ABB Power T&D Company Inc.
Power Automation and
Protection Division
Coral Springs, FL 33065

Instruction Leaflet

41-748.1F

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(|) Denotes Change Since Previous Issue

Type KLF-1 Loss-of-Field Relay (50/60 Hertz)

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.

1. APPLICATION

The KLF-1 relay is a single-phase relay connected to the ac 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, such as turbo-generator, water wheel generator or synchronous condensers.

This relay is designed for circuits using 4 wire wye-connected voltage transformers. Separate phase-to-ground voltages applied to the directional, impedance and under-voltage elements, thus minimizing the chance of false operation due to inadvertent loss-of-potential (such as due to a blown potential fuse). On circuits with 3-phase 3-wire connected voltage transformers, the type KLF relay is used.

2. CONSTRUCTION

The relay consists of two air-gap transformers (compensators), two tapped autotransformers, 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.

2.1. COMPENSATOR

The compensators which are designated T_A and T_C are two-winding air-gap transformers (figure 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, 83, 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 i 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. This a voltage which is proportional to the line current is added vectorially to the relay terminal voltage.

All possible contingencies which may arise during installation, operation or maintenance, and all details and variations of this equipment do not purport to be covered by these instructions. If further information is desired by purchaser regarding this particular installation, operation or maintenance of this equipment, the local ABB Power T&D Company Inc. representative should be contacted.

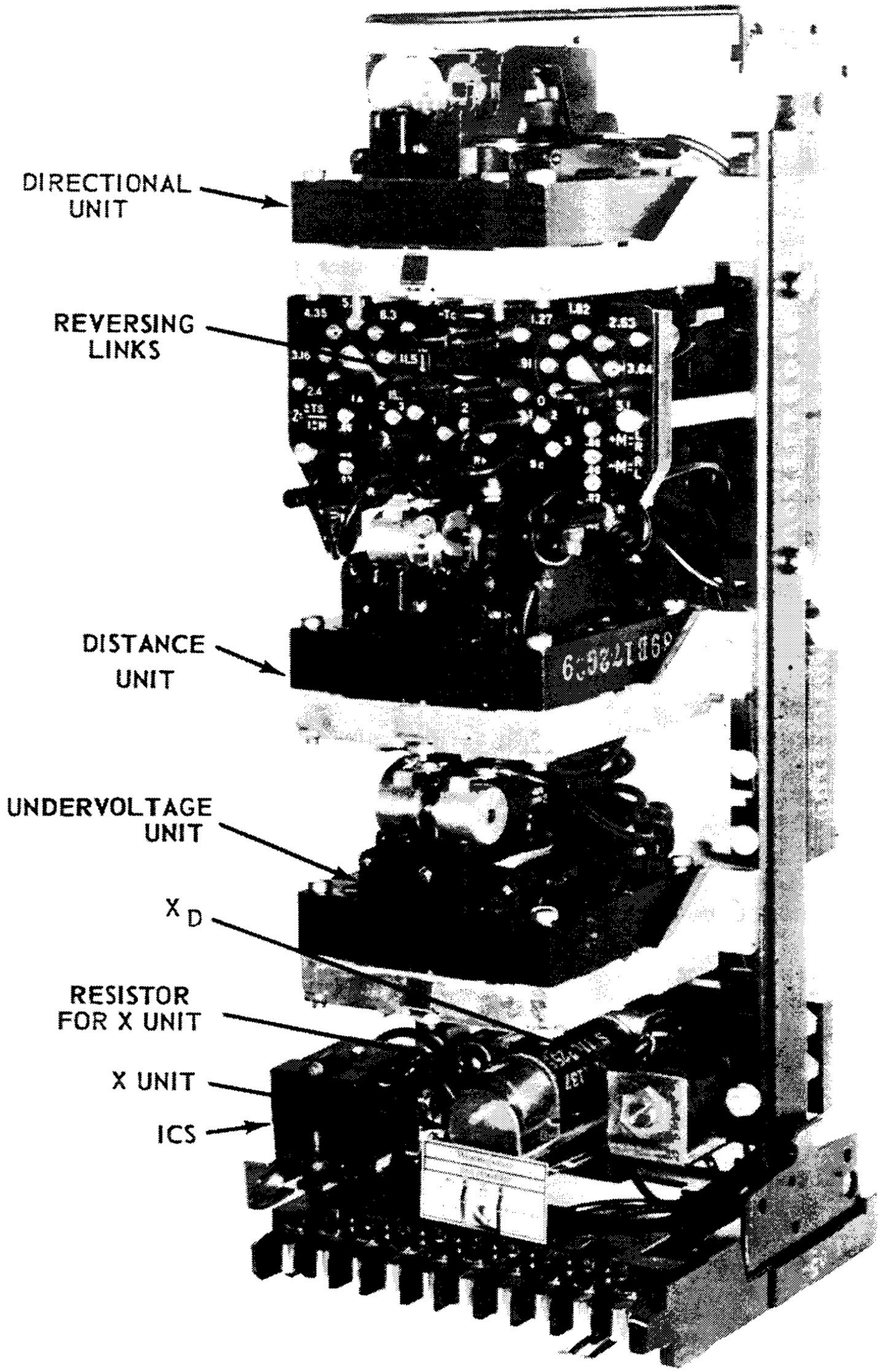

Figure 1. Type KFL-1 Relay

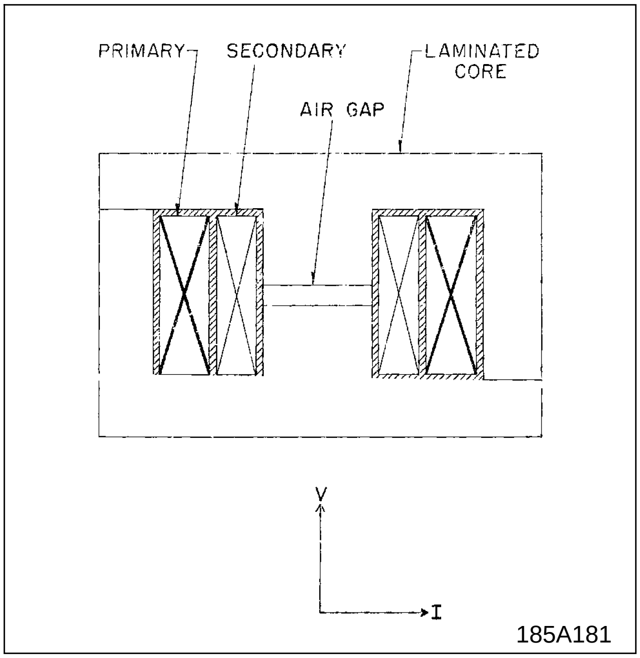

Figure 2. Compensator Construction

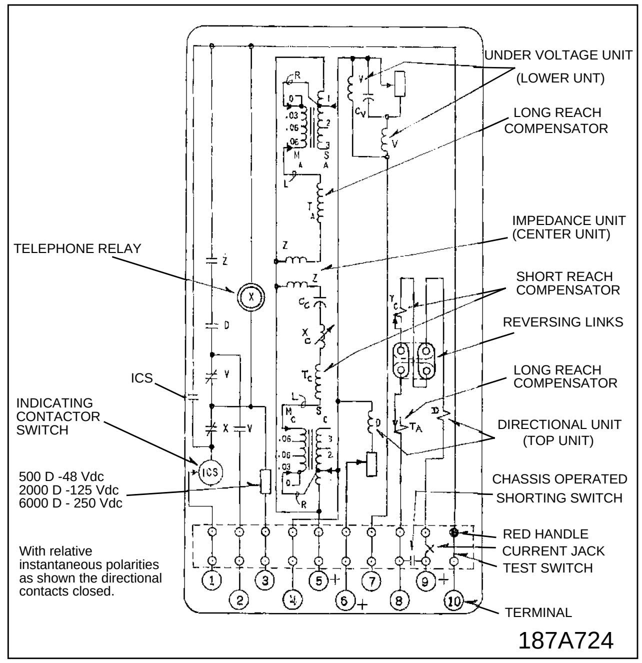

Figure 3. Internal Schematic of Type KFL-1 Relay in FT41 Case

2.2. AUTOTRANSFORMER

The autotransformer 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 autotransformer 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.

2.3. IMPEDANCE TRIPPING UNIT

The distance unit is a four-pole induction cylinder 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 impedance 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 by 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

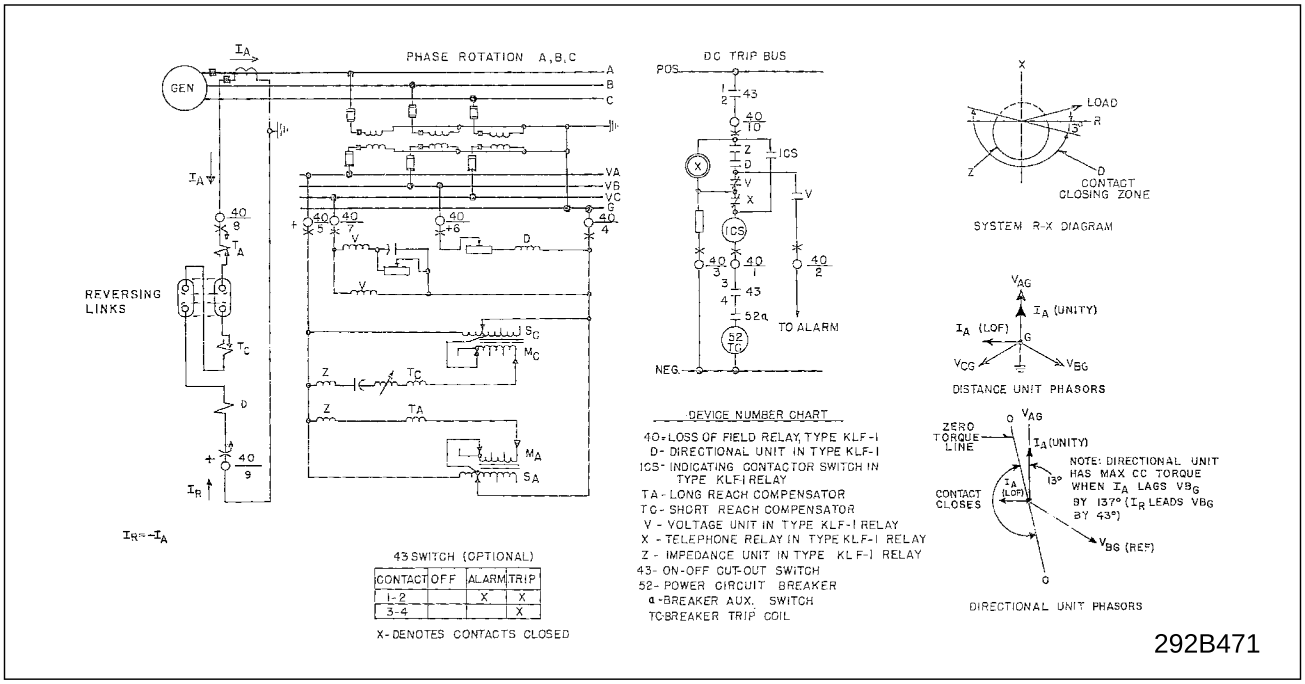

Figure 4. External Schematic of Type KLF-1 Relay

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 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 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.

2.4. 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 bottom jewel bearings. t he 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.

2.5. 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 a parallel R-C combination. These sets are in parallel as shown in figure 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.

2.6. 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.

2.7. INDICATING CONTACTOR SWITCH UNIT (ICS)

The dc 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.

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

3. OPERATION

The relay is connected and applied to the system as shown in figure 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, M 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 figure 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.

3.1. 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_{AO} 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_{AO} 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 autotransformer set-

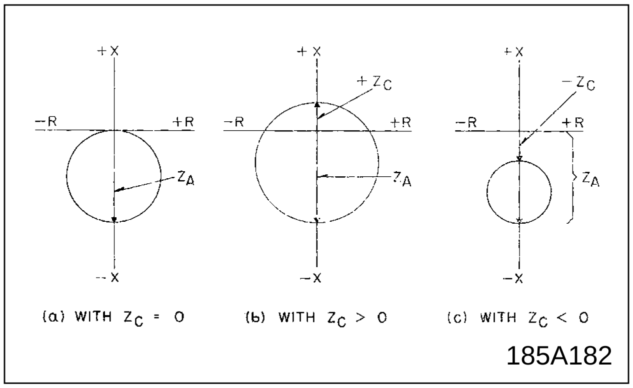

Figure 5. R-X Diagram Characteristics with Various Z_C Compensator Settings

tings. 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 voltage V_{AO}. Compensator voltages are equal to I_AZ_A for long reach compensator and I_AZ_C for short reach compensator, where I, is the relay current.

Figure 5 shows how the compensation voltages I_AZ_A and I_AZ_C influence the R-X circle. Note that Z_A independently determines the "long reach", while Z_C independently fixes the "short reach". With the reversing links in the normal position (+Z_C) 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 figure 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 figure 6(a). This relation produces restraining torque. To illustrate how Z_A fixes the long reach, assume a relay current which leads V_{AO} by 90˚ and of sufficient magnitude to operate the relay. This means the apparent impedance is along the -X axis. Note in figure 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

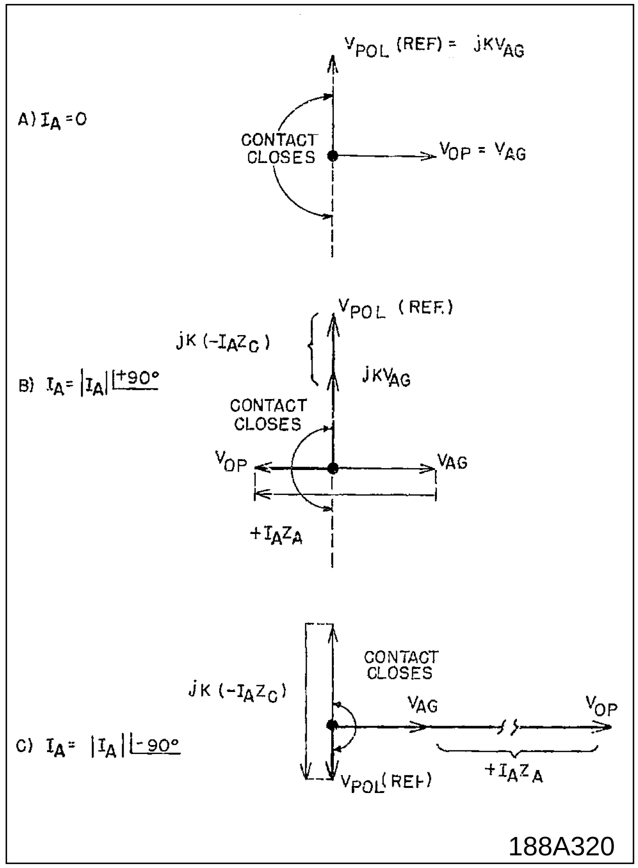

Figure 6. R-X Diagram Characteristics with Various Z_C Compensator Settings

merely increases the size of V_{POL}.

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

Figure 6 assumes that Z_C is positive (circle includes origin). If the current coil link is reversed, the compensation becomes +Z_C. In figure 6(b) this change would result in, V_{POL} being reduced rather than increased by the compensation. As the current increases V_{POL} will finally be reversed, re-establishing restraining torque. Thus, the current need not reverse in order to obtain a "short-reach" balance point. Instead of 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.

4. CHARACTERISTICS

The tupe KLF relay is available in one range. Long Reach ohms -2.08 to 56. Short Reach ohms -0.79 to 18.0

4.1. DISTANCE UNIT

The distance unit can be set to have characteristic circles that pass through origin, include it, or exclude it, as shown in figure 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 1.08 to 56 ohms for Z_A, and from 0.79 ohm to 18 ohms fro Z_C in steps of 3 percent.

The taps are marked as follows:

$$\frac{T_A}{2.4,\ 3.16,\ 4.35,\ 5.93,\ 8.3,\ 11.5,\ 15.8}$$

$$\frac{T_C}{0.0,\ 0.19,\ 1.27,\ 1.82,\ 2.55,\ 3.64,\ 5.1}$$

$$\frac{(S_A, S_C)}{1,\ 2,\ 3}$$

$$\frac{(M_A, M_C)}{\pm \text{ values between taps } .03,\ .06,\ .06}$$

4.2. 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 pickup has been set by the spring tension to be approximately 1 volt and 5 ampere at maximum torque angle.

4.3. 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 $V_{PH.3\text{-}N}$. The contacts can be adjusted to close over the range of 60 to 100 percent of normal system voltage. The actual range of adjustment is 40 to 70 $V_{L\text{-}N}$. The dropout ratio of the unit is 98 percent or higher.

4.4. TRIP CIRCUIT

The main contacts will safely close 30 amperes at 250 volts dc 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.

4.5. TRIP CIRCUIT CONSTANT

Indicating Contactor Switch (ICS)

0.2 ampere tap - 6.5 ohm dc resistance
2.0 ampere tap - 0.15 ohm dc resistance

4.6. BURDEN

Current at 5 Amps				
	VA		Angle of lag	
T_A & T_C Settings	60 Hz	50 Hz	60 Hz	50 Hz
Max.	12.05	10.6	58°	53°
Min.	4.17	3.94	36°	31°
Potential at 69 Volts (Phase-to-Ground)				
	VA		Angle of lag	
Phase 1	60 Hz	50 Hz	60 Hz	50 Hz
S = 1 S = 2 S = 3	6.1 1.5 0.7	6.1 1.5 0.7	9° 9° 9°	7.5° 7.5° 7.5°
Phase 2	3.18	2.9	48°	43°
phase 3	2.76	2.55	43°	38°

DC Circuit	
Rating	Watts @ Rated
125 250	3.9 7.8

4.7. THERMAL RATINGS

Potential: 75 volts (L-N) continuous

Current: 8 amperes continuous
200 amperes for 1 second

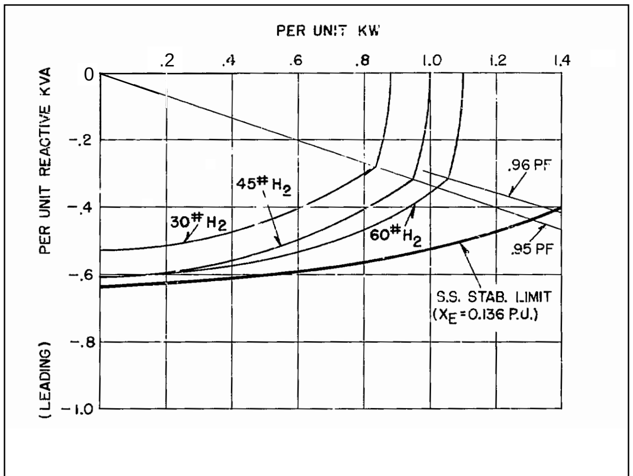

Figure 7. Typical Machine Capacity Curves Plotted on a Per Unit Basis (183,500 KVA, 45# H2, 18 KV, 0.9 pt, 0.64 SCR, inner-cooled, 3600 rmp)

5. SETTING CALCULATIONS

5.1. 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 figure 7 are obtained from the generator manufacturer.

To determine the desired setting convert the capability curve of figure 7 to the impedance curve of figure 8 by calculating $\left|\frac{V_T 2}{(KVA)_C}\right|$ where V_T is the per unit terminal voltage and $(KVA)_C$ is the per unit output. The angle of each point on the impedance curve is the same angle as the corresponding point on the capability curve.

For example, from figure 7, an output of 0.6 per unit KW on the 30# H_2 curve is -0.4 per unit reactive KVA. Therefore,

$$|(KVA)_C| = \sqrt{0.6^2 + (-0.4)^2} = 0.715 \text{ per unit}$$

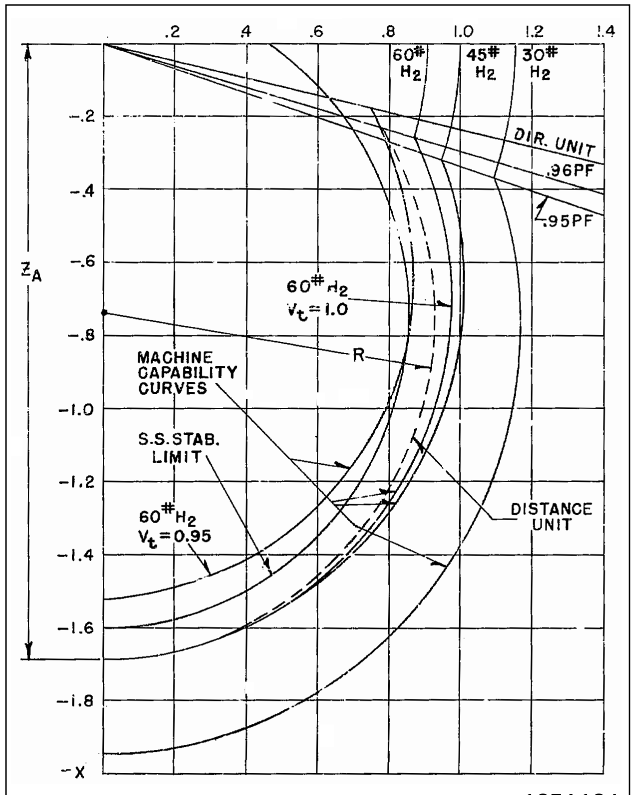

Figure 8. Typical Machine Capability Curves and Sample KLF-1 Settings - Per Unit Impedance

and, $\Theta = \tan^{-1}\left(\frac{-0.4}{0.6}\right) = -33.6°$

Converting to the impedance curve:

$$|Z| = \left|\frac{VT^2}{(KVA)_C}\right| = \frac{1.0^2}{0.715} = 1.4 \text{ per unit}$$

Since the angle remains the same, the impedance plot conversion is:

$$Z = 1.4\angle -33.6°, \text{ as shown in figure 8.}$$

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 figure 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.

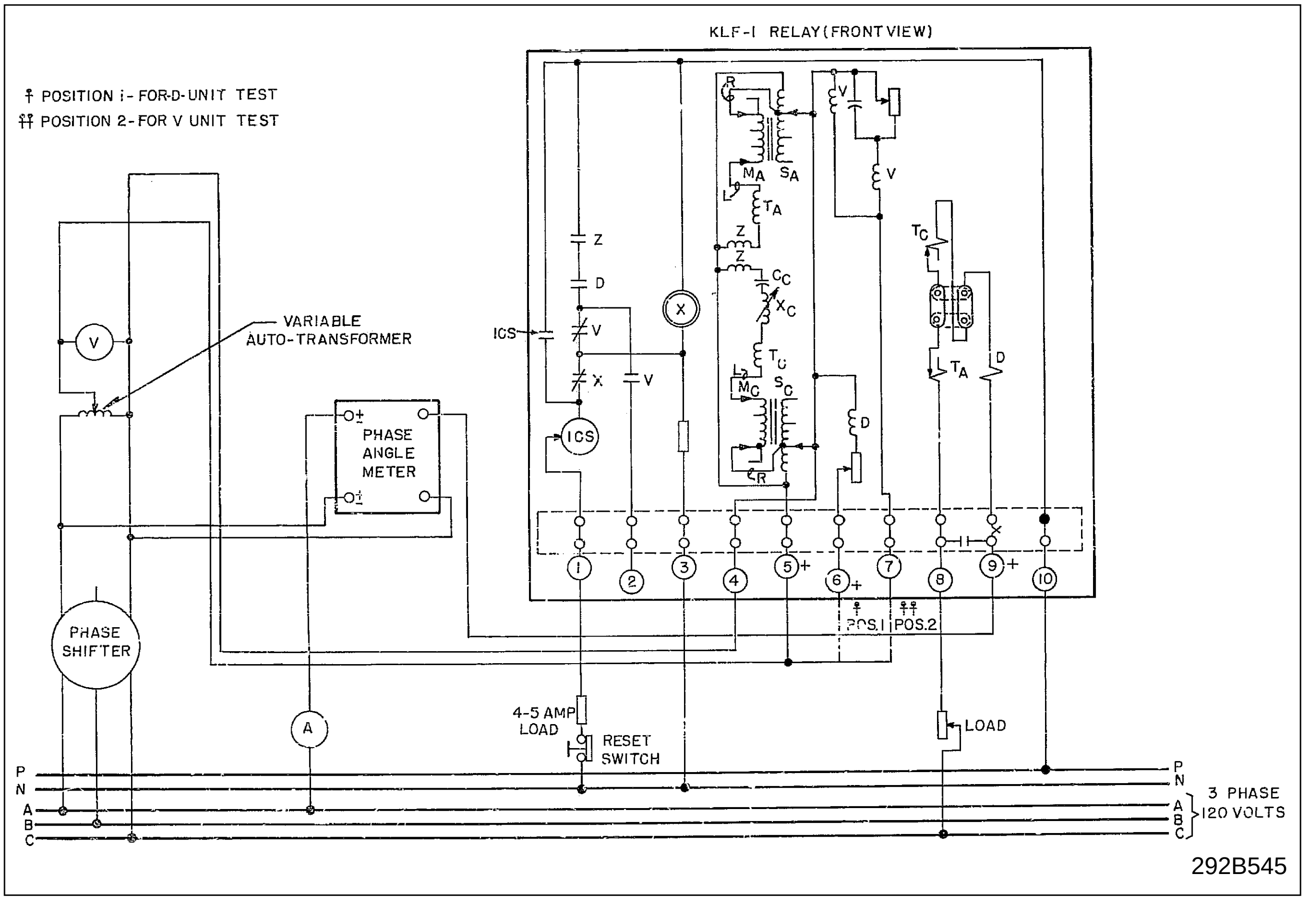

Figure 9. Diagram of Test Connections for KLF-1 Relay

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

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 per unit) x (Z_{base})

Z_C = (Z_C per unit) x (Z_{base}) = (2_R-Z_A) x (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 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.

5.2. 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 figure 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 figure 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) $Z_A = Z_A(per\ unit)(Z_{base}) = (1.68)(16.45)$

= 27.6 ohms

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

= 3.29 ohms

To set Z_A = 27.6 ohms

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 TA in 15.8 tap.

Step 3: $M_A = \frac{T_A S_A}{Z} - 1 \quad \frac{15.8 \times 2}{27.6} - 1 =$

1.145 -1 = + .145

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

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% 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).

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

98% of the desired value.

5.3. UNDERVOLTAGE UNIT

The undervoltage unit is usually set to a value corresponding to the minimum safe system voltage for stability. The voltage depends on many factors, but is usually between 70 and 80 percent of normal system voltage. The undervoltage unit is set at the factory for 77 percent of normal system voltage, or 53 volts line-neutral. In applications where multiple units are connected to the same bus, loss-of-field of one unit may not depress the bus voltage of the point where the undervoltage unit will operate if it has the standard setting. The following recommendations should be considered:

1. For cross-compound turbine generator applications, the dropout (contact closure of “back” contact of voltage unit, i.e., the contact which is in the trip circuit and is shown closed on schematic) voltage of the undervoltage unit should be set for 58 V_{L-N} (equivalent to 100 V_{L-L}).
2. For water wheel generator applications, with multiple machines tied to a common bus, the

dropout voltage of the undervoltage unit should be set for 58 V_{L-N}.

3. For all applications where the alarm function is not to be used, the undervoltage unit contact should be short circuited by means of a jumper wire.

4. For industrial applications, with two or more generators on the same bus, the undervoltage unit contact should be short circuited and the alarm circuit not used.

5. For synchronous condenser and large motor applications, the undervoltage unit contact should, in general, be short circuited and the alarm circuit not used. In general cases the machine may be treated as in 2, above.

6. for gas turbine unites, with high generator impedance, the undervoltage unit may not operate. For these applications the undervoltage contacts should be short circuited.

In cases where each generator is equipped with its own transformer (unit connected) the standard factory setting of 53 VL-N (corresponding to 92.5 VL-L) is usually satisfactory for the undervoltage unit. It should operate at a level commensurate with the minimum safe voltage for system stability.

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

6. TIME DELAY CONSIDERATIONS

It may be conservatively stated that the rotor structure and stator heating, as a result of a shorted field can be tolerated for 10 seconds on a conductor-cooled machine and 25 seconds for a conventional machine. This time may be as low as 5 seconds for an open field (as opposed to a field closed through a field discharged resistor on an exciter armature) and as high as one minute where the concern is protection of an adjacent tandem compound unit against partial loss-of-excitation in the faulted machine.

In view of the above considerations, it is often desirable to use an external timer in conjunction with the KLF-1 Relay. The following examples are applications where an external timer would be desirable:

1. Cross-compound units, with undervoltage unit setting of 58 volts, should use an external timer to assure tripping before thermal damage can result. The timer is energized at the alarm output and should be set for 10 seconds for a cross-compound conductor cooled machine. For a conventionally cooled cross-compound machine, the external timer should be set for 25 seconds. As an alternative to this, the KLF-1 with shorted underoltage contacts may be applied and the alarm feature not used. With this arrangement, tripping takes place after the 250 ms time delay provided by the X unit in the KLF-1 relay.

2. Machines connected to a common high voltage bus may be protected against partial loss of voltage due to loss-of-excitation in an adjacent machine by using a one-minute timer driven by the alarm output of the loss-of-field relay.

3. In some critical applications 2-zone loss-of-field protection may be desirable. In this case, the zone-1 KLF-1 impedance circle should be small and fully offset in the negative reactance region. The long-reach should be set equal to synchronous reactance, Xd. The short-reach should be set equal to one-half transient reactance, Xd1/2. The trip circuit should trip directly, with no time delay. The alarm circuit should operate a timer which may be set from 1/4 - 1.0 seconds, depending on use preference. If the condition persists, this timer permits tripping.

   The second-zone KLF-1 may be set with a larger impedance characteristic and will detect partial loss-of-field conditions. A typical setting would be to just allow the machine to operate at maximum hydrogen pressure and .95 per unit voltage. If a low voltage condition occurs, it is recommended that tripping be accomplished through a timer set for 3/4 second. Added to the X unit dropout time of 1/4 second, this gives an overall time of 1.0 second. If the voltage is maintained, then the alarm circuit should start a "last ditch" timer. This timer may be set anywhere from 10 seconds to one minute, depending on machine type and use preference.

7. SETTING THE RELAY

The type KLF-1 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.

7.1. GENERAL SETTING RECOMMENDATIONS

The KLF relay may be applied as a single-zone device, or two relays may be used to provide two-zone protection. The single-zone setting may be fully offset (Zone-1) or may include the origin (Zone-2). The two-zone application would require a Zone-1 KLF and a Zone-2 KLF, approximately equivalent to two-zone step-distance line protection. A generalized external schematic, which is applicable to either Zone-1 or Zone-2 relays is shown in figure 9. The recommended settings and relative advantages of these various configurations are summarized in Table 1.

The single-zone and two-zone setting recommendations are modified when two or more machines are bussed at the machine terminals.The voltage and time delay considerations are treated in detail in other sections of this leaflet. The recommended settings are outlined in Table 2.

7.2. 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 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 figure 5(b), the links should be set vertically in the $+T_C$ arrow direction. If a characteristic similar to that shown in figure 5(c) is desired, set links horizontally in the $-T_C$ arrow direction.

7.3. 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 t he 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.

7.4. AUTO-TRANSFORMER SECONDARY (M_A AND S_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
1.03TS	+.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

7.5. INDICATING CONTACTOR 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 dc type WL relay switch, or equivalent, use the 0.2 ampere tap. For 48 volt dc applications set ICS in 2 ampere tap and use Style #304C209G01 type WL relay coil or equivalent.

7.6. 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.

7.7. DIRECTIONAL SETTING

There is no setting to be made on directional unit.

Table 1:
RECOMMENDED SETTINGS FOR KLF RELAY

	ZONE 1 (ALONE)	**ZONE 2 (ALONE)**	**BOTH ZONE 1 & ZONE 2**
IMPEDANCE SETTING	See Figure 11	See Figure 12	See Figure 11 & 12
VOLTAGE SETTING	(a) Contact shorted or (b) Set at 80% for security	80%	Zone 1 voltage contact shorted with Zone 2 set at 80%
TD-1	1/4 to 1 sec (1 sec preferred)	1/4 to 1 sec (1 sec preferred)	Zone 1 timer = 1/4 sec Zone 2 timer = 1 sec
TD-2	Not required for (a) above. For (b) above use 1 min.	1 min.	1 min.
ADVANTAGES	Less sensitive to stable system swings	1) More sensitive to LOF condition 2) Can operate on partial LOF 3) Provide alarm features for manual operation	(1) Same as (1), (2) and (3) at left. (2) Provides back-up protection

Table 2:
SPECIAL SETTINGS FOR MULTI MACHINES BUSSED AT MACHINE TERMINALS

	ZONE 1 (ALONE)	**ZONE 2 (ALONE)**	**BOTH ZONE 1 & ZONE 2**
IMPEDANCE SETTING	See Figure 11	See Figure 12	See Figure 11 & 12
VOLTAGE SETTING	(a) Contact shorted or (b) Set at 87% for security	87%	Zone 1 voltage contact shorted with Zone 2 set at 87%
TD-1	1/4 to 1 sec (1 sec preferred)	1/4 to 1 sec (1 sec preferred)	Zone 1 timer = 1/4 sec Zone 2 timer = 1 sec
TD-2	Not required for (a) above (a) above. For (b) above use 10 sec for cond. cooled, 25 sec for conv. cooled	10 sec for cond. cooled. 25 sec for conv. cooled.	10 sec for cond. cooled 25 sec for conv. cooled

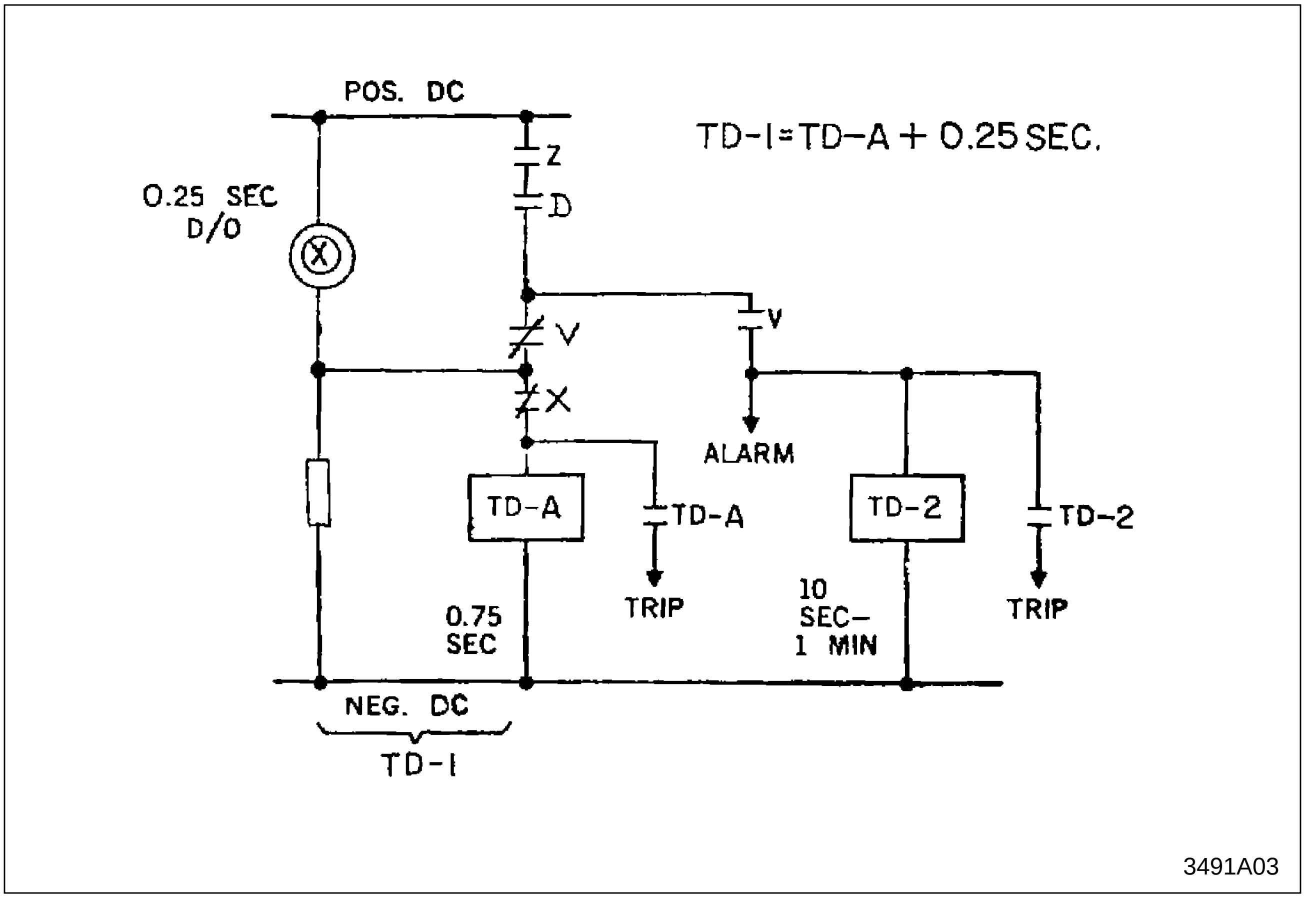

Figure 10. Generalized External Schematic

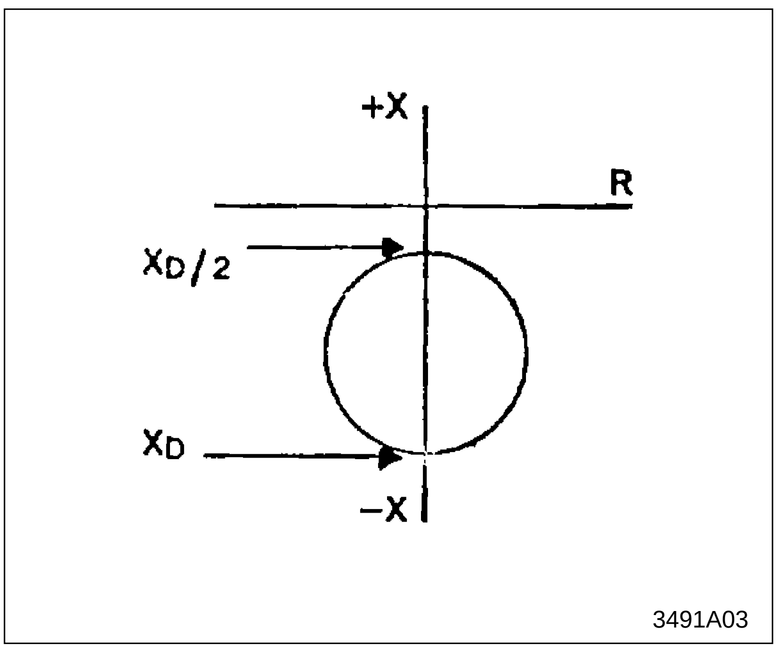

Figure 11. Zone-1 Impedance Characteristic

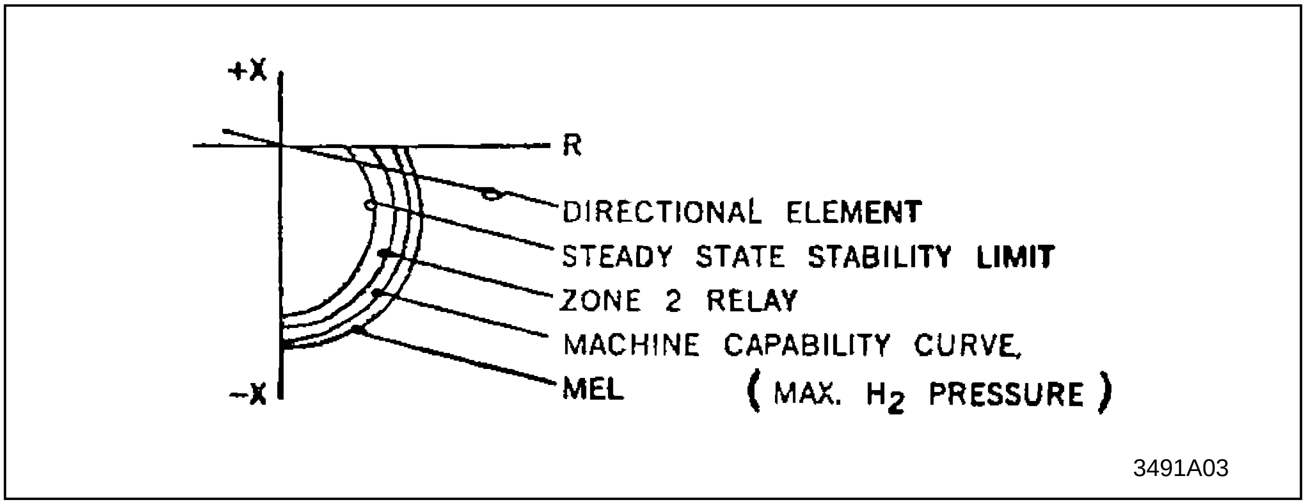

Figure 12. Zone 2 Impedance Characteristic

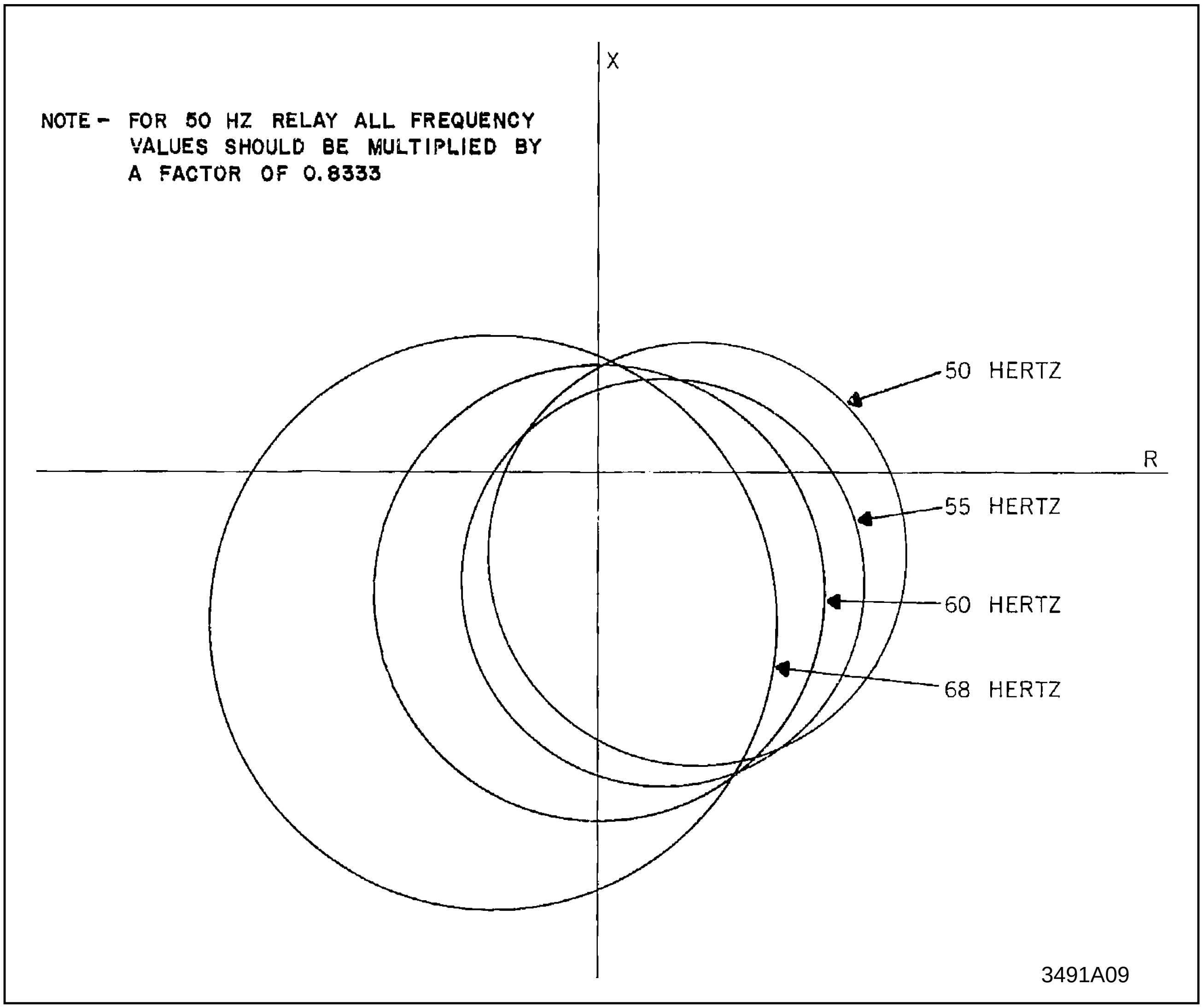

Figure 13. KLF-1 Frequency Response for Impedance Unit

8. 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.

9. 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.

9.1. 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 figure 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 figure 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.

D. Telephone Relay – Apply rated dc volts across terminal 10 and 3. The telephone relay (X) should open its contact. Manually close distance unit (Z) and directional unit (D) contacts and the X contact should close.

9.1.1. Routine maintenance

All contacts should be periodically cleaned. A contact burnisher Style #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.

9.2. REPAIR CALIBRATION

A. Auto-transformer Check

Auto-transformers may be checked for turns ratio and polarity by applying ac voltage to terminals 4 and 5 and following the procedures outlined 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. 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 MA 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_C = S_C = 1

Make M_A = M_C = -.15 settings:

“L” lead should be connected to the “0” 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 ac 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°) computes as follows:

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

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

2) Sensitivity Adjustment

Using the connections of figure 9, apply 5 volts ac 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. Deenergize 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 pickup 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. Pickup should now be .87 - .93 amp.

D. Direction 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 open 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 spring 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 to 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 (see neon light for indication) and then continue for 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. connect the brush lead of the adjustable resistor that is located n the rear (second from the bottom) to maximum. Adjust the spring so that contacts make (to the left) at 40 volts. The contact 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 dc 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 circuit, terminals 10 and 3, with rated dc voltage. The telephone relay (X) should operate positively. With an air gap of .003" – .004" the contacts should close in 167 to 250 ms when the telephone relay coil is shorted. this may be done by manually closing the distance unit (Z) and directional unit (D) contacts.

H. Compensator Check

Accuracy of the mutual impedance T of the compensators is set within very close tolerances at factory and should not be changed 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_A on the 5.1 tap.

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

3. Pass 10 amperes ac 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 LC 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.

10. 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.

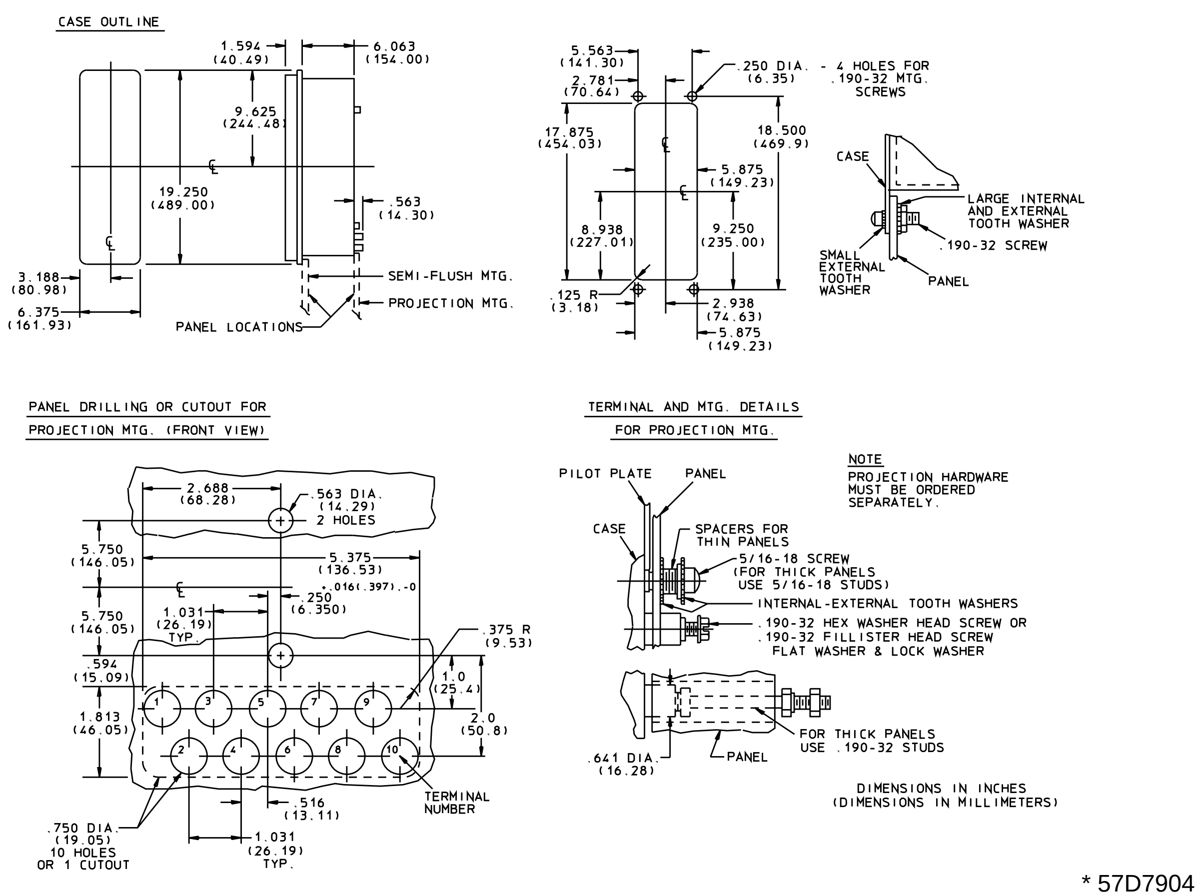

Figure 14. Outline and Drilling Plan for the Type KLF-1 Relay in the FT-41 Case.

* Denotes Change Since Previous Issue

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