Instruction Leaflet
41-748.21C

Type KLF
Loss-of-Field Relay
(For Class 1E Application)

Effective: January 1997
Supersedes I.L. 41-748.21B, Dated December 1993

(|) Denotes Changed Since Previous Issue

CAUTION

Before putting protective relays into service, make sure that all moving parts operate freely, inspect the contacts to see that they are clean and close properly, and operate the relay to check the settings and electrical connections.

1. APPLICATION

These relays have been specially designed and tested to establish their suitability for Class 1E applications in accordance with the ABB Power T&D Company program for Class 1E Qulification Testing ad detailed in bulletin STR-1. Materials have been selected and tested to insure that the relays will perform their intended functions for their design life when operated in a normal environment as defined by ANSI standards when exposed to radiation levels up to 10^4 rads, and when subjected to seismic events producing a Shock Response Spectrum within the limits of the relay rating.

"Class 1E" is the safety classification of the electronic equipment and systems in nuclear power generating stations that are essential to emergency shutdown of the reactor, containment isolation, cooling the reactor, and heat removal from the containment and reactor, or otherwise are essential in preventing significant release of radioactive material to the environment.

The KLF 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 generators, water wheel generators or motors.

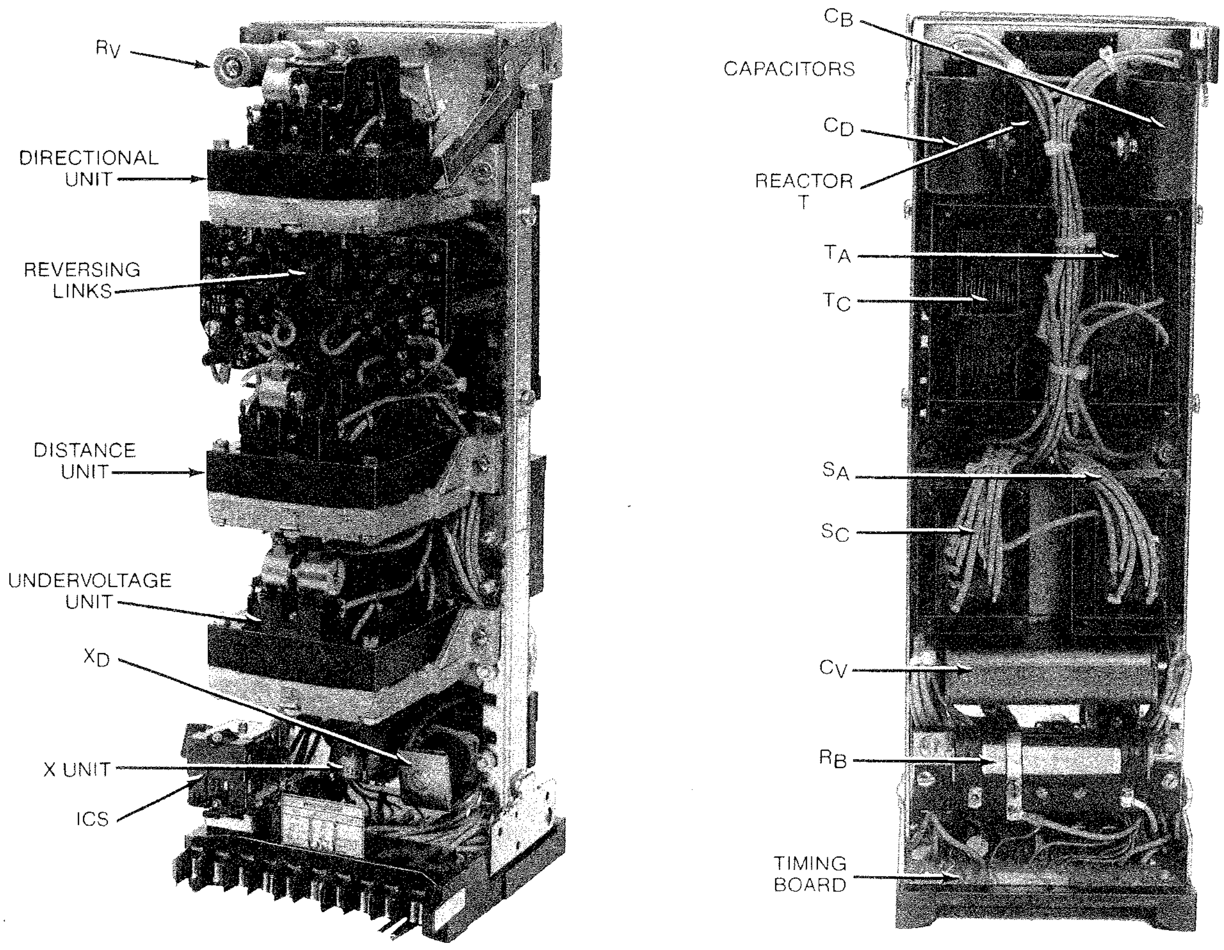
The KLF relay is designed for use with 3-phase 3-wire voltage supply and may use wye or delta-connected voltage transformers. The type KLF-1 relay may be used to increase security during inadvertent loss-of-potential (such as due to a blown potential fuse).

2. CONSTRUCTION

The relay consists of two (2) air-gap transformers (compensators), two tapped auto-transformers, one reactor, one cylinder-type distance IT, directional unit with adjustable reactor, an under-voltage unit with adjustable resistor, telephone relay with solid state time delay circuit, and an ICS indicating contactor switch.

2.1 Compensator

The compensators, which are designated T_A and T_C, are two (2) 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 tap 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. 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.



Front View

Rear View

Figure 1. Type KLF Relay

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 voltage, which is proportional to the line current, is added vectorially to the relay terminal voltage.

2.2 Auto-Transformer

The auto-transformer has three taps on its main winding, S, which are numbered 1, 2, and 3 on the tap block. A tertiary winding M has four taps which may be connected additively or subtractively to inversely modify the 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 the 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.

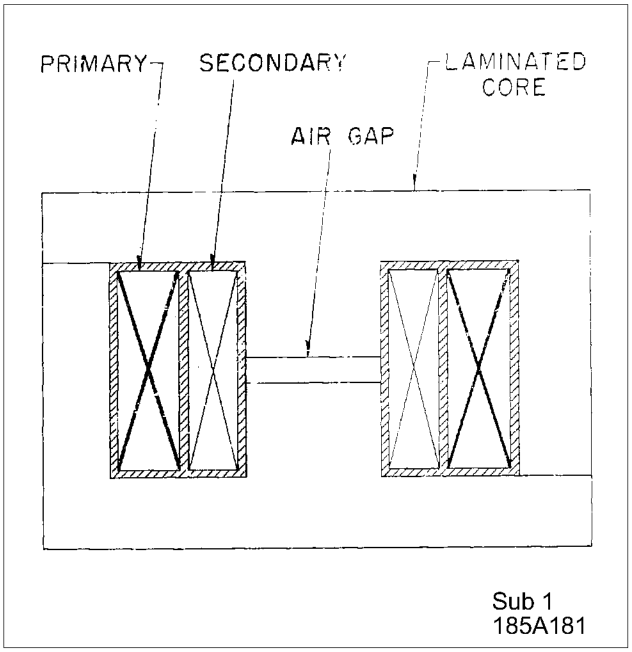


Figure 2. Compensator Construction

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 depends on the impedance phasor 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, and 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 by 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 number, 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 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 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.

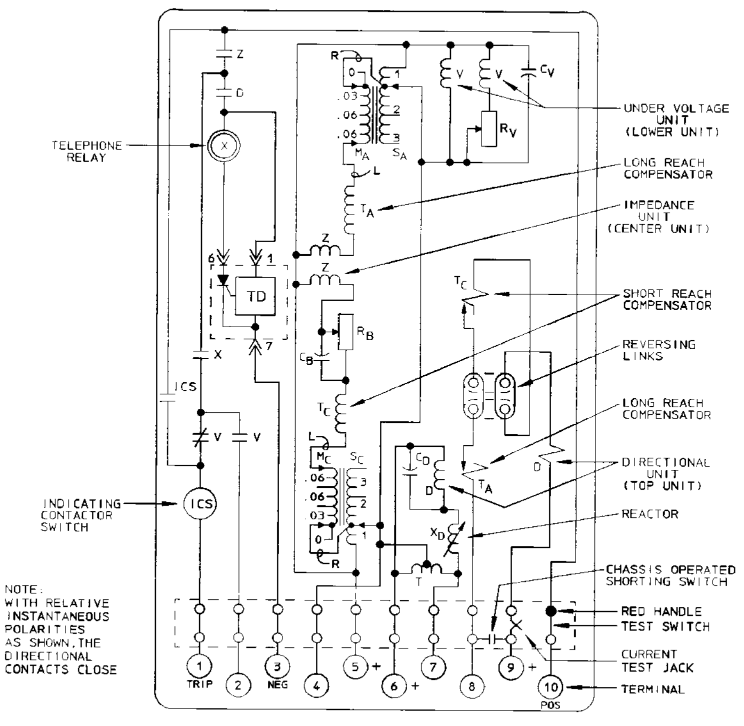
When contacts close, the electrical connection is made through the stationary contact housing clamp, to the moving contact, through the spiral spring and out to the spring adjuster clamp.

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.

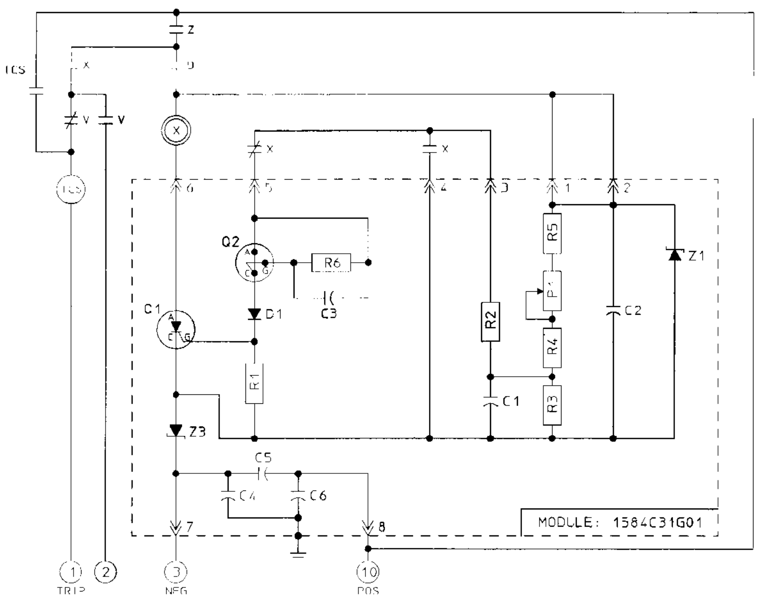
Mechanically, the directional unit is composed of the same basic components as the distance unit: a die-cast aluminum frame, an electromagnet, a moving element assembly, and a molded bridge.

The electromagnet has two series-connected polarizing coils mounted diametrically opposite one another; two series-connected operating coils



* Sub 4
3531A58

Figure 3. Internal Schematic of Type KLF Relay in FT-41 Case
*Denotes Change



Sub 4
3533A29

Figure 4. KLF Time Delay Schematic

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 an aluminum cylinder assembled to a molded hub which holds the shaft. 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.

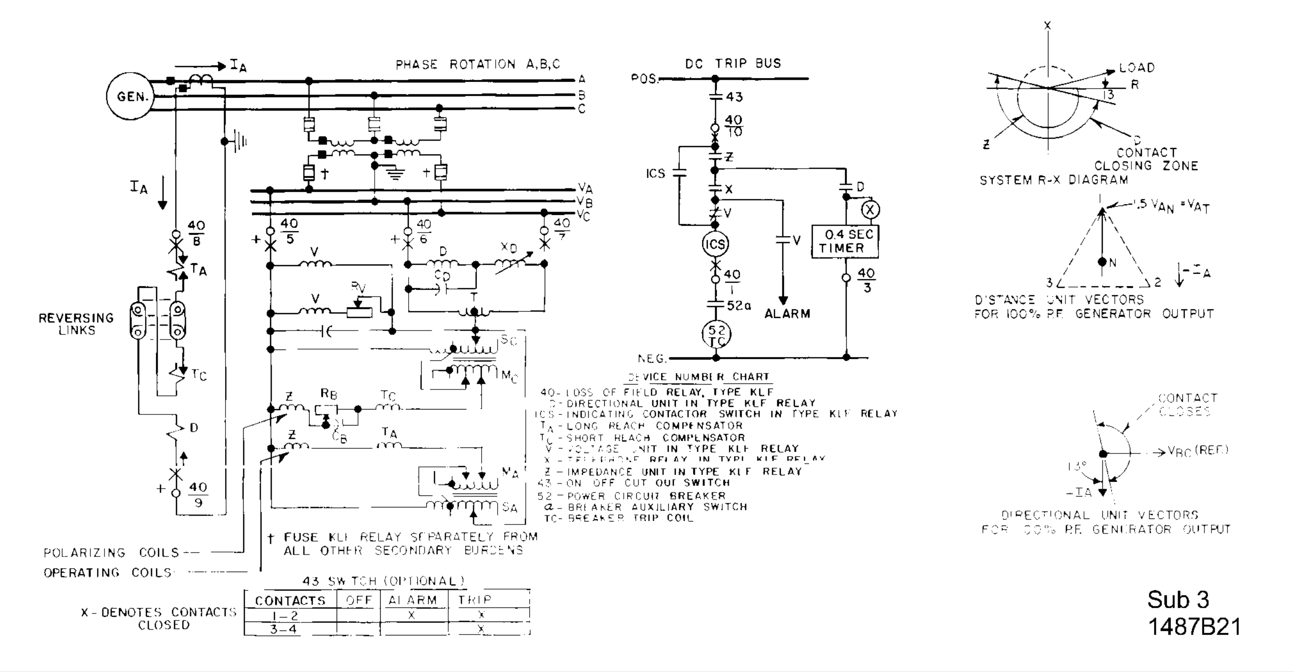
The bridge is secured to the electromagnet and frame by two mounting screws. In addition to holding the upper pin bearing, the bridge is used for mounting the adjustable stationary contact housing. The stationary contact housing is held in position by a spring-type clamp. The spring adjuster is located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



DEVICE NUMBER CHART

40 - LOSS OF FIELD RELAY, TYPE KLF
D - DIRECTIONAL UNIT IN TYPE KLF RELAY
ICS - INDICATING CONTACTOR SWITCH IN TYPE KLF RELAY
T_A - LONG REACH COMPENSATOR
T_C - SHORT REACH COMPENSATOR
V - VOLTAGE UNIT IN TYPE KLF RELAY
X - TELEPHONE RELAY IN TYPE KLF RELAY
Z - IMPEDANCE UNIT IN TYPE KLF RELAY
43 - ON OFF CUT OUT SWITCH
52 - POWER CIRCUIT BREAKER
a - BREAKER AUXILIARY SWITCH
TC - BREAKER TRIP COIL

† FUSE KLF RELAY SEPARATELY FROM ALL OTHER SECONDARY BURDENS

43 SWITCH (OPTIONAL)

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

X - DENOTES CONTACTS CLOSED

Sub 3
1487B21

Figure 5. External Schematic of Type KLF Relay

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

2.6 Solid State Time Delay Circuit

The telephone relay (x) is energized through a solid state time delay circuit (TD) as shown in Figure 3. The solid state time delay circuit shown in Figure 4 consists basically of an adjustable integrating RC circuit with quick reset. The RC circuit is adjusted to provide the voltage level to trigger the SCR through a multi-layer silicon switch. The SCR in turn energizes the relay.

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 if Figure 5. 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 impedance and directional units energize the time delay circuit which operates the X unit after .4 ±.05 seconds. The operation of impedance, directional and X unit sounds an alarm, and the additional operation of the under voltage unit trips the machine. This time delay is to insure positive contact coordination under all possible operating conditions. During a seismic event which exposes the relay to a ZPA level of 5.7g, the operate time of the X unit may vary from .25 second to 1.25 seconds due to bounce induced in the Z and the D contacts. 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.

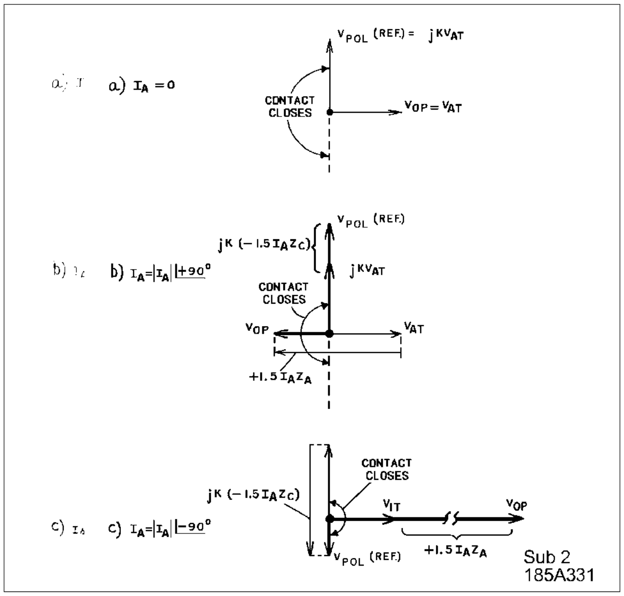


Figure 7. Effect of Compensator Voltages (Z_C is positive)

One set of opposite poles, designated as the operating poles are energized by voltage V_{1T} 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_{1T} 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.

The voltage V_{1T} is equal to:

$$V_{1T} = V_{12} + 0.5\ V_{23} = 1.5\ V_{1N} \qquad (1)$$

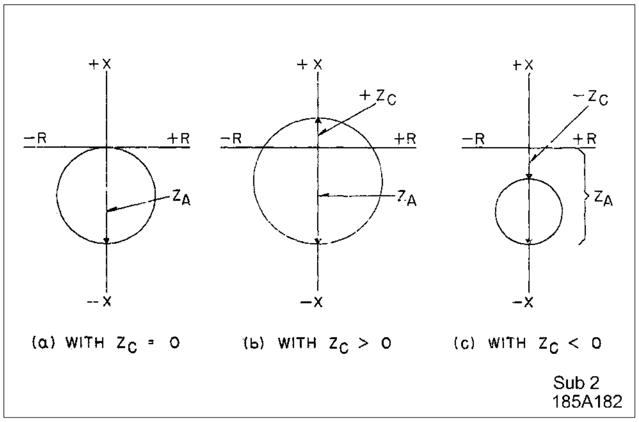


Figure 6. R-X Diagram Characteristics with various Z_C - Compensator Settings.

As shown in Figure 5, one-half of V_{23}, voltage is physically derived in the relay at midtap of a reactor connected across voltage V_{23}.

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 the their mutual impedances Z_A and Z_C have known and adjustable values as described below under "**CHARACTERISTICS**" and "**SETTING CALCULATIONS**". 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_{1T}. Compensator voltages are equal to 1.5 I_1 Z_A for long reach compensator and 1.5 I_1 Z_C for short reach compensator, where I, is the relay current.

Figure 6 shows how the compensation voltages 1.5 I_1 Z_A and 1.5 I_1 Z_C influence the R-X circle. Notice that Z_A independently determines the "long reach", while Z_C independently determines 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 5 notice that resistor R_B and capacitor C_B 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 and of sufficient magnitude to operate the relay. This means the apparent impedance is along the X axis. Notice in Figure 7(b) that the Z_A compensation reverses the operating voltage phase position. The relay balances when this voltage is zero. Note also this balance is unaffected by the Z_C compensation, since this compensation merely increases the size of V_{POL}.

For lagging current conditions notice Figure 7(c) illustrates how V_{POL} is reversed by the Z_C compensation. In this case the Z_A compensation has no effect of the balance point. This explains why the reach point is fixed independently by Z_C.

Figure 7 assumes that Z_C is positive (circle includes origin). If the current coil link is reversed, the compensation becomes +1.5 IZ_C. In Figure 7(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 establishing 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 circle region to find the balance point. Therefore the circle does not include the origin with a reversed link position.

4. CHARACTERISTICS

The type KLF relay is available in one range.

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 6.

The Z_A and Z_C values are determined by compensator settings and modified by auto-transformer 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

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 approximately 13 degrees. The minimum pickup has been set by the spring tension to be approximately 1 volt and 5 amperes 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_{1T}-voltage. This voltage is equal to 1.5 V_{1N} 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.

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.

4.5 Trip Circuit Constant

Indicating Contactor Switch (ICS)	
0.2 ampere rating	8.5 ohm dc resistance
1.0 ampere rating	.37 ohms dc resistance
2.0 ampere rating	.1 ohm dc resistance

4.6 Burden

<table>
<tr><th colspan="5">Current
5 amps, 60 Hz</th></tr>
<tr><td colspan="2">T_A & T_C Settings</td><td>VA</td><td colspan="2">Angle of LAG</td></tr>
<tr><td colspan="2">MAX.
MIN.</td><td>18.6
3.8</td><td colspan="2">77°
51°</td></tr>
<tr><td colspan="5">POTENTIAL
120 VOLTS, 60 Hz</td></tr>
<tr><td colspan="2">Phase AB
$S_A = S_C$ VA</td><td>Angle of LAG</td><td colspan="2">Phase BC
Angle VA of LAG</td></tr>
<tr><td>1</td><td>18.0</td><td>2°</td><td>2.6</td><td>12°</td></tr>
<tr><td>2</td><td>14.4</td><td>31°</td><td>5.9</td><td>38°</td></tr>
<tr><td>3</td><td>13.9</td><td>39°</td><td>6.6</td><td>42°</td></tr>
<tr><td colspan="5">dc Circuit</td></tr>
<tr><td colspan="2">Rating</td><td></td><td colspan="2">Watts + Rated</td></tr>
<tr><td colspan="2">125
250</td><td></td><td colspan="2">3.9
7.8</td></tr>
</table>

4.7 Thermal Ratings

Potential:	132 volts (L-L) continuous
Current:	8 amperes continuous

200 amperes for 1 second

5. SETTING CALCULATIONS

5.1 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 10. The recommended settings and relative advantages of these varioi4us configurations are summarized on 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.

5.2 Zone 2 Setting 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 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 8 are obtained from the generator manufacturer.

To determine the desired setting convert the capability curve Figure 8 of the impedance curve Figure 9 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. The angle of each point on the impedance curve (from the horizontal) is the same angle as the corresponding point on the capability curve.

For example, from Figure 8, an output of 0.6 per unit KW on 30# hydrogen pressure curve is -0.4 per unit reactive KVA. Therefore,

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

$$\text{and,} \quad \theta = \mathrm{Tan}-1\left(\frac{-0.4}{0.6}\right) = -33.6°$$

Converting to the impedance curve:

$$|Z| = \frac{|V_T^2|}{(KVA)_C} = \frac{1.0^2}{0.715}$$

$$= 1.4 \text{ per unit}$$

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

$Z = 1.4\angle{-33.6°}$, as shown in Figure 9.

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 9 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.

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

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:

$$Z_A = (Z_A \text{ per unit}) \times (Z_{base}) \qquad (3)$$

$$Z_C = (Z_C \text{ per unit}) \times (Z_{base})$$
$$= (ZR - Z_A) \times (Z_{base}) \qquad (4)$$

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.

5.3 Sample Calculations

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

3-phase, 60 hertz, 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 9 is used:

Z_A per unit = 1.68

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

(The relay circle in Figure 9 was obtained by trial and error using a compass to get the desired radius and offset.)

(1)

$$_{\text{ase}} = \frac{1000(\text{kv})^2 R_c}{(\text{kva}) R_V} = \frac{1000 \times (18)^2 \times 1400}{183,500 \times 150} = 16.48\Omega$$

(2)

$$Z_A = Z_A(\text{per unit}) Z_{base} = (1.68)(16.48) = 27.6\Omega$$

(3)

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

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 0, 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.)

Then, $Z_C = \frac{T_C S_C}{(1 + M_C)} = \frac{3.64 \times 1}{1 + 0.12} = 3.25\Omega$, or

98.8% of the desired value.

5.4 Undervoltage Unit

A. The undervoltage unit is usually set to a value corresponding to the minimum safe system voltage for stability. This 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% of normal system voltage, or 92 V_{L-L} (equivalent to 80 volts on the undervoltage unit). In cases where each generator is equipped with its own transformer (unit connected system) the standard factory setting is usually satisfactory for the undervoltage unit.

B. In applications where multiple units are connected to the same bus, loss of field of one unit may not depress the bus voltage to the point where the undervoltage unit will operate if it has the standard setting. The following recommenda-

TABLE 1

RECOMMENDED SETTINGS FOR KLF RELAY

	ZONE 1 (ALONE)	ZONE 2 (ALONE)	BOTH ZONE 1 AND 2
IMPEDANCE SETTING	See Figure 11	See Figure 12	See Figures 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 AND 2
IMPEDANCE SETTING	See Figure 11	See Figure 12	See Figures 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. 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.

tions should be considered:

1. For cross-compound turbine generator applications, the dropout voltage (i.e., the voltage at which the back contact of the undervoltage unit closes) of the undervoltage unit should be set for 87% of normal voltage (equivalent to 90 volts on the undervoltage unit).
2. For waterwheel generator applications, with multiple machine tied to a common bus, the dropout voltage of the undervoltage unit should be set at 87%.
3. For all applications where the alarm function is not to be used the undervoltage unit contact should be jumped (shorted).
4. For industrial applications, with two or more generators on the same bus, the undervoltage unit contact should be jumped (shorted) and the alarm circuit not used.
5. For small Synchronous condenser and large motor applications, the undervoltage unit contact should, in general, be jumped (shorted), and the alarm circuit not used. In special cases the machine may be treated as in 2, above, where knowledge exists of expected undervoltage level.
6. For gas turbine units, with high generator impedance, the undervoltage unit may not operate. For these applications the undervoltage contacts should be short circuited.

C. The desired undervoltage unit setting is computed by:

Setting = V_{IT} = 1.5 V_{IN}
where V_{IN} is phase-to-neutral voltage.

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

5.5 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 discharge resistor or 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 Relay. The following examples are applications where an external timer would be desirable:

1. Cross-compound units, with undervoltage unit setting of 90 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 with shorted undervoltage contacts may be applied and the alarm feature not used. With this arrangement, tripping takes place after the 0.4 second time delay provided by the X unit in KLF relay.
2. Machines connected to a common high voltage bus may be protected against 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-offield protection may be desirable. In this case, the Zone 1 KLF 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 0.4 - 1.0 seconds, depending on user preference. If the condition persists, this timer permits tripping.

   The second-zone KLF 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 9.5 per unit voltage. If a low voltage condition occurs, it is recommended that tripping be accomplished through a timer set for 0.6 second. Added to the X unit operate time of 0.4 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 user preference.

5.6 Performance During Reduced Frequency

During major system break-ups, it is possible that the generators may be called upon to operate at reduced frequency for long periods of time. During this condition the loss-of-field relay should be secure and not over-trip for load conditions. The KLF relay has a favorable characteristic during this condition, since its tripping characteristic becomes more secure during reduced frequencies, as shown in Figure 13.

6. 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.

6.1 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 connectors 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 6b, the links should be set vertically in the + T_C arrow direction. If a characteristic similar to that shown in Figure 6c is desired, set links horizontally in the - T_C arrow direction.

6.2 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.

6.3 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 comes 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.

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

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.

6.4 Undervoltage Unit

The voltage unit is calibrated to close its contact when the applied voltage is reduced to 80 volts. The voltage unit can be set to close its contacts from 70 volts to 90 volts by adjusting the resistor located next to the directional unit (to the left of the upper operating unit). The spiral spring is not disturbed when making any setting other than the calibrated setting of 80 volts.

The undervoltage unit range of 70 to 90 volts is equivalent to 80 to 104 V_{L-L} (or 67% to 87% normal system voltage). This is because the voltage on the unit is equal to 1.5 times V_{L-N}.

6.5 Directional Setting

There is no setting to be made on the directional unit.

6.6 Indicating Contactor Switch (ICS)

No setting is required on the ICS.

7. 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 of 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.

8. 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.

8.1 Performance Check

The following check is recommended to insure that the relay is in proper working order: Relay should be energized for at least one hour.

A. Distance Unit (Z)

1. Connect the relay as shown in Figure 14 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 80 volts, increase current until contacts just close. This current should be within ±3% of 2.25 amps (2.32 - 2.18 amps). This value corresponds to 1.5 Z_A setting since the voltage as applied to terminals 4 and 5 is equivalent to 1.5 V_{IN} voltage, or

$$Z_A = \frac{V_{1N}}{I_1} = \frac{80}{1.5} \times \frac{1}{2.25} = 23.7\Omega$$

4. Adjust phase shifter for 90° current leading the voltage.
5. With the terminal voltage at 80 volts increase current until contacts just close. This current should be within ±3% of 19.0 amps. (19.6 - 18.4 amps.) This value corresponds $1.5Z_C$ setting for the same reason as explained above.
5. 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 14 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 13° (current leads voltage). The contacts should be closed. This is the maximum torque position.
3. Raise the voltage to 120 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 283° and 103°, ± 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 14 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 80 ± 3% volts.

D. Reactor Check

Apply 120 volts ac across terminals 6 and 7. Measure voltage from terminal 6 to 4 and 7 to 4. These voltages should be equal to each other within ± 1volt.

E. Solid State Time Delay Circuit

Block the contacts of the Z unit closed. Apply 125 volts dc with positive at terminal 10 and negative at terminal 3. Manually close the contacts of the D unit. Using oscilloscope measure the time delay by observing the voltage block waveform between the relay terminal 3 (-) and terminal 1 (+). Operate time should be 0.4 ± .05 second.

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 nameplate rating. The indicator target should drop freely.

Repeat above except pass 85% of ICS nameplate rating current. Contacts should not pickup and target should not drop.

8.2 Routine Maintenance

All relays should be inspected periodically. They should receive a “Performance Check” at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application. A minimum suggest check on the relay system is to close the contacts manually so that the breaker trips and the target drops. Then release the contacts and observe that they open positively.

All contacts should be checked and cleaned if necessary. A contact burnisher Number 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 contact.

8.3 Repair Calibration

Relay should be energized for at least one hour.

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 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 voltages (± 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 the 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 5, 6,

& 7 with 120 volts, 3 phase.

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 $1\frac{1}{3}$ turn for a contact gap of .040".

2. Sensitivity Adjustment
   Using the connections of Figure 14 apply 10 volts ac 90° lagging, to terminals 4 and 5 pass .420 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.

C. Impedance characteristic Check

1. Maximum Torque Angle

   Adjust resistor R_B (mounted on the back of the relay) to measure 8800 ohms. Applying 100 volts ac to terminals 5 and 4 and passing 5.2 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 closes again. Note degrees. The maximum torque angle should be (± 3°) computed as follows:

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

   Adjust resistor R_B until the correct maximum-torque angle is obtained.

2. Impedance Check

   a. Adjust voltage to be 90 volts.
   For current lagging 90° the impedance unit should close its contacts at 3.12 – 3.35 amp.

   Reverse current leads, the impedance unit should close its contacts at 9.7 – 10.3 amperes.

   b. Reverse the links in the middle tap block to -T_C position. Apply current of 10 amps. The contacts should stay open. Reverse current leads to original position. The contacts should open when current is increased above 9.7 – 10.3 amperes.

   Set links back to +T_C position. Change S_A and S_C to setting "2". Keeping voltage at 90 volts, 90° lagging, check pick-up current. It should be 1.56 – 1.68 amperes. Now set the phase shifter so that voltage leads the current by 90°. Impedance unit should trip now at 4.85 – 5.15 amperes.

   c. Set T_A = 11.5, T_C = 2.55, S_A = 2, S_C = 1, M_A = -.03 M_C = -.09. Set voltage at 90 volts leading the current by 90°. Impedance unit should trip at 2.61 – 2.45 amp. Reverse current leads. Pickup should be 20.8 –22.1 amp.

   Change S_A, S_C = 3. Check pickup. It should be 6.95 – 7.35 amps. Reverse current leads. Pick-up should now be 1.74 – 1.63 amps.

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 open position, i.e., against right stop 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 .022".

2. Sensitivity Adjustment

   With reactor X having its core screwed out by about 1/8 inch apply 1.00 volt to terminals 6 and 7. Observing polarities as per schematic, and 5 amperes current leading the voltage by 13°, 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.

3. 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 6 and 7.
   - 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 6 and 7 short-circuited.

4. Maximum Torque Angle Check

With 120 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 283° ±4 and 103° ± 1. Readjust the reactor X_d if necessary.

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 and 5. With the adjustable resistor, which is located at the upper left hand corner, set for maximum resistance (2500 ohms) adjust the spring so that contacts make (to the left) at 70 volts. The contacts should open when unit is energized with 71 or more volts.
   - b. Relay is shipped with 80 volts setting. This is accomplished by lowering resistance value until contacts make at 80 volts and open when unit is energized with 81 or more volts. The spring should not be used for this setting.

F. Solid State Time Delay Circuit
Refer to Figure 4 for the following test.

- a. Connect a jumper between the “D” contacts (top unit) and connect a switch between the D-contact and relay terminal 10.
- b. Connect a scope probe, common and external trigger to relay terminals 1, 3 and contact “D” respectively.
- c. Connect a rated dc power supply between relay terminals 10 (+) and 3 (-).
- d. Turn on the dc power supply and then turn on the switch. The voltage at terminal 1 should jump from 0 to the rated voltage after a time delay of 0.4± 10% seconds. A trimpot on the PC board can be adjusted to obtain the desired time delay from 0.3 to 0.5 seconds.

G. Indicating Contactor Switch (ICS)

Initially adjust unit on pedestal so that armature fingers do not touch the yoke in the reset position. This can be done by loosening the mounting screw in the molded pedestal and moving the ICS in the downward direction.

1. Contact Wipe. Adjust the stationary contacts so that both stationary contacts make with the moving contacts simultaneously and wipe 1/64” to 3/64” when the armature is against the core.
2. Target. Manually raise the moving contacts and check to see that the target drops at the same time as the contacts make or up to 1/16” ahead. The cover may be removed and the tab holding the target reformed slightly if necessary. However, care should be exercised so that the target will not drop with a slight jar.
3. Pickup. Unit should pickup at 98% of rating and not pickup at 85% of rating. If necessary the cover leaf springs may be adjusted. To lower the pickup current use a tweezer or similar tool and squeeze each leaf spring approximately equal by applying the tweezer between the leaf spring and the front surface of the cover at the bottom of the lower window.

   If the pickup is low, the front cover must be removed and the leaf springs bent outward equally.

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

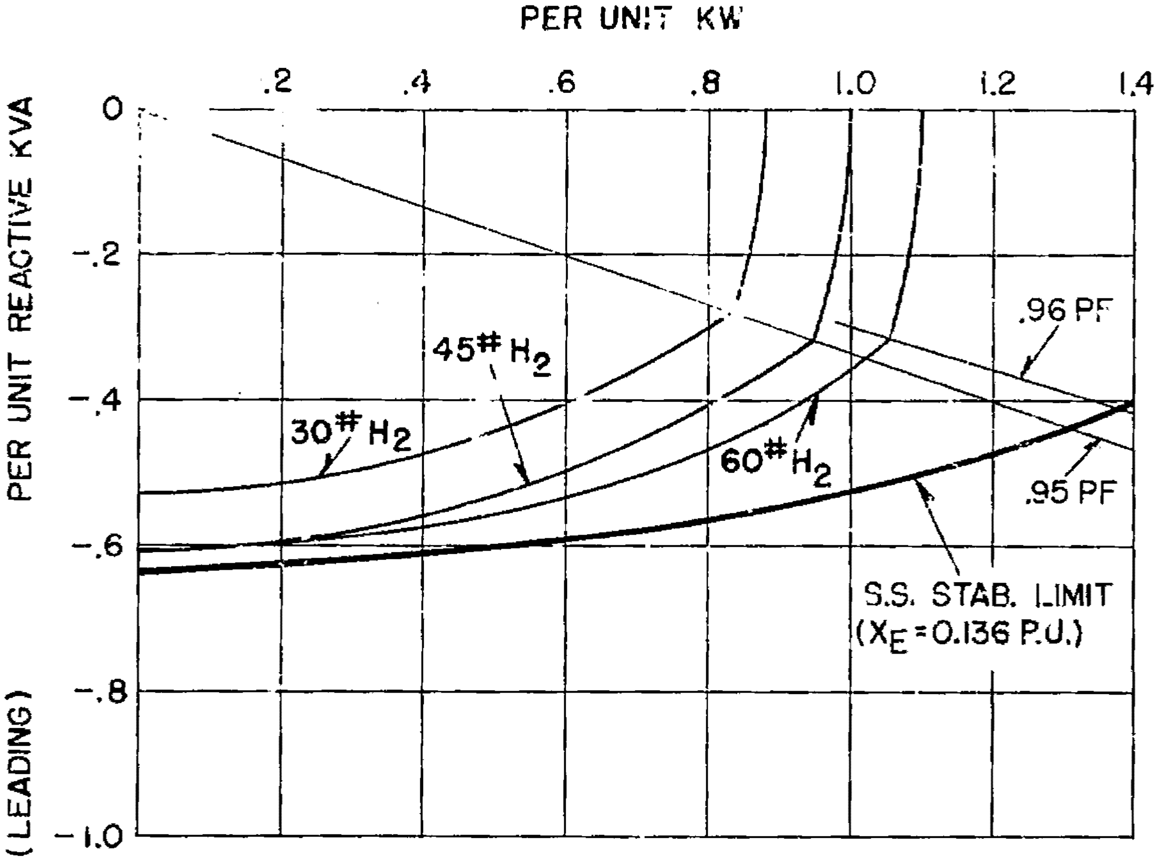
   T_C on the 5.1 tap
2. Disconnect the L-leads of sections M_A and M_C
3. Pass 10 amperes ac current in terminal 9 and out of terminal 8.
4. Measure the compensator voltage with an accurate high resistance voltmeter (5000 ohms/volt).
5. Compensator A-voltage should be checked between lead L_A and terminal 5.

   For T_A = 15.8 the voltage measured should be 23.7 volts (±3%).
6. Compensator C voltage should be checked between lead L_C and the fixed terminal on the resistor which is mounted in the rear.

   For T_C = 5.1, the voltage should be 76.5 volts (±3%).
7. For all other taps the compensator voltage is 1.5IT (±3%).
   Where I = relay current
   T = tap setting

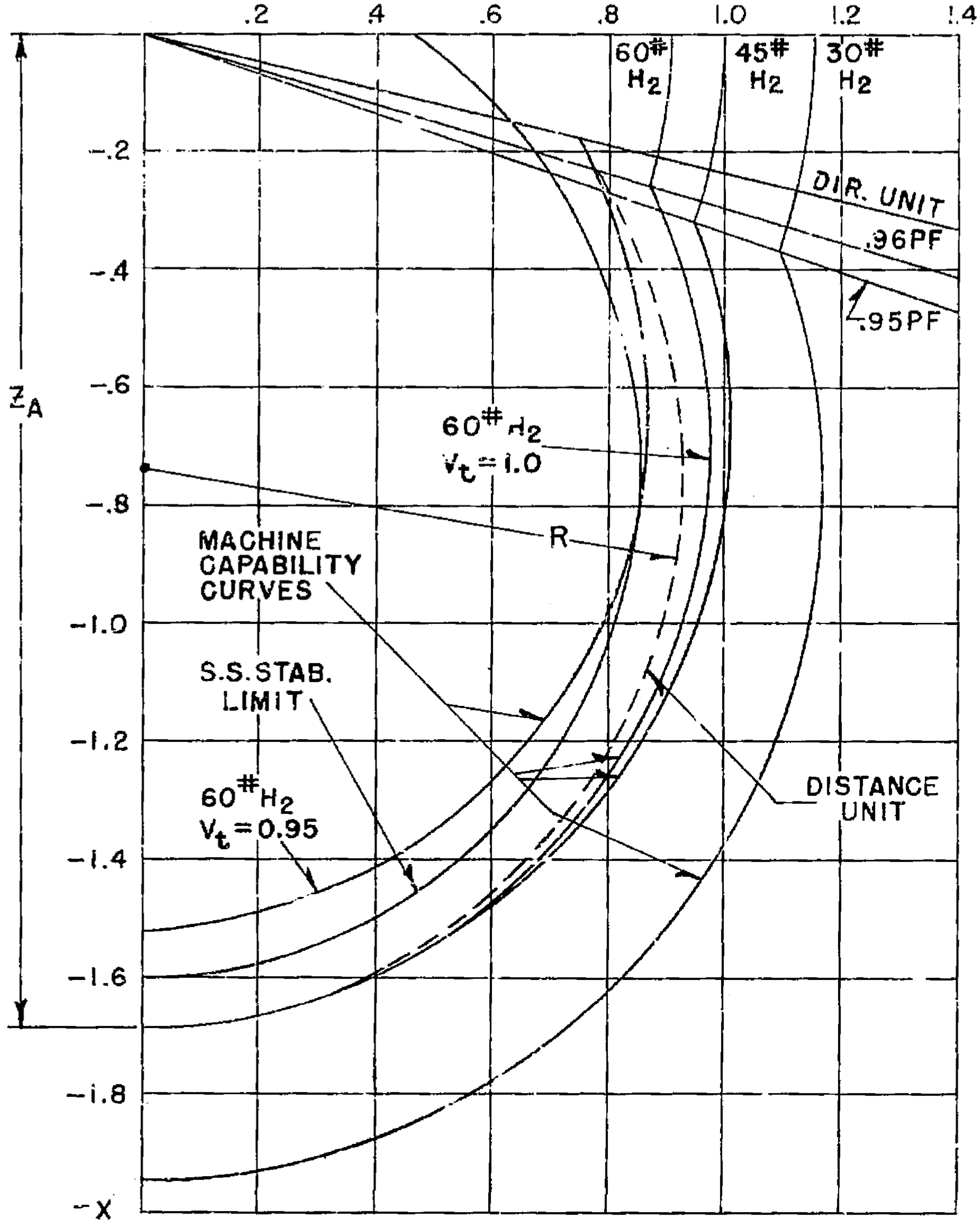
9. RENEWAL PARTS

Repair work can be done and the relay recertified 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. Note that replacement parts are not “certified” and repair work done outside the factory can not be certified by ABB.



Sub 2
185A183

Figure 8. Typical Machine Capability Curves



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185A184

Figure 9. Typical Machine Capability Curves and Sample KLF Relay Setting

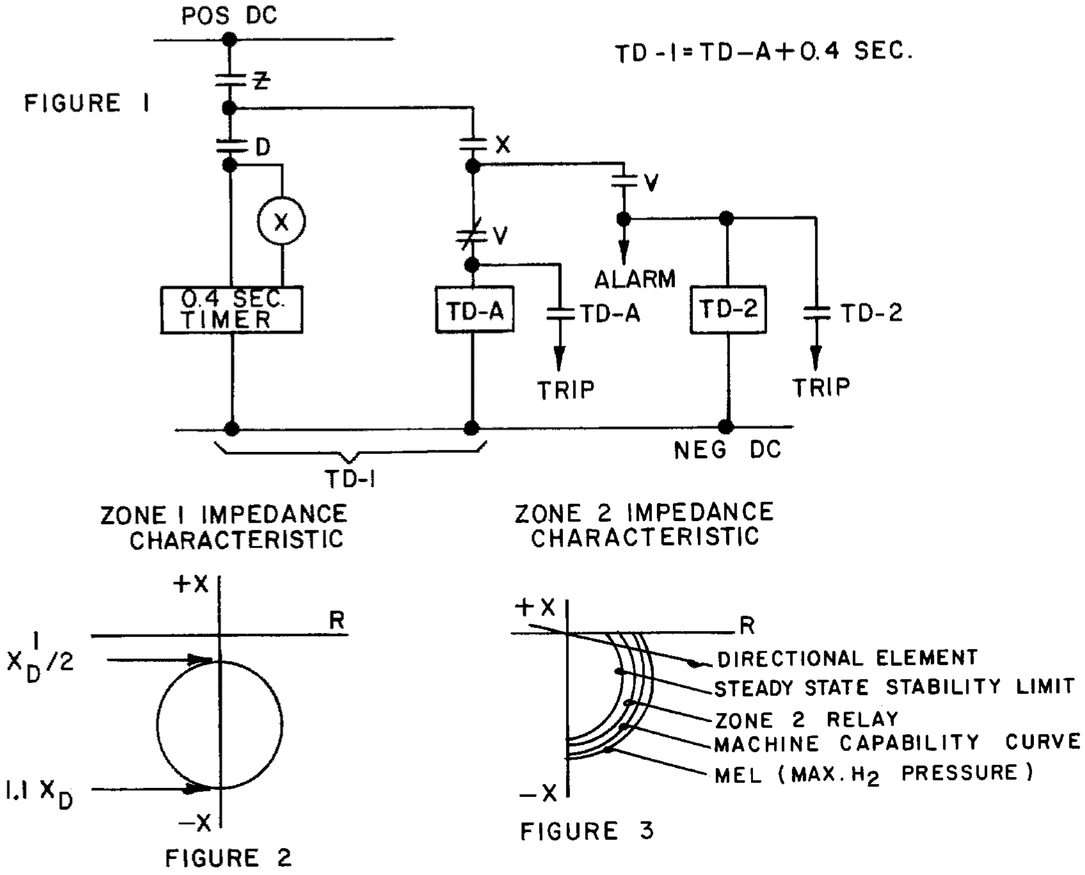
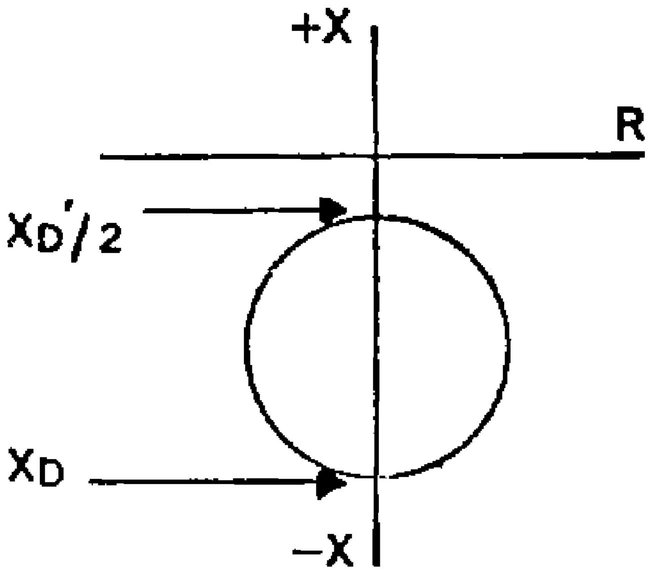


Figure 10. Generalized External Schematic



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3491A03

Figure 11. Zone 1 Impedance Characteristic

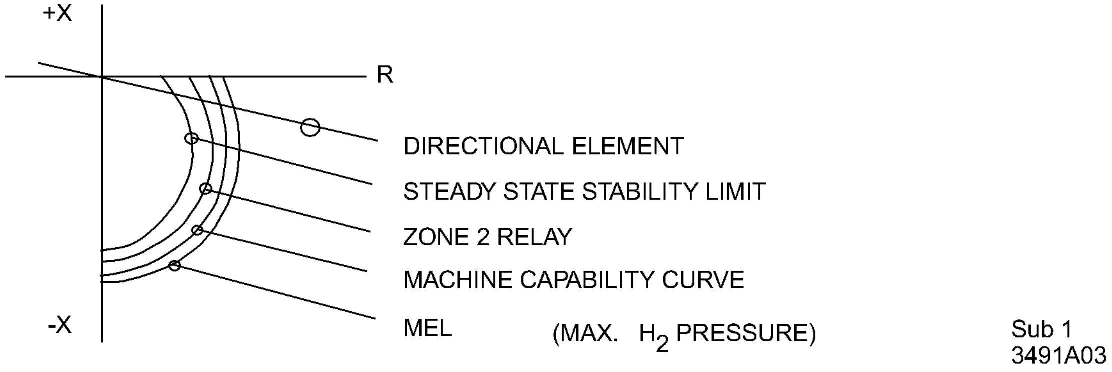


Figure 12. Zone 2 Impedance Characteristic

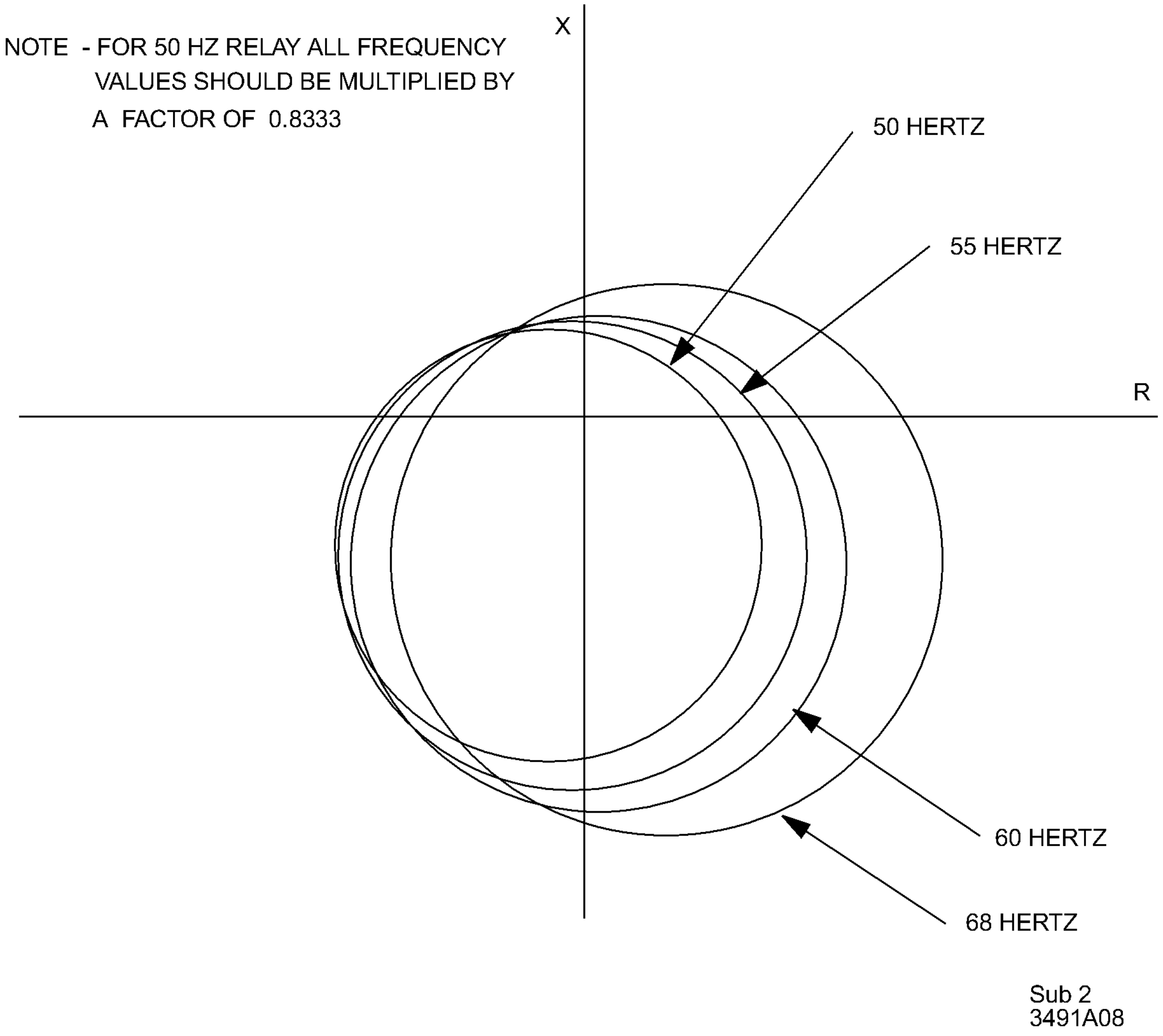
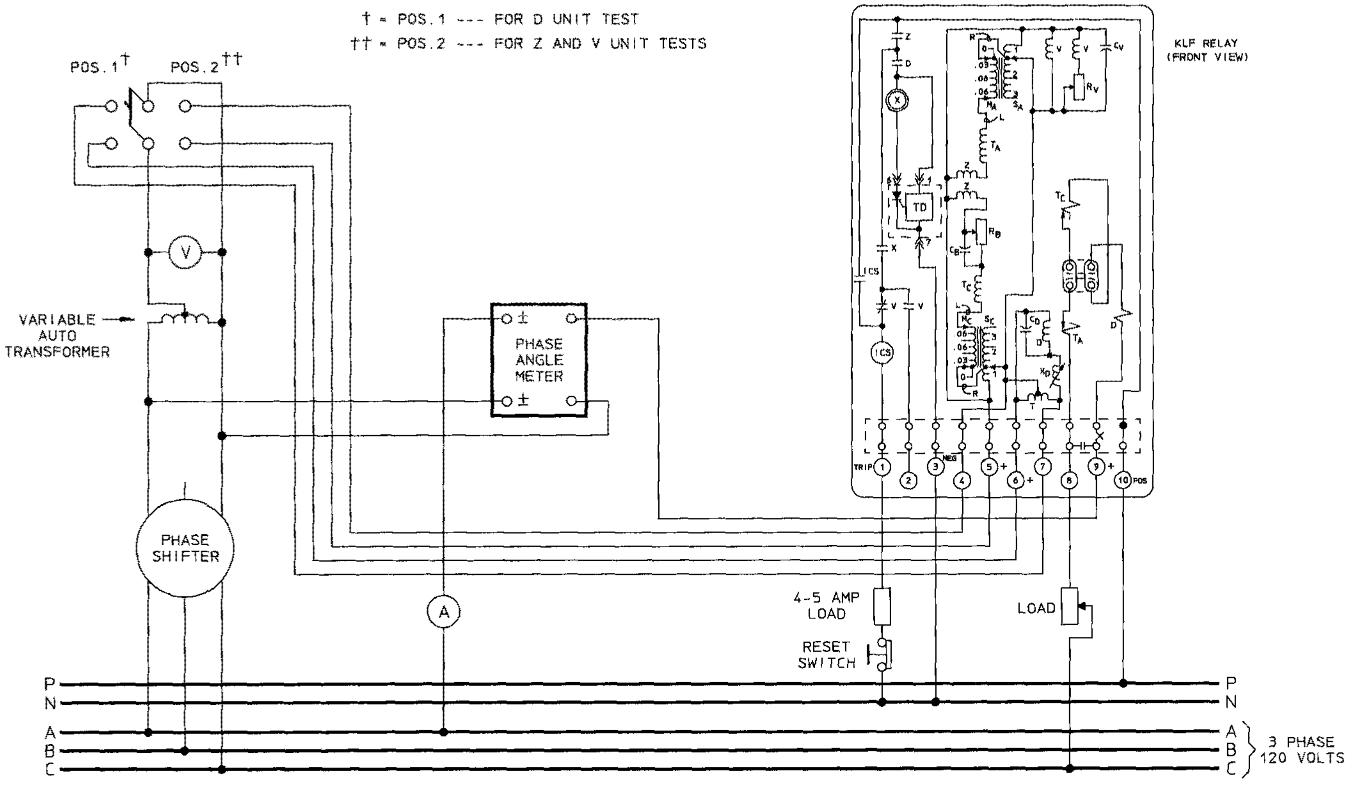


Figure 13. KLF Frequency Response for Impedance Unit



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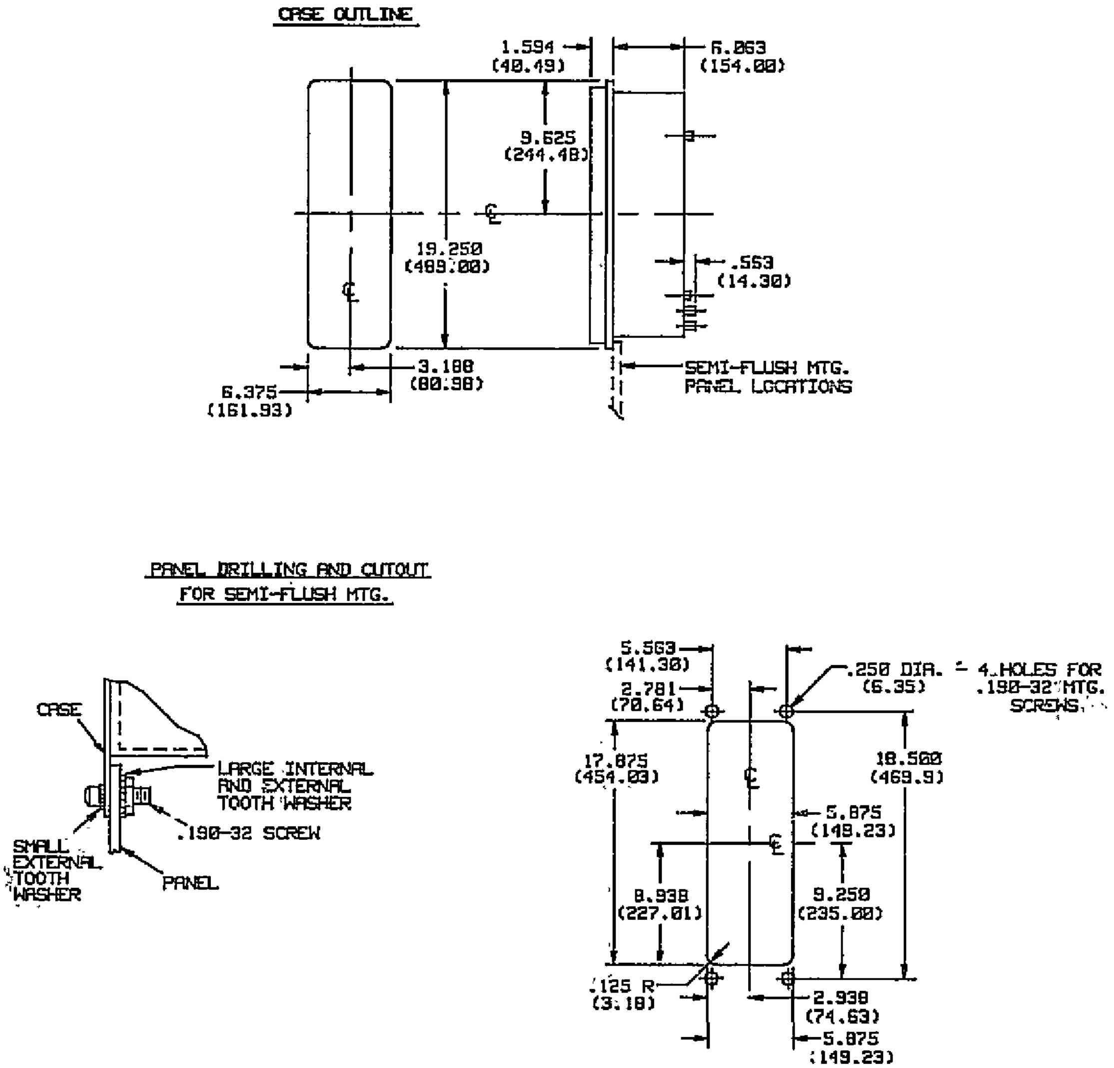
1487B22

Figure 14. Diagram of Test Connections for KLF Relay



Sub 4
3519A70

Figure 15. Outline and Drilling Plan for the Type KLF Relay in the FT-41 Case

IL 41-748.21 - Revision C

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