INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE SKDU-3 OFFSET MHO PHASE DISTANCE RELAY

APPLICATION

The SKDU-3 is a single-phase impedance relay with independent adjustments of forward and reverse reach. It uses phase to neutral voltage and corresponding phase current.

This relay is used in a distance phase comparison system and serves the function of a high-speed sensitive fault-detector relay for 3-phase faults. Therefore, the SKDU-3 should not be used for direct tripping due to its transient overreach tendencies.

CONSTRUCTION

The type SKDU-3 relay consists of two single air gap transformers (compensators), two tapped auto-transformers, a phase shift network, an operating circuit board, a polarizing circuit board, an output circuit board, mounted in a standard 19 inch wide panel, 8 3/4 inches high (5 rack units).

Compensator

Compensators which are designated as T_A and T_C are two-winding air-gap transformers (Figure 2). The primary or current winding compensator has seven taps which terminate at the tap block (Figure 3). T_A is the "short reach" compensator. Tap markings for respective units are as follows:

T_A = 2.05, 2.74, 3.76, 5.13, 7.18, 9.92, 13.7

T_C = 1.64, 2.19, 2.75, 4.1, 5.78, 7.94, 10.9

Current flowing through the primary coil provides an mmf which produces magnetic lines of flux in the core. A voltage is induced in the secondary which is proportional to the primary tap setting and current magnitude. This proportionality is established by the cross sectional area of the laminated steel core, the length of an air gap which is located in the center of the coil and the tightness of the laminations. All of these factors which influence the secondary voltage proportionality have been precisely set at the factory. The clamps which hold the laminations should not be disturbed by either tightening or loosening the clamp screws.

The secondary winding has a single tap which divides the winding into two sections. One section is connected subtractively in series with the relay terminal voltage. Thus a voltage which is proportional to the line current is subtracted vectorially from the relay terminal voltage. The second terminal is connected to the potentiometer and provides a means of adjusting the phase angle relation between primary current and the induced secondary voltage. The phase angle may be set for any value between 60° and 80° by adjusting the potentiometer between its minimum and maximum values respectively. The maximum sensitivity angle is set for 75 degrees (current lagging voltage) at the factory.

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 has four taps which may be connected additively or subtractively to inversely modify the S setting by any value from -18 to +18 percent in steps of 3 percent.

The sign of M is negative when "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, .09 and .06. The auto-transformer makes it possible to expand the basic range of the compensators by the multiplier $\frac{S}{1+M}$. Therefore, any relay ohm setting can be made within +1.5 percent from 1.74 ohms to 50 ohms for the long reach setting, and from 1.43 ohms to 40 ohms for the short reach setting by combining the compensator taps T_A and T_C with the auto-transformer taps S_A and M_A, and S_C and M_C.

Printed Circuit Board Assembly

The detailed internal schematic shown in Fig. 4

consists of three separate boards: (1) operating circuit board, (2) polarizing circuit board, and (3) output circuit board. They contain all the resistors, diodes, transistors and thyristors necessary to perform the function of a polarized phase angle comparison unit. On the circuit boards in Fig. 4, the resistors are identified by "R", the diodes by "D", the zener diodes by "Z", transistors by "Q", thyristors by "QS", capacitors by "C", and the test points by "TP". Boxed in Q numbers indicate normally conducting transistors. The first the test points by "TP". Boxed in Q numbers indicate normally conducting transistors. The first number of a component defines which board it is mounted on.

When facing the component side of the printed circuit board, with terminals at the bottom, terminals are numbered 1 to 14 from right to left. These terminal numbers are shown in the internal schematic and will be referred to as printed circuit terminals, PCT, in the trouble shooting section.

Relay Case

Jack plug on the rear has 24 terminals numbered left to right and top to bottom. Thus terminal No. 1 located in the upper left hand corner when viewed from the rear and terminal 24 is in the lower right hand corner. Terminal No. 1 is connected internally to the chassis ground and may be used for grounding the connecting cable shields.

There are also 8 terminal strip used for current terminal and are located in the right hand side of rear when viewed from the back. They are numbered from left to right.

The chassis case, cover, and front panel have electrical connections assured by the use of shakeproof washers which cut through any paint or protecting coating to make electrical contact with the base metal. The complete relay rack is then grounded to the switchboard or cabinet by shakeproof washers.

The front door is connected to the relay's case by two hinger and a slotted strap from the bottom, and can be closed by two screws which are located at the top of the door. The slotted straps in the bottom allows the door to be opened up to 90 degrees and stops the door from sliding to the left and right.

The door can be removed by unscrewing the slotted strap from the door.

The front panel is located in front of the relay and consist of 3 parts. 1) The circuit boards which are located in the middle; 2) The phase angle adjusting potentiameter in the right; and 3) The auto-transformers and compensators tap setting in the left, when the relay is viewed from front.

OPERATION

The SKDU-3 relay has two major components, the compensators and the tripping unit. In the internal schematic of Fig. 4, compensators designated T_A and T_C are shown connected so as to modify the the voltage to the long-reach coils (T1) and short-reach coils (T2) respectively.

Operation of the SKDU-3 can be explained by referring to Fig. 5. In this figure, the addition of voltage phasors, at various fault locations, results in a set of phasors so that V_{ZY} leads V_{XY} phase rotation for restraining the tripping unit or so that V_{ZY} lags V_{XY} phase rotation for operating the tripping unit.

In Fig. 5 the short-reach setting $Z\theta_{SR}$ is about 4/5 of the long-reach setting ($Z\theta_{LR}$) and is in the reverse direction. This produces a solid line offset circle characteristic which includes the origin when plotted on an R-X diagram. Terms and symbols used in the diagrams are defined as follows:

- $Z\theta$ = the desired ohmic reach of the relay and relates equally to long reach ($Z\theta_{LR}$) and short reach ($Z\theta_{SR}$)
- V_{SM} = output voltage from each individual autotransformer which receives phase to neutral voltage.
- Z_A = mutual impedance setting of the long-reach compensator
- Z_C = mutual impedance setting of the short-reach compensator
- I = phase current
- V_{XY} = operating circuit voltage (across T1 in Fig.4)
- V_{ZY} = polarizing circuit voltage (across T2 in Fig. 4)
- V_{ZY} leads V_{XY} = restraining phase rotation
- V_{ZY} lags V_{XY} = operating phase rotation

Consider a fault at location "A" which is beyond the long-reach setting. For the sake of simplicity, assume both the line angle and the relay maximum sensitivity angle to be 90°. Compensator T_A modifies voltage V_{SM} by adding the mutual impedance drop IZ_A which leaves voltage V_{XY} across the input of transformer T1. Compensator T_C modifies its voltage V_{SM} by adding IZ_C to produce $V_{Z'Y}$. This voltage is then advanced 90° by phase shifting action of capacitor C_2 to provide voltage V_{ZY} across the transformer T2. The resulting diagram shows V_{ZY} leads V_{XY} and restrains the unit for this fault beyond the protection zone.

Using the same method of analysis as above for a fault at location "B", the balance point voltage IZ_A is equal and opposite to voltage V_{SM}. The result is that V_{XY} is equal to zero. There the relay does not operate.

Within the protected zone, for a fault at location "C", the V_{XY} phasor leads polarizing phasor V_{ZY}. Thus the relay produces an output voltage.

At location "D" a fault within the short reach setting, phasor V_{XY} leads phasor V_{ZY} to produce a relay output voltage.

A fault at Location "E" theoretically results in a balance point condition and the relay does not produce an output voltage.

A fault at location "F" produces restraining operation since V_{ZY} leads V_{XY}. The relay does not produce an output voltage.

The combination of series resistor R_A and parallel capacitor C1 shown in Fig. 4 controls transients in the operating circuit and also provides a small amount of phase shift. In the polarizing circuit I, capacitor C2 provides memory action to improve the operating characteristics for faults near the relay location. C2 also provides the major phase shifting effect which makes the voltage across T2 lead the voltage across T1 by 90° when only voltage is applied to the relay. The maximum sensitivity (75° or other angles up to 90 degrees) can be adjusted by means of reactor X. Reactor X is connected to the potentiometer PC which is used to obtain the adjustment for reactor X.

Phase Angle Comparison Unit (Tripping Unit)

Referring to Fig. 4, the phase angle comparison unit is tripped when current flows into the base of transistor 3Q1 through zener diode 3Z1, Such tripping must come from the 20 volt bus, through either transistor 1Q2 or 1Q4 located in "operating" circuit board. The operating circuit, driven by transformer T1, is continually trying to trip the unit by supply current through 1Q2 and 1Q4 on alternate half cycles. 1Q2 conducts when the polarity marked terminals of T1 are positive.

When 1Q2 conducts, a portion of the current goes through 2R9,. This current, IR9, may take either of two paths to the negative bus. If 2QS1 is in a conducting state, IR9 flows through it directly to the negative bus. If 2QS1 is in the blocking state, IR9 passes through diode 2D16 and then through 3Z1 to transistor 3Q1 to cause tripping. Thyristor 2QS1 is located in the "polarizing" circuit and is driven by transformer T2.

To prevent the operating circuit from causing trippring, the polarity marked terminal of T2 must go positive before the polarity terminals of T1. This causes 2Q1 to conduct current through 2R5 and drive the base of 2Q4. 2Q4 then conducts the current through 2R6 to gate 2QS1 into conduction. When 2QS1 conducts, it short circuits the current which might otherwise pass through diodes D16 to cause tripping. Once 2QS1 begins to conduct, the gate loses control and it remains in the conducting state until the current is turned off by 2Q1. No tripping output can develop as long as the T2 voltage leads T1 voltage.

The operating circuit switches for the next half cycle so that transistors 1Q3 and 1Q4 conducts in an attempt to cause tripping. In the polarizing circuit, 2Q2, 2Q5 and 2QS2 seek to prevent tripping by short circuiting the current which might otherwise pass through 2D1, 3Z1 and 3Q1.

Restraint Squelch

When the operating transistor 1Q2 conducts, approximately 18V is applied through diode 2D15 to back biase 2D14 and prevent 2Q4 from turning on. Thus a trip signal, initiated because the T1 voltage is leading cannot be improperly interrupted when the T2 polarity voltage goes positive. A full half cycle tripping output is therefore produced by 1Q2. This back biasing connection is called the restraint squelch circuit. The same is true for 2D18, 2D17 and 2Q5.

Voltage Detector

If for some reason a condition developed so that no polarizing voltage appears at transformers T2, then no gating signal would be available to switch 2QS1 and short circuit the 1Q2 current. This, of course, could cause incorrect tripping. A voltage detector circuit prevents this from happening. Transistors 2Q1 and 2Q2 are maintained in the conducting state alternately when a useful voltage level is supplied to T2, and the current through 2R3 is short circuited alternately by 2Q1 and 2Q2 transistors through diodes 2D5 and 2D6 respectively during this time. When the voltage from T2 drops too low, the transistors 2Q1 and 2Q2 turn off and 2R3 current flows through 2Z2 and turns on transistors 2Q3 and 2Q4 which in in turn gate 2QS1 and short circuits the 2R9 current. Similar action drives 2Q5 and 2QS2 through the zener diode 2Z1.

Distance Characteristic

A characteristic circle is established by setting two points on the circle, diametrically opposite one another by means of the Long Reach (T_A) and Short Reach (T_C) compensators, as shown in Fig. 6.

Sensitivity

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

General Characteristic

Impedance settings in ohms reach can be made for any value from 1.74 to 50 ohms for $Z\theta_{LR}$ and from 1.4 to 40 ohms for $Z\theta_{SR}$ in steps of 3 percent. The maximum sensitivity angle which is set for 75 degrees at the factory may be set for any value from 60 degrees to 80 degrees. A change in maximum sensitivity angle will produce a slight change in reach for any given setting of the relay. Referring to Fig. 2, note that the compensator voltage output V is largest when V leads the primary current I by 90 degrees. This 90 degree relationship is approached when the compensator loading resistor (P2A or P2C) is open circuited. The effect of loading the resistor, when connected, is to produce a drop in the compensator which is out of phase with the induced voltage. Thus, the output voltage of the compensator is phase-shifted to change the maximum sensitivity angle. As a result of this phase shift. the magnitude of V is reduced as shown in Fig. 2.

Tap markings in Fig. 3 are based upon a 75 degree compensator angle setting. If the potentiometers P2A and P2C are adjusted for some other maximum sensitivity angle, the nominal reach is different than indicated by the taps. The reach $Z\theta$ varies with the maximum sensitivity angle θ as follows:

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

Tap Plate Markings:

T_A

2.05	2.74	3.76	5.13	7.18	9.92	13.7

T_C

1.64	2.19	2.75	4.1	5.75	7.94	10.9

S_A and S_C

1	2	3

M_A and M_C

0.03	0.09	0.06

TIME CURVES AND BURDEN DATA

Operating Time

The speed of operation for the SKDU-3 relay is shown by the time curves in Fig. 9. The curves indicate the time in milliseconds required for the relay to produce a 20 volt dc output for tripping after the inception of a fault at any point on a line within the relay setting.

Current Circuit Rating In Amperes

Tap Setting	Continuous S = 1	Continuous S = 2	Continuous S = 3	1 Second
10.9	5	8.5	8.5	240
7.94	5	8.5	8.5	240
5.75	10	10	10	240
4.1	10	10	10	240
2.75	10	10	10	240
2.19	10	10	10	240
1.64	10	10	10	240

Burden

The burden which the relay imposes upon potential and current transformers is shown tabulated on pages 7 and 8.

VOLTAGE BURDEN
S = 1, V_{AN} = 69.4

X	Iamp = 0			Iamp = 5A $T_A + T_C$			Iamp = 5A $T_A - T_C$		
TAP SETTING	VA	WATT	VAR	VA	WATT	VAR	VA	WATT	VAR
-.18	2.56	2.40	.93	3.66	3.14	1.88	5.55	5.5	.58
-.15	2.76	2.56	1.06	3.90	3.35	2.00	5.85	5.85	.71
-.12	2.95	2.72	1.18	4.1	3.50	2.12	6.18	6.15	.86
-.09	3.16	2.93	1.22	4.3	3.64	2.24	6.50	6.45	1.01
-.06	3.40	3.17	1.47	4.58	3.82	2.36	6.85	6.80	1.31
-.03	3.60	3.22	1.61	4.80	4.1	2.48	7.24	7.10	1.45
0	3.86	3.46	1.76	5.05	4.26	2.70	7.55	7.40	1.64
.03	4.10	3.70	1.90	5.28	4.45	2.86	7.90	7.75	1.74
.06	4.36	3.84	2.05	5.50	4.60	2.98	8.25	8.05	2.06
.09	4.60	4.08	2.2	5.75	4.82	3.22	8.60	8.35	2.24
.12	4.85	4.30	2.36	6.05	5.05	3.40	8.95	8.65	2.42
.15	5.10	4.42	2.54	6.30	5.25	3.53	9.30	8.95	2.64
.18	5.40	4.70	2.7	6.60	5.50	3.70	9.70	9.30	2.92

VOLTAGE BURDEN
S = 2, V_{AN} = 69.4

X	Iamp = 0			Iamp = 5A $T_A + T_C$			Iamp = 5A $T_A - T_C$		
TAP SETTING	VA	WATT	VAR	VA	WATT	VAR	VA	WATT	VAR
-.18	2.52	2.82	.925	3.60	2.9	2.12	5.4	5.35	-.376
-.15	2.70	2.51	1.06	3.80	3.07	2.22	5.66	5.60	-.394
-.12	2.90	2.68	1.15	4.00	3.23	2.35	6.00	5.95	-.370
-.09	3.10	2.88	1.30	4.22	3.42	2.48	6.30	6.25	-.22
-.06	3.40	3.16	1.50	4.42	3.58	2.60	6.63	6.58	-.115
-.03	3.53	3.23	1.58	4.65	3.76	2.73	6.94	6.90	-.097
0	3.78	3.42	1.75	4.85	3.92	2.85	7.35	7.30	+.127
+.03	3.98	3.60	1.87	5.05	4.07	2.97	7.60	7.55	+.265
.06	4.24	3.80	2.05	5.27	4.28	3.10	8.00	7.95	+.416
.09	4.50	4.0	2.18	5.54	4.50	3.25	8.25	8.20	+.585
.12	4.73	4.2	2.28	5.80	4.70	3.40	8.60	8.55	+.75
.15	4.98	4.35	2.49	6.10	4.94	3.58	9.00	8.95	+.95
.18	5.25	4.56	2.63	6.38	5.15	3.76	9.35	9.30	+.15

VOLTAGE BURDEN

$S = 3,\ V_{AN} = 69.4$

X	$I_{amp} = 0$			$I_{amp} = 5_A\ T_A + T_C$			$I_{amp} = 5_A\ T_A - T_C$		
TAP SETTING	VA	WATT	VAR	VA	WATT	VAR	VA	WATT	VAR
-.18	2.53	2.39	.825	3.5	2.93	1.91	5.35	5.3	-1.11
-.15	2.70	2.53	.92	3.68	3.08	2.0	5.60	5.55	-.97
-.12	2.90	2.70	1.04	3.88	3.25	2.12	5.95	5.90	-.78
-.09	3.10	2.87	1.16	4.10	3.44	2.24	6.25	6.20	-.71
-.06	3.30	3.03	1.23	4.90	3.60	2.35	6.60	6.55	-.63
-.03	3.54	3.22	1.36	4.50	3.78	2.46	6.88	6.82	-.65
0	3.75	3.40	1.49	4.80	4.00	2.62	7.25	7.20	-.68
+.03	4.0	3.60	1.63	5.0	4.20	2.73	7.60	7.55	-.66
+.06	4.23	3.80	1.79	5.34	4.50	2.92	7.90	7.85	-.69
+.09	4.41	4.0	1.95	5.55	4.65	3.02	8.30	8.2	-.59
+.12	4.70	4.18	2.13	5.80	4.85	3.16	8.60	8.5	-.376
+.15	5.0	4.40	2.36	6.05	5.05	3.30	8.90	8.8	-.15
+.18	5.2	4.55	2.52	6.25	5.25	3.40	9.30	9.2	-.112

CURRENT BURDEN

$S = 1,\ M = 0,\ V_A = 69.4,\ I_A = 75°$

TAP SETTING		Z		R	JX
T_A	T_C				
1.37	10.93	.54	60	.27	.477
9.92	7.94	.3	56	.167	.248
7.18	5.75	.16	51	.101	.124
5.13	4.1	.08	37	.063	.048
3.76	2.75	.038	14	.049	.027
2.74	2.19	.038	14	.037	.0092
2.05	1.64	.024	6	.0238	.0025

SETTING CALCULATIONS

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

T_A

2.05	2.74	3.76	5.13	7.18	9.92	13.7

T_C

1.64	2.19	2.75	4.1	5.75	7.94	10.9

S_A and S_C

1	2	3

M_A and M_C

.03	.09	.06

Maximum sensitivity angle is set in the factory for 75 degrees (current lags voltage). It should not be necessary to change this calibration.

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

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

The terms used in this formula are defined as follows:

$Z\theta$ = the desired ohmic reach of the relay and relates equally to long reach ($Z\theta_{LR}$) and short reach ($Z\theta_{SR}$).

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

T = compensator tap value

S = auto-transformer primary tap value

θ = maximum sensitivity angle setting of the relay (for a factory setting of 75°, then, $\frac{\text{Sin } \theta}{\text{Sin } 75°} = 1$).

M = auto-transformer secondary tap value (this is a per unit value and is determined by the sum of the values between the "L" and the "R" leads. The sign is positive when "L" is above "R" and acts to lower the Z setting. The sign is negative when "R" is above "L" and acts to raise the Z setting).

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

R_C = current transformer ratio

R_V = potential transformer ratio

The following procedure should be followed in order to obtain an optimum setting of the relay. Relate the general equation of long reach or short reach by sub-letters "LR" and "SR" respectively.

Now refer to Tables I and II which list optimum relay settings for relay range from 1.74 to 50 ohms for long reach and 1.4 to 40 ohms for short reach compensators.

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

Table I is relay settings for the long reach compensator. Table II is relay settings for the short reach compensator.

c) Recheck the obtained S, T, and M settings by using equation:

$$Z = \frac{TS}{1 \pm M}$$

For example:

(Step 1a) Assume the desired reach, $Z\theta_{LR}$, is 30 ohms for the long reach setting at 60 degrees.

(Step 1b) Making correction for maximum sensitivity angle of the line (60 degrees) that is different from factory setting of 75 degrees. Find the relay tap setting

$$Z = \frac{(30) \text{ Sin } 75°}{\text{Sin } 60°} = (30)\,(1.11) = 33.2 \text{ ohms}$$

Next, in Table I, we find nearest value to 33.2 ohms: 33.8; that is $\frac{33.8 \times 100}{33.2} = 102$ percent of the desired reach.

(Step 2b) From Table I read off: S = 3, T = 9.92, M = .12, and "R" lead should be connected over "L" lead, with "L" lead connected on zero, and "R" lead on .09.

The last step is to recheck setting:

$$Z = \frac{TS}{1 \pm M} = \frac{(3)\,(9.92)}{1 - .12} = 33.8$$

$Z_{60°}$ = Z Sin 60 = (33.8) (.895) = 30.2 ohms or less than 1 percent of the desired setting.

The same procedure can be done for short reach compensator.

TABLE I
RELAY SETTING FOR LONG REACH COMPENSATOR

	"S" = 1							"S" = 2		"S" = 3		"M"		Lead Connection		
T=	2.05	2.74	3.76	5.13	7.18	9.92	13.7	9.92	13.7	9.92	13.7	+M	-M	"L" Lead	"R" Lead	
	1.74	2.32	3.18	4.35	6.1	8.4	11.6	16.8	23.2	-	34.8	+.18		.06	0	"L" OVER "R"
	1.78	2.38	3.27	4.47	6.25	8.62	11.9	17.3	23.8	-	35.8	+.15		.06	.03	
	1.83	2.44	3.36	4.59	6.42	8.85	12.2	17.7	24.5	-	36.7	+.12		.09	0	
	1.88	2.52	3.45	4.70	6.60	9.10	12.5	18.2	25.2	-	37.7	+.09		.09	.03	
	1.93	2.58	3.55	4.84	6.78	9.35	12.9	18.7	25.9	-	38.8	+.06		.06	.09	
	1.99	2.66	3.66	4.98	6.98	9.64	13.3	19.3	26.6	-	40.0	+.03		.03	0	
	2.05	2.74	3.76	5.13	7.18	9.92	13.7	19.8	27.4	-	41.1	0	0	0	0	
	2.12	2.82	3.88	5.30	7.40	10.3	14.1	20.4	28.3	-	42.4		-.03	0	.03	"R" OVER "L"
	2.18	2.92	4.00	5.46	7.65	10.6	14.5	21.1	29.2	-	43.6		-.06	.09	.06	
	2.25	3.02	4.15	5.65	7.90	10.9	15.0	21.8	30.2	32.8	45.1		-.09	.03	.09	
	-	3.12	4.27	5.82	8.16	11.3	15.5	22.6	31.2	33.8	47.8		-.12	0	.09	
	-	-	-	-	-	-	16.1	-	32.3	-	48.4		-.15	.03	.06	
	-	-	-	-	-	-	-	-	-	-	50		-.18	0	.06	

TABLE II
RELAY SETTINGS FOR SHORT REACH COMPENSATOR

	"S" = 1							"S" = 2		"S" = 3		"M"		Lead Connection		
T =	1.64	2.19	2.75	4.1	5.75	7.94	10.9	7.94	10.9	7.94	10.9	+M	-M	"L" Lead	"R" Lead	
	1.39	1.86	2.33	3.47	4.95	6.72	9.25	-	-	-	27.8	+.18		.06	0	"L" OVER "R"
	1.43	1.91	2.39	3.57	5.10	6.9	9.48	13.8	19.0	-	28.4	+.15		.06	.03	
	1.47	1.96	2.46	3.66	5.22	7.09	9.72	14.2	19.5	-	29.2	+.12		.09	0	
	1.51	2.00	2.52	3.76	5.37	7.28	10.0	14.6	20	-	30.0	+.09		.09	.03	
	1.55	2.07	2.60	3.87	5.52	7.46	10.3	15.1	20.6	-	30.9	+.06		.06	.09	
	1.60	2.12	2.67	3.98	5.69	7.7	10.6	15.4	21.2	-	31.8	+.03		.03	0	
	1.64	2.19	2.75	4.1	5.75	7.94	10.9	15.9	21.8	-	32.7	0	0	0	0	
	1.68	2.26	2.84	4.22	6.04	8.16	11.2	16.4	22.5	-	33.8		-.03	0	.03	"R" OVER "L"
	1.74	-	2.93	4.36	6.21	8.44	11.6	16.9	23.2	-	34.8		-.06	.09	.06	
	1.80	-	3.02	4.5	6.43	8.72	12.0	17.5	23.0	-	36.0		-.09	.03	.09	
	-	-	3.12	4.66	6.65	9.00	12.4	18.1	24.8	27.0	37.2		-.12	0	.09	
	-	-	3.24	4.82	-		12.8	18.7	25.7	-	38.5		-.15	.03	.06	
	-		3.36	-	-		13.3		26.6	-	4.0		-.18	0	.06	

SETTING THE RELAY

The SKDU-3 relay requires setting for each of the two compensators (T_A and T_C), each of the two auto-transformer primaries (S_A and S_C), and for the two auto-transformer secondaries (M_A and M_C). of these settings are made on the tap plate located on the left inside the door. Fig. 3 shows the tap plate.

Compensator (T_A and T_C)

Each set of compensator taps terminate in inserts which are grouped on a socket and form approximately three quarters of a circle around a center which is the common connection for all of the taps. Electrical connections between common insert and tap insets are made with a link that is held in place with two connector screws, one in the common and one in the tap.

A compensator tap setting is made by loosening the connector screw in the center. Remove the connector screw in the tap end of the link, swing the link around until it is in position over the insert for the desired tap setting, replace the connector screw to bind the link to this insert, and retighten the connector screw in the center. Since the link and connector screws carry operating current, be sure that the screws are turned to bind snugly.

Auto-Transformer Primary (S_A and S_C)

Primary tap connections are made through a single lead for each transformer. The lead comes out of the tap plate through a small hole located just below the taps and is held in place on the proper tap by a connector screw (Fig. 3).

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

Auto-Transformer Secondary (M_A and M_C)

Secondary tap connections are made through two leads identified as "L" and "R" for each transformer. These leads come out of the tap plate, each through a small hole, one on each side of the vertical row of "M" tap inserts. The lead connectors are held in place on the proper tap by connector screws. Values for which an "M" setting can be made are from -.18 to +.18 in steps of .03. The value of a setting is the sum of the numbers that are crossed when going from the "R" lead position to the "L" lead position. The sign of "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 in higher position.

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.

TABULATED SETTINGS

Z	M	L LEAD	R LEAD
.846 TS	+.18	.06	0
.87 TS	+.15	.06	.03
.89 TS	+.12	.09	0
.92	+.09	.09	.03
.94 TS	+.06	.06	0.09
.97 TS	+.03	.03	0
TS	0	0	0
1.03 TS	-.03	0	.03
1.06 TS	-.06	.09	.06
1.10 TS	-.09	.03	.09
1.14 TS	-.12	0	.09
1.18 TS	-.15	.03	.06
1.22 TS	-.18	0	.06

Line Angle Adjustment

Maximum sensitivity angle is set for 75 degrees (current lagging voltage) in the factory. It is not expected that this adjustment need be disturbed. However, if a change is desired, refer to Repair Calibration.

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 by means of the four slotted holes on the front of the case. Additional support should be provided toward the rear of the relay in addition to front panel mounting. This will protect against warping of the front panel due to the extended weight within the relay case.

ACCEPTANCE TESTS

Acceptance tests in general for SKDU-3 consists of:

1. a visual inspection to make sure there are no loose connections, broken resistors, or broken resistor wires.
2. an electrical test to make certain the relay measures the balance point impedance accurately.

Distance Unit

Check the electrical response of the relay by using the test connections for test number 4 table III and Fig. 10. Set T_A for 13.7 ohms, T_C for 1.64 ohms, S_A and S_C for 1, and M_A and M_C for zero.

a) Adjust the voltage V1 for 30 volts.

b) Set a high sensitivity dc voltmeter (at least 20,000 ohms/V) at the varicon terminals 5 and 3 to measure a 20 volt dc output. (5 is pos.)

c) The current required to obtain a 20 volt dc output for the long-reach balance point should be between 2.18 and 2.22 amperes at the maximum sensitivity angle of 75 degrees current lag.

d) The current required to reset (to lose that 20 volt dc output) at the short-reach balance point should be between 18.3 and 19 amperes at 75 degree current lag.

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

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.

When performing routine maintenance, the distance characteristic of the relay can be checked by using the same procedure as outlined in "Acceptance Tests". The balance point impedance measured by the relay is $Z_R = \frac{V_{L-N}}{I_L}$ where V_{L-N} is phase to neutral voltage applied to the relay terminals and I_L is the phase current.

Repair Calibration

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

Connect the relay for testing as shown in Fig. 10 for best results in checking calibration.

Electrical Calibration

1. Setting: Check to see that:

   T_A set on 13.7 and T_C set on 10.9

   S_A and S_C set on 1

   "R" for M_A and M_C set on 0.0

   "L" for M_A and M_C hangs free

Compensator Angle Adjustment

Long Reach Compensator T_A:
Refer to Table III of connections and connect the test circuit as per Test #1.

2. Connect the relay as per Fig. 10, Test #1.
3. Unscrew the "L" lead of the long reach transformer in front of relay's panel, and insert a voltmeter between "L" lead and "O" tap.
4. Apply 40 volts between varicon terminals 7 and 10.
5. Apply 3.1 ± .1 amperes to terminal block 1 out of 2.
6. Adjust the potentiometer P2A to obtain a "null" on the voltmeter when the phase shifter is on 75° ± 1° (current lags voltage).

Short Reach Compensator T_C

7. Connect the relay as per Table III, Test #2.
8. Unscrew the "L" lead of the short reach transformer in front of relay's panel, and insert a voltmeter between "L" lead to "O" tap.
9. Reverse the voltage applied to the varicon terminals 7 and 10, and apply 40 volts between them.
10. Apply 3.76 amperes to terminal block 1 out of 2.
11. Adjust the potentiometer P2C to obtain a "null" on the voltmeter when the phase shifter is on 75° + 1° (current lags voltage).

Auto-Transformer Check, Test #3

12. Set S_A and S_C on tap number 3. Apply 90 (± 1) volts between terminals 7 and 10. Measure the voltage from terminal 10 to the number 1 tap of S_A and S_C. It should be 39 (± 1) volts. From 10 to the number 2 tap of S_A and S_C should be 60 (± 1) volts.

13. Set S_A and S_C on 1 and apply a voltage VT (which is equal to 100 volts ± 1 volt) between terminals 7 and 10. Measure the voltage drop from terminal 10 to each of the M_A and M_C taps. This voltage should be equal (± 1 volt) to the sum of V_T plus (the sum of digits between "R" and the tap being measured).

    Example: 99 + (.03 + .09 + 0.06) 100 = 117 volts - - if the voltage reading is not within limits, then either the turn ratio or the connection is wrong.

14. Set T_A on 13.7 and T_C on 1.64

    Set S_A and S_C on 1

    "R" for M_A and M_C set on 0.0

    "L" for M_A and M_C set on 0.0

Maximum Sensitivity Angle, Test #3

15. Set the phase shifter to 30° ± 20° (current lags voltage). Apply 40 volts between terminals 7 and 10, and adjust the current to about 3.8 ± 1 amperes. Measure the output voltage from terminal 5 to terminal 3 with a dc voltmeter, and adjust the potentiometer P_C for "just" to read a 20 volt dc output. Turn the phase shifter until the dc voltage drops to zero, this angle should be 120° ± 2°. (The total angle is 30° + 120° = 150°).

16. Apply 40 volts across terminals 7 and 10, turn the phase shifter to 255°, and apply approximately 24 amperes, the relay should "just" trip. (Don't leave 24 amperes on more than 5 seconds).

Impedance Curve, Test #4

17. Increase the voltage to 40 volts, set the phase-shifter to 75° (current lags voltage). A 20 volt dc output should be obtained when the current is between 2.9 and 3.0 amperes.

TABLE III
TABLE OF TEST CONNECTIONS

TEST NO.	ADJUST	CONNECT TO TERMINAL					
		1	2	V1	V2	V3	V4
1	P2A	L2	I_B	L_A	0.0	–	–
2	P2C	L2	I_B	I_C	0.0	–	–
3	P_C	L2	I_B	–	–	Varicon 5	Varicon 3
4	Imp. Curve	L2	I_B	–	–	Varicon 5	Varicon 3

To determine the limits of current when θ is not equal to 75 degrees, multiply the nominal values tabulated below by the ratio:

$$\frac{\sin 75^\circ}{\sin \theta}$$

VOLTAGE	SETTING	Imin	Imax
50	13.7 ohm	3.64	3.74 (75°)
50	10.9 ohm	4.55	4.65 (225°)

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. For components mounted on the printed circuit board, give the circuit symbol, electrical value and sytle number.

ELECTRICAL PARTS LIST

CIRCUIT SYMBOL	STYLE	REFERENCE
RESISTORS		
2R7, 2R9, 2R11,	184A763H37	2.7 K
2R12, 2R13		
1R1, 1R2, 3R10	184A763H83	220 K
1R4, 1R6	184A763H49	3.2 K
2R4	184A763H59	22 K
2R1, 2R2, 3R9	184A763H75	100 K
2R3	184A763H63	33 K
2R6-2R10	629A531H42	2.7 K
1R3-1R5	184A763H99	1 MEG
3R3	629A531H66	27 K
3R1, 3R2	184A763H69	56 K
3R4	629A531H52	6.8 K
3R5	184A763H47	6.8 K
3R6	762A679H01	150 ohm
3R7	184A763H45	5.6 K
3R8-3R11	184A763H61	27 K
3R12	184A763H57	18 K
RA	1267210	2.8 K
RDC	1202587	400 48 V. DC
RDC	1267293	15 K, 125 V. DC
ZENER DIODES		
2Z1	186A797H06	IN957B
3Z1	186A797H12	IN752A
3Z2	186A797H01	IN758

CIRCUIT SYMBOL	STYLE	REFERENCE
DIODES		
1D1 to 1D8	188A342H06	IN957B
2D1 to 2D18	188A342H06	IN752A
3D1 to 3D7	188A342H06	IN758
CAPACITORS		
1C1	187A508H10	18 M.F.
3C2	187A624H02	.25 M. F.
3C1	187A624H10	.015 M.F.
C1	14C9400H15	8 M.F.
C2	14C9400H28	1.0 M.F.
TRANSISTORS		
1Q1, 1Q3, 2Q1	848A851H01	2N3391
2Q2, 3Q3		
2Q3-3Q1, 3Q4	184A638H18	2N697
1Q1-1Q4-2Q4	184A638H20	2N1132
2Q5-3Q2		
TRANSFORMERS		
T1, T2	262B563G09	
POTENTIAMETER		
P2A-P2C	836A635H04	2500 ohm
PC	836A635H02	5 K
SWITCH		
2QS1-2QS2	185A517H05	2N884

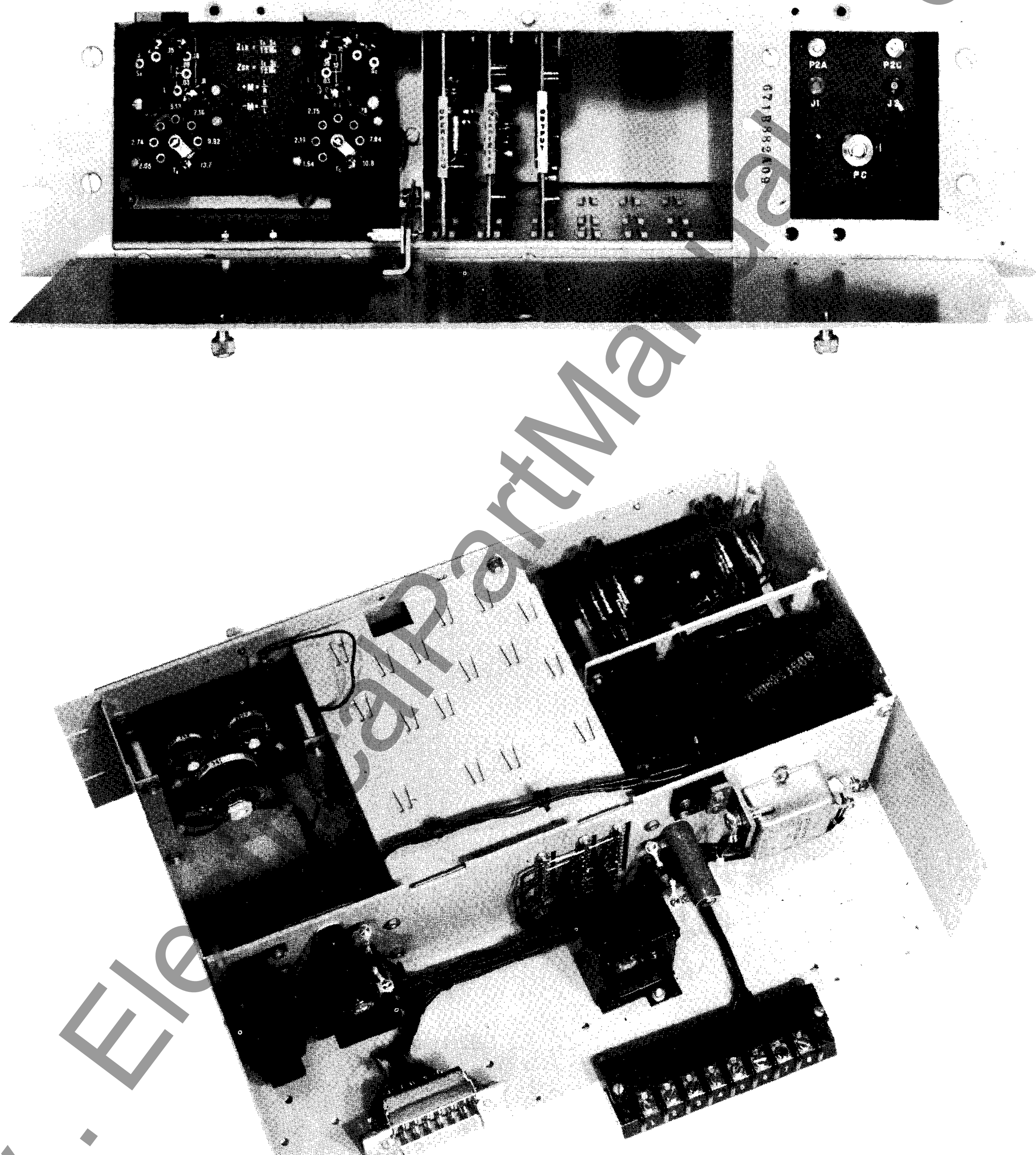

Fig. 1. Type SKDU Relay Without Case.

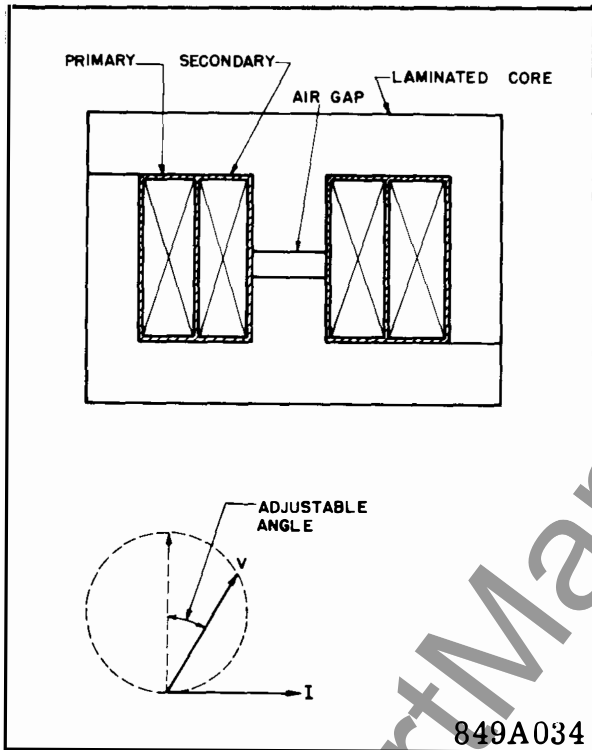

Fig. 2. Compensator Construction.

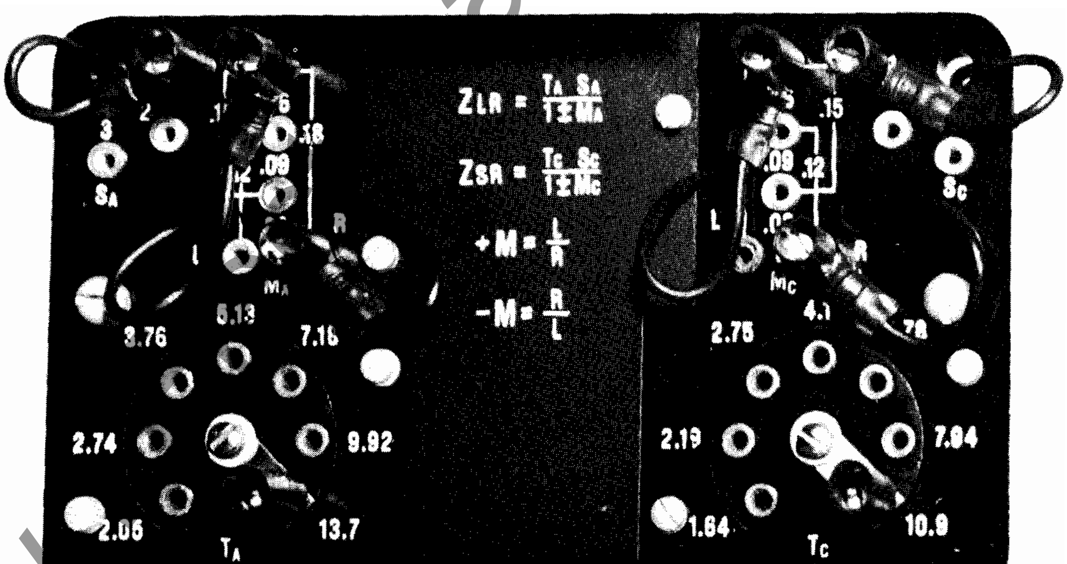

Fig. 3. Tap Plate

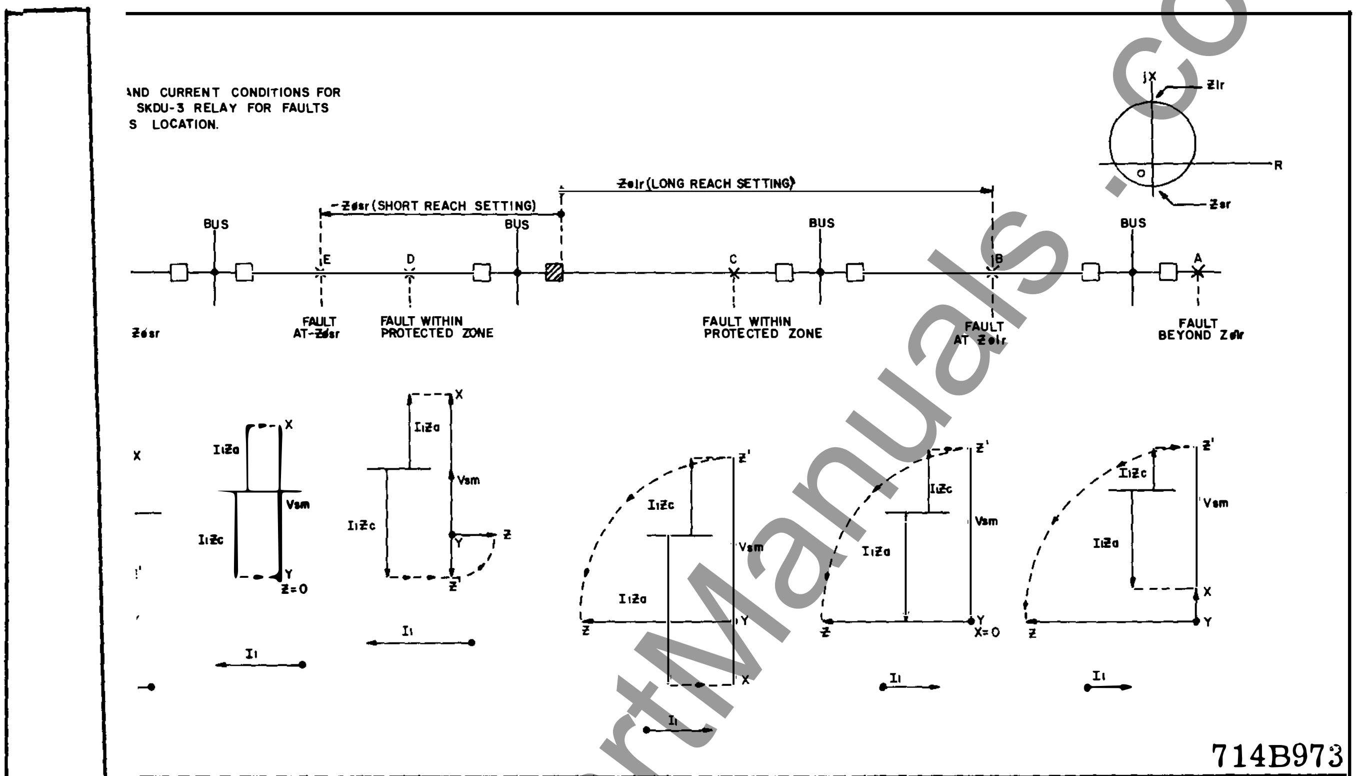

Fig. 5. Voltage and Current Conditions for Type SKDU-3 Relay for Faults at Various Locations.

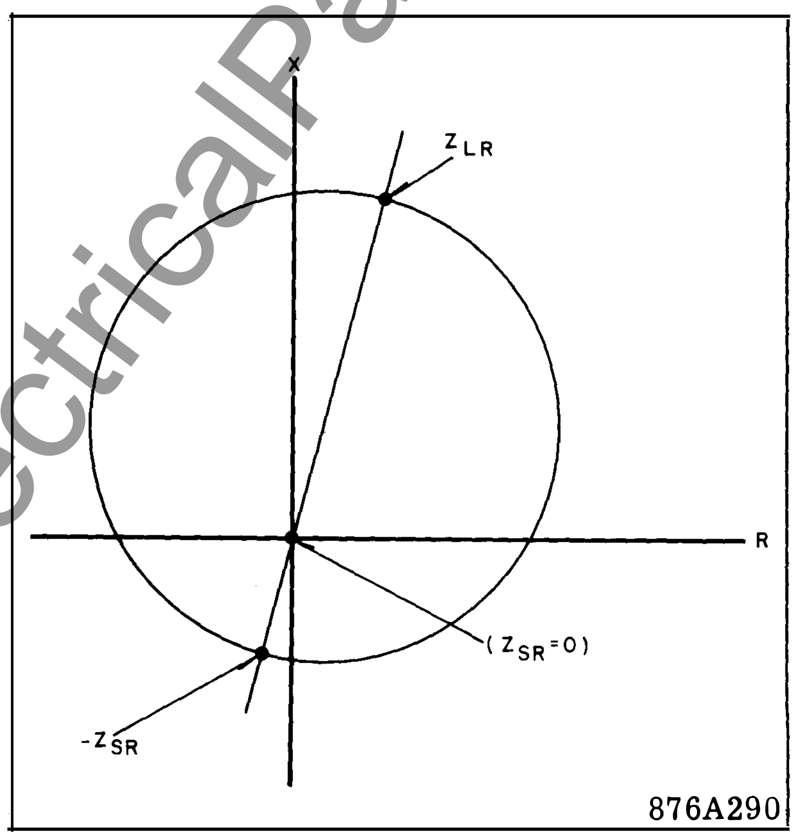

Fig. 6. Impedance Circle for Type SKDU-3 Relay.

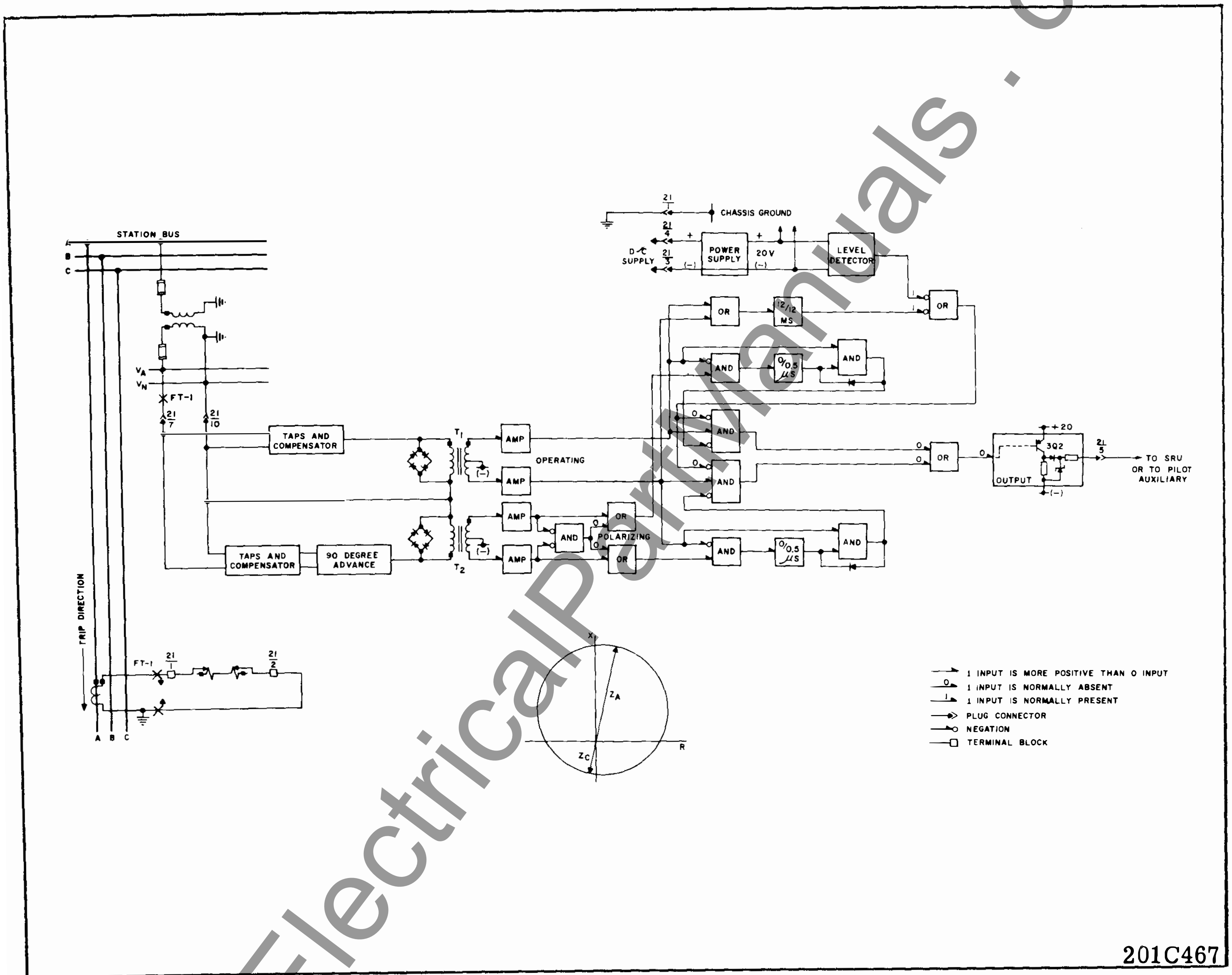

Fig. 7. External Schematic for the Type SKDU-3 Relay.

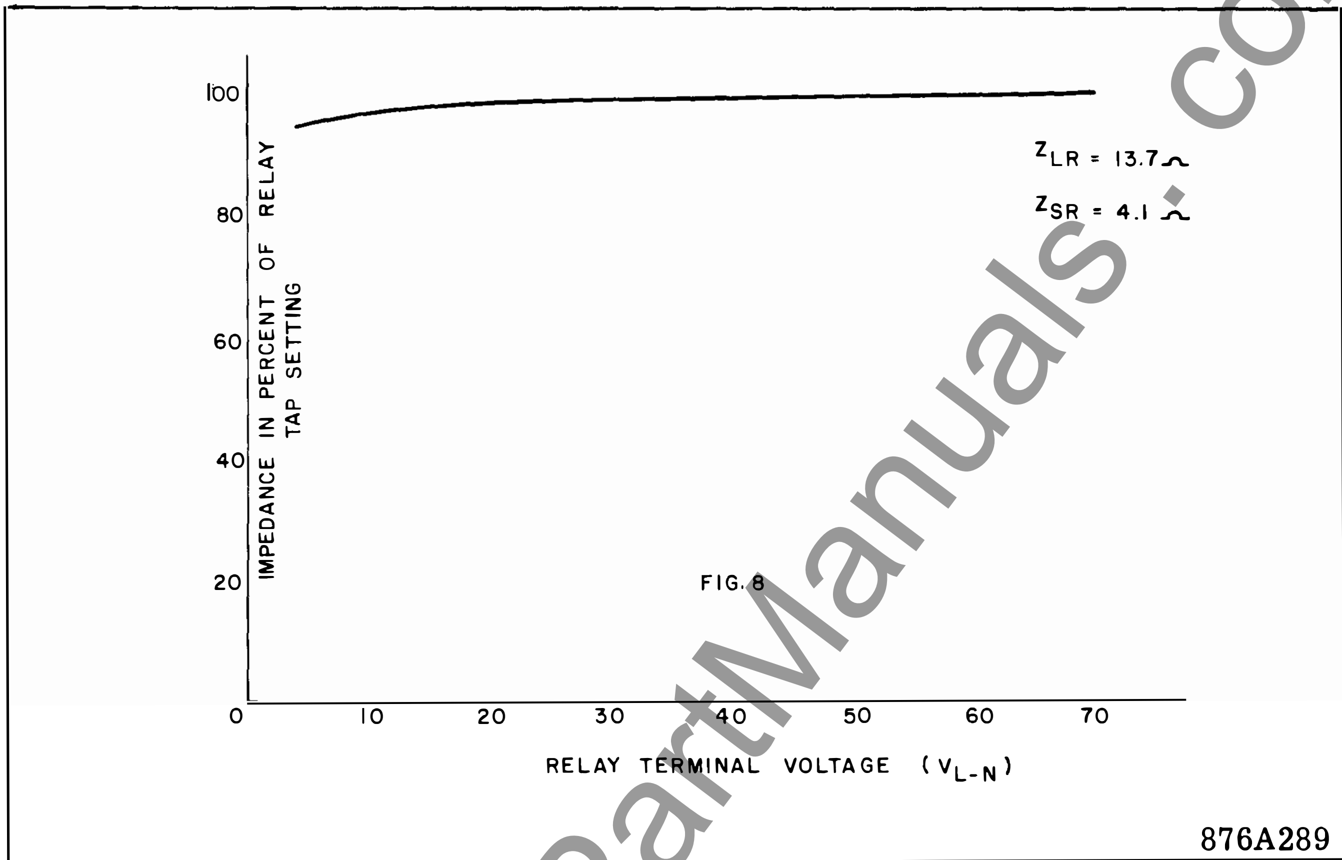

Fig. 8. Impedance Curve for Type SKDU-3 Relay.

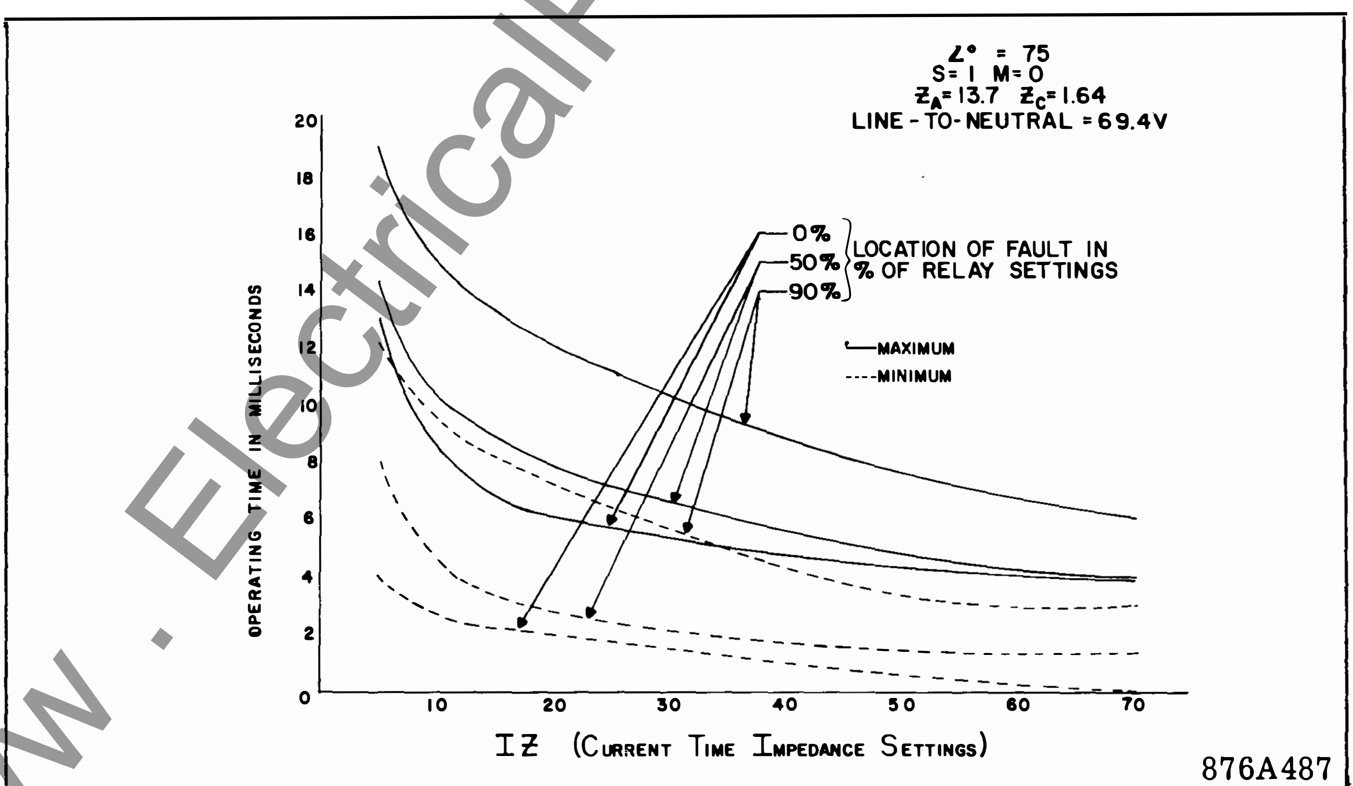

Fig. 9. Typical Operating Time Curve of the Type SKDU-3 Relay. Normal Voltage Before Fault is 70 Volts.

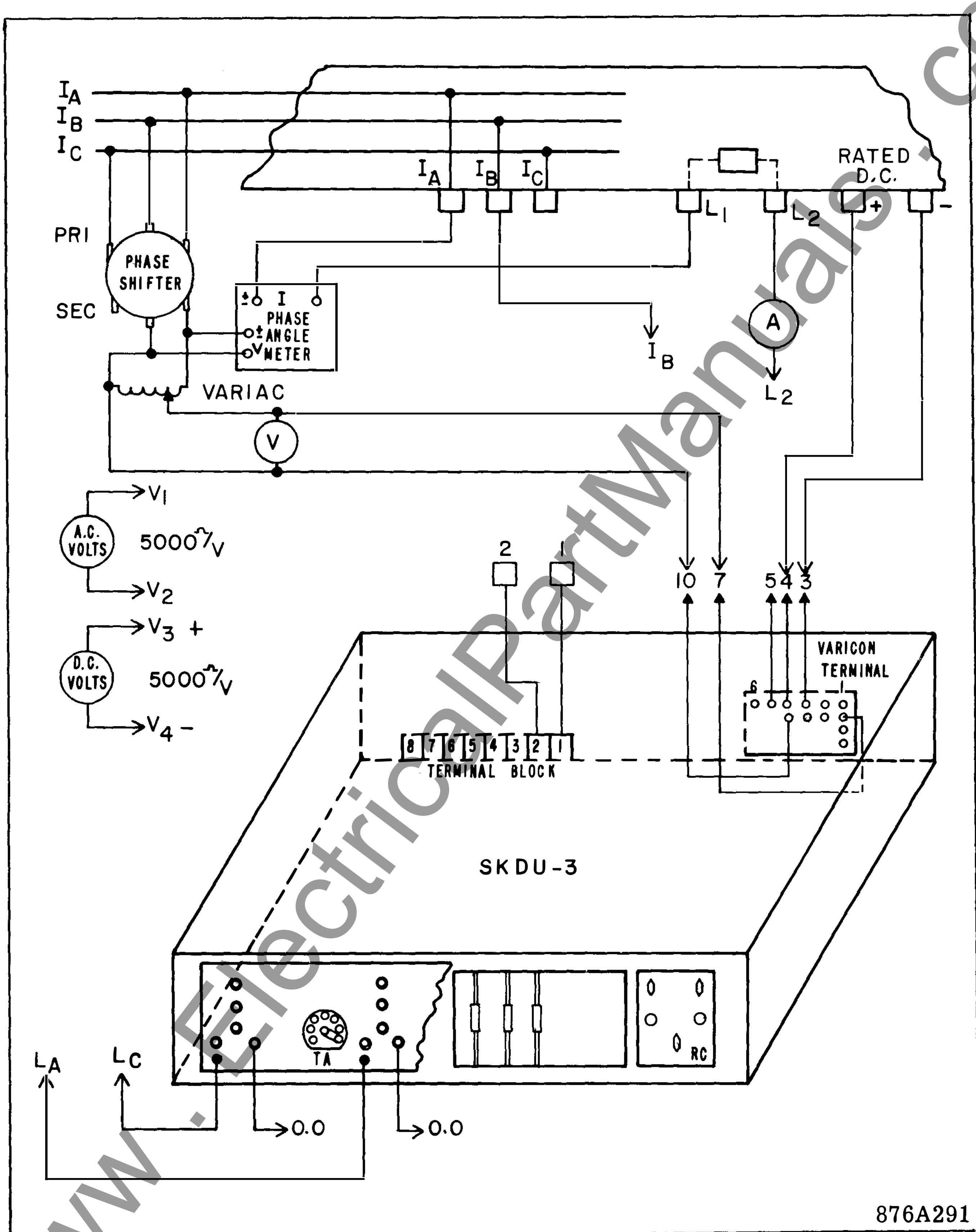

Fig. 10. Test Connections for Type SKDU-3 Relay.

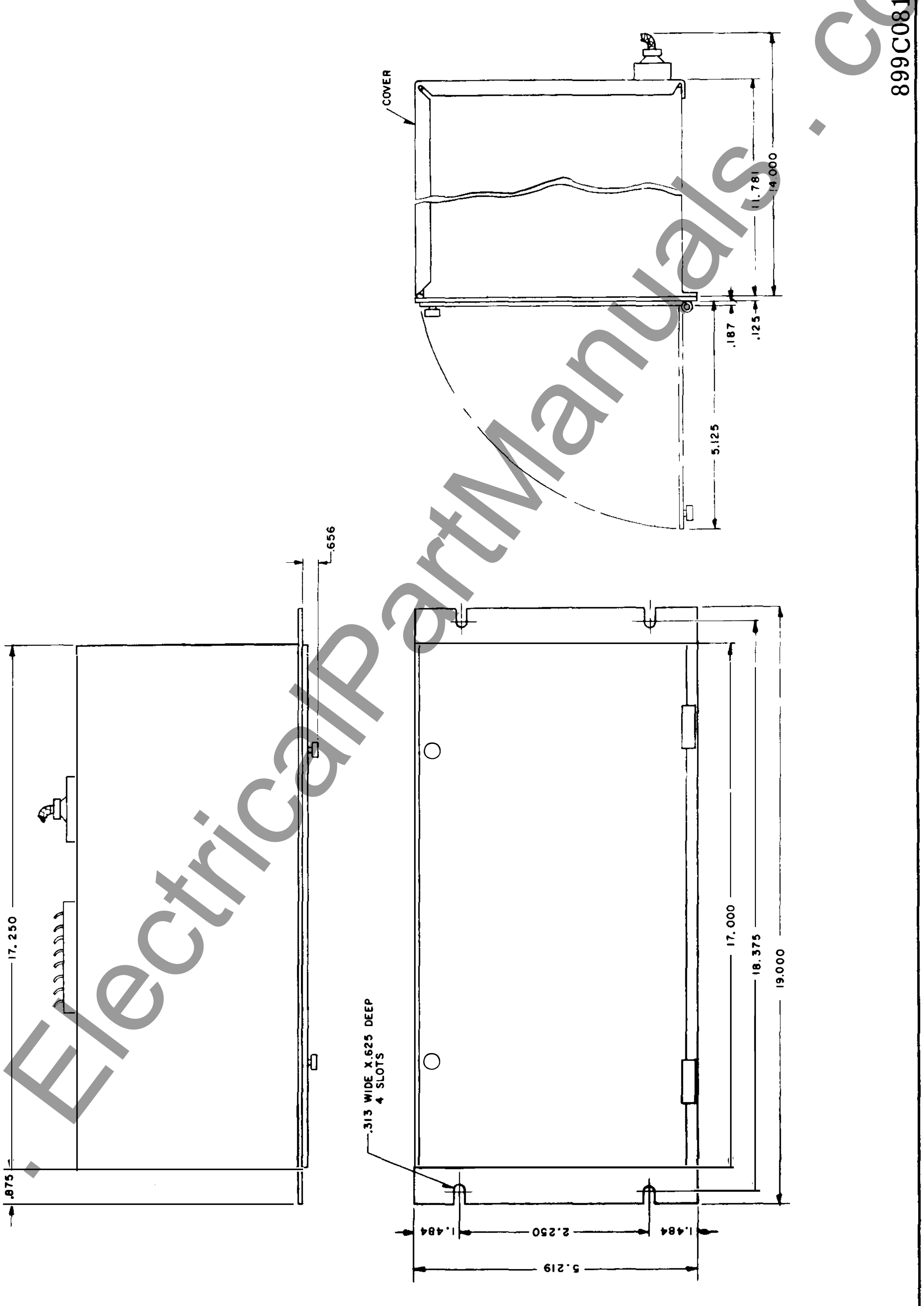

Fig. 11. Outline and Drilling Plan for Type SKDU Relay.

WESTINGHOUSE ELECTRIC CORPORATION

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

Printed in U.S.A.