INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KLF-1 LOSS-OF-FIELD RELAY

CAUTION Before putting protective relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The KLF-1 relay is a single-phase relay connected to the a-c side of a synchronous machine and contains three units connected so that the operation of two units sounds an alarm warning the operator of a low excitation condition, and the additional operation of the third unit sets up the trip circuit. The relay can be applied without modification to all types of synchronous machines. This relay is used where a wye-wye potential transformer connection is available.

CONSTRUCTION

The relay consists of two air-gap transformers (compensators), two tapped auto-transformers, one reactor, one cylinder-type distance unit, directional unit with adjustable resistor, an undervoltage unit with adjustable resistor, telephone relay, and an ICS indicating contactor switch.

Compensator

The compensators which are designated T_A and T_C are two-winding air gap transformers (Fig. 2). The primary or current winding of the long-reach-compensator T_A has seven taps which terminate at the block. They are marked 2.4, 3.16, 4.35, 5.93, 8.3, 11.5, 15.8. The primary winding of the short-reach compensator T_C also has seven taps which terminate at this tap block. They are marked 0.0, 0.91, 1.27, 1.82, 2.55, 3.64, 5.1. A voltage is induced in the secondary which is proportional to the primary tap and current magnitude. This proportionality is established by the cross sectional area of the laminated steel core, the length of an air gap which is located in the center of the coil, and the tightness of the laminations. All of these factors which influence the secondary voltage proportionality have been precisely set at the factory. The clamps which hold the laminations should not be disturbed by either tightening or loosening the clamp screws.

The secondary winding is connected in series with the relay terminal voltage. Thus a voltage which is proportional to the line current is added vectorially to the relay terminal voltage.

Auto-Transformer

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

The sign of M is negative when the R lead is above the L lead. M is positive when L is in a tap location which is above the tap location of the R lead. The M setting is determined by the sum of per unit values between the R and L lead. The actual per unit values which appear on the tap plate between taps are 0. .03, .06, and .06.

The auto-transformer makes it possible to expand the basic ranges of the long and short reach compensators by a multiplier of $\frac{S}{1 \pm M}$. Any relay ohm setting can be made within ± 1.5 percent from 2.08 ohms to 56 ohms for the long reach and from .79 ohms to 18 ohms for the short reach.

Impedance Tripping Unit

The distance unit is a four pole induction cyl-

SUPERSEDES I.L. 41-748.1A
*Denotes change from superseded issue

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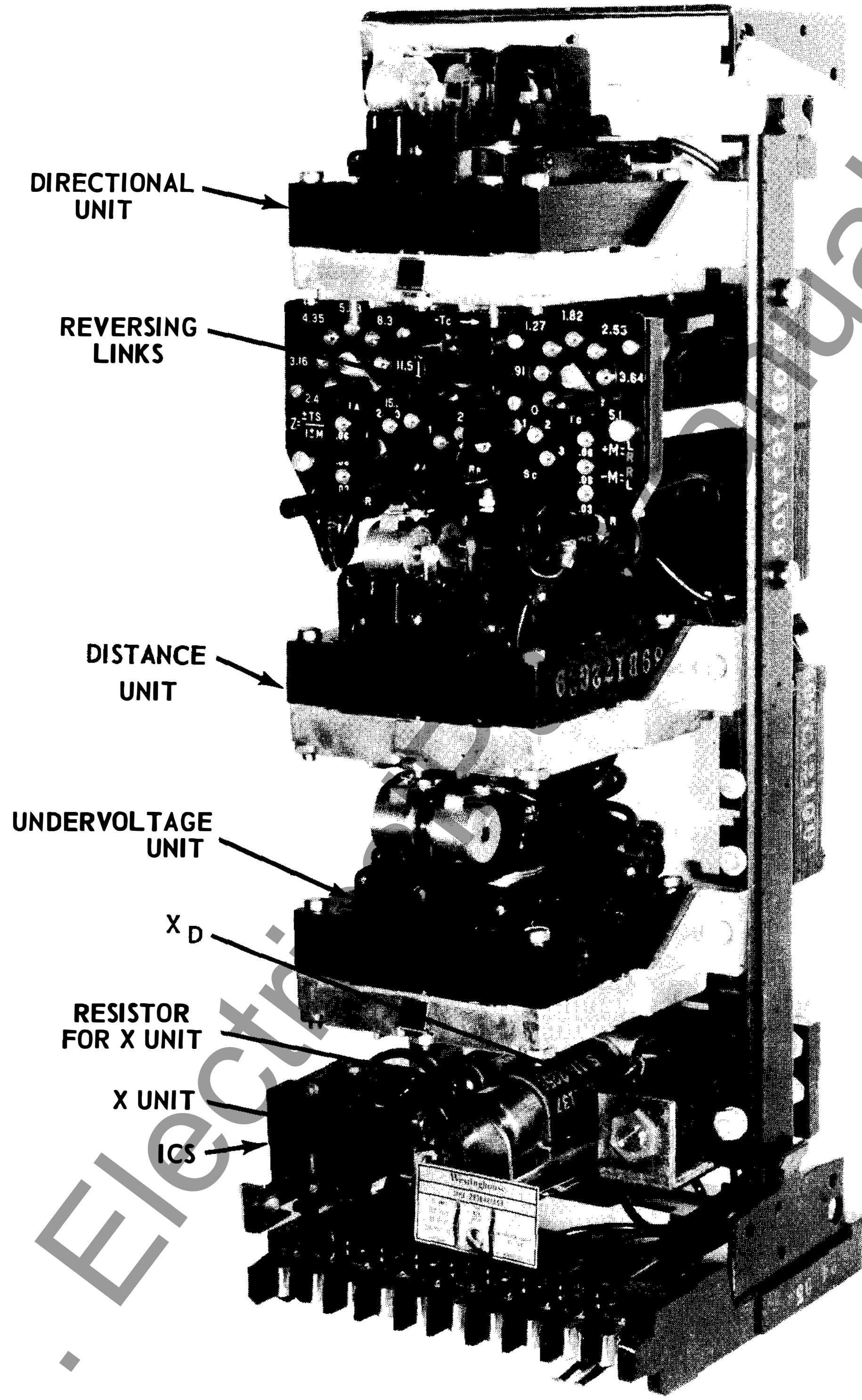


Fig. 1 Type KLF-1 Relay

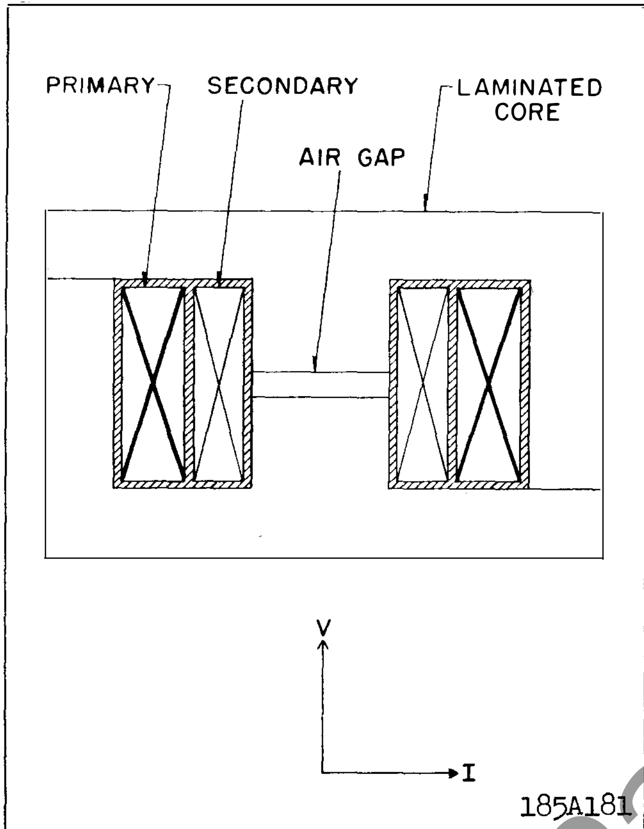


Fig. 2 Compensator Construction

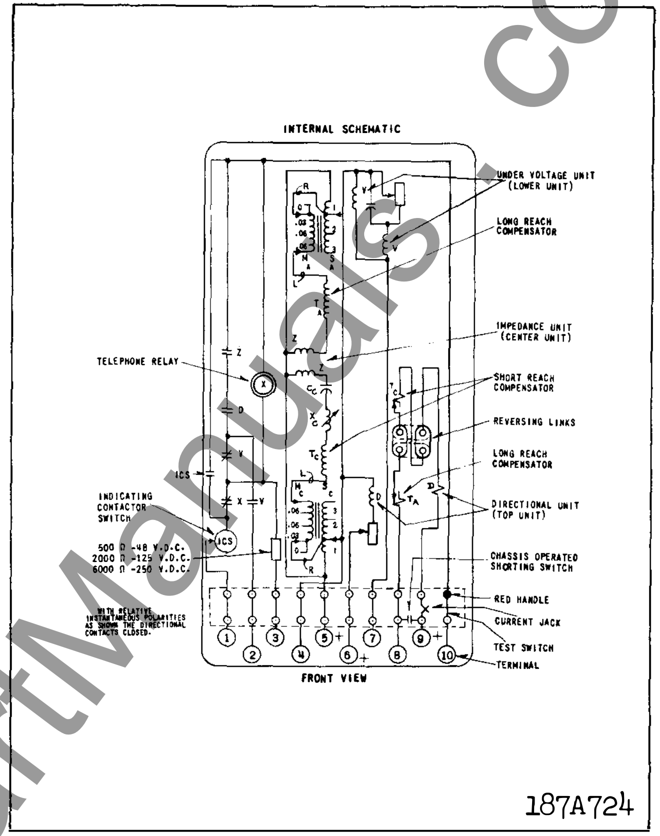


Fig. 3 Internal Schematic of Type KLF-1 Relay in FT41 Case

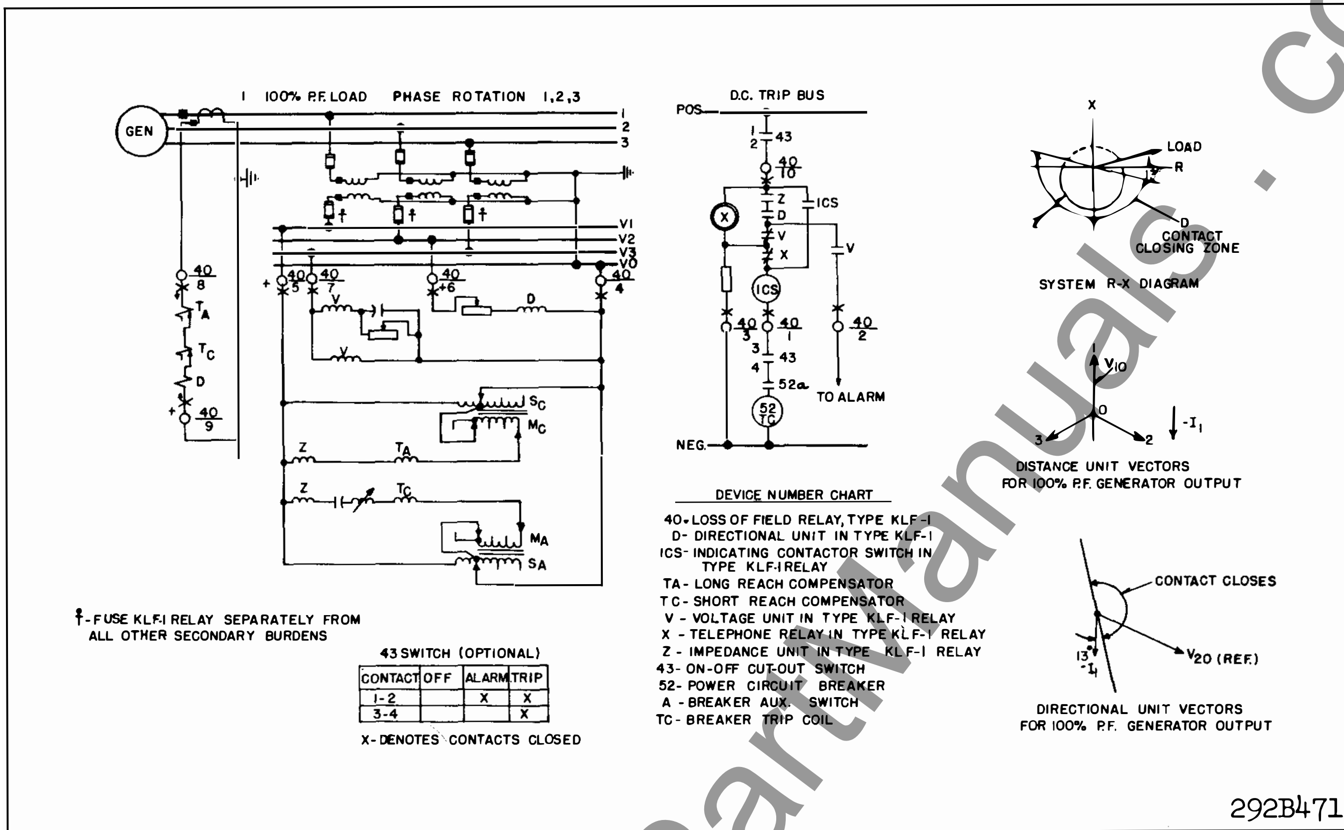
inder type unit. The operating torque of the unit is proportional to the product of the voltage quantities applied to the unit and the sine of the phase angle between the applied voltages. The direction of the
* torque so produced depends on the impedence vector seen by the relay with respect to its characteristic circle.

Mechanically, the cylinder unit is composed of four basic components: A die-cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge. The frame serves as a mounting structure for the magnetic core. The magnetic core which houses the lower pin bearing is secured to the frame by a locking nut. The bearing can be replaced, if necessary, without having to remove the magnetic core from the frame.

The electromagnet has two sets of 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 secured to the frame by four mounting screws.

The moving element assembly consists of a spiral spring, contact carrying member, and an aluminum cylinder assembled to a molded hub which holds the shaft. The hub to which the moving-contact arm is clamped has a wedge-and-cam construction, to provide low-bounce contact action. A casual inspection of the assembly might lead one to think that the contact arm bracket does not clamp on the hub as tightly as it should. However, this adjustment is accurately made at the factory and is locked in place with a lock nut and should not be changed. Optimum contact action is obtained when a force of 4 to 10 grams pressure applied to the face of the moving contact will make the arm slip one-fourth of its total free travel. Free travel is the angle through which the hub will slip from the condition of reset to the point where the clamp projection begins to ride up on the wedge. The free travel can vary between 15° to 20°.

The shaft has removable top and bottom jewel bearings. The shaft rides between the bottom pin



CONTACT	OFF	ALARM	TRIP
1-2		X	X
3-4			X

Fig. 4 External Schematic of Type KLF-1 Relay

bearing and the upper pin bearing with the cylinder rotating in an air gap formed by the electromagnet and the magnetic core. The stops are an integral part of the bridge.

The bridge is secured to the electromagnet and frame by two mounting screws. In addition to holding the upper pin bearing, the bridge is used for mounting the adjustable stationary contact housing. 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 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.

Directional Unit

The directional unit is an induction cylinder unit operating on the interaction between the polarizing circuit flux and the operating circuit flux.

Mechanically, the directional unit is composed of the same basic components as the distance unit: A die-cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge.

The electromagnet has two series-connected polarizing coils mounted diametrically opposite one another; two series-connected operating coils mounted diametrically opposite one another; two magnetic adjusting plugs; upper and lower adjusting plug clips, and two locating pins. The locating pins are used to accurately position the lower pin bearing, which is threaded into the bridge. The electromagnet is secured to the frame by four mounting screws.

The moving element assembly consists of a spiral spring, contact carrying member, and aluminum cylinder assembled to a molded hub which holds the shaft. The shaft has removable top and

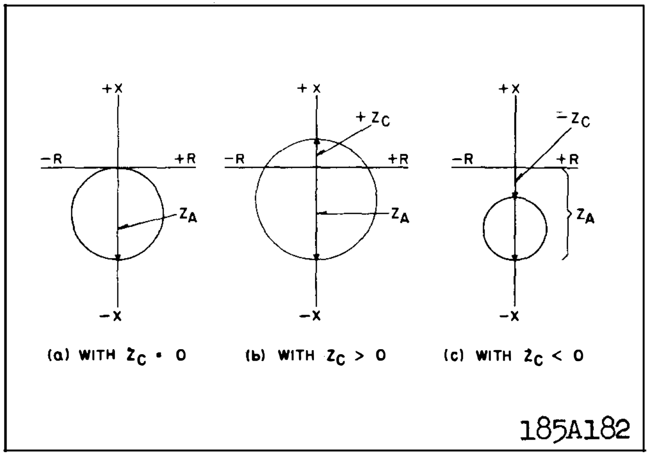


Fig. 5 R-X Diagram Characteristics with Various Z_C Compensator Settings

bottom jewel bearings. The shaft rides between the bottom pin bearing and the upper pin bearing with the cylinder rotating in an air gap formed by the electromagnet and the magnetic core.

The bridge is secured to the electromagnet and frame by two mounting screws. In addition to holding the upper pin bearing, the bridge is used for mounting the adjustable stationary contact housing. The stationary contact housing is held in position by a spring type clamp. The spring adjuster is located on the underside of the bridge and is attached to the moving contact arm by spiral spring. The spring adjuster is also held in place by a spring type clamp.

Undervoltage Unit

The voltage unit is an induction-cylinder unit.

Mechanically, the voltage unit is composed like the directional unit, of four components: A die cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge.

The electromagnet has two pairs of voltage coils. Each pair of diametrically opposed coils is connected in series. In addition one pair is in series with an parallel R-C combination. These sets are in parallel as shown in Fig. 3. The adjustable resistor serves not only to shift the phase angle of the one flux with respect to the other to produce torque, but it also provides a pick-up adjustment.

Otherwise the undervoltage unit is similar in its construction to the directional unit.

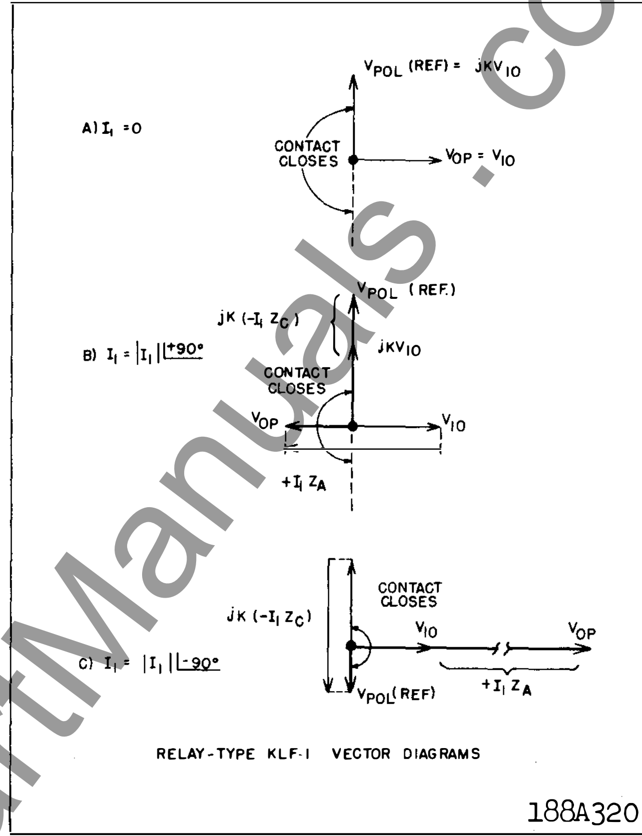


Fig. 6 Effect of Compensator Voltages (Z_C is positive)

Telephone Relay

The telephone relay (X) has a slow drop-out characteristic. When energized, the solenoid core attracts an iron right-angle armature bracket which in turn opens the break contacts. In actual service, the relay is normally energized holding the break contacts open. (Note: the make contacts are not used.) Drop-out delay adjustment is obtained by varying the air-gap between the armature and the core.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small 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 the outside of the case by a push rod located at the bottom of the cover.

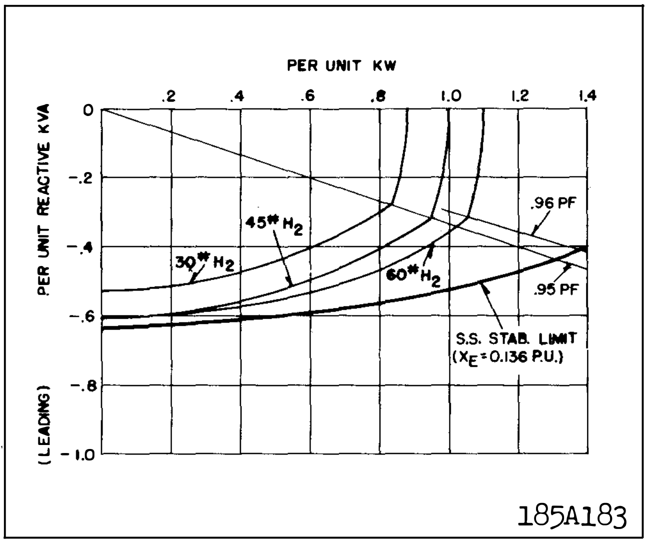


Fig. 7 Typical Machine Capacity Curves Plotted on a Per Unit KVA Basis (183,500 KVA, 45# H2, 18KV, 0.9 pf, 0.64 SCR, inner-cooled, 3600 rpm.)

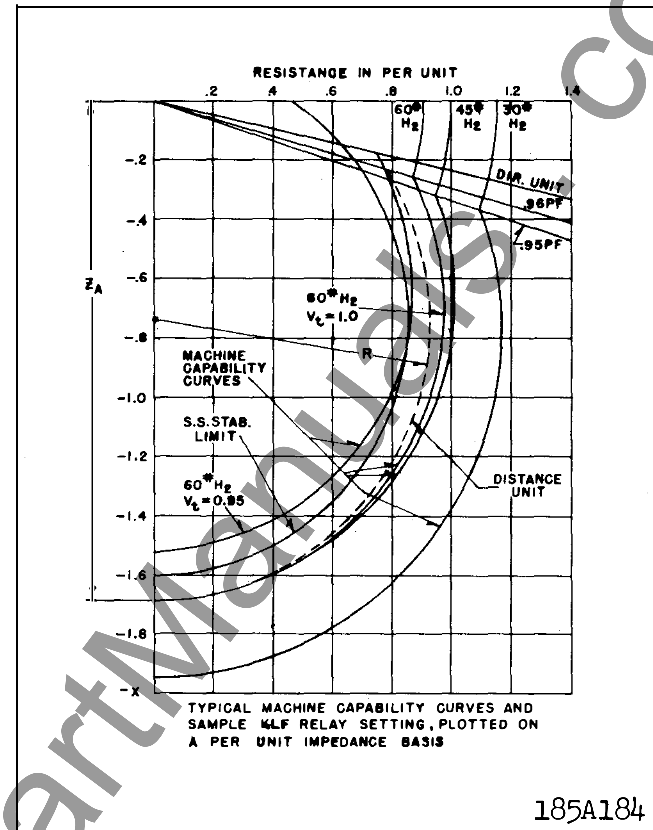


Fig. 8 Typical Machine Capability Curves and Sample KLF-1 Settings - Per Unit Impedance

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

OPERATION

The relay is connected and applied to the system as shown in Fig. 4. The directional unit closes its contacts for lagging var flow into the machine. Its zero torque line has been set at $-13°$ from the R-axis. Its primary function is to prevent operation of the relay during external faults. The impedance unit closes its contacts when, as a result of reduction in excitation, the impedance of the machine as viewed from its terminals is less than a predetermined value. The operation of both the impedance and directional units sounds an alarm, and the additional operation of the undervoltage unit trips the machine. As shown in Fig. 4, the contacts of all three units are connected in series across a telephone type relay designated X, which provides approximately 15 cycles time delay on dropout before energizing the trip coil. This time delay is to insure positive contact coordination under all possible operating conditions. During normal conditions, all contacts are open.

Principle of Distance Unit Operation

The distance unit is an induction cylinder unit having directional characteristics. Operation depends on the phase relationship between magnetic fluxes in the poles of the electromagnet.

One set of opposite poles, designated as the operating poles are energized by voltage V_{10} modified by a voltage derived from the long reach compensator T_A. The other set of poles (polarizing) are energized by the same voltage V_{10} except modified by a voltage derived from the short reach compensator T_C. The flux in the polarizing pole is so adjusted that the unit closes its contacts whenever flux in the operating set of poles leads the flux in the polarizing set.

Reach of the distance unit is determined by compensators T_A and T_C as modified by auto-transformer settings. Compensators T_A and T_C are designed so that its mutual impedance Z_A or Z_C has known and adjustable values as described below under CHARACTERISTICS and SETTINGS. The mutual impedance of a compensator is defined here as the ratio of secondary induced voltage to primary current and is equal to T. Each secondary compensator voltage is in series with the voltage V_{10}. Compensator voltages are equal to $I_1 Z_A$ for long reach compensator and $I_1 Z_C$ for short reach compensator, where I, is the relay current.

Fig. 5 shows how the compensation voltages I_1Z_A and I_1Z_C influence the R-X circle. Note that that Z_A independently determines the "long reach", while Z_C independently fixes the "short reach". With the reversing links in the normal position (+ZC) the circle includes the origin; with the opposite link position ($-Z_C$) the circle misses the origin. The following paragraphs explain this compensator action.

Referring to Fig. 4 note that X_C and C_C cause the polarizing voltage to be shifted 90° in the leading direction. Thus, when the current is zero, polarizing voltage V_{POL} leads the operating voltage V_{OP} by 90°, as shown in Fig. 6(a). This relation produces restraining torque. To illustrate how Z_A fixes the long reach, assume a relay current which leads V_{10} by 90° and of sufficient magnitude to operate the relay. This means the apparent impedance is along the -X axis. Note in Fig. 6(b) that the Z_A compensation reverses the operating voltage phase position. The relay balances when this voltage is zero. Note that this balance is unaffected by the Z_C compensation, since this compensation merely increases the size of V_{POL}.

For lagging current conditions note in Fig. 6(c) how V_{POL} is reversed by the Z_C compensation. In this case the Z_A compensation has no effect on the balance point. This explains why the short reach point is fixed independently by Z_C.

Fig. 6 assumes that Z_C is positive (circle includes origin). If the current coil link is reversed, the compensation becomes $+Z_C$. In Fig. 6(b) this change would result in, V_{POL} being reduced rather increased by the compensation. As the current increases V_{POL} will finally be reversed, reestablishing restraining torque. Thus, the current need not reverse in order to obtain a "short-reach" balance point. Instead the apparent impedance need only move towards the origin in the -X region to find the balance point. Therefore, the circle does not include the origin with a reversed link position.

CHARACTERISTICS

The type KLF relay is available in one range.

Distance Unit

The distance unit can be set to have characteristic circles that pass through origin, include it, or exclude it, as shown in Fig. 5.

The Z_A and Z_C values are determined by compensator settings and modified by autotransformer settings S, L, and R. The impedance settings in ohms reach can be made for any value from 2.08 to 56 ohms for Z_A, and from 0.79 ohm to 18 ohms for Z_C in steps of 3 percent.

The taps are marked as follows:

T_A
2.4, 3.16, 4.35, 5.93, 8.3, 11.5, 15.8

T_C
0.0, 0.91, 1.27, 1.82, 2.55, 3.64, 5.1

(S_A, S_C)
1, 2, 3

(M_A, M_C)
± values between taps .03, .06, .06

Directional Unit

The KLF relay is designed for potential polarization with an internal phase shifter, so that maximum torque occurs when the operating current leads the polarizing voltage by 43 degrees. The minimum pick-up has been set by the spring tension to be approximately 1 volt and 5 ampere at maximum torque angle.

Undervoltage Unit

The undervoltage unit is designed to close its contacts when the voltage is lower than the set value. The undervoltage unit is energized with V_{30}-voltage. The contacts can be adjusted to close over the range of 65 to 85 percent of normal system voltage. The dropout ratio of the unit is 98 percent or higher.

Trip Circuit

The main contacts will safely close 30 amperes at 250 volts d.c. and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pick-up setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

Trip Circuit Constant

Indicating Contactor Switch (ICS)

0.2 ampere tap - 6.5 ohm d-c resistance
2.0 ampere tap - 0.15 ohm d-c resistance

Burden

Current
@5 amps, 60 cycles

T_A & T_C SETTINGS	VA	ANGLE OF LAG
MAX.	12.05	58°
MIN.	4.17	36°

Potential
@69 volts, (Phase-To Ground) 60 cycles

Phase 1	S = 1	6.1 VA at 9° current lag
	S = 2	1.5 VA at 9° current lag
	S = 3	0.7 VA at 9° current lag
Phase 2		3.18 VA at 48° current lag
Phase 3		2.76 VA at 43° current lag

D-C Circuit

RATING	WATTS @ RATED
125	3.9
250	7.8

Thermal Ratings

Potential: 75 volts (L–N) continuous

Current: 8 amperes continuous
200 amperes for 1 second

SETTINGS CALCULATIONS

Distance Unit

Set the distance unit to operate before the steady-state stability limit is exceeded. Also, to allow maximum output without an alarm, set the distance unit to allow the machine to operate at maximum hydrogen pressure and 0.95 per unit voltage (lowest voltage for which the capability curve applies). Where the maximum capability of the machine cannot be realized without exceeding the steady-state stability limit, set the distance unit to operate before the steady-state limit is exceeded. Capability curves similar to Fig. 7 are obtained from the generator manufacturer.

To determine the desired setting convert the capability curve of Fig. 7 to the impedance curve of Fig. 8 by calculating $\frac{V_T 2,}{(KVA)_C}$ where V_T is the per unit terminal voltage and $(KVA)_C$ is the per unit output. If the capability curve is a circle the radius R^1 and offset C^1 of the inverse circle (V_T = 1) can be calculated as follows:

$$C^1 = \frac{C_C}{C_C^2 - R_C^2} \angle \theta^\circ \qquad (2)$$

$$R^1 = \frac{R_C}{C_C^2 - R_C^2} \qquad (3)$$

where C^1 = distance of capabiltiy - circle center from origin of R-X diagram.

R^1 = radius of capability circle on R-X diagram.

C_C = distance of power-circle center from origin.

R_C = radius of power circle.

θ = offset angle

After plotting the steady-state stability limit and the machine capability curves on the R-X diagram, plot the relay circle between the stability limit and the capability curve. (Note in Fig. 8 that the relay circle cannot be plotted within the 60# – V_T = 0.95 curve, since the machine is beyond the steady-state stability limit for these conditions.) This plot defines the desired reach Z_A and radius R of the relay circle. Then use the following procedure to select tap settings.

$$Z_{base} = \frac{1000\ (kv)^2 R_C}{(kva)\ R_V} \text{ ohms}$$

where

Z_{base} = one per unit primary ohms/as seen from the relay

kv = rated phase-to-phase voltage of the machine.

kva = rated kva of the machine.

R_c = the current transformer ratio.

R_v = the potential transformer ratio.

The actual settings, Z_A and Z_C, are:

$$Z_A = (Z_A \text{ per unit}) \times (Z_{base})$$

$$Z_C = (Z_C \text{ per unit}) \times (Z_{base}) = (2R - Z_A) \times (Z_{base})$$

where R = radius of circle in per unit.

The tap-plate settings are made according to equations:

$$Z_A (\text{or } Z_C) = \frac{TS}{1 \pm M} \quad (5)$$

where:

T = compensator tap value.

S = auto-transformer primary tap value.

M = auto-transformer secondary tap value.

(M is a per-unit value determined by taking 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).

The following procedure should be followed to obtain an optimum setting of the relay:

1. Select the lowest tap S which give a product of $18.6S_A$ greater than desired Z_A and a product of $6S_C$ greater than desired Z_C.
2. Select a value of M that will most nearly make it equal to:

$$M = \frac{TS}{Z} - 1.$$

If the sign is negative, then the M taps are connected with the R lead above the L lead to raise the setting.

Sample Calculations

Assume that a KLF relay is to be applied to the following machine:

3-phase, 60 cycles, 3600 rpm, 18 kv, rated at 0.9 pf, 183,500 KVA at 45 # H_2.

R_c = 1400/1 R_v = 150/1

If the recommended setting from Fig. 8 is used:

The relay circle needed for a particular set of machine capability curves may be obtained by trial and error using a compass. The offset and radius of the relay circle in fig. 8 were drawn by this method.

Z_A per unit = 1.68

Z_C per unit = $2R - Z_A$ = 2 x 0.94 − 1.68 = 0.20

(1) $$Z_{base} = \frac{1000(kv)^2 R_c}{(kva)R_v} = \frac{1000 \times (18)^2 \times 1400}{183{,}500 \times 150} = 16.45 \text{ ohms}$$

(2) $Z_A = Z_A(\text{per unit})(Z_{base}) = (1.68)(16.45) = 27.6$ ohms

(3) $Z_C = Z_C(\text{per unit})(Z_{base}) = (0.20)(16.45) = 3.29$ ohms

To set Z_A = 27.6

Step 1: The lowest tap S_A for 18.6 S_A greater than Z_A = 27.6 is 2. Set S_A in tap 2.

Step 2: T_A nearest to $\frac{27.6}{2}$ = 13.8 is T_A = 15.8

Set T_A in 15.8 tap

Step 3: $$M_A = \frac{T_A S_A}{Z} - 1 = \frac{15.8 \times 2}{27.6} - 1 = 1.145 - 1 = +.145$$

Set M = + .15. Place R lead in O, L lead in upper .06. The relay setting is now:

$$\text{Actual } Z_A = \frac{T_A S_A}{1 \pm M} = \frac{15.8 \times 2}{1 + 0.15} = \frac{31.6}{1.15} = 27.5$$

This is 99.7% of the desired setting.

To set Z_C = 3.29 ohms:

Step 1: The lowest tap S_C for $6S_C$ greater than 3.29 is S_C = 1.

Set S_C = 1

Step 2: T_C nearest to $\frac{3.29}{1}$ = 3.29 is 3.64

Set T_C in 3.64 tap.

Step 3: $$M_C = \frac{T_C S_C}{Z_C} - 1 = \frac{3.64 \times 1}{3.29} - 1 = 1.107 - 1 = +.107$$

Hence, the nearest M_C value is + .12. Now set R lead in 0.03 tap and L lead in the upper .06 tap.

(Since M_C has plus sign, lead L must be over R.)

$$\text{Then, } Z_C = \frac{T_C S_C}{(1 + M_C)} = \frac{3.64 \times 1}{1 + .12} = 3.25 \text{ ohms, or}$$

98.8% of the desired value.

Undervoltage Unit

The undervoltage unit is usually set to a value corresponding to the minimum safe system voltage for stability. This voltage depends upon system constants and is usually between 70 and 80 percent. A higher value could be used if it is desired to trip the machine sooner upon loss of field. The undervoltage unit is set at the factory for 77 percent of system voltage, or 53 volts.

Note: An electrical check of this particular setting is outlined in this instruction leaflet, under the heading "Acceptance Check".

SETTING THE RELAY

The type KLF relay requires a setting for each of the two compensators T_A and T_C, for each of the two auto-transformers primaries S_A and S_C, and for the undervoltage unit.

Compensator (T_A and T_C)

Each set of compensator taps terminates 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 the taps. Electrical connections between common insert and tap inserts are made with a link that is held in place with two connector screws, one in the common and one in the tap.

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

Compensator T_C requires an additional setting for including or excluding the origin of R-X diagram from the distance unit characteristic. If the desired characteristic is similar to that shown on Fig. 5b, the links should be set vertically in the + T_C arrow direction. If a characteristic similar to that shown in Fig. 5c is desired, set links horizontally in the - T_C arrow direction.

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.

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

Auto-Transformer Secondary (M_A and M_C)

Secondary tap connections are made through two leads identified as L and R for each transformer. These leads come out of the tap plate each through a small hole, one on each side of the vertical row of M tap inserts. The lead connectors are held in place on the proper tap by connector screws.

Values for which an M setting can be made are from - .15 to + .15 in steps of .03. The value of a setting is the sum of the numbers that are crossed when going from the R lead position to the L lead position. The sign of the M value is determined by which lead is in the higher position on the tap plate. The sign is positive (+) if the L lead is higher and negative (-) if the R lead is higher.

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

Tabulated Settings

Z	M	L Lead	R Lead
0.87 TS	+ .15	Upper .06	0
0.89 TS	+ .12	Upper .06	.03
0.92 TS	+ .09	Lower .06	0
0.94 TS	+ .06	Upper .06	Lower .06
0.97 TS	+ .03	.03	0
TS	0	0	0
1.03 TS	+ .03	0	.03
1.06 TS	- .06	Lower .06	Upper .06
1.1 TS	- .09	0	Lower .06
1.14 TS	- .12	.03	Upper .06
1.18 TS	- .15	0	Upper .06

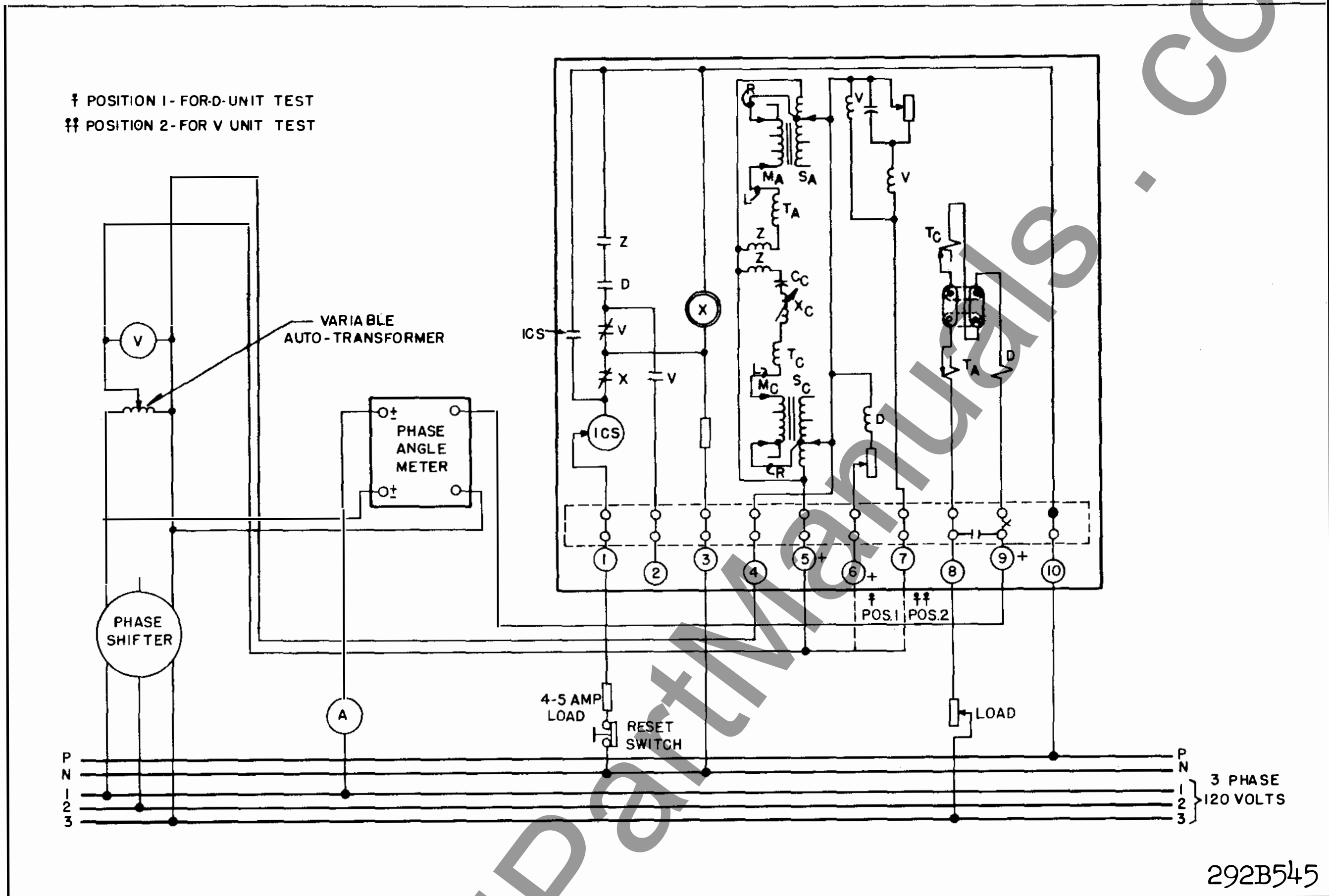


Fig. 9 Diagram of Test Connections for KLF-1 Relay

Undervoltage Unit

The voltage unit is calibrated to close its contact when the applied voltage is reduced to 53 volts. The voltage unit can be set to close its contacts from 40 volts to 70 volts by adjusting the resistor located in the rear, second from the bottom. The spiral spring is not disturbed when making any setting other than the calibrated setting of 53 volts.

Directional Setting

There is no setting to be made on directional unit.

Indicating Contractor Switch (ICS)

No setting is required on the ICS unit except the selection of the 0.2 or 2.0 ampere tap setting. This selection is made by connecting 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 volt or 250 volt d.c. type WL relay switch, or equivalent, use the 0.2 ampere tap. For 48 volt d.c. applications set ICS in 2 ampere tap and use S#304C209G01 type WL relay coil or equivalent.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting 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 the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT Case information refer to I.L. 41-076.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory. Upon receipt of the relay, no customer adjustments, other than those covered under "SETTINGS", should be required.

Acceptance Check

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

A. Distance Unit (Z)

1. Connect the relay as shown in Fig. 9 with the switch in position 2 and the trip circuit deenergized.
2. Make the following tap settings:

T_A = 11.5	T_C = 2.55
S_A = 2	S_C = 1
M_A = - .03	M_C = - .09

T_C link in middle block should be set for $+T_C$ direction.

This setting corresponds to Z_A = 23.7 Z_C = 2.80.

Adjust the phase shifter for 90° current lagging the voltage.

3. With the terminal voltage at 50 volts, increase current until contacts just close. This current should be within ± 3% of 2.11 amp (2.20-2.05 amp.).
4. Adjust phase shifter for 90° current leading the voltage.
5. With the terminal voltage at 50 volts increase current until contacts just close. This current should be within ± 3% of 17.9 amps. (18.5 17.3 amps.)

Contact Gap The gap between the stationary contact and moving contact with the relay in deenergized position should be approximately .040".

B. Directional Unit Circuit (D)

1. Connect the relay as shown in Fig. 9, with the switch in position 1 and the trip circuit deenergized.
2. With a terminal voltage of 1 volt and 5 amperes applied, turn the phase shifter to 43° (current leads voltage). The contacts should be closed. This is the maximum torque position.
3. Raise the voltage to 69 volts and vary the phase shifter to obtain the two angles where the moving contact just makes with the left hand contact. These two angles (where torque reverses) should be where the current leads the voltage by 313° and 133°, (± 4°.)
4. Contact Gap The gap between the stationary contact and moving contact with the relay in deenergized position should be approximately .020".

C. Undervoltage Circuit

1. Connect the relay as shown in figure 9, with switch in position 2 and the trip circuit deenergized.
2. Decrease the voltage until the contacts close to the left. This value should be 53 ±3% volts.

Routine Maintenance

All contacts should be periodically cleaned. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contacts.

Repair Calibration

A. Auto-transformer Check

Auto-transformers may be checked for turns ratio and polarity by applying a.c. voltage to terminals 4 and 5 and following the procedure below.

1) Set S_A and S_C on tap number 3. Set the "R" leads of M_A and M_C all on 0.0 and disconnect the "L" leads. Adjust the voltage for 90 volts. Measure voltage from terminal 5 to the tap #1 of S_A. It should be 30 volts (±1). From terminal 5 to tap #2 of S_A should be 60 volts. The same procedure should be followed for taps #1 and #2 of S_C.

2) Set S_A and S_C on 1 and adjust the voltage at the relay terminals for 100 volts. Measure voltage drop from terminals 5 to each of the M_A and M_C taps. This voltage should be equal to 100 (± 1) plus the sum of values between R and tap being measured. Example 100 (1 + .03 + .06) = 109 volts.

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

B. Distance Unit (Middle Unit) Calibration

Make following tap plate settings.

T_A = 15.8; T_C = 5.1

S_A = S_C = 1

Make M_A = M_C = - .15 settings:

"L" lead should be connected to the "O" insert "R" lead should be connected to the upper ".06" insert. (-.03-.06 .06 = -.15 between L & R).

For the most accurate calibration preheat relay for at least an hour by energizing terminals 4,5, 6 & 7 with 70 volts, phase, -to-neutral or terminals 5,6,7, with 3 phase 120 volts phase-to-phase voltages.

The links in the middle tap block should be set for the +T_C direction.

1) Contact Gap Adjustment

The spring type pressure clamp holding the stationary contact in position should not be loosened to make the necessary gap adjustments.

With moving contact in the opened position, i.e. against right stop on bridge, screw in stationary contact until both contacts just make (use neon light for indication). Then screw the stationary contact away from the moving contact 1-1/3 turn for contact gap of .040".

2.) With relay deenergized adjust the restraint spring so that contact arm just floats.

C) Impedance Characteristic Check

1) Maximum Torque Angle

Adjust the adjustable reactor for about 5 turns out. Applying 60 volts a.c. to terminals 5 and 4 and passing 4.8 amperes, through the current circuit turn the phase shifter until the moving contact opens. Turn the phase shifter back (few degrees) until contacts close. Note degrees. Continue to turn the phase shifter until contact opens, then swing phase shifter back until contact closes again. Note degrees. The maximum torque angle should be ($\pm 1^\circ$) computed as follows:

$$\frac{\text{Degrees to Close Contacts at Left + Degrees to Close Contacts at Right (6)}}{2} = 90^\circ$$

Adjust reactor X_C until the correct maximum-torque angle is obtained.

2) Sensitivity Adjustment

Using the connections of Fig. 9, apply 5 volts a.c. 90° leading, to terminals 4 and 5 pass .325 amperes through current circuit (terminals 9 and 8). The spiral spring is to be adjusted such that the contacts will just close. De-energize the relay. The moving contact should return to open position against the right hand stop.

3) Impedance Check

a. Adjust voltage to be 50 volts.
For current lagging 90° the impedance unit should close its contacts at 2.60 – 2.76 amp. Reverse current leads, the impedance unit should close its contacts 8.1 – 8.6 amperes.

b. Reverse the links in the middle tap block to–T_C position. Apply current of 8.6 amps. The contacts should stay open. Reverse current leads to original position. The contacts should open when current is increased above 8.1 amperes.

Set links back to +T_C position. Change S_A and S_C to setting "2". Keeping voltage at 50 volts, 90° leading check pick-up current. It should be 1.30 – 1.40 amperes. Now set the phase shifter so that voltage lags the current by 90°. Impedance unit should trip now at 4.05 – 4.3 amperes.

c. Change S_A, S_C = 3. Check pickup. It should be 2.70 – 2.90. Reverse current leads. Pick - up should be now .87 – 93 amp.

D) Directional unit (Top Unit)

1) Contact Gap Adjustment

The spring type pressure clamp holding the stationary contact in position should not be loosened to make the necessary gap adjustments.

With moving contact in the opened position, i.e. against right stop on bridge, screw in stationary contact until both contacts just make. Then screw the stationary contact away from the moving contact 3/4 of one turn for a contact gap of .22".

2) With relay deenergized adjust the restraint spring so that contact arm just floats.

3) Maximum Torque Angle Check

With 50 volts and 5 amperes applied, vary the phase shifter to obtain the two angles where the moving contacts just close. These two angles (where torque reverses) should be where the current leads the voltage by 313° ± 4° and 133° ±1. Readjust the bottom resistor located in the rear for correct reading.

4) Sensitivity Adjustment

Apply 1.0 volt to terminals 4 and 6. Observing polarities as per schematic, and 5 amperes current leading the voltage by 43°, the spiral spring is to be adjusted such that the contacts will just close. The adjustment of the spring is accomplished by rotating the spring adjuster which is located on the underside of the bridge. The spring adjuster has a notched periphery so that a tool may be used to rotate it. The spring type clamp holding the srping adjuster should not be loosened prior to rotating the spring adjuster.

5) Plug Adjustment for Reversing of Spurious Torques.

a. Set T_C = 0.0. Connect a heavy current lead from T_A center link to terminal 8.

b. Short circuit terminals 4 and 6.

c. Screw in both plugs as far as possible prior to starting the adjustment.

d. Apply 80 amps only momentarily, and the directional unit need not be cooled during initial rough adjustment. But, the directional unit should be cool when final adjustment is made.

e. When relay contact closes move the left screw out the right hand plug until spurious torque is reversed.

f. When plug adjustment is completed check to see that there is no closing torque when relay is energized with 40 amps and voltage terminals 4 and 6 short-circuited.

E) Undervoltage Unit (Lower Unit)

Note: The moving contact is in closed position to the left when deenergized.

1) Contact Gap Adjustments

a) L.H. (Normally Closed) Contact Adjustment

With the moving contact arm in the closed position, against left hand side of bridge, screw the left-hand contact in to just touch the moving contact (use neon light for indication) and then continue for one more complete turn.

b) R.H. (Normally Open) Contact Adjustment

With moving contact arm against the left hand stationary contact screw the right hand stationary contact until it just touches the moving contact. Then back the right hand contact out two-thirds of one turn to give 0.020 inch contact gap.

2) Sensitivity Adjustment

a) Apply voltage to terminals 4&7. Open the adjustable resistor that is located in the rear (second from the bottom). Adjust the spring so that contacts make (to the left) at 40 volts. The contacts should open when unit is energized with 41 or more volts.

b) Relay is set for 53 volts. This is accomplished by lowering resistance value until contacts make at 53 volts and open when unit is energized when 54 or more volts. The spring should not be used for this setting.

F) Indicating Contactor Switch (ICS)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap settings being used. The indicator target should drop freely.

G) Telephone Relay

Energize the telephone relay with 120 volts d-c. The telephone relay should operate positively. With armature gap set for .003" – .004" the contacts should not close for approximately 15 cycles after the relay is de-energized.

H) Compensator Check

Accuracy of the mutual impedance T of the compensators is set within very close tolerances at factory and should not change under normal conditions. The mutual impedance of the compensators can be checked with accurate instruments by the procedure outlined below.

1. Set T_A on the 15.8 tap

   T_C on the 5.1 tap

2. Disconnect the L-leads of sections M_A and M_C

3. Pass 10 amperes a.c. current in terminal 9 and out of terminal 8.

4. Measure the compensator voltage with an accurate high resistance voltmeter (5000 ohms/volt).

5. Compensator A-voltage should be checked between lead L_A and terminal 5.

   For T_A = 15.8 the voltage measured should be 158 volts ± 3%.

6. Compensator C voltage should be checked between lead L_C and the front terminal of the reactor (X_D).

   For T_C = 5.1, the voltage should be 51 volts (±3%).

7. For all other taps the compensator voltage is IT (±3%)
   where I - relay current
   T - tap setting.

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.

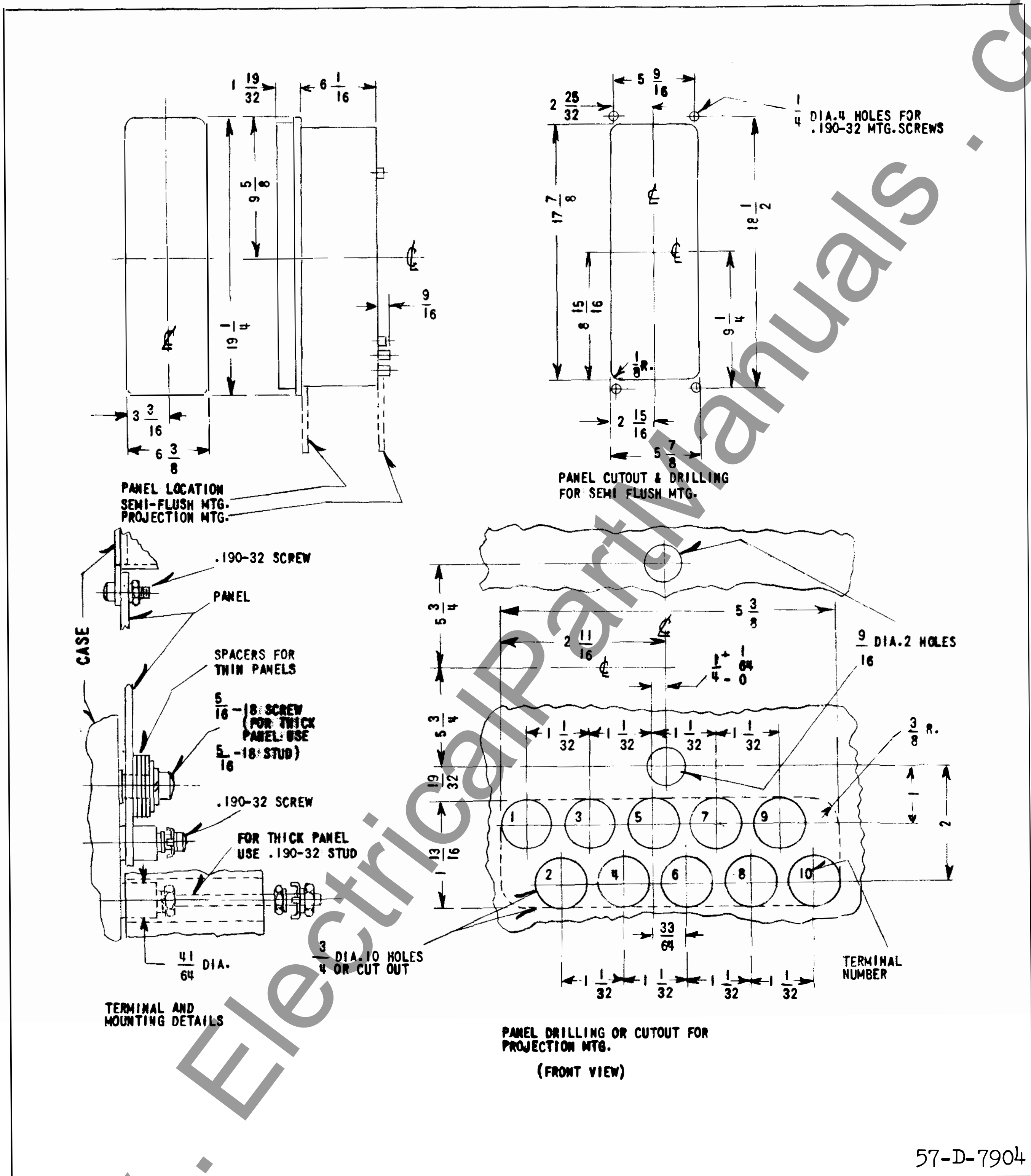


Fig. 10 Outline and Drilling Plan for the Type KLF-1 Relay in the FT41 Case.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE KLF-1 LOSS-OF-FIELD RELAY

CAUTION Before putting protective relays into service, remove all blocking which may have been inserted for the purpose of securing the parts during shipment, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

APPLICATION

The KLF-1 relay is a single-phase relay connected to the a-c side of a synchronous machine and contains three units connected so that the operation of two units sounds an alarm warning the operator of a low excitation condition, and the additional operation of the third unit sets up the trip circuit. The relay can be applied without modification to all types of synchronous machines. This relay is used where a wye-wye potential transformer connection is available.

CONSTRUCTION

The relay consists of two air-gap transformers (compensators), two tapped auto-transformers, one reactor, one cylinder-type distance unit, directional unit with adjustable resistor, an undervoltage unit with adjustable resistor, telephone relay, and an ICS indicating contactor switch.

Compensator

The compensators which are designated T_A and T_C are two-winding air gap transformers (Fig. 2). The primary or current winding of the long-reach-compensator T_A has seven taps which terminate at the block. They are marked 2.4, 3.16, 4.35, 5.93, 8.3, 11.5, 15.8. The primary winding of the short-reach compensator T_C also has seven taps which terminate at this tap block. They are marked 0.0, 0.91, 1.27, 1.82, 2.55, 3.64, 5.1. A voltage is induced in the secondary which is proportional to the primary tap and current magnitude. This proportionality is established by the cross sectional area of the laminated steel core, the length of an air gap which is located in the center of the coil, and the tightness of the laminations. All of these factors which influence the secondary voltage proportionality have been precisely set at the factory. The clamps which hold the laminations should not be disturbed by either tightening or loosening the clamp screws.

The secondary winding is connected in series with the relay terminal voltage. Thus a voltage which is proportional to the line current is added vectorially to the relay terminal voltage.

Auto-Transformer

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

The sign of M is negative when the R lead is above the L lead. M is positive when L is in a tap location which is above the tap location of the R lead. The M setting is determined by the sum of per unit values between the R and L lead. The actual per unit values which appear on the tap plate between taps are 0. .03, .06, and .06.

The auto-transformer makes it possible to expand the basic ranges of the long and short reach compensators by a multiplier of $\frac{S}{1 \pm M}$. Any relay ohm setting can be made within ± 1.5 percent from 2.08 ohms to 56 ohms for the long reach and from .79 ohms to 18 ohms for the short reach.

Impedance Tripping Unit

The distance unit is a four pole induction cyl-

SUPERSEDES I.L. 41-748.1
*Denotes change from superseded issue

EFFECTIVE DECEMBER 1965

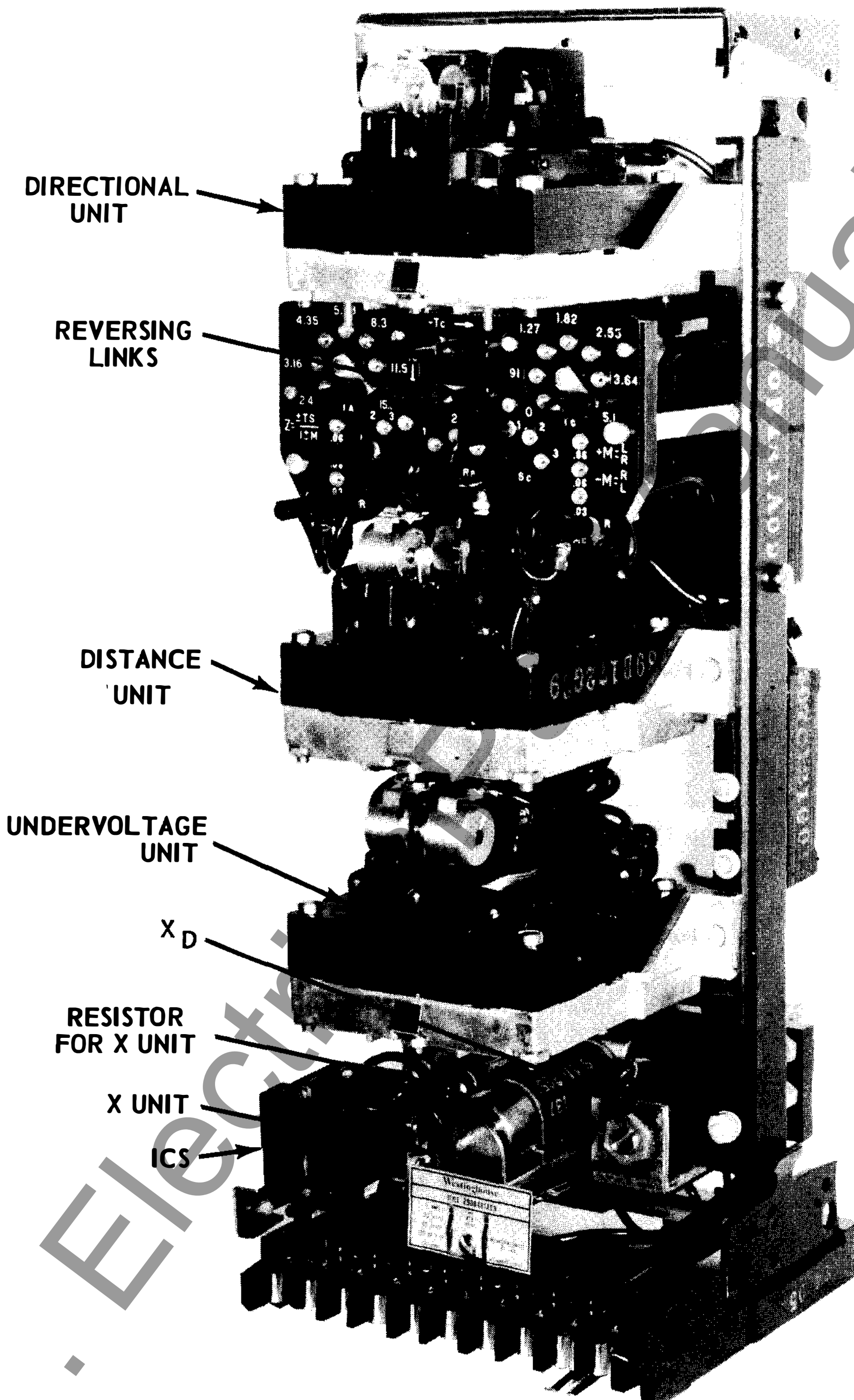


Fig. 1 Type KLF-1 Relay

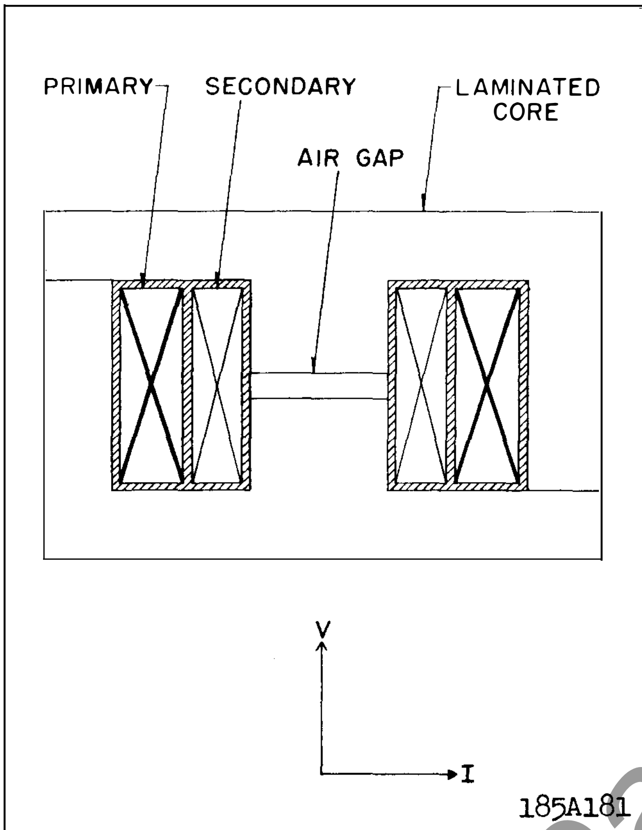
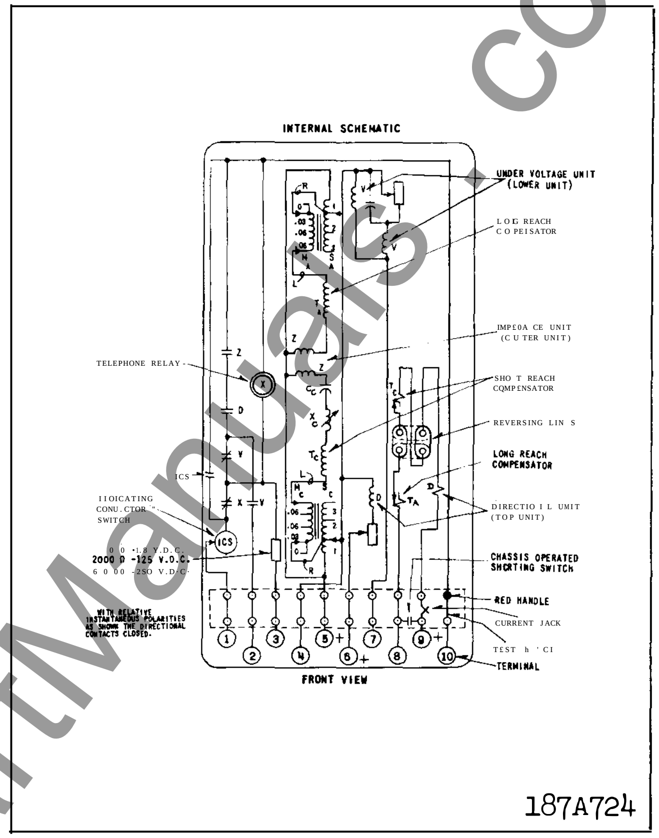


Fig. 2 Compensator Construction



* *Fig. 3 Internal Schematic of Type KLF-1 Relay in FT41 Case*

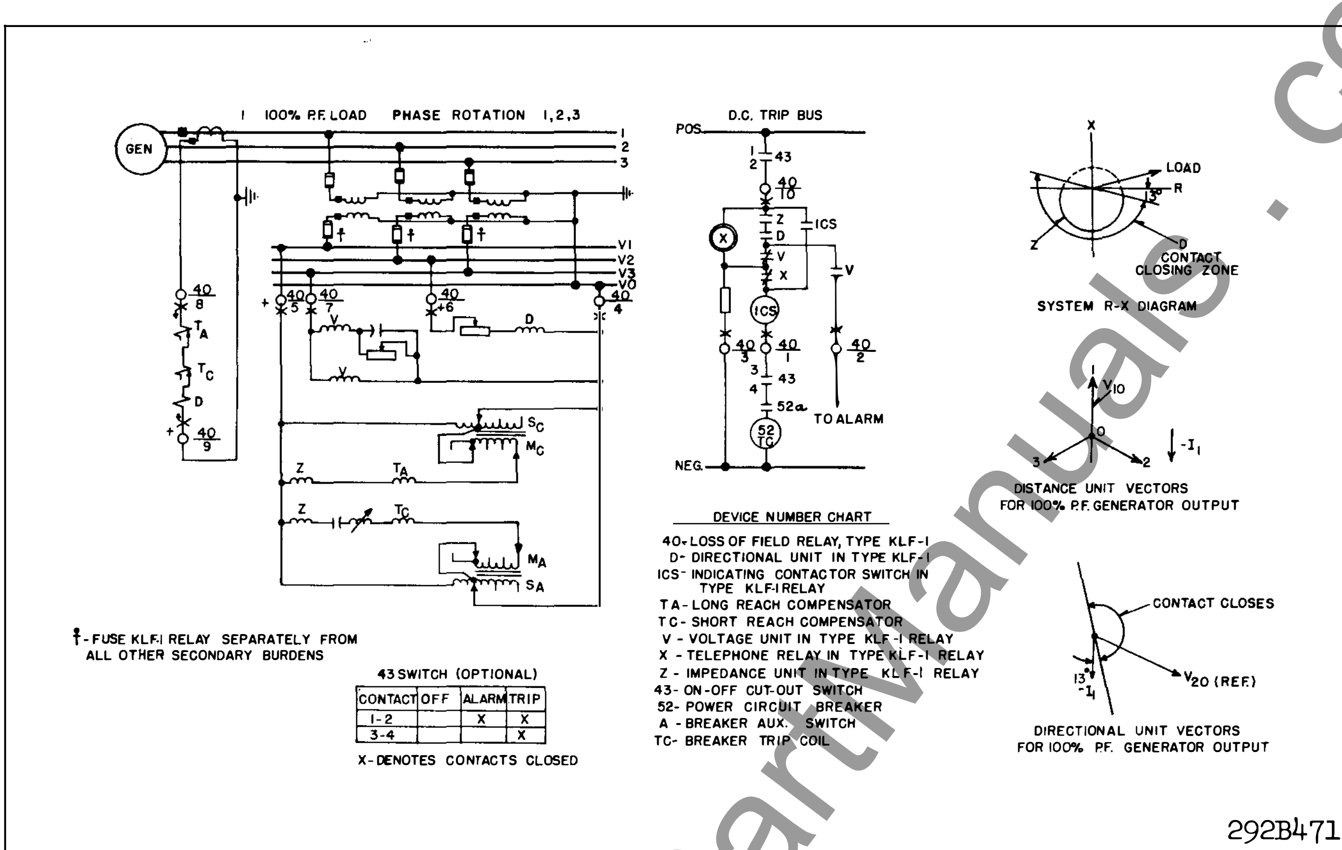
inder type unit. The operating torque of the unit is proportional to the product of the voltage quantities applied to the unit and the sine of the phase angle between the applied voltages. The direction of the torque so produced depends on the fault location with respect to the balance point setting.

Mechanically, the cylinder unit is composed of four basic components: A die-cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge. The frame serves as a mounting structure for the magnetic core. The magnetic core which houses the lower pin bearing is secured to the frame by a locking nut. The bearing can be replaced, if necessary, without having to remove the magnetic core from the frame.

The electromagnet has two sets of 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 secured to the frame by four mounting screws.

The moving element assembly consists of a spiral spring, contact carrying member, and an aluminum cylinder assembled to a molded hub which holds the shaft. The hub to which the moving-contact arm is clamped has a wedge-and-cam construction, to provide low-bounce contact action. A casual inspection of the assembly might lead one to think that the contact arm bracket does not clamp on the hub as tightly as it should. However, this adjustment is accurately made at the factory and is locked in place with a lock nut and should not be changed. Optimum contact action is obtained when a force of 4 to 10 grams pressure applied to the face of the moving contact will make the arm slip one-fourth of its total free travel. Free travel is the angle through which the hub will slip from the condition of reset to the point where the clamp projection begins to ride up on the wedge. The free travel can vary between 15° to 20°.

The shaft has removable top and bottom jewel bearings. The shaft rides between the bottom pin



** Fig. 4 External Schematic of Type KLF-1 Relay*

bearing and the upper pin bearing with the cylinder rotating in an air gap formed by the electromagnet and the magnetic core. The stops are an integral part of the bridge.

The bridge is secured to the electromagnet and frame by two mounting screws. In addition to holding the upper pin bearing, the bridge is used for mounting the adjustable stationary contact housing. 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 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.

Directional Unit

The directional unit is an induction cylinder unit operating on the interaction between the polarizing circuit flux and the operating circuit flux.

Mechanically, the directional unit is composed of the same basic components as the distance unit: A die-cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge.

The electromagnet has two series-connected polarizing coils mounted diametrically opposite one another; two series-connected operating coils mounted diametrically opposite one another; two magnetic adjusting plugs; upper and lower adjusting plug clips, and two locating pins. The locating pins are used to accurately position the lower pin bearing, which is threaded into the bridge. The electromagnet is secured to the frame by four mounting screws.

The moving element assembly consists of a spiral spring, contact carrying member, and aluminum cylinder assembled to a molded hub which holds the shaft. The shaft has removable top and

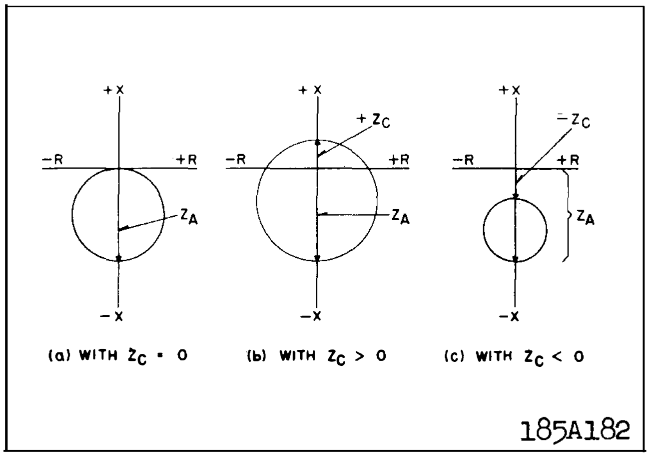


Fig. 5 R-X Diagram Characteristics with Various Z_c Compensator Settings

bottom jewel bearings. The shaft rides between the bottom pin bearing and the upper pin bearing with the cylinder rotating in an air gap formed by the electromagnet and the magnetic core.

The bridge is secured to the electromagnet and frame by two mounting screws. In addition to holding the upper pin bearing, the bridge is used for mounting the adjustable stationary contact housing . The stationary contact housing is held in position by a spring type clamp. The spring adjuster is located on the underside of the bridge and is attached to the moving contact arm by spiral spring. The spring adjuster is also held in place by a spring type clamp.

Undervoltage Unit

The voltage unit is an induction-cylinder unit.

Mechanically, the voltage unit is composed like the directional unit, of four components: A die cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge.

The electromagnet has two pairs of voltage coils. Each pair of diametrically opposed coils is connected in series. In addition one pair is in series with an parallel R-C combination. These sets are in parallel as shown in Fig. 3. The adjustable resistor serves not only to shift the phase angle of the one flux with respect to the other to produce torque, but it also provides a pick-up adjustment.

Otherwise the undervoltage unit is similar in its construction to the directional unit.

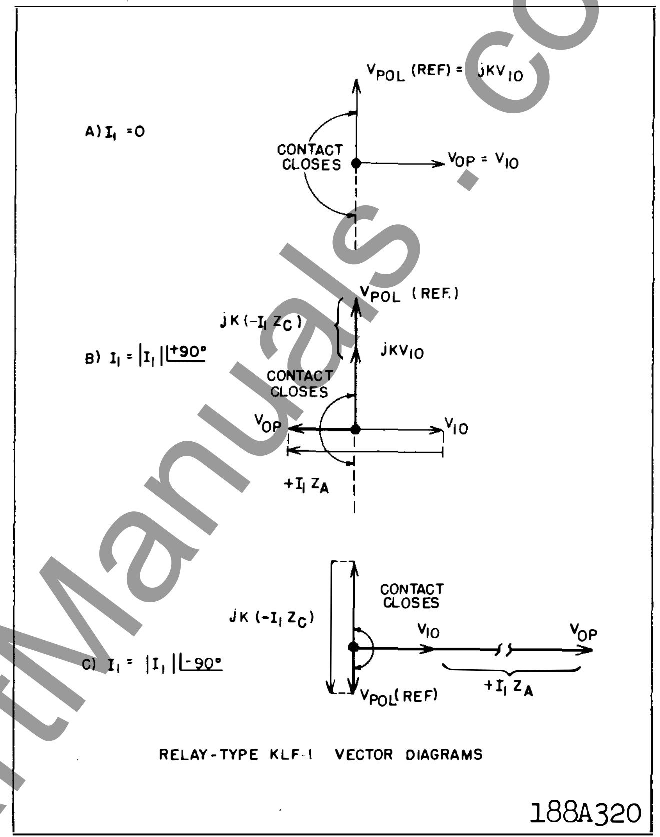


Fig. 6 Effect of Compensator Voltages (Z_c is positive)

Telephone Relay

The telephone relay (X) has a slow drop-out characteristic. When energized, the solenoid core attracts an iron right-angle armature bracket which in turn opens the break contacts. In actual service, the relay is normally energized holding the break contacts open. (Note: the make contacts are not used.) Drop-out delay adjustment is obtained by varying the air-gap between the armature and the core.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small 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 the outside of the case by a push rod located at the bottom of the cover.

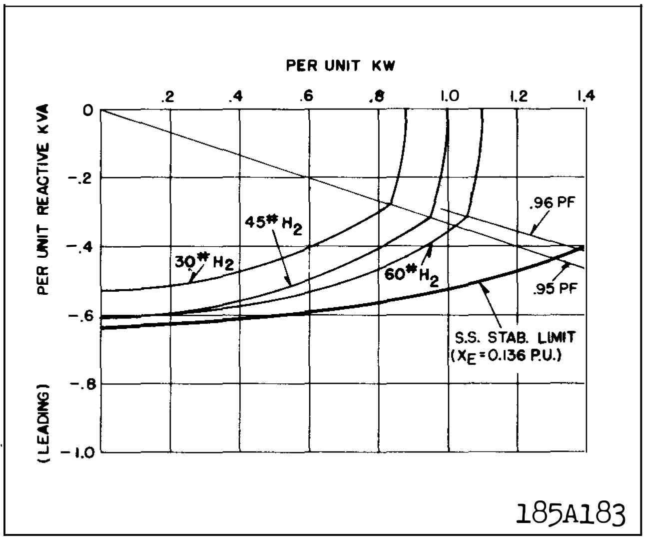
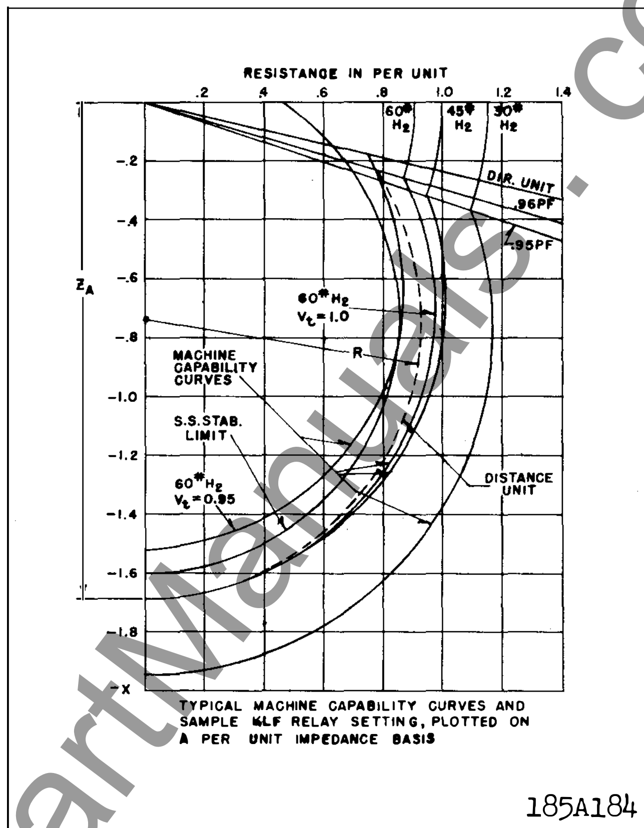


Fig. 7 Typical Machine Capacity Curves Plotted on a Per Unit KVA Basis (183,500 KVA, 45# H2, 18KV, 0.9 pf, 0.64 SCR, inner-cooled, 3600 rpm.)



* *Fig. 8 Typical Machine Capability Curves and Sample KLF-1 Settings - Per Unit Impedance*

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

OPERATION

The relay is connected and applied to the system as shown in Fig. 4. The directional unit closes its contacts for lagging var flow into the machine. Its zero torque line has been set at $-13°$ from the R-axis. Its primary function is to prevent operation of the relay during external faults. The impedance unit closes its contacts when, as a result of reduction in excitation, the impedance of the machine as viewed from its terminals is less than a predetermined value. The operation of both the impedance and directional units sounds an alarm, and the additional operation of the undervoltage unit trips the machine. As shown in Fig. 4, the contacts of all three units are connected in series across a telephone type relay designated X, which provides approximately 15 cycles time delay on dropout before energizing the trip coil. This time delay is to insure positive contact coordination under all possible operating conditions. During normal conditions, all contacts are open.

Principle of Distance Unit Operation

The distance unit is an induction cylinder unit having directional characteristics. Operation depends on the phase relationship between magnetic fluxes in the poles of the electromagnet.

One set of opposite poles, designated as the operating poles are energized by voltage V_{10} modified by a voltage derived from the long reach compensator T_A. The other set of poles (polarizing) are energized by the same voltage V_{10} except modified by a voltage derived from the short reach compensator T_C. The flux in the polarizing pole is so adjusted that the unit closes its contacts whenever flux in the operating set of poles leads the flux in the polarizing set.

Reach of the distance unit is determined by compensators T_A and T_C as modified by auto-transformer settings. Compensators T_A and T_C are designed so that its mutual impedance Z_A or Z_C has known and adjustable values as described below under CHARACTERISTICS and SETTINGS. The mutual impedance of a compensator is defined here as the ratio of secondary induced voltage to primary current and is equal to T. Each secondary compensator voltage is in series with the voltage V_{10}. Compensator voltages are equal to $I_1 Z_A$ for long reach compensator and $I_1 Z_C$ for short reach compensator, where I, is the relay current.

Fig. 5 shows how the compensation voltages I_1Z_A and I_1Z_C influence the R-X circle. Note that that Z_A independently determines the "long reach", while Z_C independently fixes the "short reach". With the reversing links in the normal position (+ZC) the circle includes the origin; with the opposite link position ($-Z_C$) the circle misses the origin. The following paragraphs explain this compensator action.

Referring to Fig. 4 note that X_C and C_C cause the polarizing voltage to be shifted 90° in the leading direction. Thus, when the current is zero, polarizing voltage V_{POL} leads the operating voltage V_{OP} by 90°, as shown in Fig. 6(a). This relation produces restraining torque. To illustrate how Z_A fixes the long reach, assume a relay current which leads V_{10} by 90° and of sufficient magnitude to operate the relay. This means the apparent impedance is along the −X axis. Note in Fig. 6(b) that the Z_A compensation reverses the operating voltage phase position. The relay balances when this voltage is zero. Note that this balance is unaffected by the Z_C compensation, since this compensation merely increases the size of V_{POL}.

For lagging current conditions note in Fig. 6(c) how V_{POL} is reversed by the Z_C compensation. In this case the Z_A compensation has no effect on the balance point. This explains why the short reach point is fixed independently by Z_C.

Fig. 6 assumes that Z_C is positive (circle includes origin). If the current coil link is reversed, the compensation becomes $+Z_C$. In Fig. 6(b) this change would result in, V_{POL} being reduced rather increased by the compensation. As the current increases V_{POL} will finally be reversed, reestablishing restraining torque. Thus, the current need not reverse in order to obtain a "short-reach" balance point. Instead the apparent impedance need only move towards the origin in the −X region to find the balance point. Therefore, the circle does not include the origin with a reversed link position.

CHARACTERISTICS

The type KLF relay is available in one range.

Distance Unit

The distance unit can be set to have characteristic circles that pass through origin, include it, or exclude it, as shown in Fig. 5.

The Z_A and Z_C values are determined by compensator settings and modified by autotransformer settings S, L, and R. The impedance settings in ohms reach can be made for any value from 2.08 to 56 ohms for Z_A, and from 0.79 ohm to 18 ohms for Z_C in steps of 3 percent.

The taps are marked as follows:

T_A
2.4, 3.16, 4.35, 5.93, 8.3, 11.5, 15.8

T_C
0.0, 0.91, 1.27, 1.82, 2.55, 3.64, 5.1

(S_A, S_C)
1, 2, 3

(M_A, M_C)
± values between taps .03, .06, .06

Directional Unit

The KLF relay is designed for potential polarization with an internal phase shifter, so that maximum torque occurs when the operating current leads the polarizing voltage by 43 degrees. The minimum pick-up has been set by the spring tension to be approximately 1 volt and 5 ampere at maximum torque angle.

Undervoltage Unit

The undervoltage unit is designed to close its contacts when the voltage is lower than the set value. The undervoltage unit is energized with V_{30}-voltage. The contacts can be adjusted to close over the range of 65 to 85 percent of normal system voltage. The dropout ratio of the unit is 98 percent or higher.

Trip Circuit

The main contacts will safely close 30 amperes at 250 volts d.c. and the seal-in contacts of the indicating contactor switch will safely carry this current long enough to trip a circuit breaker.

The indicating contactor switch has two taps that provide a pick-up setting of 0.2 or 2 amperes. To change taps requires connecting the lead located in front of the tap block to the desired setting by means of a screw connection.

Trip Circuit Constant

Indicating Contactor Switch (ICS)

0.2 ampere tap - 6.5 ohm d-c resistance
2.0 ampere tap - 0.15 ohm d-c resistance

Burden

Current
@5 amps, 60 cycles

T_A & T_C SETTINGS	VA	ANGLE OF LAG
MAX.	12.05	58°
MIN.	4.17	36°

Potential
@69 volts, (Phase-To Ground) 60 cycles

Phase 1	S = 1	6.1 VA at 9° current lag
	S = 2	1.5 VA at 9° current lag
	S = 3	0.7 VA at 9° current lag
Phase 2		3.18 VA at 48° current lag
Phase 3		2.76 VA at 43° current lag

D-C Circuit

RATING	WATTS @ RATED
125	3.9
250	7.8

Thermal Ratings

* Potential: 75 volts (L–N) continuous

Current: 8 amperes continuous
200 amperes for 1 second

SETTINGS CALCULATIONS

Distance Unit

Set the distance unit to operate before the steady-state stability limit is exceeded. Also, to allow maximum output without an alarm, set the distance unit to allow the machine to operate at maximum hydrogen pressure and 0.95 per unit voltage (lowest voltage for which the capability curve applies). Where the maximum capability of the machine cannot be realized without exceeding the steady-state stability limit, set the distance unit to operate before the steady-state limit is exceeded. Capability curves similar to Fig. 7 are obtained from the generator manufacturer.

To determine the desired setting convert the capability curve of Fig. 7 to the impedance curve of Fig. 8 by calculating $\frac{V_T 2,}{(KVA)_C}$ where V_T is the per unit terminal voltage and $(KVA)_C$ is the per unit output. If the capability curve is a circle the radius R^1 and offset C^1 of the inverse circle (V_T = 1) can be calculated as follows:

$$C^1 = \frac{C_C}{C_C^2 - R_C^2} \angle \theta^\circ \qquad (2)$$

$$R^1 = \frac{R_C}{C_C^2 - R_C^2} \qquad (3)$$

where C^1 = distance of capabiltiy - circle center from origin of R-X diagram.

R^1 = radius of capability circle on R-X diagram.

C_C = distance of power-circle center from origin.

R_C = radius of power circle.

θ = offset angle

After plotting the steady-state stability limit and the machine capability curves on the R-X diagram, plot the relay circle between the stability limit and the capability curve. (Note in Fig. 8 that the relay circle cannot be plotted within the 60# — V_T = 0.95 curve, since the machine is beyond the steady-state stability limit for these conditions.) This plot defines the desired reach Z_A and radius R of the relay circle. Then use the following procedure to select tap settings.

$$Z_{base} = \frac{1000\ (kv)^2 R_C}{(kva)\ R_V} \text{ ohms}$$

where

Z_{base} = one per unit primary ohms/as seen from the relay

kv = rated phase-to-phase voltage of the machine.

kva = rated kva of the machine.

R_c = the current transformer ratio.

R_v = the potential transformer ratio.

The actual settings, Z_A and Z_C, are:

$$Z_A = (Z_A \text{ per unit}) \times (Z_{base})$$

$$Z_C = (Z_C \text{ per unit}) \times (Z_{base}) = (2R - Z_A) \times (Z_{base})$$

where R = radius of circle in per unit.

The tap-plate settings are made according to equations:

$$Z_A (\text{or } Z_C) = \frac{TS}{1 \pm M} \qquad (5)$$

where:

T = compensator tap value.

S = auto-transformer primary tap value.

M = auto-transformer secondary tap value.

(M is a per-unit value determined by taking 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).

The following procedure should be followed to obtain an optimum setting of the relay:

1. Select the lowest tap S which give a product of $18.6S_A$ greater than desired Z_A and a product of $6S_C$ greater than desired Z_C.
2. Select a value of M that will most nearly make it equal to:

$$M = \frac{TS}{Z} - 1.$$

If the sign is negative, then the M taps are connected with the R lead above the L lead to raise the setting.

Sample Calculations

Assume that a KLF relay is to be applied to the following machine:

3-phase, 60 cycles, 3600 rpm, 18 kv, rated at 0.9 pf, 183,500 KVA at 45 # H_2.

R_C = 1400/1 $\qquad$ R_V = 150/1

If the recommended setting from Fig. 8 is used:

* The relay circle needed for a particular set of machine capability curves may be obtained by trial and error using a compass. The offset and radius of the relay circle in fig. 8 were drawn by this method.

Z_A per unit = 1.68

Z_C per unit = $2R - Z_A$ = 2 x 0.94 − 1.68 = 0.20

(1) $Z_{base} = \frac{1000(kv)^2 R_C}{(kva)R_V} = \frac{1000 \times (18)^2 \times 1400}{183{,}500 \times 150} = 16.45$ ohms

(2) $Z_A = Z_A (\text{per unit})(Z_{base}) = (1.68)(16.45) = 27.6$ ohms

(3) $Z_C = Z_C(\text{per unit})(Z_{base}) = (0.20)(16.45) = 3.29$ ohms

To set Z_A = 27.6

Step 1: The lowest tap S_A for 18.6 S_A greater than Z_A = 27.6 is 2. Set S_A in tap 2.

Step 2: T_A nearest to $\frac{27.6}{2} = 13.8$ is T_A = 15.8

Set T_A in 15.8 tap

Step 3: $M_A = \frac{T_A S_A}{Z} - 1 = \frac{15.8 \times 2}{27.6} - 1 = 1.145 - 1 = +.145$

Set M = + .15. Place R lead in O, L lead in upper .06. The relay setting is now:

$$\text{Actual } Z_A = \frac{T_A S_A}{1 \pm M} = \frac{15.8 \times 2}{1 + 0.15} = \frac{31.6}{1.15} = 27.5$$

This is 99.7% of the desired setting.

To set Z_C = 3.29 ohms:

Step 1: The lowest tap S_C for $6S_C$ greater than 3.29 is S_C = 1.

Set S_C = 1

Step 2: T_C nearest to $\frac{3.29}{1} = 3.29$ is 3.64

Set T_C in 3.64 tap.

Step 3: $M_C = \frac{T_C S_C}{Z_C} - 1 = \frac{3.64 \times 1}{3.29} - 1 = 1.107 - 1 = +.107$

Hence, the nearest M_C value is + .12. Now set R lead in 0.03 tap and L lead in the upper .06 tap.

(Since M_C has plus sign, lead L must be over R.)

$$\text{Then, } Z_C = \frac{T_C S_C}{(1 + M_C)} = \frac{3.64 \times 1}{1 + .12} = 3.25 \text{ ohms, or}$$

98.8% of the desired value.

Undervoltage Unit

The undervoltage unit is usually set to a value corresponding to the minimum safe system voltage for stability. This voltage depends upon system constants and is usually between 70 and 80 percent. A higher value could be used if it is desired to trip the machine sooner upon loss of field. The undervoltage unit is set at the factory for 77 percent of system voltage, or 53 volts.

Note: An electrical check of this particular setting is outlined in this instruction leaflet, under the heading "Acceptance Check".

SETTING THE RELAY

The type KLF relay requires a setting for each of the two compensators T_A and T_C, for each of the two auto-transformers primaries S_A and S_C, and for the undervoltage unit.

Compensator (T_A and T_C)

Each set of compensator taps terminates 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 the taps. Electrical connections between common insert and tap inserts are made with a link that is held in place with two connector screws, one in the common and one in the tap.

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

Compensator T_C requires an additional setting for including or excluding the origin of R-X diagram from the distance unit characteristic. If the desired characteristic is similar to that shown on Fig. 5b, the links should be set vertically in the + T_C arrow direction. If a characteristic similar to that shown in Fig. 5c is desired, set links horizontally in the - T_C arrow direction.

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.

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

Auto-Transformer Secondary (M_A and M_C)

Secondary tap connections are made through two leads identified as L and R for each transformer. These leads come out of the tap plate each through a small hole, one on each side of the vertical row of M tap inserts. The lead connectors are held in place on the proper tap by connector screws.

Values for which an M setting can be made are from - .15 to + .15 in steps of .03. The value of a setting is the sum of the numbers that are crossed when going from the R lead position to the L lead position. The sign of the M value is determined by which lead is in the higher position on the tap plate. The sign is positive (+) if the L lead is higher and negative (−) if the R lead is higher.

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

Tabulated Settings

Z	M	L Lead	R Lead
0.87 TS	+ .15	Upper .06	0
0.89 TS	+ .12	Upper .06	.03
0.92 TS	+ .09	Lower .06	0
0.94 TS	+ .06	Upper .06	Lower .06
0.97 TS	+ .03	.03	0
TS	0	0	0
1.03 TS	+ .03	0	.03
1.06 TS	- .06	Lower .06	Upper .06
1.1 TS	- .09	0	Lower .06
1.14 TS	- .12	.03	Upper .06
1.18 TS	- .15	0	Upper .06

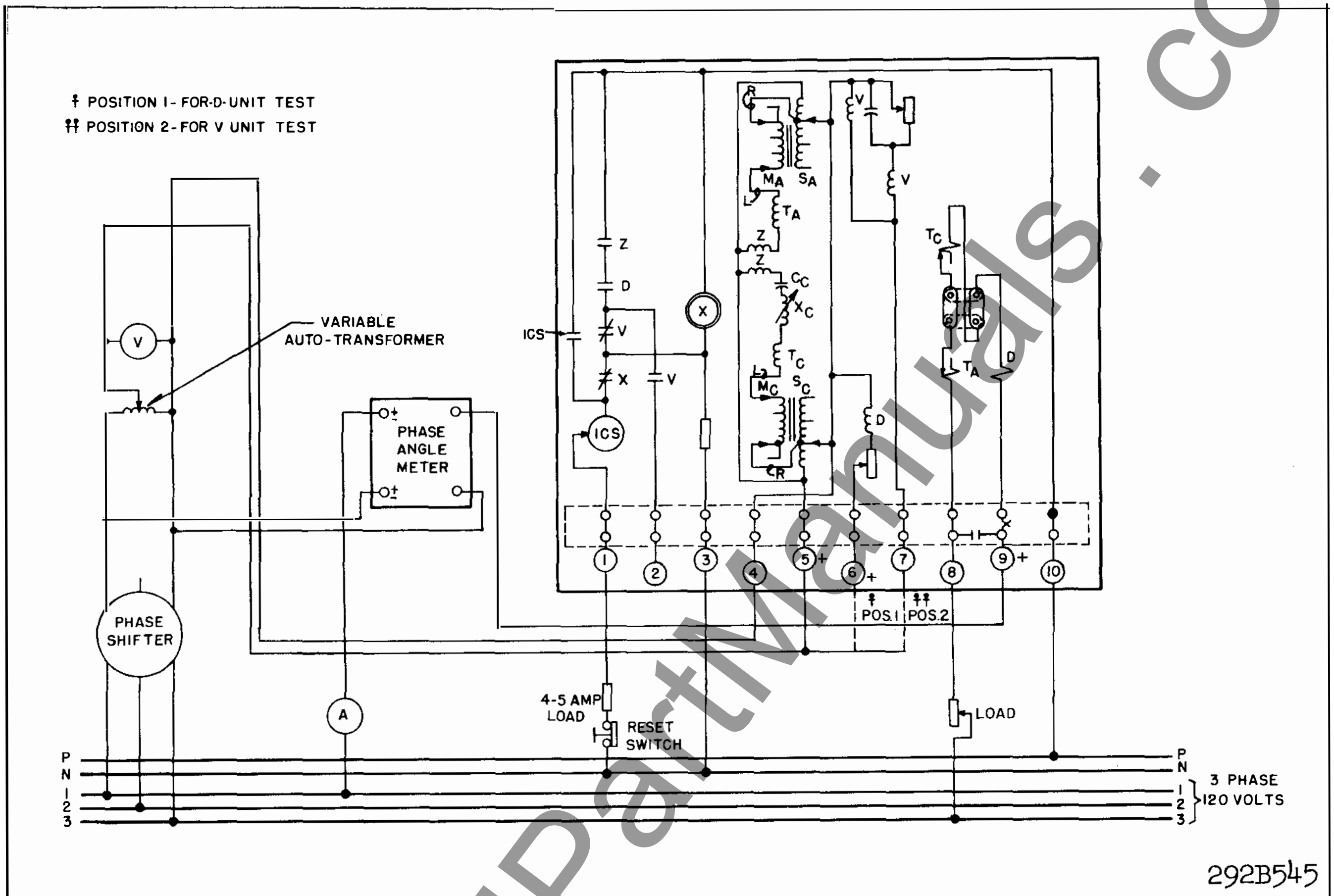


Fig. 9 Diagram of Test Connections for KLF-1 Relay

Undervoltage Unit

The voltage unit is calibrated to close its contact when the applied voltage is reduced to 53 volts. The voltage unit can be set to close its contacts from 40 volts to 70 volts by adjusting the resistor located in the rear, second from the bottom. The spiral spring is not disturbed when making any setting other than the calibrated setting of 53 volts.

Directional Setting

There is no setting to be made on directional unit.

Indicating Contractor Switch (ICS)

No setting is required on the ICS unit except the selection of the 0.2 or 2.0 ampere tap setting. This selection is made by connecting 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 volt or 250 volt d.c. type WL relay switch, or equivalent, use the 0.2 ampere tap. For 48 volt d.c. applications set ICS in 2 ampere tap and use S#304C209G01 type WL relay coil or equivalent.

INSTALLATION

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt, moisture, excessive vibration, and heat. Mount the relay vertically by means of the four mounting holes on the flange for semi-flush mounting or by means of the rear mounting stud or studs for projection mounting. Either a mounting 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 the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT Case information refer to I.L. 41-076.

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory. Upon receipt of the relay, no customer adjustments, other than those covered under "SETTINGS", should be required.

Acceptance Check

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

A. Distance Unit (Z)

1. Connect the relay as shown in Fig. 9 with the switch in position 2 and the trip circuit deenergized.

2. Make the following tap settings:

T_A = 11.5	T_C = 2.55
S_A = 2	S_C = 1
M_A = - .03	M_C = - .09

T_C link in middle block should be set for $+T_C$ direction.

This setting corresponds to $Z_A = 23.7$ $Z_C = 2.80$.

Adjust the phase shifter for 90° current lagging the voltage.

3. With the terminal voltage at 50 volts, increase current until contacts just close. This current should be within ± 3% of 2.11 amp (2.20–2.05 amp.).

4. Adjust phase shifter for 90° current leading the voltage.

5. With the terminal voltage at 50 volts increase current until contacts just close. This current should be within ± 3% of 17.9 amps. (18.5 17.3 amps.)

Contact Gap The gap between the stationary contact and moving contact with the relay in deenergized position should be approximately .040".

B. Directional Unit Circuit (D)

1. Connect the relay as shown in Fig. 9, with the switch in position 1 and the trip circuit deenergized.

2. With a terminal voltage of 1 volt and 5 amperes applied, turn the phase shifter to 43° (current leads voltage). The contacts should be closed. This is the maximum torque position.

3. Raise the voltage to 69 volts and vary the phase shifter to obtain the two angles where * the moving contact just makes with the left hand contact. These two angles (where torque reverses) should be where the current leads the voltage by 313° and 133°, (± 4°.)

4. Contact Gap The gap between the stationary contact and moving contact with the relay in deenergized position should be approximately .020".

C. Undervoltage Circuit

1. Connect the relay as shown in figure 9, with switch in position 2 and the trip circuit deenergized.

2. Decrease the voltage until the contacts close to the left. This value should be 53 ±3% volts.

Routine Maintenance

All contacts should be periodically cleaned. A contact burnisher S#182A836H01 is recommended for this purpose. The use of abrasive material for cleaning contacts is not recommended, because of the danger of embedding small particles in the face of the soft silver and thus impairing the contacts.

Repair Calibration

A. Auto-transformer Check

Auto-transformers may be checked for turns ratio and polarity by applying a.c. voltage to terminals 4 and 5 and following the procedure below.

1) Set S_A and S_C on tap number 3. Set the "R" leads of M_A and M_C all on 0.0 and disconnect the "L" leads. Adjust the voltage for 90 volts. Measure voltage from terminal 5 to the tap #1 of S_A. It should be 30 volts (±1). From terminal 5 to tap #2 of S_A should be 60 volts. The same procedure should be followed for taps #1 and #2 of S_C.

2) Set S_A and S_C on 1 and adjust the voltage at the relay terminals for 100 volts. Measure voltage drop from terminals 5 to each of the M_A and M_C taps. This voltage should be equal to 100 (±1) plus the sum of values between R and tap being measured. Example 100 (1 + .03 + .06) = 109 volts.

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

B. Distance Unit (Middle Unit) Calibration

Make following tap plate settings.

T_A = 15.8; T_C = 5.1

S_A = S_C = 1

Make M_A = M_C = - .15 settings:

"L" lead should be connected to the "O" insert "R" lead should be connected to the upper ".06" insert. (-.03-.06 .06 = -.15 between L & R).

For the most accurate calibration preheat relay for at least an hour by energizing terminals 4,5, 6 & 7 with 70 volts, phase, -to-neutral or terminals 5,6,7, with 3 phase 120 volts phase-to-phase voltages.

The links in the middle tap block should be set for the $+T_C$ direction.

1) Contact Gap Adjustment

The spring type pressure clamp holding the stationary contact in position should not be loosened to make the necessary gap adjustments.

With moving contact in the opened position, i.e. against right stop on bridge, screw in stationary contact until both contacts just make (use neon light for indication). Then screw the stationary contact away from the moving contact 1-1/3 turn for contact gap of .040".

2.) With relay deenergized adjust the restraint spring so that contact arm just floats.

C) Impedance Characteristic Check

1) Maximum Torque Angle

Adjust the adjustable reactor for about 5 turns out. Applying 60 volts a.c. to terminals 5 and 4 and
* passing 4.8 amperes, through the current circuit turn the phase shifter until the moving contact opens. Turn the phase shifter back (few degrees) until contacts close. Note degrees. Continue to turn the phase shifter until contact opens, then swing phase shifter back until contact closes again. Note degrees. The maximum torque angle should be (± 1°) computed as follows:

$$\frac{\text{Degrees to Close Contacts at Left} + \text{Degrees to Close Contacts at Right (6)}}{2} = 90^\circ$$

Adjust reactor X_C until the correct maximum-torque angle is obtained.

2) Sensitivity Adjustment

Using the connections of Fig. 9, apply 5 volts a.c. 90° leading, to terminals 4 and 5 pass .325 amperes through current circuit (terminals 9 and 8). The spiral spring is to be adjusted such that the contacts will just close. De-energize the relay. The moving contact should return to open position against the right hand stop.

3) Impedance Check

a. Adjust voltage to be 50 volts.
For current lagging 90° the impedance unit should close its contacts at 2.60 – 2.76 amp. Reverse current leads, the impedance unit should close its contacts 8.1 – 8.6 amperes.

b. Reverse the links in the middle tap block to– T_C position. Apply current of 8.6 amps. The contacts should stay open. Reverse current leads to original position. The contacts should open when current is increased above 8.1 amperes.

Set links back to $+T_C$ position. Change S_A and S_C to setting "2". Keeping voltage at 50 volts, 90° leading check pick-up current. It should be 1.30 – 1.40 amperes. Now set the phase shifter so that voltage lags the current by 90°. Impedance unit should trip now at 4.05 – 4.3 amperes.

c. Change S_A, S_C = 3. Check pickup. It should be 2.70 – 2.90. Reverse current leads. Pick - up should be now .87 – 93 amp.

D) Directional unit (Top Unit)

1) Contact Gap Adjustment

The spring type pressure clamp holding the stationary contact in position should not be loosened to make the necessary gap adjustments.

With moving contact in the opened position, i.e. against right stop on bridge, screw in stationary contact until both contacts just make. Then screw the stationary contact away from the moving contact 3/4 of one turn for a contact gap of .22".

2) With relay deenergized adjust the restraint spring so that contact arm just floats.

3) Maximum Torque Angle Check

With 50 volts and 5 amperes applied, vary the phase shifter to obtain the two angles where the moving contacts just close. These two angles (where torque reverses) should be where the current leads the voltage by 313° ± 4° and 133° ± 1. Readjust the bottom resistor located in the rear for correct reading.

4) Sensitivity Adjustment

Apply 1.0 volt to terminals 4 and 6. Observing polarities as per schematic, and 5 amperes current leading the voltage by 43°, the spiral spring is to be adjusted such that the contacts will just close. The adjustment of the spring is accomplished by rotating the spring adjuster which is located on the underside of the bridge. The spring adjuster has a notched periphery so that a tool may be used to rotate it. The spring type clamp holding the srping adjuster should not be loosened prior to rotating the spring adjuster.

5) Plug Adjustment for Reversing of Spurious Torques.

a. Set T_C = 0.0. Connect a heavy current lead from T_A center link to terminal 8.

b. Short circuit terminals 4 and 6.

c. Screw in both plugs as far as possible prior to starting the adjustment.

d. Apply 80 amps only momentarily, and the directional unit need not be cooled during initial rough adjustment. But, the directional unit should be cool when final adjustment is made.

e. When relay contact closes move the left screw out the right hand plug until spurious torque is reversed.

f. When plug adjustment is completed check to see that there is no closing torque when relay is energized with 40 amps and voltage terminals 4 and 6 short-circuited.

E) Undervoltage Unit (Lower Unit)

Note: The moving contact is in closed position to the left when deenergized.

1) Contact Gap Adjustments

a) L.H. (Normally Closed) Contact Adjustment

With the moving contact arm in the closed position, against left hand side of bridge, screw the left-hand contact in to just touch the moving contact (use neon light for indication) and then continue for one more complete turn.

b) R.H. (Normally Open) Contact Adjustment

With moving contact arm against the left hand stationary contact screw the right hand stationary contact until it just touches the moving contact. Then back the right hand contact out two-thirds of one turn to give 0.020 inch contact gap.

2) Sensitivity Adjustment

a) Apply voltage to terminals 4&7. Open the adjustable resistor that is located in the rear (second from the bottom). Adjust the spring so that contacts make (to the left) at 40 volts. The contacts should open when unit is energized with 41 or more volts.

b) Relay is set for 53 volts. This is accomplished by lowering resistance value until contacts make at 53 volts and open when unit is energized when 54 or more volts. The spring should not be used for this setting.

F) Indicating Contactor Switch (ICS)

Close the main relay contacts and pass sufficient d-c current through the trip circuit to close the contacts of the ICS. This value of current should not be greater than the particular ICS tap settings being used. The indicator target should drop freely.

G) Telephone Relay

Energize the telephone relay with 120 volts d-c. The telephone relay should operate positively. With armature gap set for .003" – .004" the contacts should not close for approximately 15 cycles after the relay is de-energized.

H) Compensator Check

Accuracy of the mutual impedance T of the compensators is set within very close tolerances at factory and should not change under normal conditions. The mutual impedance of the compensators can be checked with accurate instruments by the procedure outlined below.

1. Set T_A on the 15.8 tap

   T_C on the 5.1 tap

2. Disconnect the L-leads of sections M_A and M_C

3. Pass 10 amperes a.c. current in terminal 9 and out of terminal 8.

4. Measure the compensator voltage with an accurate high resistance voltmeter (5000 ohms/volt).

5. Compensator A-voltage should be checked between lead L_A and terminal 5.

   For T_A = 15.8 the voltage measured should be 158 volts ± 3%.

* 6. Compensator C voltage should be checked between lead L_C and the front terminal of the reactor (X_D).

   For T_C = 5.1, the voltage should be 51 volts (±3%).

7. For all other taps the compensator voltage is IT (±3%)
   where I - relay current
   T - tap setting.

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.

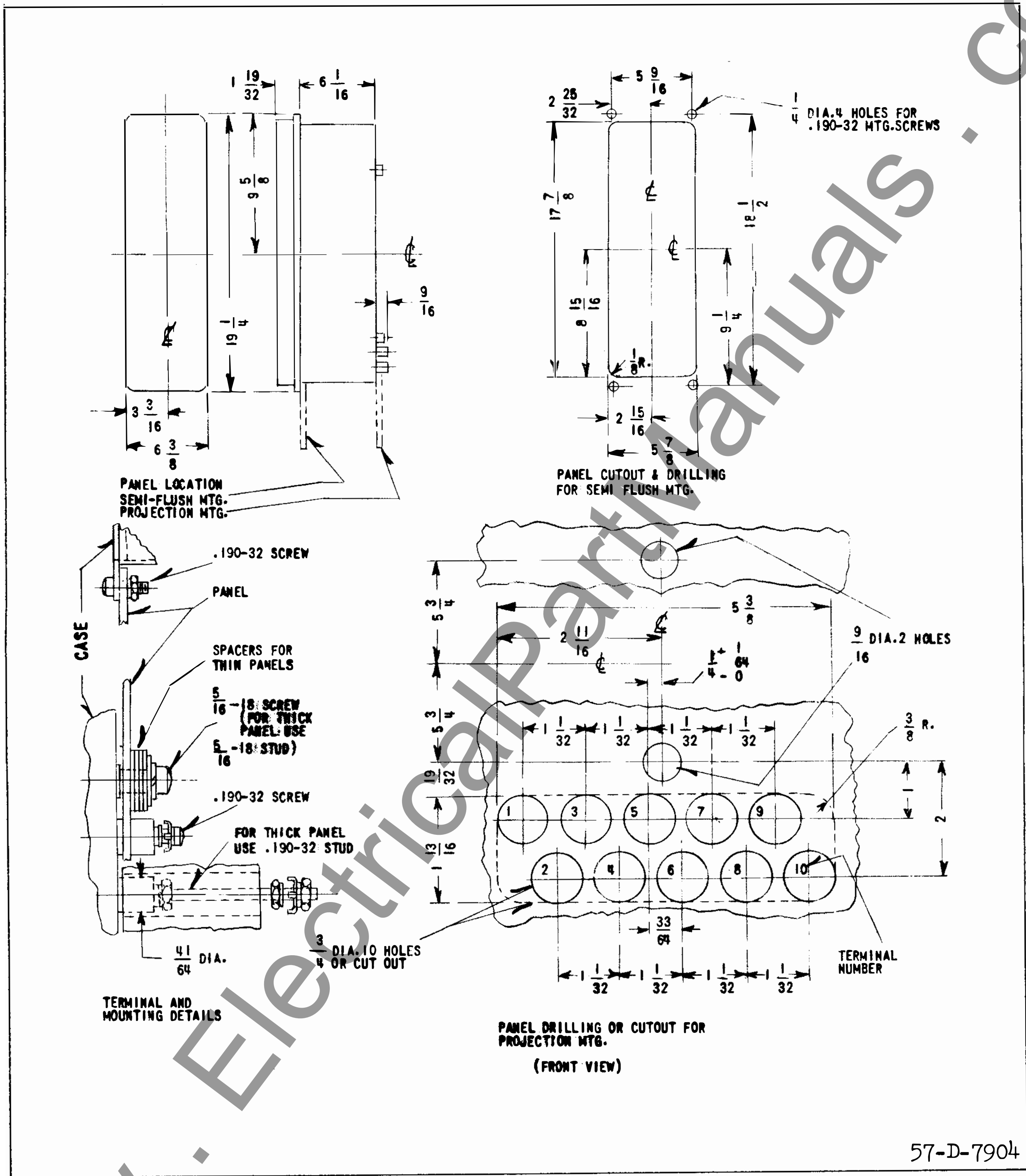


Fig. 10 Outline and Drilling Plan for the Type KLF-1 Relay in the FT41 Case.