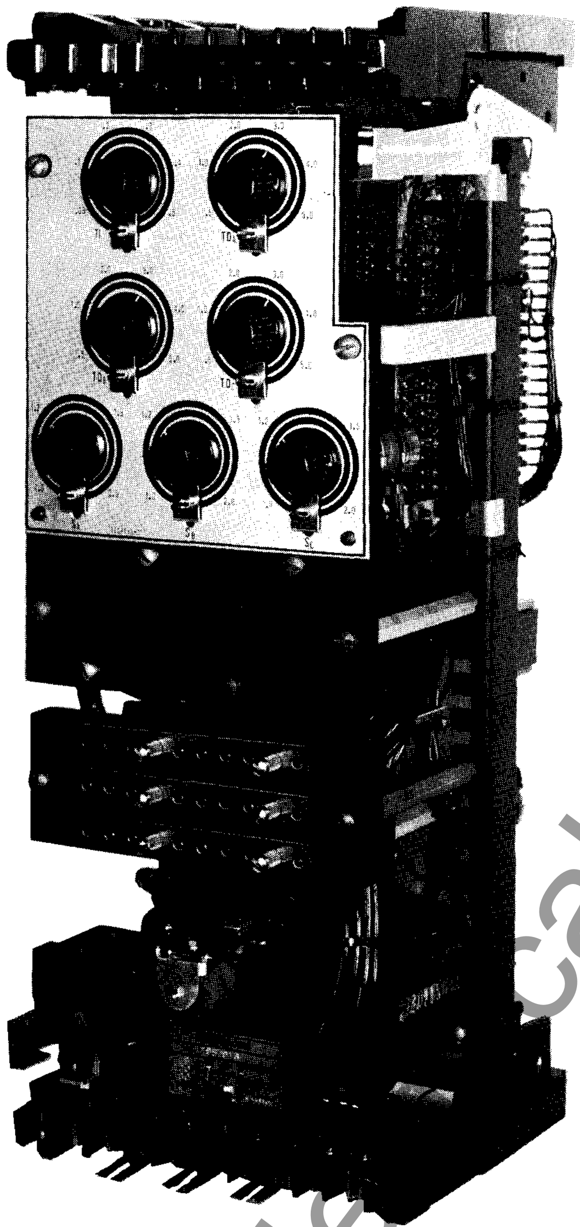
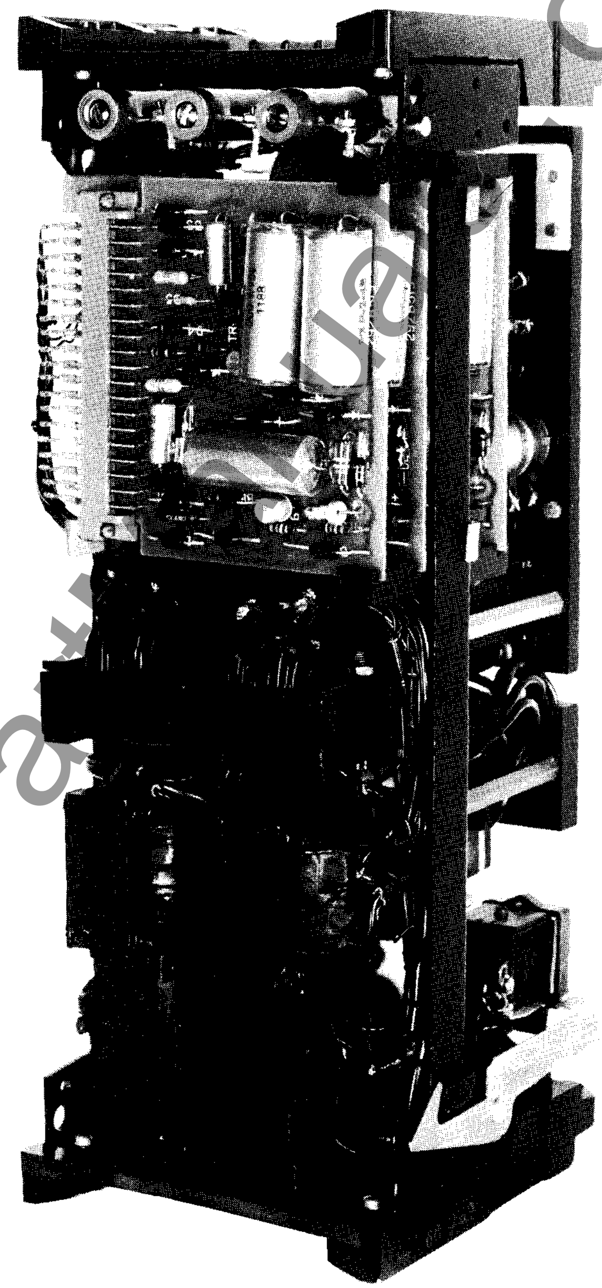


(Front View)



(Rear View)

Fig. 1 Type SD-2 Relay without case.

in Figure 2. The scales indicate time required for the relay to trip for faults at 75% of the relay setting.

An additional single potentiometer designated TI is used to add a fixed delay to the operating time. TI has a calibrated scale marked in major divisions of .05, .1, .2, .3, and .5 seconds. This is fixed time delay and does not vary with fault location.

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 coil. 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

SD-2 relays contain three single-phase circuits (Figure 3) which operate independently to protect each phase. The three circuits are identical, so a description of one is applicable to all three.

Time Adder Circuit

As shown in Figure 4, the output telephone relay SD-2 is energized when transistor TR2 conducts. This is delayed by the RC timing circuit, P3, R15 and C3, which is controlled by transistors TR5 and TR4. When TR4 turns on TR5 allows current to flow through resistance P3 + R15 to charge capacitor C3. After a sufficient voltage develops across C3, current flows into the base of TR2 and causes SD-2 to trip. Figure 5 shows the printed circuits assembly of the time adder circuit.

Time Distance Circuit

Transistor TR4 is normally biased off by the restraint voltage supplied by the B3 restraint bridge. This voltage is proportional to VAB and to the setting of P4. (Potentiometers P1, P4 and P5 are all on one shaft and are adjusted when making an SA setting). When capacitor C4 is permitted to charge from the operate bridge B1 to a level that exceeds the restraint voltage, TR4 becomes forward biased and therefore conducts. Capacitor C4 is part of an RC timing circuit which includes P2 and R10. Charging current can flow only when transistor TR1 conducts. Figure 6 shows the printed circuit assembly of the sensing circuit for one phase.

Operating principles of the time distance timer are illustrated in Figures 7a and 7b. In Figure 7a, voltage V_G is the generated voltage. At the SD-2 location restraint voltages V_{F1}, V_{F2} and V_{F3} result from faults at F1, F2, and F3 respectively. Figure 7b illustrates how the voltage across capacitor C4 increases with time and reaches a final level which is a function of the compensator output and is expressed in the figure as I_F $(I_F Z_R)$. I_F is the equivalent compensator primary current and Z_R is the compensator setting in ohms. It can be seen that the time required for the restraint voltage to be exceeded is less for a fault at F3 than it is for a fault at location F1. The time is proportional to the distance from the relay to the fault location.

Mho Supervising Circuit

Transistor TR1 is normally biased off by voltage from the B2 restraint bridge. This voltage, which appears across R6 is normally greater than the operate voltage from bridge B1. When a fault occurs within the protected zone, the operate voltage of B1 exceeds the restraint of B2. TR1 is then switched on by B1 current flowing through R6, D1, and TR1 base.

B1 input voltage is a function of delta current and potentiometer P1 setting, B2 input voltage is compensated and is a function of potentiometer P5 setting and line voltage minus a current derived voltage. This is expressed as $f(V - I_F Z_R)$ where V is the output of voltage transformer T3 and $I_F Z_R$ is the output of coupling transformer T2.

CHARACTERISTICS

Phase Angle Response

Impedance circles in Figure 8 indicate the phase angle response. Here, relay reach in ohms is plotted at various angles of current lagging voltage for constant voltages at the relay terminals.

Balance Point Accuracy

The accuracy with which the SD-2 relay determines the threshold between a trip condition and a non-trip condition is illustrated by the impedance curve in Figure 9. This is a record of points at which

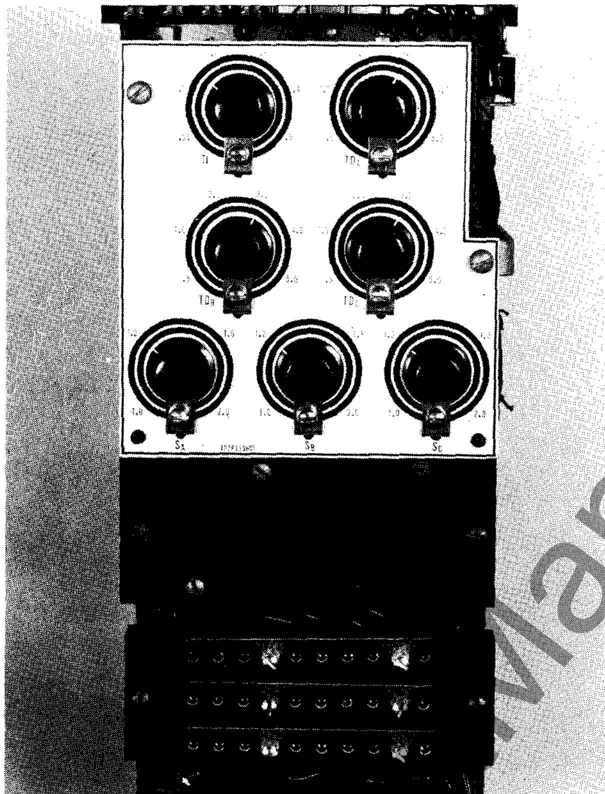


Fig. 2 Dial Plate & Taps for Relay Settings.

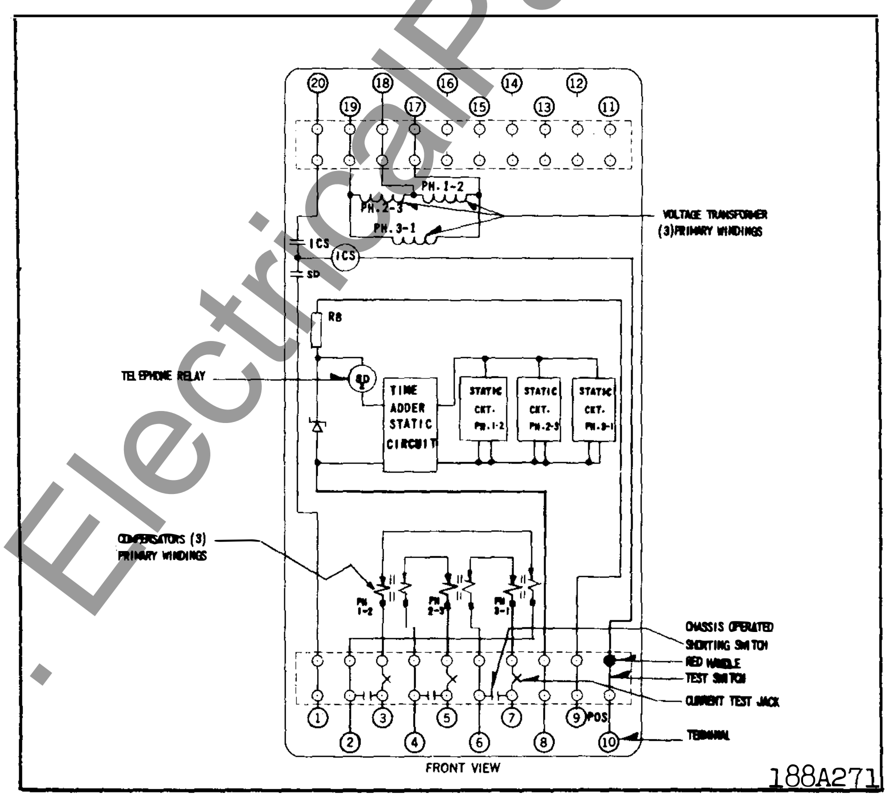


Fig. 3 Internal Schematic of SD-2 Relay with 1.0 Ampere ICS in the FT-42 Case. (Relay with 0.2/2.0 Ampere ICS unit has identical wiring except that the ICS coil is tapped on Terminal 10).

the relay just trips, plotted as per cent of relay setting (%Z_R) vs. relay voltage under fault conditions. Z_R equals relay setting TS.

General Characteristics

Impedance setting in ohms reach can be made for any value from 0.8 ohms to 25.6 ohms. The maximum sensitivity angle is designed for 60' current lagging voltage and is not adjustable. However, a slight shift in this angle might occur at various voltage levels as indicated in Figure 8.

Settings are made in discreet steps of .8, 1.6, 3.2, 6.4, and 12.8 ohms. Between tap settings are made by a potentiometer setting which acts as a multiplier. The potentiometer can be set for any value from 1 to 2.

TIME CURVES AND BURDEN DATA

Operating Times

The speed of operation of the SD-2 relay is shown by the time curves in Figure 10. The curves indicate the time in seconds required for the relay to trip after the inception of a fault within the protected section. The time dial TD is based on a fault located at 75% of the relay setting Z_R. Note in Figure 11 that the SD-2 relay will not trip for close-in low energy faults because the internal circuits do not receive sufficient energy for proper operation.

Burden

The burden which the relay imposes upon current transformers is listed for each tap setting when 5 amperes current is flowing.

CURRENT BURDEN

TAP SETTING	5 AMPERES			50 AMPERES		
	VA/PHASE	OHMS	ANGLE	VA/PHASE	OHMS	ANGLE
.8	1.55	0.062	30°	155	0.062	30°
1.6	1.83	0.073	30°	170	0.068	30°
3.2	2.65	0.106	30°	190	0.076	30°
6.4	3.35	0.134	30°	325	0.130	42°
12.8	10.2	0.406	30°	680	0.272	47°

VOLTAGE BURDEN

S Setting	Volt Amperes per Phase ($V = 69.4\ V_L$-N)
1	4.16 VA, 0°
2	4.03 VA, 0°

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

An application of the type SD-2 relay is illustrated in Figure 12. Here, a source of power is shown at the left energizing two adjacent line sections with relays at points A, B, and C. The distance in ohms between relay locations is plotted horizontally, and the time of operation is plotted vertically. The time-distance characteristics of the relays are plotted as straight lines sloping upwardly from left to right.

Considering the relay at location A, a time of operation t_S' is allowed for clearing a fault at location B. A time t_S is allowed to clear a fault at location C. By drawing a straight line from t_S through t_S' and extending it to a vertical line at A, the intersection at A determines the value of fixed time, t_F, necessary to provide the desired time-distance characteristics.

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

$$Z_R = Z_p \left(\frac{R_C}{.75\ R_V}\right)$$

Z_R = TS = the desired ohmic reach of the relay in secondary ohms

T = compensator tap value at 60° max. sensitivity angle

S = potentiometer setting

Z_p = primary ohms per phase for which precise timing is desired

.75 = the fraction of relay reach at which the time TD is defined

RC = current transformer ratio

R_V = potential transformer ratio

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

1. Select the value of T that is nearest to but not greater than Z_R.
2. Determine the proper value of S by dividing Z_R by T.

For example, assume Z_{pri} from location A to location C equals

5.16 $\angle 73°$ ohms,

R_C = 120/1, R_V = 240/1. Assume also that relay reach at 73° is the same as at 60°. (See Fig.8).

Then:

$$Z_R = \frac{5.16 \times 120}{.75 \times 240}$$

$$= 3.44 \text{ ohms}$$

Select T = 3.2

$$S = \frac{Z_R}{T} = \frac{3.44}{3.2}$$

$$= 1.07$$

SETTING THE RELAY

The SD-2 relay requires setting for six compensator primaries, T, on the tap plate and for three potentiometer settings (S_A, S_B, and S_C), on the dial plate. Set all the T taps for the same values (two settings per scale) and set potentiometers S_A, S_B, and S_C for the same S value.

Potentiometer TI should be set for the fixed time tF. Then TD_A so that TD_A + TI equals the desired trip time t_s for faults at C. TD_B, TD_C should be set for the same value as TD_A.

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 tripping directly, use the 2 ampere tap. When tripping through an auxiliary relay, use the 0.2 ampere tap.

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 grounding relay. The electrical connections may be made directly to the terminals by means of screws for steel 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.

EXTERNAL CONNECTIONS

Figure 13 shows the connections for two zones of protection. Here a type KD-4 relay is used for first zone instantaneous fault detection and the type SD-2 relay is used for second zone time-distance delayed operation.

RECEIVING ACCEPTANCE

Check the electrical response of the relay by using test connections shown in Figure 14. Note that 3 phase voltages are used. The unfaulted phase voltages are required to prevent those phase units from tripping while receiving fault current in one primary winding of each of the delta-connected compensators. Set all six taps for 12.8; S_A, S_B, and SC for 1; TD_A, TD_B, TD_C, and TI for minimum time delay.

A. RELAY REACH

Use connection for test No. 1 and adjust voltage V_{1F2F} for 60 volts. The current required to make the relay trip should not be less than 2.3 amperes at the maximum sensitivity angle of 60° current lagging voltage. (V_{LL} = line-to-line voltage, Z_R = relay setting in ohms.) This test should be repeated using connections for test No. 2 and 3 after completing the time distance delay tests in part B below.

B. TIME DISTANCE DELAY

Set TD_A for a specific time delay such as 3 seconds. Adjust the trip current to 3.13 amperes, i.e., $(\frac{V_{LL}}{2 \times 75\% Z_R})$ at 60° lag. With V_{1F2F} set for 60 volts, check the time required for the relay to trip after suddenly applying current. This time should be within 10% of the TD_A setting. Set TD_B and TD_C with connections for test No. 2 and test No. 3 respectively.

C. TI TIME ADDER DELAY

Use any one of the three test connections in Figure 14. Set TD_A, TD_B, and TD_C for a minimum time delay. Adjust the current to 9.4 amperes i.e., $(\frac{V_{LL}}{2 \times 25\% Z_R})$. With V_{1F2F} set for 60 volts, check the time required for the relay to trip after suddenly applying current. This is TD, Time-Distance, delay.

Now set TI to some specific value such as .5 seconds and repeat the timing test to record total time to trip. This should be TD + (TI ± 5%).

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 1.0 ampere unit between the bridging moving contact and the adjustable stationary contacts. The bridging 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 and identify the part by its designation on the internal schematic drawing, as well as all information in the Electrical Parts List.

ELECTRICAL PARTS LIST

BRIDGES AND DIODES = HC69

D5 = 1N482A LOW LEAKAGE DIODE

CAPACITORS

C1 = 2MFD
C2 = C5 = 4MFD
C3 = 12MFD
C4 = 68MFD
C6 = 100MFD
C7 = 0.25MFD
C8 = 2MFD

POTENTIOMETERS

† P1 = END POT. 750 OHMS, 4W
P2 = 100K OHMS, 4W
P3 = 50K OHMS, 3W
† P4 = MIDDLE POT. 1000 OHMS, 4W
† P5 = NEAREST TO SHAFT 500 OHMS, 4W
† ON COMMON SHAFT

RESISTORS

R1 = 1060 OHMS, 25W
R3 = 750 OHMS, ½W
R4 = 330 OHMS, ½W
R5 = 22K OHMS, ½W
R6 = 47K OHMS, ½W
R7 = 18K OHMS, ½W

RESISTORS (Continued)

R8 = 2500 OHMS, 25W
R9 = 560 OHMS, ½W
R10 = R20 = 820 OHMS, ½W
R11 = 1000 OHMS, 3W
R12 = 560 OHMS, ½W
R13 = 220 OHMS, ½W
R14 = 39K OHMS, ½W
R15 = 3900 OHMS, 3W
R16 = 1000 OHMS, 3W
R17 = 15K OHMS, 1W
R18 = 350 OHMS, 3W
R19 = 3900 OHMS, ½W

TELEPHONE RELAY

SD-2 = 750 OHMS

TRANSISTORS

TR1 = TI-481
TR2 = TR3 = TI-495
TR4 = 2N335
TR5 = 2N332

ZENER DIODES

Z1 = 1N1832C, CLIPPER, 62V ± 10%
Z2 = 1N1824A, 30V ± 5%
Z3 = 1N3029, 24V ± 20%

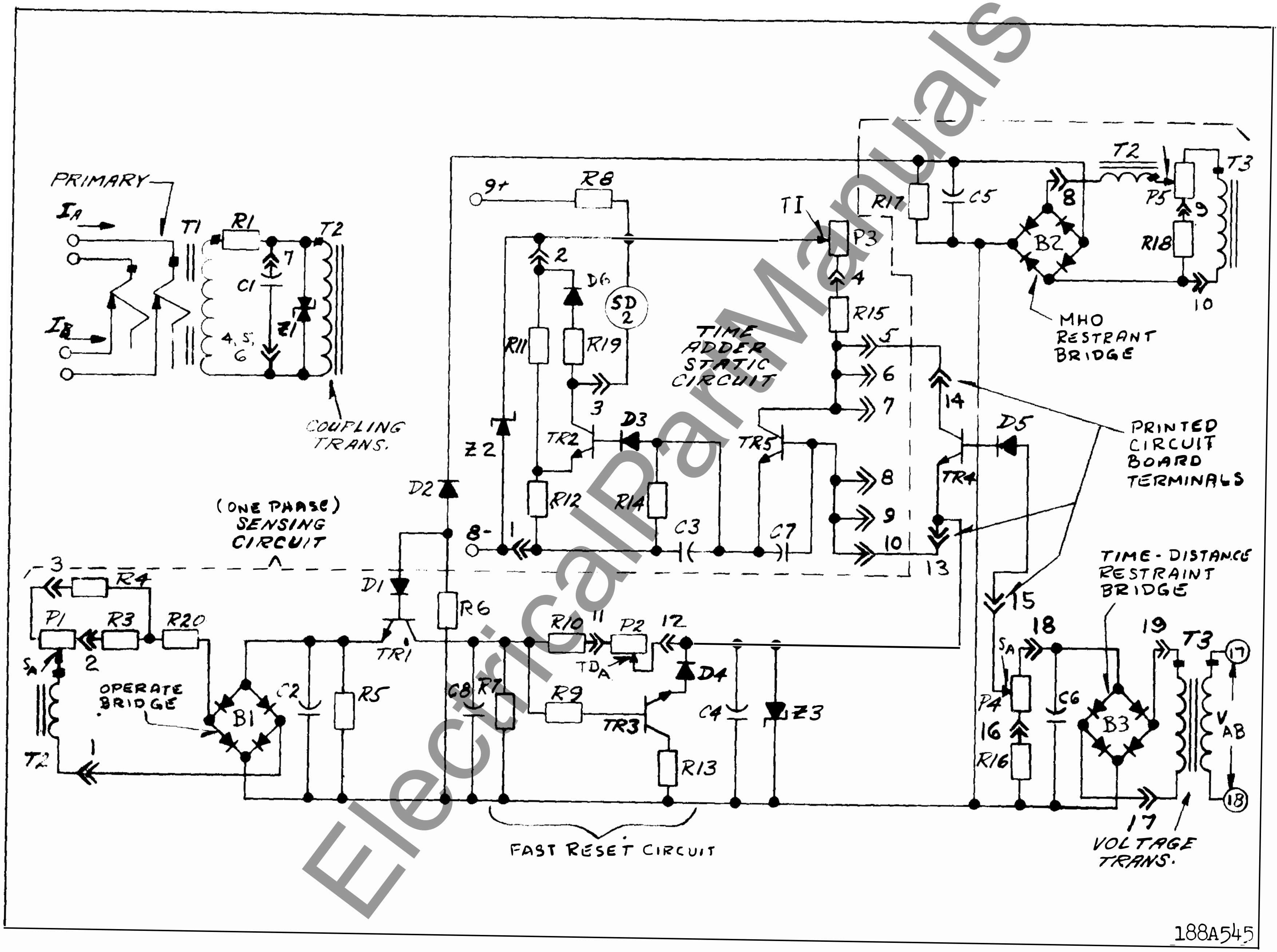


Fig. 4 Elementary Schematic for One Phase in the SD-2 Relay.

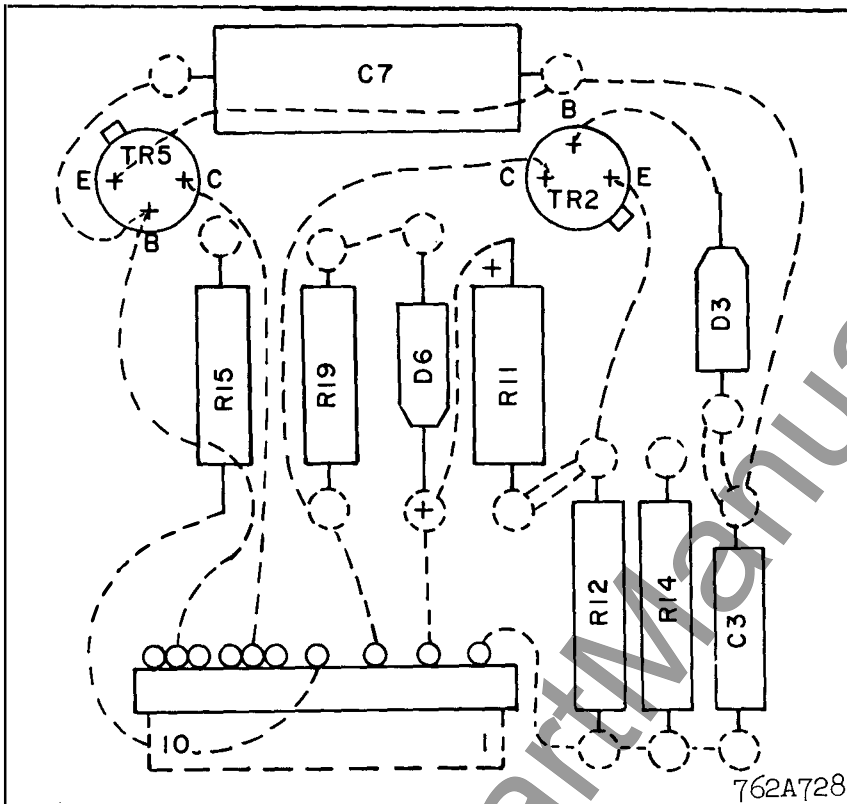


Fig. 5 Printed Circuit Assembly for Time Adder Circuit in the SD-2 Relay.

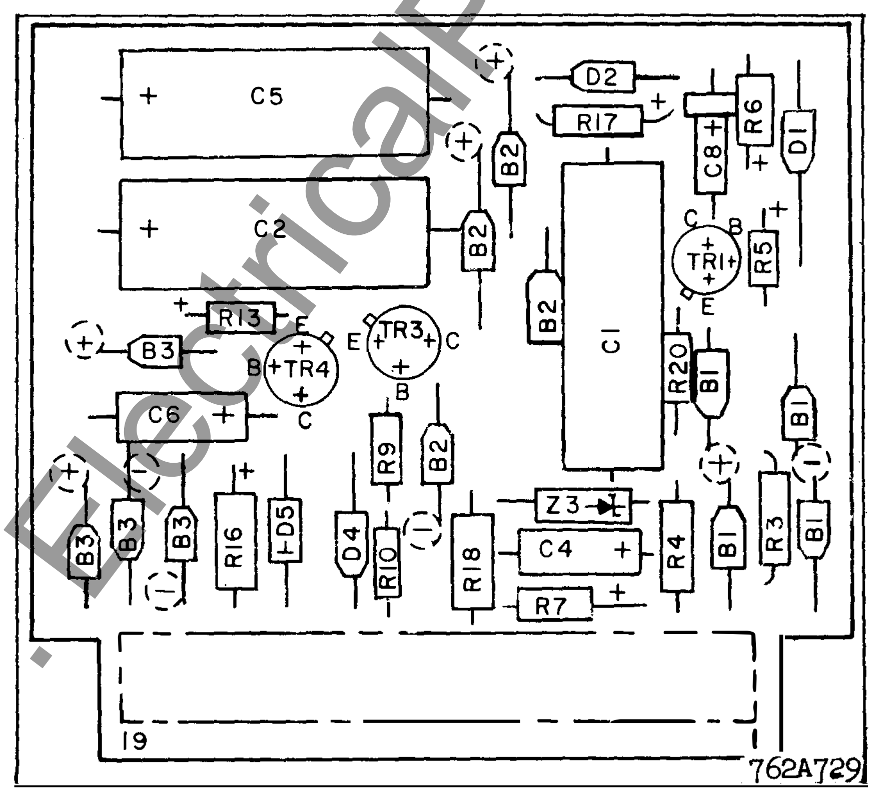


Fig. 6 Printed Circuit Assembly for Sensing Circuit in the SD-2 Relay (one phase).

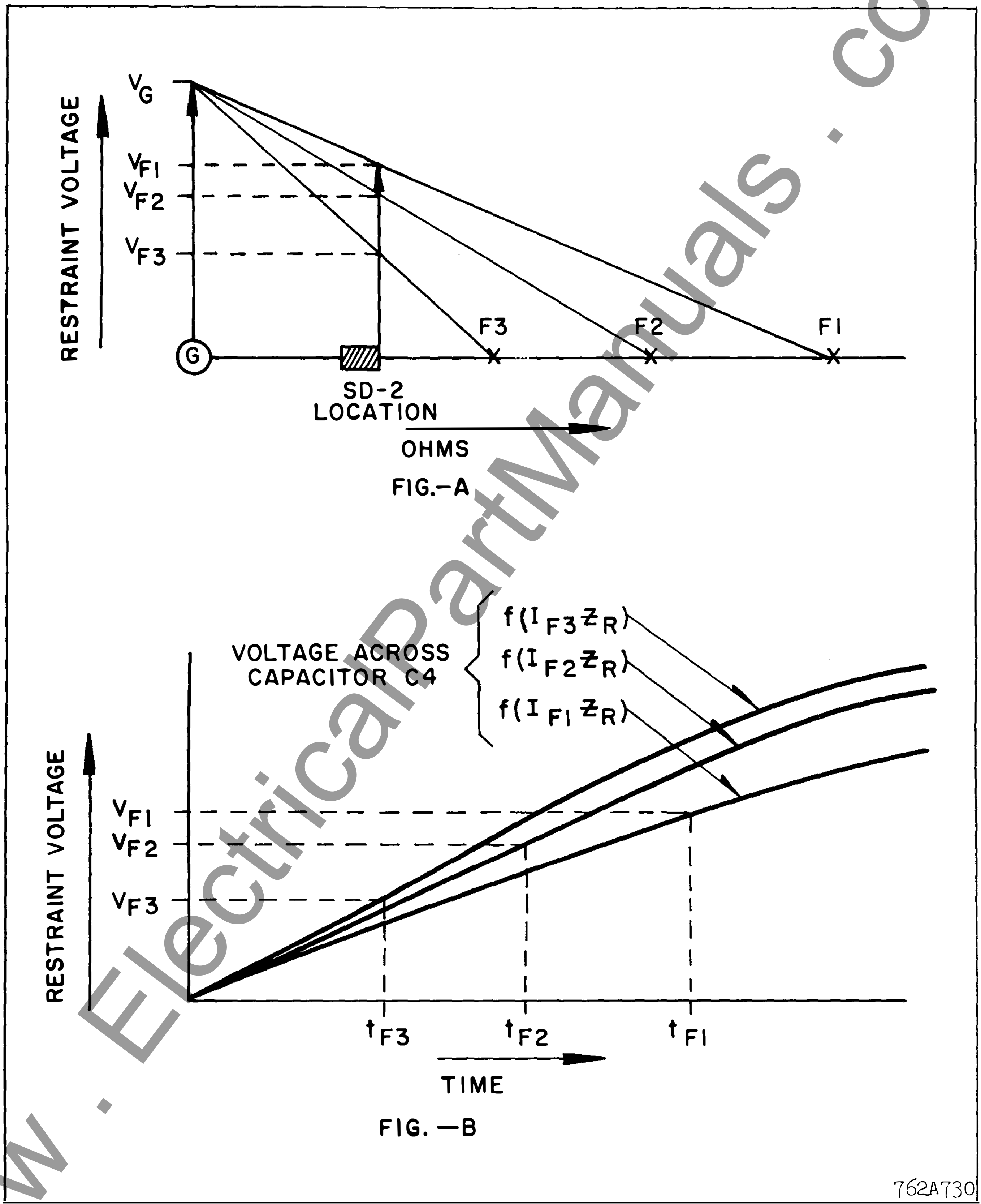


Fig. 7 Principle of the Time Distance Timer (A-Voltage with Respect to Distance) (B-Time with Respect to V).

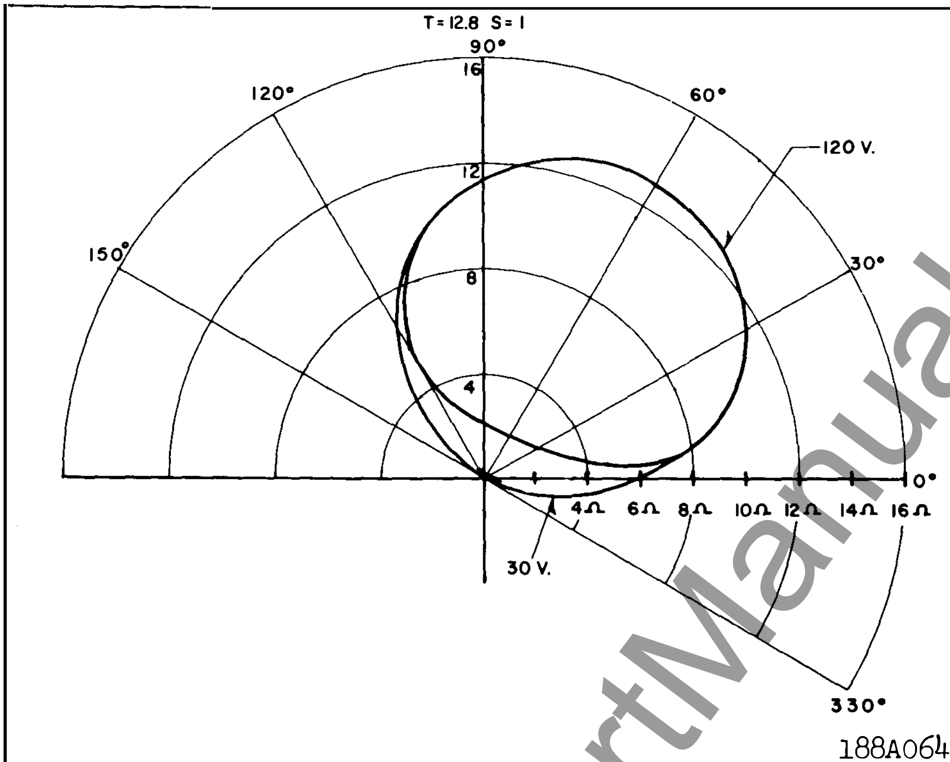


Fig. 8 Impedance Circles for the SD-2 Relay.

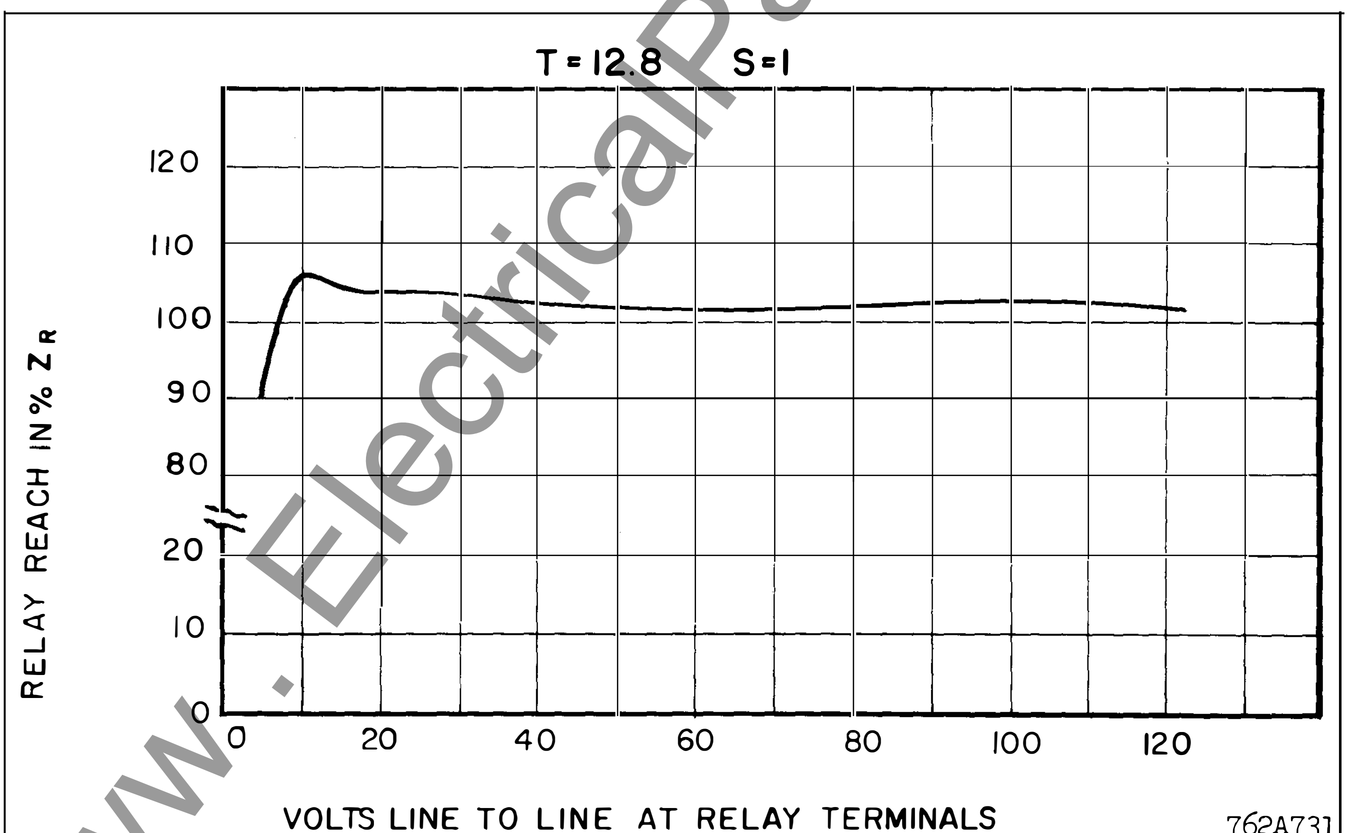


Fig. 9 Impedance Curves for the SD-2 Relay.

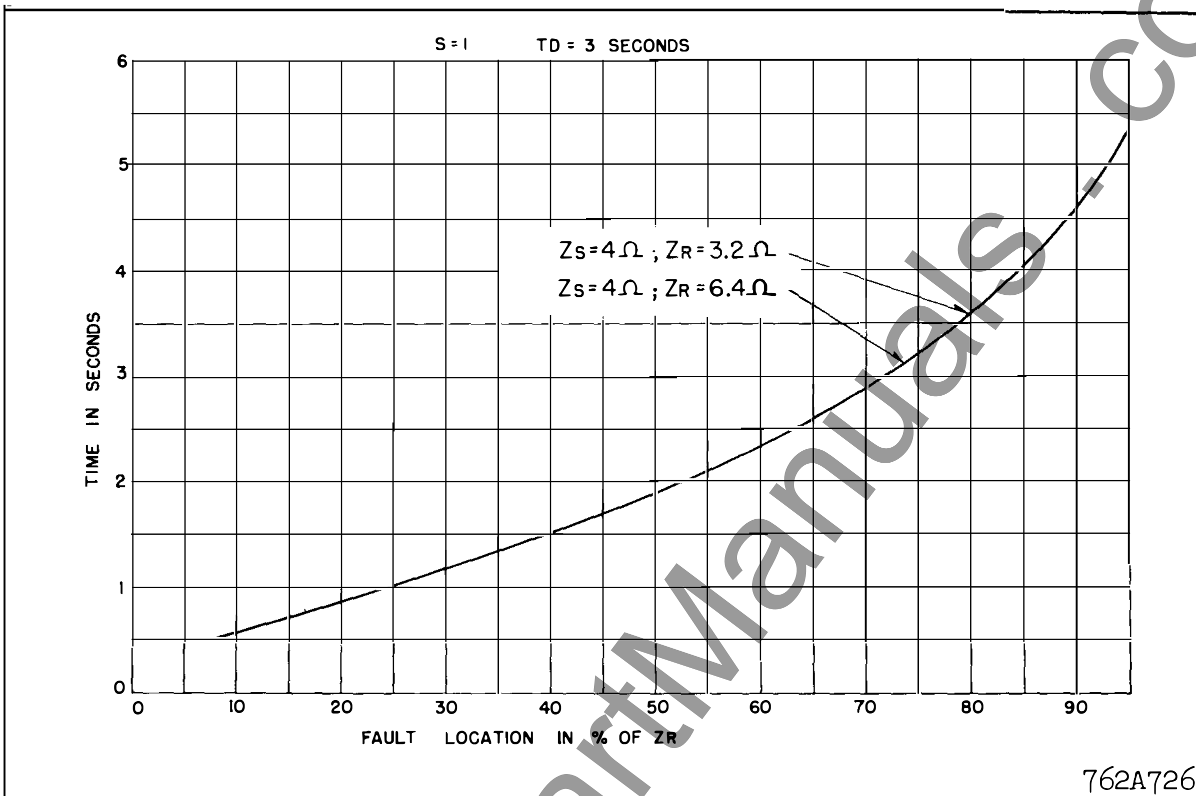


Fig. 10. Typical Operating Time Curves of the SD-2 Relay.

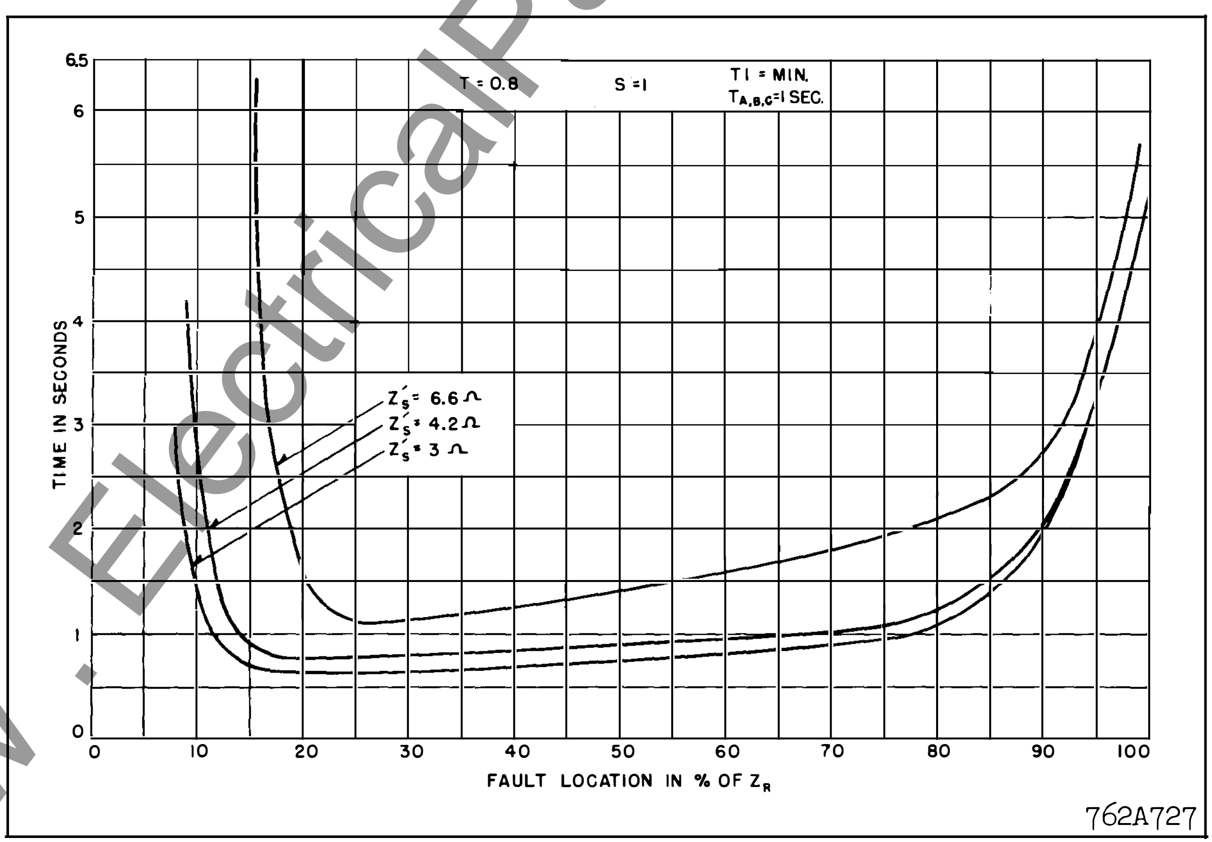


Fig. 11 Typical Operating Time Curves for Low Energy Faults.

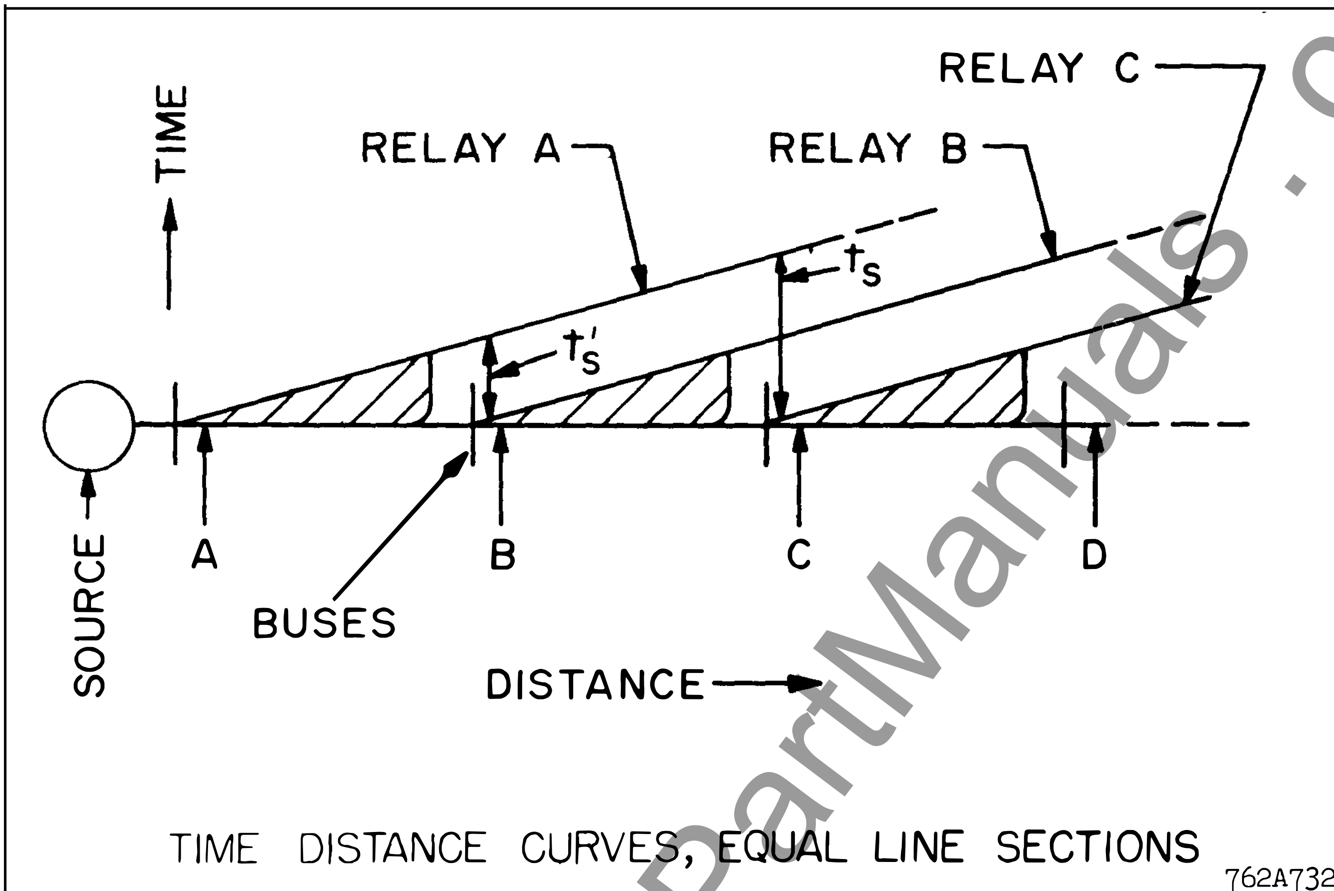


Fig. 12 Coordinating Curves for the SD-2 Relay.

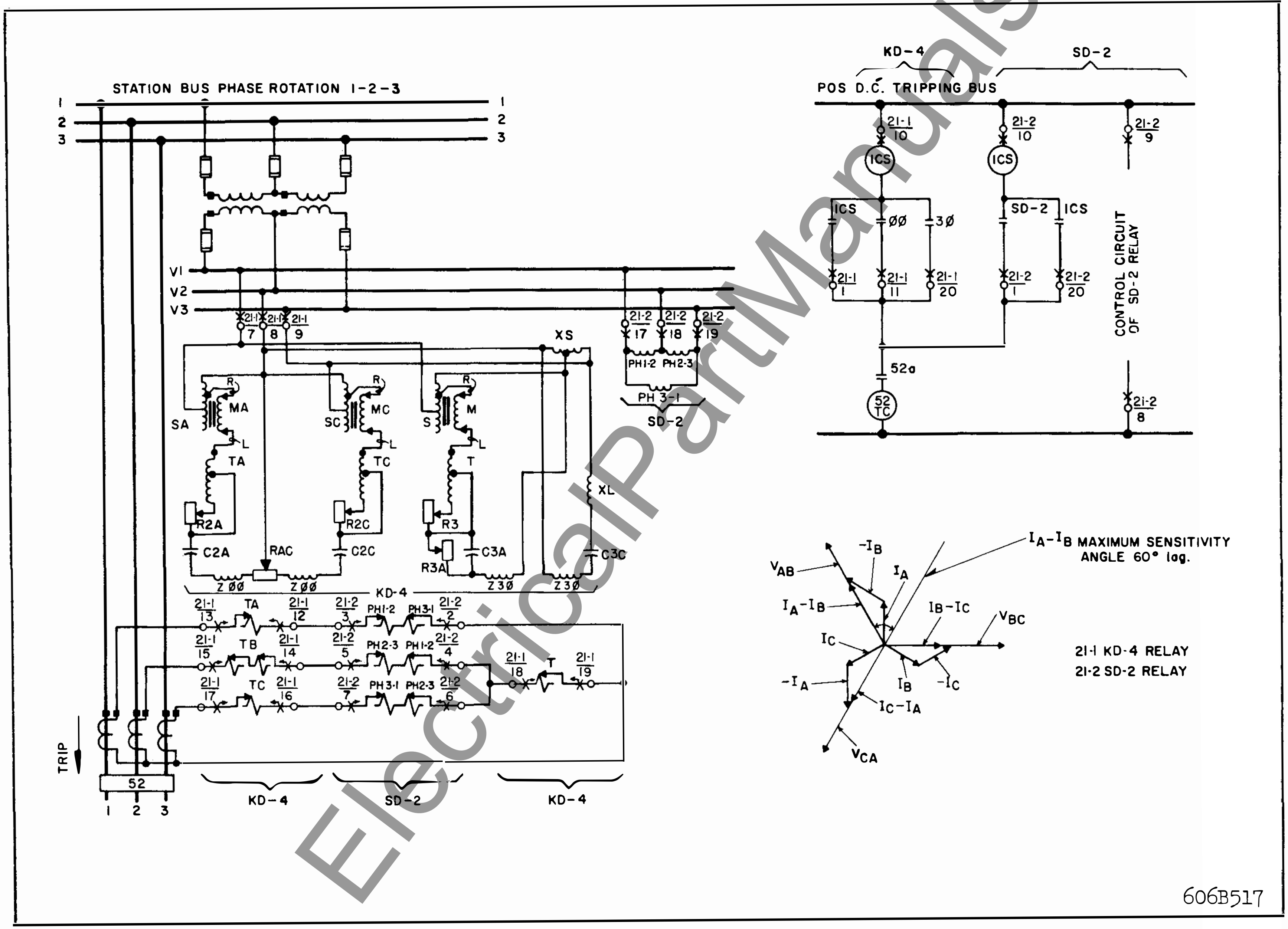
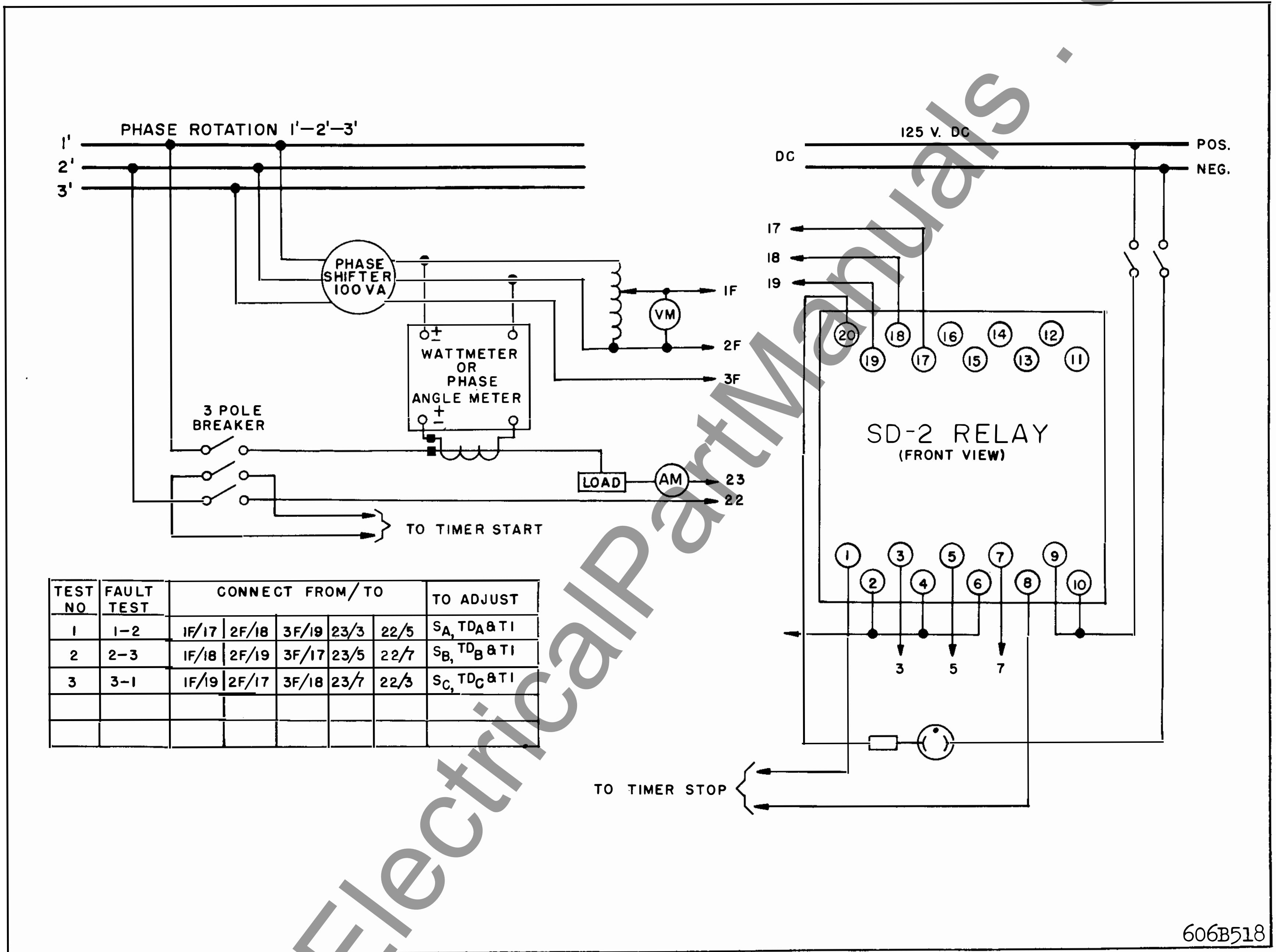


Fig. 13 External Schematic of the SD-2 Relay with Type KD-4 Relay First Zone.



TEST NO	FAULT TEST	CONNECT FROM/TO					TO ADJUST
1	1-2	1F/17	2F/18	3F/19	23/3	22/5	S_A, TD_A & TI
2	2-3	1F/18	2F/19	3F/17	23/5	22/7	S_B, TD_B & TI
3	3-1	1F/19	2F/17	3F/18	23/7	22/3	S_C, TD_C & TI

Fig. 14 Test Connections for the SD-2 Relay.

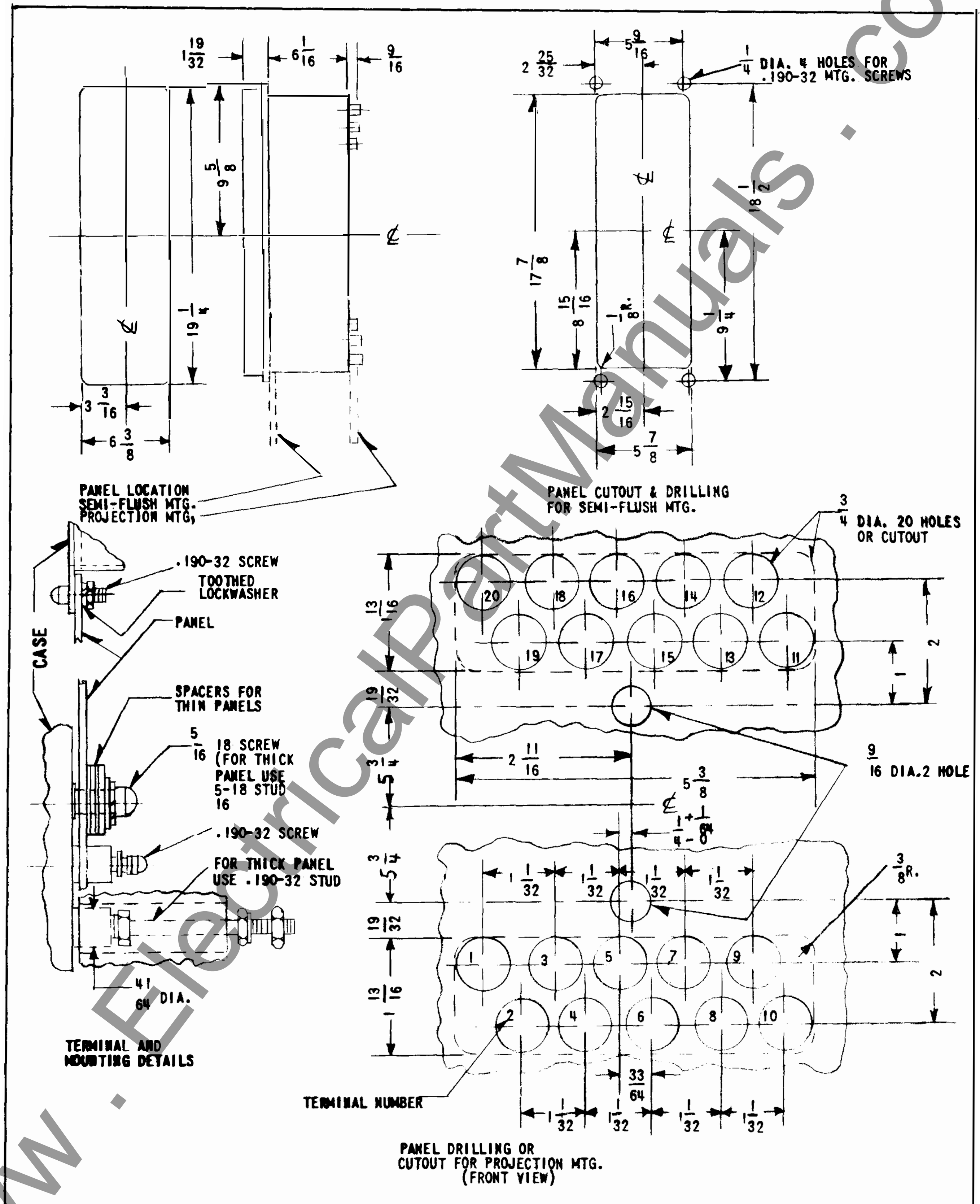


Fig. 15 Outline & Drilling Plan for the SD-2 Relay in the FT-42 Case.

WESTINGHOUSE ELECTRIC CORPORATION

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

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The type SD-2 relay provides time-proportional-to-distance tripping for all combinations of phase-to-phase, two phase-to-ground, and three phase faults. It can be set to any value of reach from 0.8 ohms to 25.6 ohms. Time-proportional-to-distance delays of .5 to 5.0 seconds for faults at 75% of the relay setting can be set with the time scale in addition to fixed time delays of from .05 to .5 seconds.

CONSTRUCTION

The type SD-2 relay contains an ICS indicating contactor switch, a single output telephone type relay and a complete set of components for each of the three phases. Each set of components consists of an air-gap transformer (compensator), a coupling transformer, a voltage transformer, and a static sensing circuit with a transistor output which controls a timing circuit.

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Compensators are three winding air-gap transformers. The double wound primary, or current winding, has five taps per winding which terminate at the tap block. They are marked .8, 1.6, 3.2, 6.4, and 12.8 (Figure 2). Current flowing through each of the primary coils comes from different phases and produces magnetic lines of flux in the core which is proportional to delta current.

A voltage is induced in the secondary which is proportional to the primary tap settings and current magnitudes. This voltage is then applied to the coupling transformer which operates to compensate the voltage as well as provide an operate and a timing quantity.

COUPLING TRANSFORMER

The coupling transformer is a three winding unit with a single primary and two secondaries. It is designed to saturate in the presence of high fault currents and thereby limit the magnitude of voltage applied to the static sensing and timing circuits. The two secondaries are equal. One is connected to the operate side of a sensing and timing network and permits the relay to start timing when the operate quantity exceeds the magnitude of the restraint quantity produced by compensated voltage. The other is connected subtractively in series with the voltage to provide compensation and thereby produces the restraint quantity.

VOLTAGE TRANSFORMER

The voltage transformer is a three winding isolating transformer which reduces the applied restraint voltage to a level within the rating of the static sensing and timing circuit. Voltage of the restraint quantity in the distance measuring circuit is adjusted by means of a potentiometer designated as S_A, S_B, or S_C. The potentiometer shown in Figure 2 has a dial calibrated between the values of 1.0 and 2.0 and is used in setting the relay reach.

TIMING CIRCUIT

The timing circuit contains a potentiometer in series with a capacitor. Charging of the timing capacitor is accomplished by the operate quantity and is supervised by the sensing circuit. When voltage across the timing capacitor exceeds the voltage output of the potential transformer, a circuit is energized to operate the telephone relay.

The three potentiometers used for setting time delay are designated TD_A, TD_B, and TD_C. They have calibrated scales which are marked in major divisions of .5, 1.0, 2.0, 3.0, 4.0, and 5.0 seconds as shown in Figure 2. The scales indicate time required for the relay to trip for faults at 75% of the relay setting.

An additional single potentiometer designated TI is used to add a fixed delay to the operating time. TI has a calibrated scale marked in major divisions of .05, .1, .2, .3 and .5 seconds. This is fixed time delay and does not vary with fault location.

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✪ Denotes changes since previous issue.

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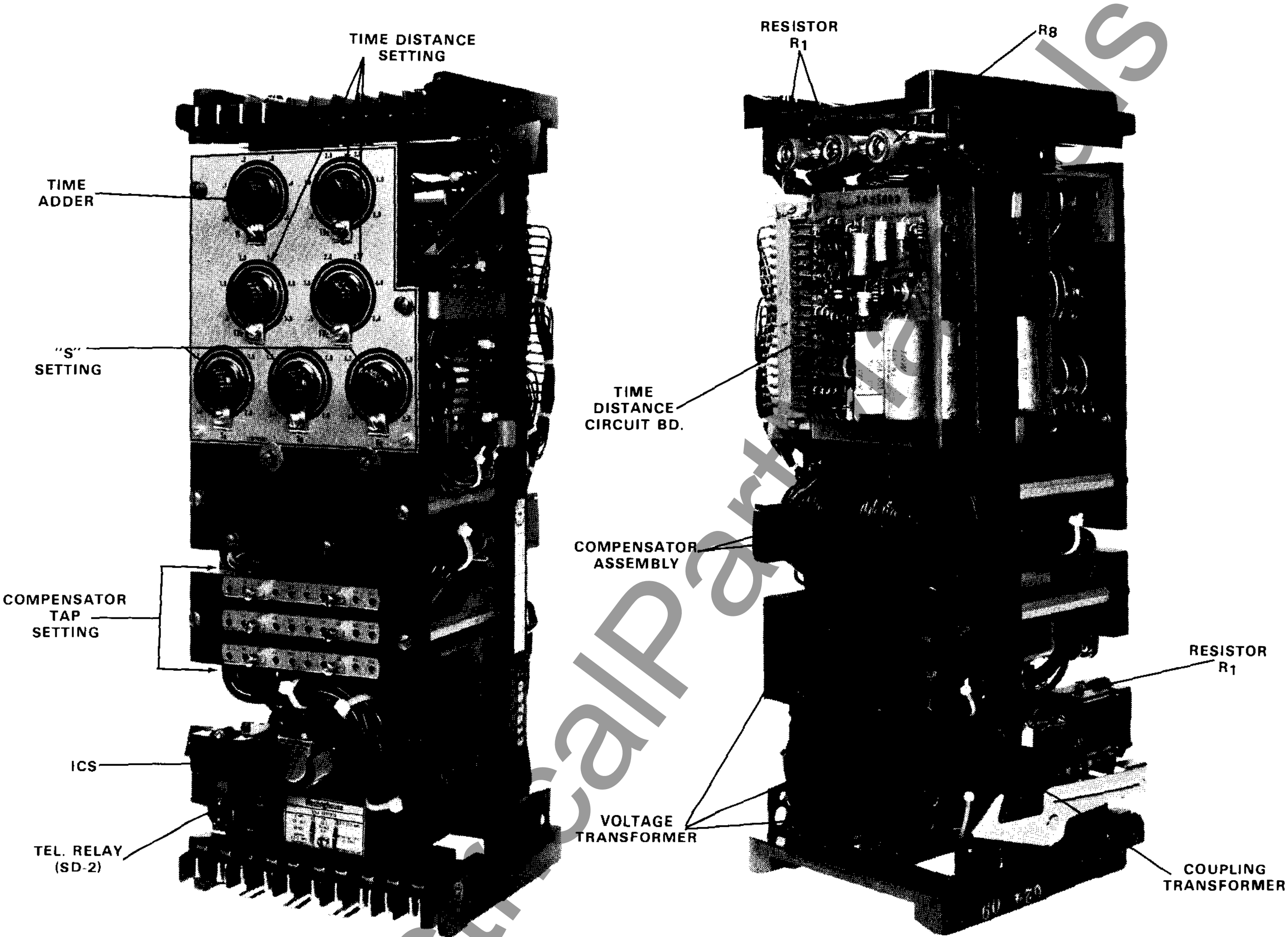


(Front View) *(Rear View)*

Fig. 1. Type SD-2 Relay without case.

INDICATING CONTACTOR SWITCH UNIT (ICS)

The indicating contactor switch is a small dc 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 coil. 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

SD-2 relays contain three single-phase circuits (Figure 3) which operate independently to protect each phase. The three circuits are identical, so a description of one is applicable to all three.

TIMER ADDER CIRCUIT

As shown in Fig. 4, the output telephone relay SD-2 is energized when transistor Q2 conducts. This is delayed by the RC timing circuit, P3, R15, R19 and the zener diode Z4 which is controlled by the transistor Q4 and Q5. When the transistor Q4 turns on, transistor Q5 turns off, and allows the capacitor C3 to charge up to the reference voltage of the zener diode and current flows through the base of the transistor Q2 to turn it on and cause the SD-2 telephone relay to pick up. When transistor Q4 turns off, transistor Q5 turns on, and capacitor C3 discharges through R19 and collector of transistor Q5 to ground and hence the telephone relay contact drops out.

TIME DISTANCE CIRCUIT

Transistor Q4 is normally biased off by the restraint voltage supplied by the B3 restraint bridge. This voltage is proportional to VAB and to the setting of P4. (Potentiometers P1, P4 and P5 are all on one shaft and are adjusted when making an SA setting). When capacitor C4 is permitted to charge from the operate bridge B1 to a level that exceeds the restraint voltage, Q4 becomes forward biased and therefore conducts. Capacitor C4 is part of an RC timing circuit which includes P2 and R10. Charging current can flow only when transistor Q1 conducts. Figure 6 shows the printed circuit assembly of the sensing circuit for one phase.

Operating principles of the time distance timer are illustrated in Figures 7a and 7b. In Figure 7a, voltage V_G is the generated voltage. At the SD-2 location restraint voltages V_{F1}, V_{F2} and V_{F3} result from faults at F1, F2, and F3 respectively. Figure 7b illustrates how the voltage across capacitor C4 increases with time and reaches a final level which is a function of the compensator output and is expressed in the figure as $I_F\ (I_F Z_R)$. I_F is the equivalent compensator primary current and Z_R is the compensator setting in ohms. It can be seen that the time required for the restraint voltage to be exceeded is less for a fault at F3 than it is for a fault at location F1. The time is proportional to the distance from the relay to the fault location.

MHO SUPERVISING CIRCUIT

Transistor Q1 is normally biased off by voltage from the B2 restraint bridge. This voltage, which appears across R6 is normally greater than the operate voltage from bridge B1. When a fault occurs within the protected zone, the operate voltage of B1 exceeds the restraint of B2. Q1 is then switched on by B1 current flowing through R6, D1, and Q1 base.

B1 input voltage is a function of delta current and potentiometer P1 setting, B2 input voltage is compensated and is a function of potentiometer P5 setting and line voltage minus a current derived voltage. This is expressed as $f(V - I_F Z_R)$ where V is the output of voltage transformer T3 and $I_F Z_R$ is the output of coupling transformer T2.

CHARACTERISTICS

PHASE ANGLE RESPONSE

Impedance circles in Figure 8 indicate the phase angle response. Here, relay reach in ohms is plotted at various angles of current lagging voltage for constant voltages at the relay terminals.

BALANCE POINT ACCURACY

The accuracy with which the SD-2 relay determines the threshold between a trip condition and a non-trip condition is illustrated by the impedance curve in Figure 9. This is a record of points at which the relay just trips, plotted as per cent of relay setting ($\%Z_R$) vs. relay voltage under fault conditions. Z_R equals relay setting TS.

GENERAL CHARACTERISTICS

Impedance setting in ohms reach can be made for any value from 0.8 ohms to 25.6 ohms. The maximum sensitivity angle is designed for 60° current lagging voltage and is not adjustable. However, a slight shift in this angle might occur at various voltage levels as indicated in Figure 8.

Settings are made in discreet steps of .8, 1.6, 3.2, 6.4, and 12.8 ohms. Between tap settings are made by a potentiometer setting which acts as a multiplier. The potentiometer can be set for any value from 1 to 2.

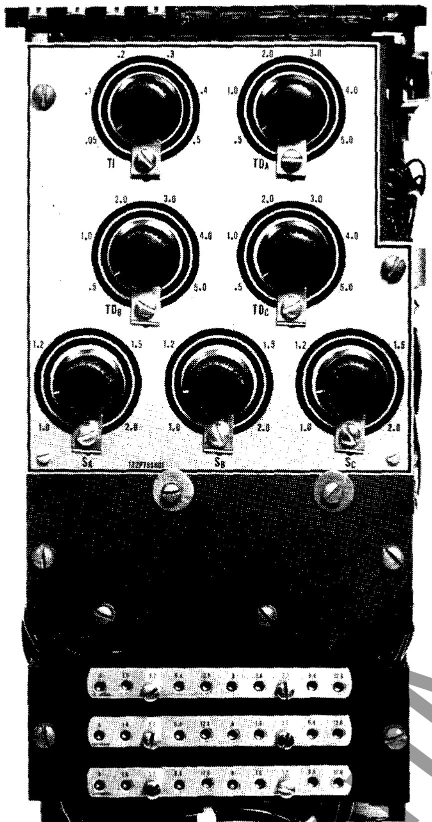


Fig. 2. Dial Plate & Taps for Relay Setting.

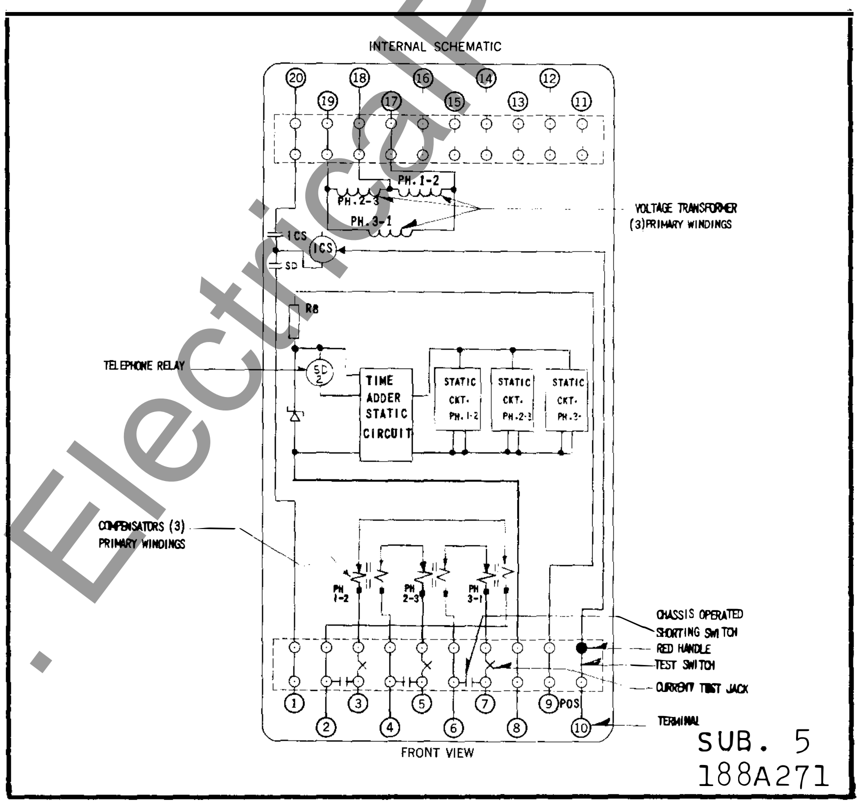


Fig. 3. Internal Schematic of SD-2 Relay with 1.0 Ampere ICS in the FT-42 Case. (Relay with 0.2/2.0 Ampere ICS unit has identical wiring except that the ICS coil is tapped on Terminal 10).

CURRENT BURDEN

TAP SETTING	5 AMPERES			50 AMPERES		
	VA/PHASE	OHMS	ANGLE	VA/PHASE	OHMS	ANGLE
.8	1.55	0.062	30°	155	0.062	30°
1.6	1.83	0.073	30°	170	0.068	30°
3.2	2.65	0.106	30°	190	0.076	30°
6.4	3.35	0.134	30°	325	0.130	42°
12.8	10.2	0.406	30°	680	0.272	47°

TIME CURVES AND BURDEN DATA

OPERATING TIMES

The speed of operation of the SD-2 relay is shown by the time curves in Figure 10. The curves indicate the time in seconds required for the relay to trip after the inception of a fault within the protected section. The time dial TD is based on a fault located at 75% of the relay setting Z_R. Note in Figure 11 that the SD-2 relay will not trip for close-in low energy faults because the internal circuits do not receive sufficient energy for proper operation.

BURDEN

The burden which the relay imposes upon current transformers is listed for each tap setting when 5 amperes current is flowing.

VOLTAGE BURDEN

S Setting	Volt Amperes per Phase ($V = 69.4\ V_{L}$-N)
1	4.16 VA, 0°
2	4.03 VA, 0°

TRIP CIRCUIT CONSTANTS

1 ampere rating:	0.1 ohms dc resistance
0.2/2.0 ampere rating:	0.2 tap - 6.5 ohms
	2 tap - 0.15 ohms

SETTING CALCULATIONS

An application of the type SD-2 relay is illustrated in Figure 12. Here, a source of power is shown at the left energizing two adjacent line sections with relays at points A, B, and C. The distance in ohms between relay locations is plotted horizontally, and the time of operation is plotted vertically. The time-distance characteristics of the relays are plotted as straight lines sloping upwardly from left to right.

Considering the relay at location A, a time of operation t_s' is allowed for clearing a fault at location B. A time t_s is allowed to clear a fault at location C. By drawing a straight line from t_s through t_s' and extending it to a vertical line at A, the intersection at A determines the value of fixed time, t_F, necessary to provide the desired time-distance characteristics.

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

$$Z_R = Z_p\left(\frac{R_C}{.75\ R_V}\right)$$

Z_R = TS = the desired ohmic reach of the relay in secondary ohms

T = compensator tap value at 60° max. sensitivity angle

S = potentiometer setting

Z_p = primary ohms per phase for which precise timing is desired

.75 = the fraction of relay reach at which the time TD is defined

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.

1. Select the value of T that is nearest to but not greater than Z_R.
2. Determine the proper value of S by dividing Z_R by T.

For example, assume Z_{pri} from location A to location C equals

5.16 $\angle 73°$ ohms,

R_C = 120/1, R_V = 240/1. Assume also that relay reach at 73° is the same as at 60°. (See Fig. 8).

Then:

$$Z_R = \frac{5.16 \times 120}{.75 \times 240}$$

$$= 3.44 \text{ ohms}$$

Select T = 3.2

$$S = \frac{Z_R}{T} = \frac{3.44}{3.2}$$

$$= 1.07$$

SETTING THE RELAY

The SD-2 relay requires setting for six compensator primaries, T, on the tap plate and for three potentiometer settings (S_A, S_B, and S_C), on the dial plate. Set all the T taps for the same values (two settings per scale) and set potentiometers S_A, S_B, and S_C for the same S value.

Potentiometer TI should be set for the fixed time tF. Then TD_A so that TD_A + TI equals the desired trip time t_s for faults at C. TD_B, TD_C should be set for the same value as TD_A.

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 tripping directly, use the 2 ampere tap. When tripping through an auxiliary relay, use the 0.2 ampere tap.

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 grounding relay. The electrical connections may be made directly to the terminals by means of screws for steel 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.

EXTERNAL CONNECTIONS

Figure 13 shows the connections for two zones of protection. Here a type KD-10 relay is used for first zone instantaneous fault detection and the type SD-2 relay is used for second zone time-distance delayed operation.

RECEIVING ACCEPTANCE

Check the electrical response of the relay by using test connections shown in Figure 14. Note that 3 phase voltages are used. The unfaulted phase voltages are required to prevent those phase units from tripping while receiving fault current in one primary winding of each of the delta-connected compensators. Set all six taps for 12.8; S_A, S_B, and SC for 1; TD_A, TD_B, TD_C, for TI for minimum time delay.

A. RELAY REACH

Use connection for test No. 1 and adjust voltage V_{1F2F} for 60 volts. The current required to make the relay trip should not be less than 2.3 amperes at the maximum sensitivity angle of 60° current lagging voltage. (V_{LL} = line-to-line voltage, Z_R = relay setting in ohms.) This test should be repeated using connections for test No. 2 and 3 after completing the time distance delay tests in part B below.

B. TIME DISTANCE DELAY

Set TD_A for a specific time delay such as 3 seconds. Adjust the trip current to 3.13 amperes, i.e., $(\frac{V_{LL}}{2 \times 75\% \; Z_R})$ at 60° lag. With V_{1F2F} set for 60 volts, check the time required for the relay to trip after suddenly applying current. This time should be within 10% of the TD_A setting. Set TD_B and TD_C with connections for test No. 2 and test No. 3 respectively.

C. TI TIME ADDER DELAY

Use any one of the three test connections in Figure 14. Set TD_A, TD_B, and TD_C for a minimum time delay. Adjust the current to 9.4 amperes i.e., $(\frac{V_{LL}}{2 \times 25\% \; Z_R})$. With V_{1F2F} set for 60 volts, check the time required for the relay to trip after suddently applying current. This is TD, Time-Distance, delay.

Now set TI to some specific value such as .5 seconds and repeat the timing test to record total time to trip. This should be TD + (TI $\pm$ 5%).

INDICATING CONTACTOR SWITCH (ICS)

Close the main relay contacts and pass sufficient dc current through the trip curcuit 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 1.0 ampere unit between the briding moving contact and the adjustable stationary contacts. The briding 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 and identify the part by its designation on the internal schematic drawing, as well as all information in the Electrical Parts List.

✪ ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NO.
RESISTORS		
R1	1060 Ohms 25 Watt	1262789
R8 (48VDC)	250 Ohms 25 Watt	5D1327H83
R8 (125VDC)	1800 Ohms 25 Watt	1201004
R8 (250VDC)	4000 Ohms 40 Watt	1334003
R14 – R21	10 K ½ Watt	629A530H56
R11 – R12	27 K ½ Watt	692A530H66
R19	27 Ohms ½ Watt	187A290H11
R15	1000 Ohms 3 Watt	763A127H02
R16	800 Ohms 3 Watt	184A859H06
R17	15K 1 Watt	187A644H55
R18	350 Ohms 3 Watt	184A636H02
R3	750 Ohms ½ Watt	184A764H24
R4	330 Ohms ½ Watt	184A764H15
R5	22 K ½ Watt	184A763H59
R6	47 K ½ Watt	184A763H67
R7	18 K ½ Watt	184A763H57
R9	560 Ohms ½ Watt	184A763H21
R10 - R20	820 Ohms ½ Watt	187A641H25
R13	220 Ohms ½ Watt	184A763H11
POTENTIOMETERS		
†P1	750 Ohms 4 Watt	188A333H02
P2	100 K 4 Watt	185A072H08
P3	50 K 3 Watt	185A072H07
†P4 Middle Pot	1000 Ohms 4 Watt	188A333H02
†P5 Nearest to Shaft	500 Ohms 4 Watt	188A333H02

† On common shaft

CIRCUIT SYMBOL	DESCRIPTION	WESTINGHOUSE STYLE NO.
DIODES		
D6	1N4818 200V 1500MA	188A342H06
D1,D2,D4,D7 to D18	1N4818 200V 1500MA	188A342H06
D5	1N482A 30V 200MA	184A855H04
TRANSISTORS		
Q2, Q5, Q3	2N3417	848A851H02
Q4	2N5306	3497A01H01
Q1	2N2102	762A585H09
ZENER DIODES		
Z4	1N752A 5.5V 400MW	186A797H12
Z3	1N3029 24V 1W	188A302H01
Z1	1N1832C 62V 10W	184A617H06
Z2	1N2989B 30V 10W	629A798H01
CAPACITORS		
C3	68 MFD 35V	187A508H02
C1	2 MFD 200V	764A278H13
C2	4 MFD 100V	837A192H02
C5	4 MFD 200V	184A662H06
C4	47 MFD 35V	187A508H12
C6	100 MFD 20V	184A761H04
C8	2 MFD 100V	184A759H10
Telephone Relay	750 Ohms	541D514H16

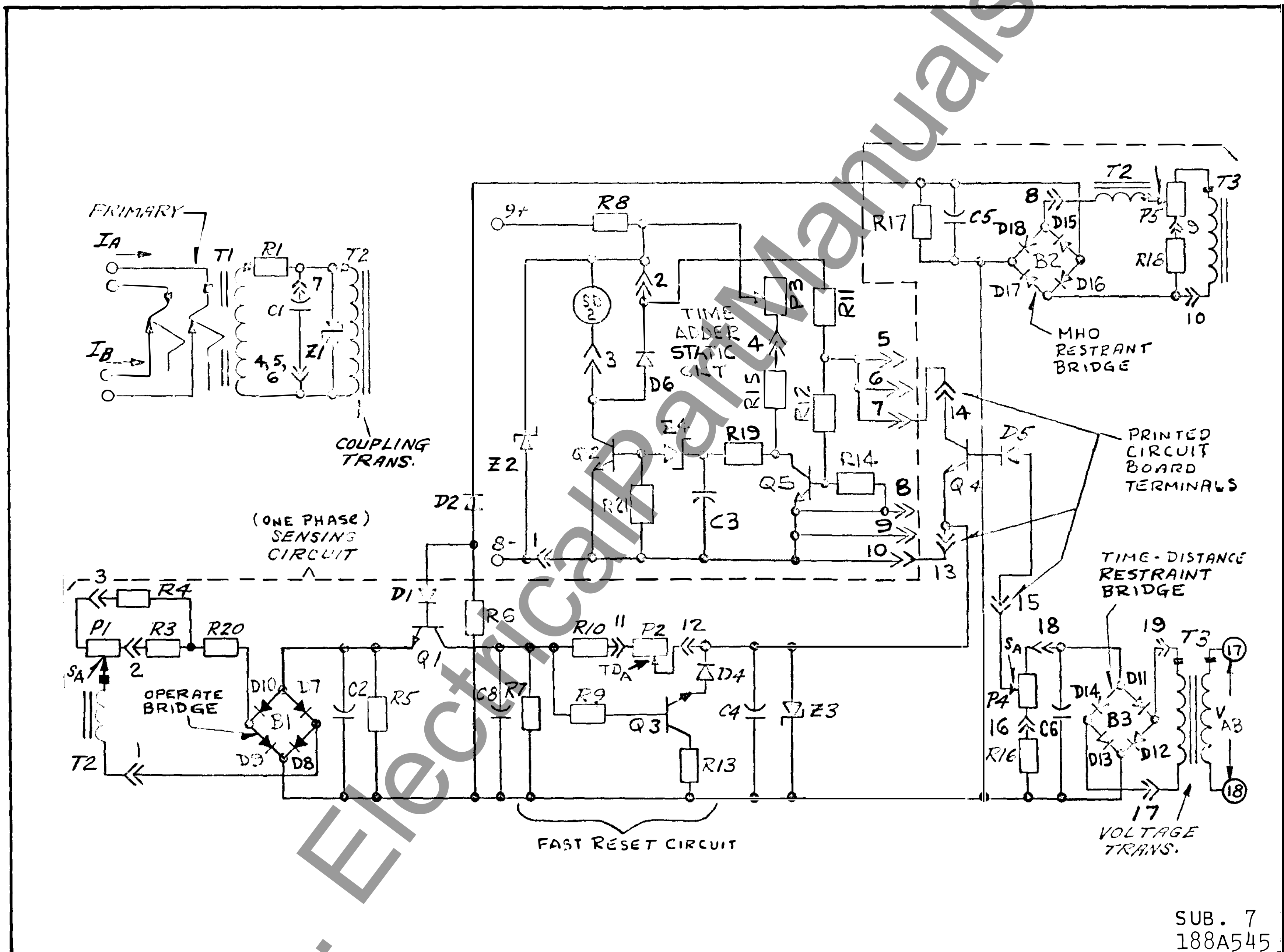


Fig. 4. Elementary Schematic for One Phase in the SD-2 Relay.

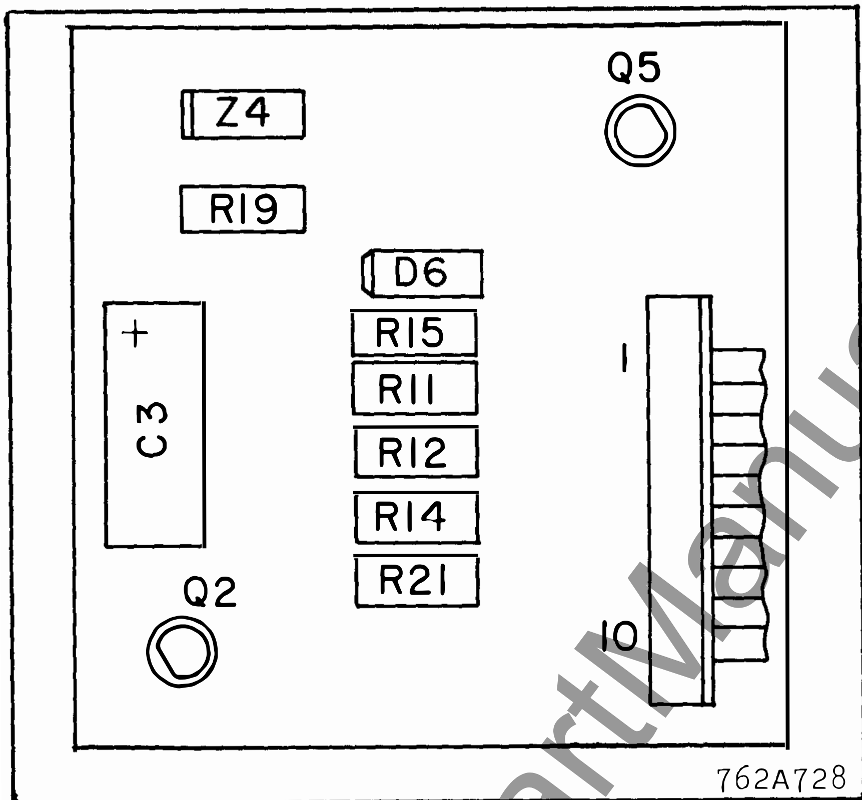


Fig. 5. Printed Circuit Assembly for Time Adder Circuit in the SD-2 Relay.

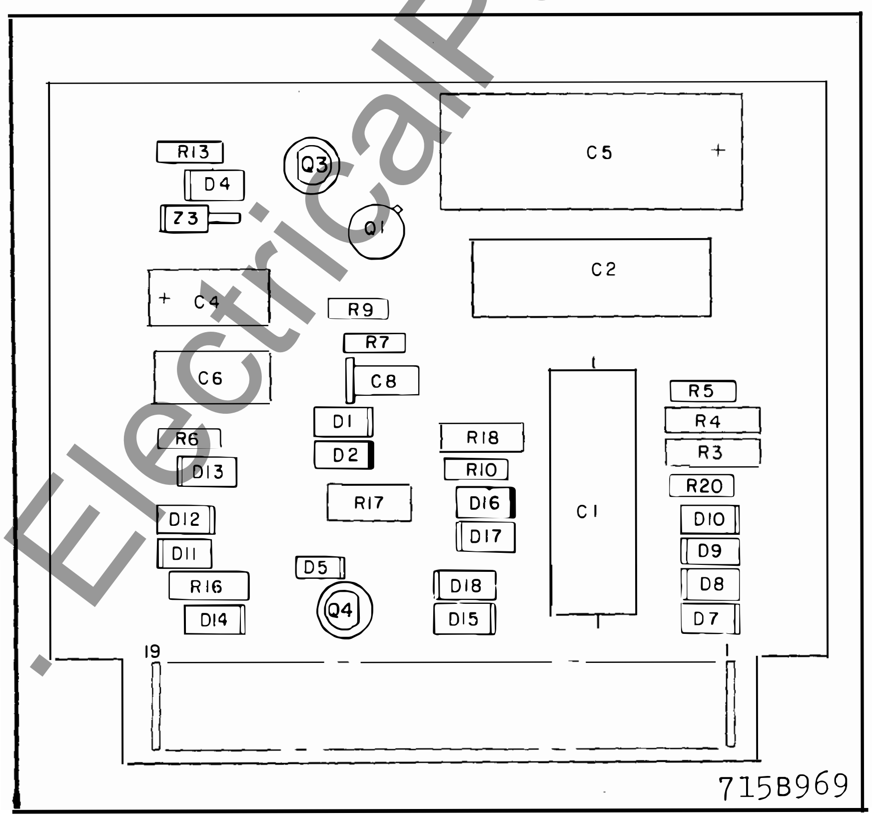


Fig. 6. Printed Circuit Assembly for Sensing Circuit in the SD-2 Relay (one phase).

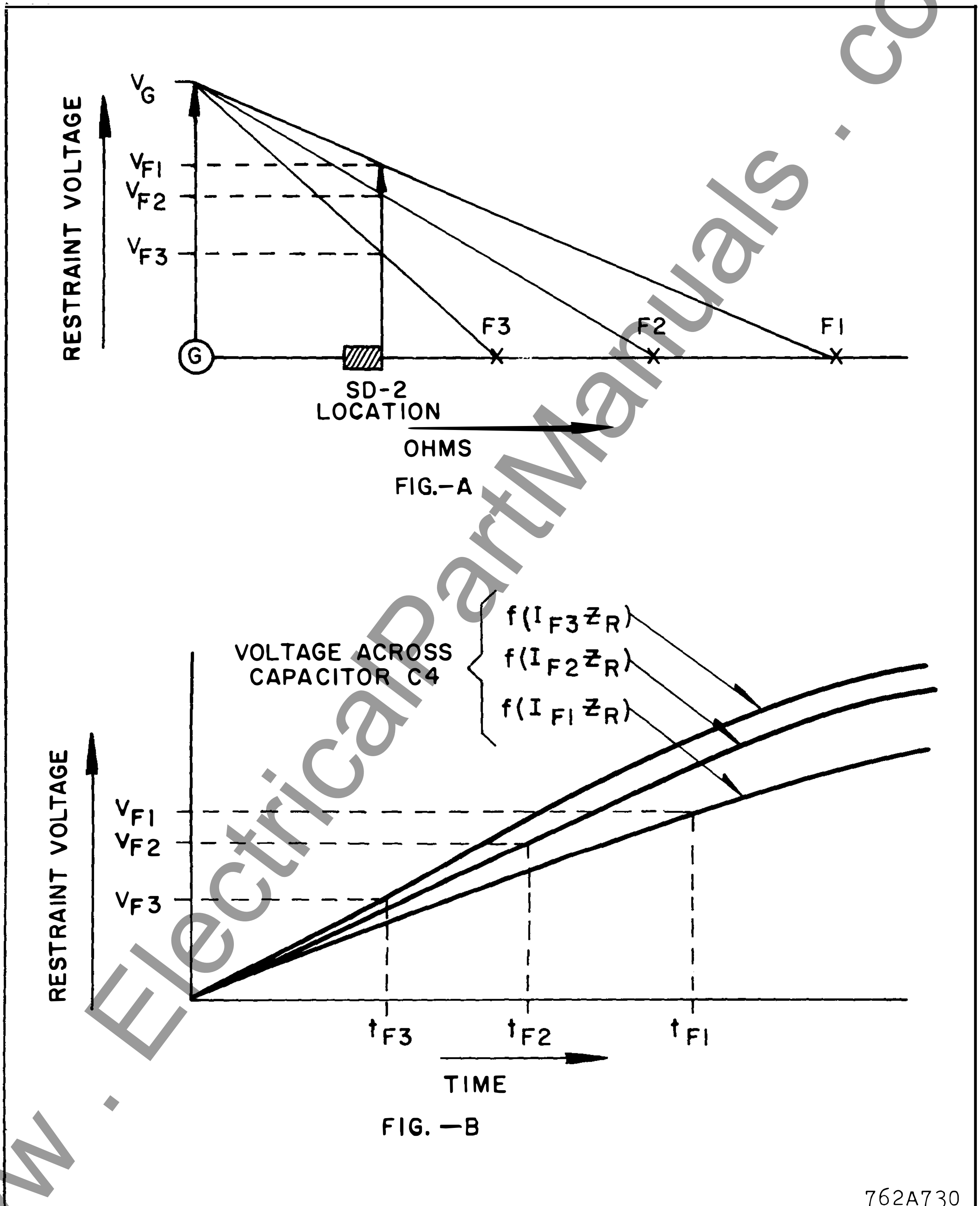


Fig. 7. Principle of the Time Distance Timer (A-Voltage with Respect to Distance) (B-Time with Respect to V).

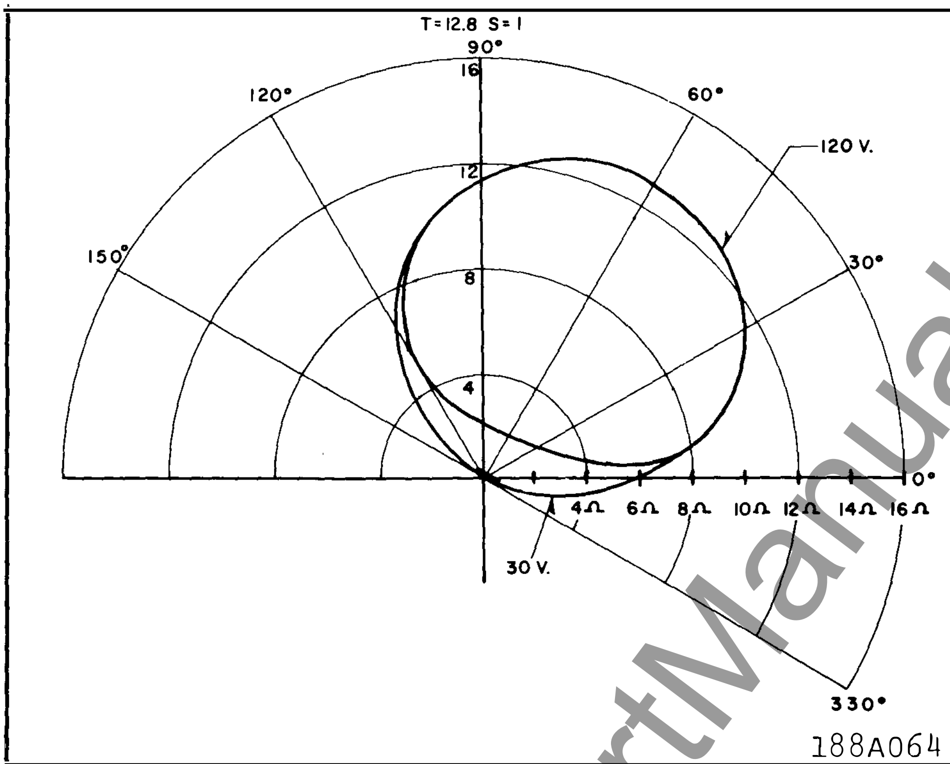


Fig. 8. Impedance Circles for the SD-2 Relay.

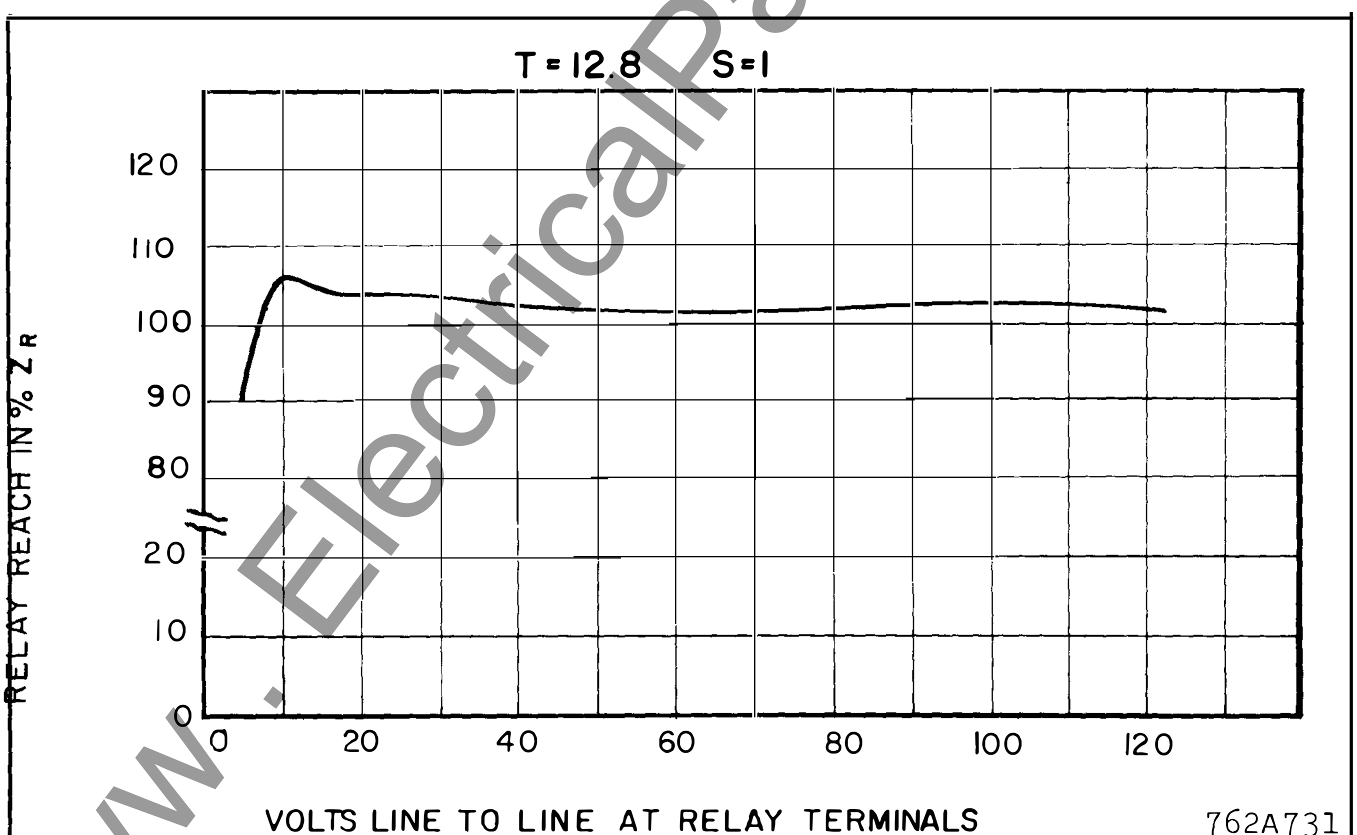


Fig. 9. Impedance Curves for the SD-2 Relay.

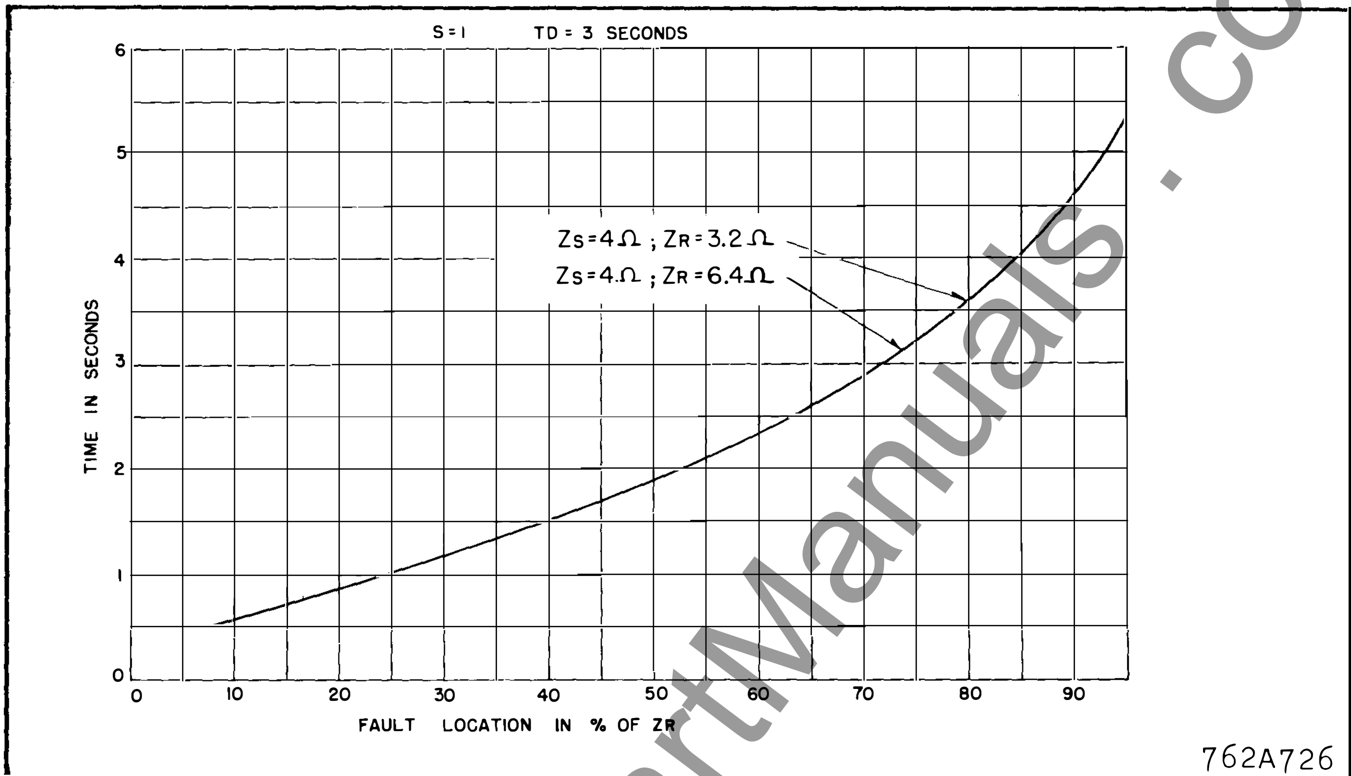


Fig. 10. Typical Operating Time Curves of the SD-2 Relay.

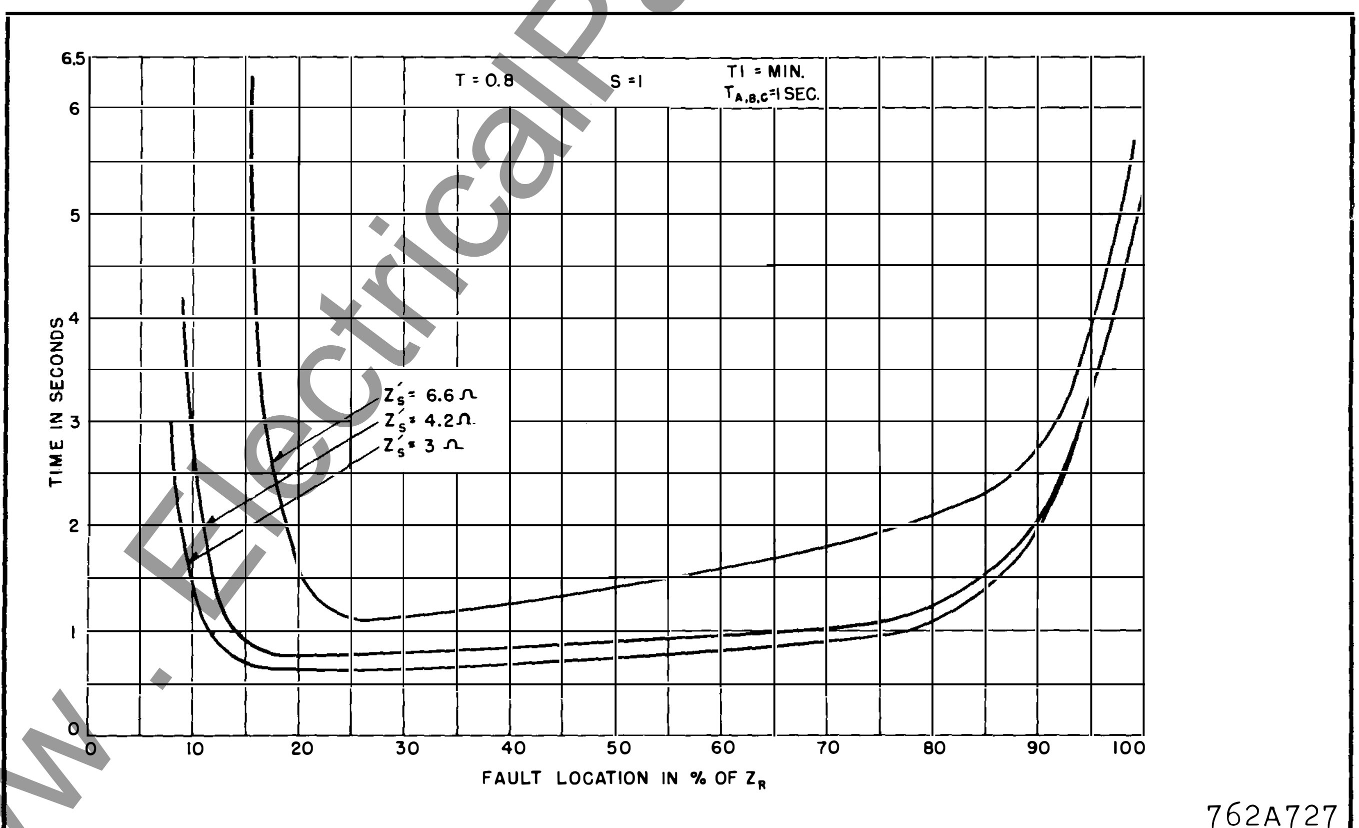


Fig. 11. Typical Operating Time Curves for Low Energy Faults.

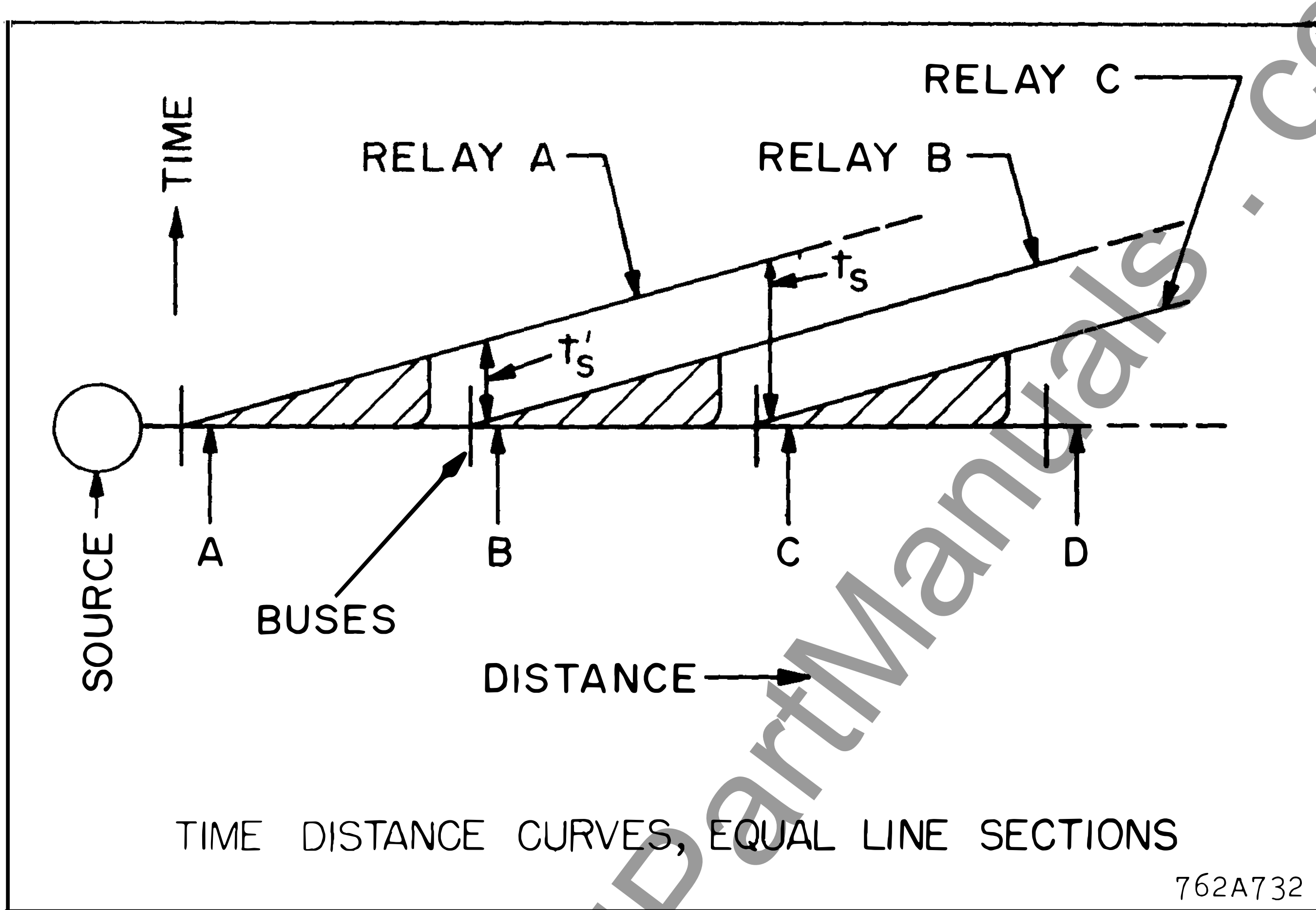
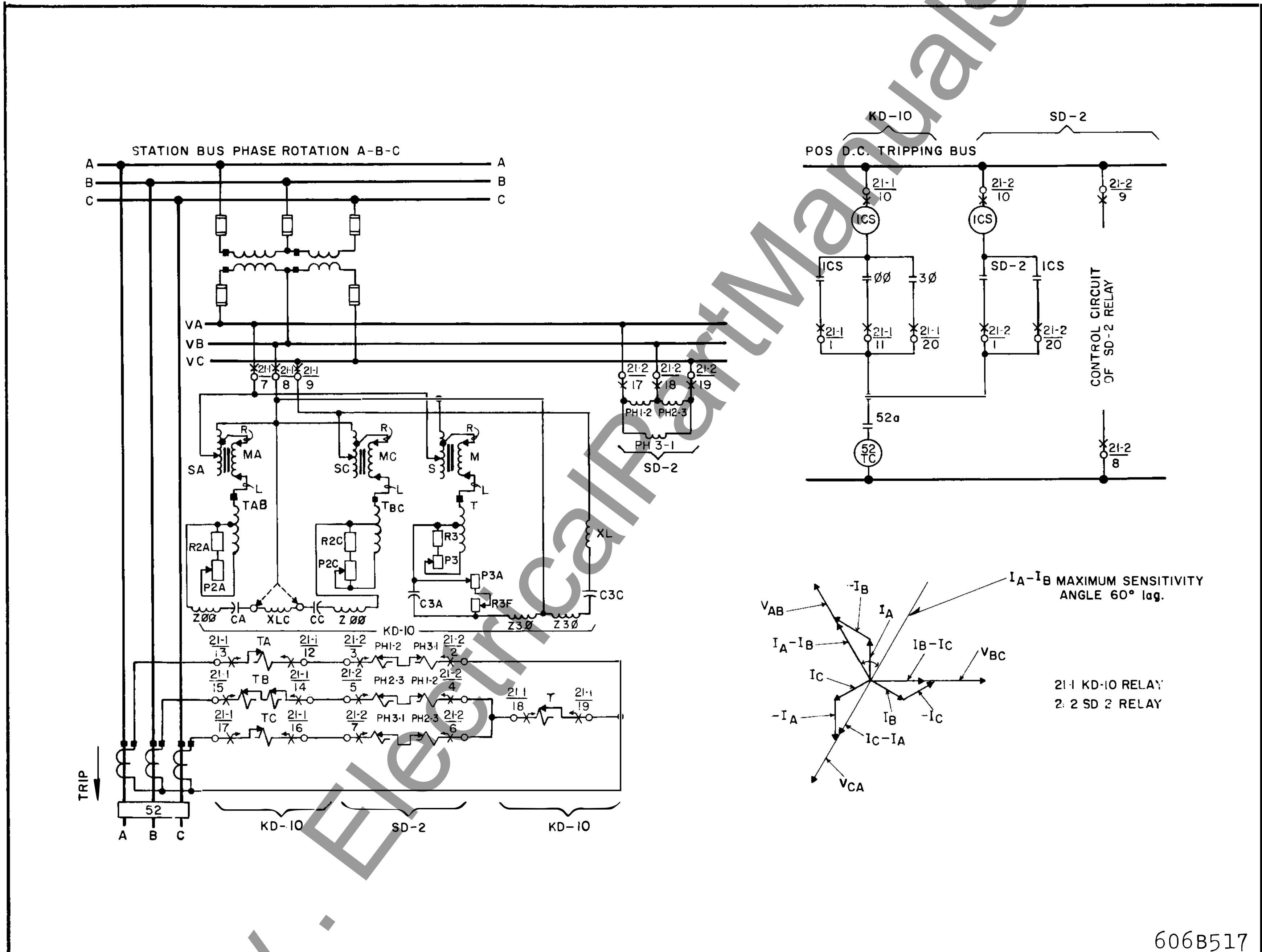
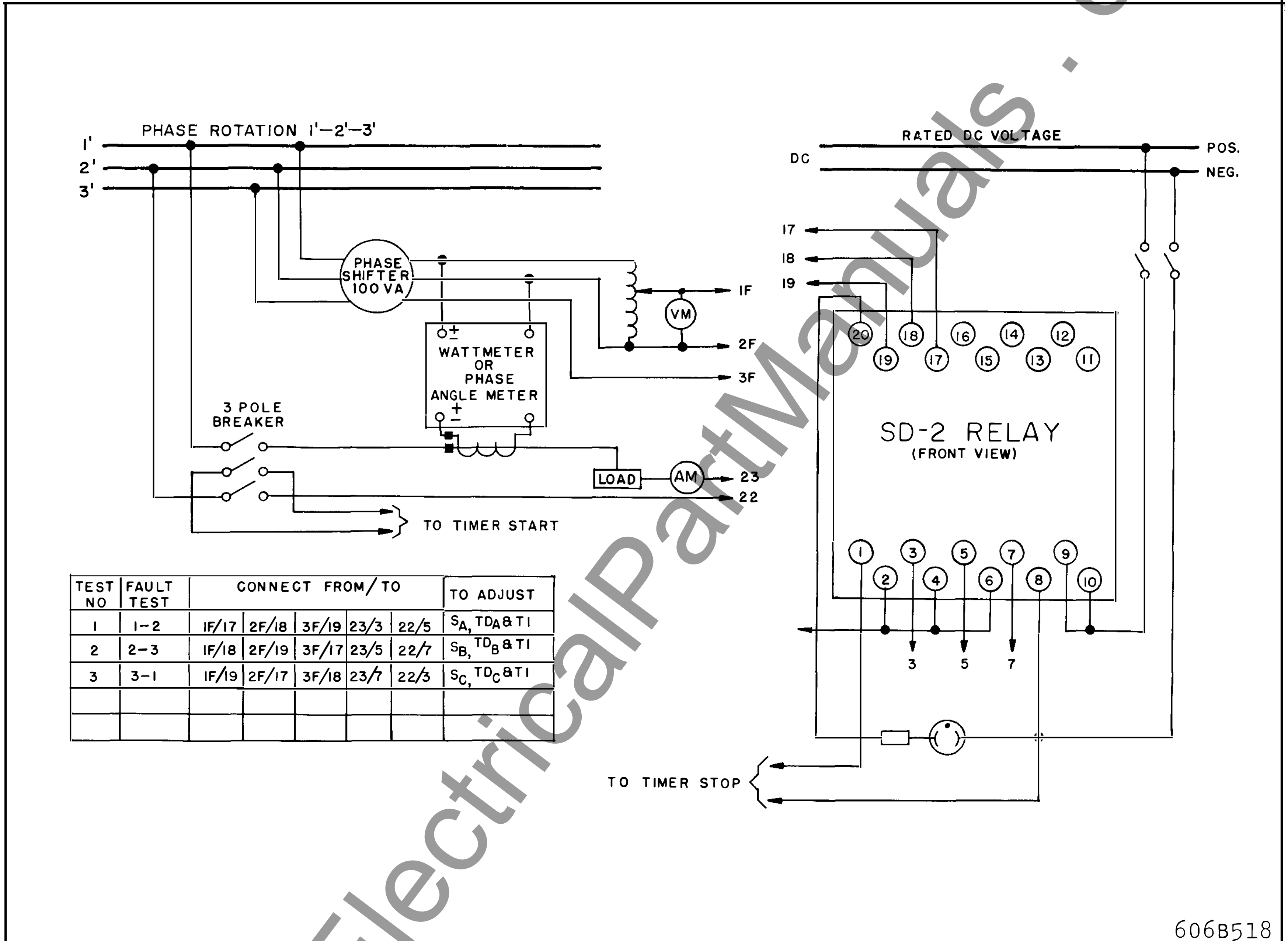


Fig. 12. Coordinating Curves for the SD-2 Relay.



✪ *Fig. 13. External Schematic of the SD-2 Relay with Type KD-10 Relay First Zone.*



TEST NO	FAULT TEST	CONNECT FROM/TO					TO ADJUST
1	1-2	1F/17	2F/18	3F/19	23/3	22/5	S_A, TD_A & T1
2	2-3	1F/18	2F/19	3F/17	23/5	22/7	S_B, TD_B & T1
3	3-1	1F/19	2F/17	3F/18	23/7	22/3	S_C, TD_C & T1

Fig. 14. Test Connections for the SD-2 Relay.

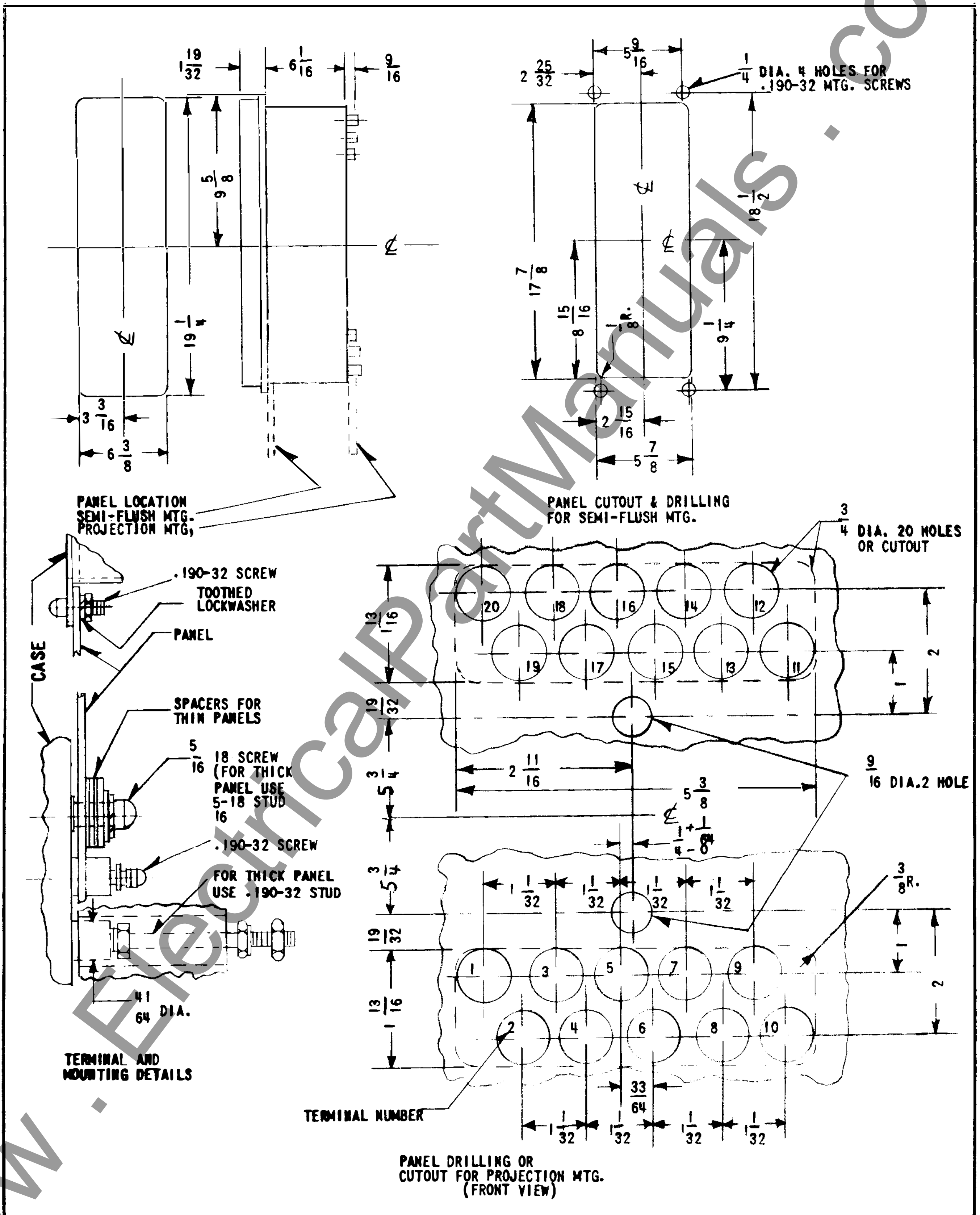


Fig. 15. Outline & Drilling Plan for the SD-2 Relay in the FT-42 Case.

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