INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES HU AND HU-1 TRANSFORMER DIFFERENTIAL RELAYS*

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

APPLICATION

The types HU and HU-1 relays are high-speed single phase relays used in the differential protection of transformers. These relays can be applied where the magnetizing inrush current to the transformers is severe.

Current transformer ratio error should not exceed 10% with maximum external fault current flowing, or with eight times relay tap current flowing.

The HU-1 relay has three restraint transformers and associated rows of taps; whereas, the HU relay has one less restraint transformer and two rows of taps. Otherwise the two relays are identical. Three-winding banks normally require the HU-1 relay, although the autotransformer application uses the HU if the tertiary is not loaded.

Both the HU or the HU-1 are available with a sensitivity of either 0.30 or 0.35 times tap. The 30%-sensitivity relay satisfactorily handles up to 15% mismatch (e.g. ±10% transformer tap changing plus 5% CT mismatch). The 35%-sensitivity relay handles as much as 20% mismatch. See Fig. 7 for a comparison of the characteristics of the two sensitivities. Any of the relays may be recalibrated in the field to obtain either characteristic.

Ordinarily the 30%-sensitivity relay will suffice; however, where CT mismatch is abnormally high or where the transformer tap-changing range exceeds ±10%, this calibration may be too sensitive.

CONSTRUCTION

The types HU and HU-1 relays consist of a differential unit (DU), a harmonic-restraint unit (HRU), and an indicating contactor switch (ICS). The principal parts of the relay and their locations are shown in Figs. 1 to 4.

Differential Unit (DU)

The differential unit of the HU relay consists of two air-gap restraint transformers, three full-wave rectifiers, saturating operating-transformer, and a d-c polar unit.

The HU-1 relay, in addition to the above components, has a third air-gap restraint transformer, and a fourth full-wave rectifier.

Each of the restraint transformers and the operating transformer are provided with taps to compensate for mismatch of line current transformers. These taps are incorporated in the relay in such a manner that changing a tap on a restraint transformer automatically changes the same tap on the operating transformer.

Harmonic-Restraint Unit (HRU)

The harmonic-restraint unit of the HU and HU-1 relays consists of an air-gap operating transformer, a second harmonic block filter, a fundamental block-second harmonic pass filter, two full-wave rectifiers, indicating instantaneous trip unit, varistor, and a d-c polar unit.

Taps are also incorporated in this unit to compensate for mismatch of the line current transformers. Changing a tap on the restraint transformer of the differential unit also changes the tap of this unit.

Polar Unit

The polar unit consists of a rectangular shaped

SUPERSEDES I.L. 41-347.1H
*Denotes change from superseded issue.

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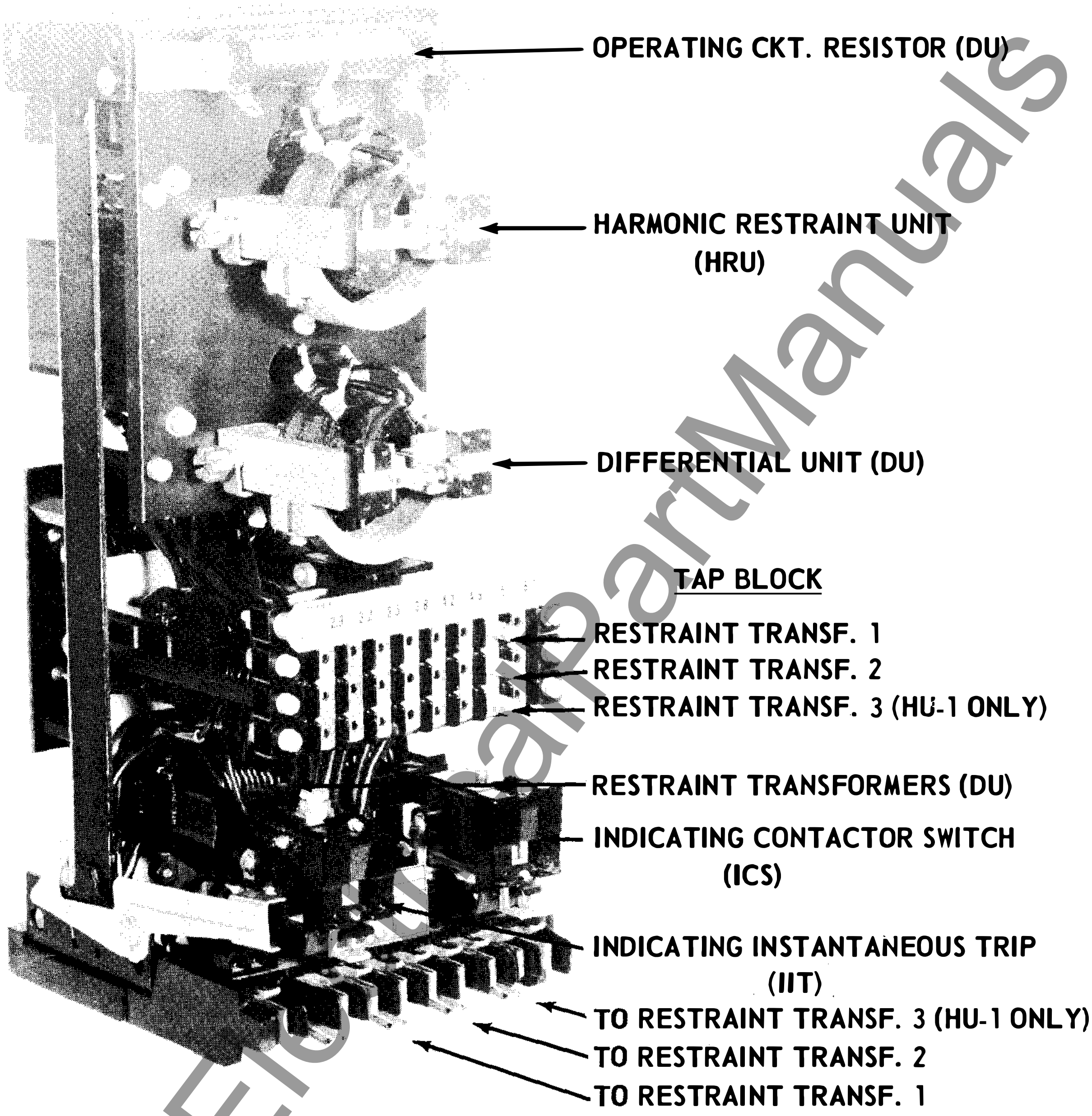
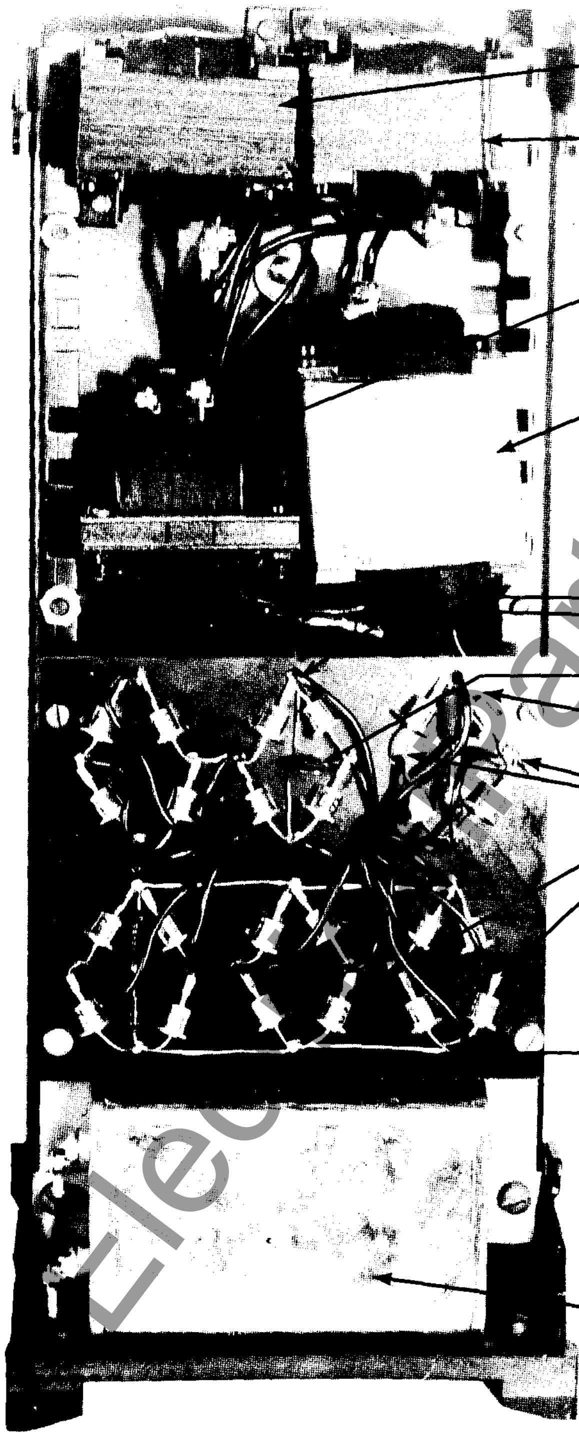
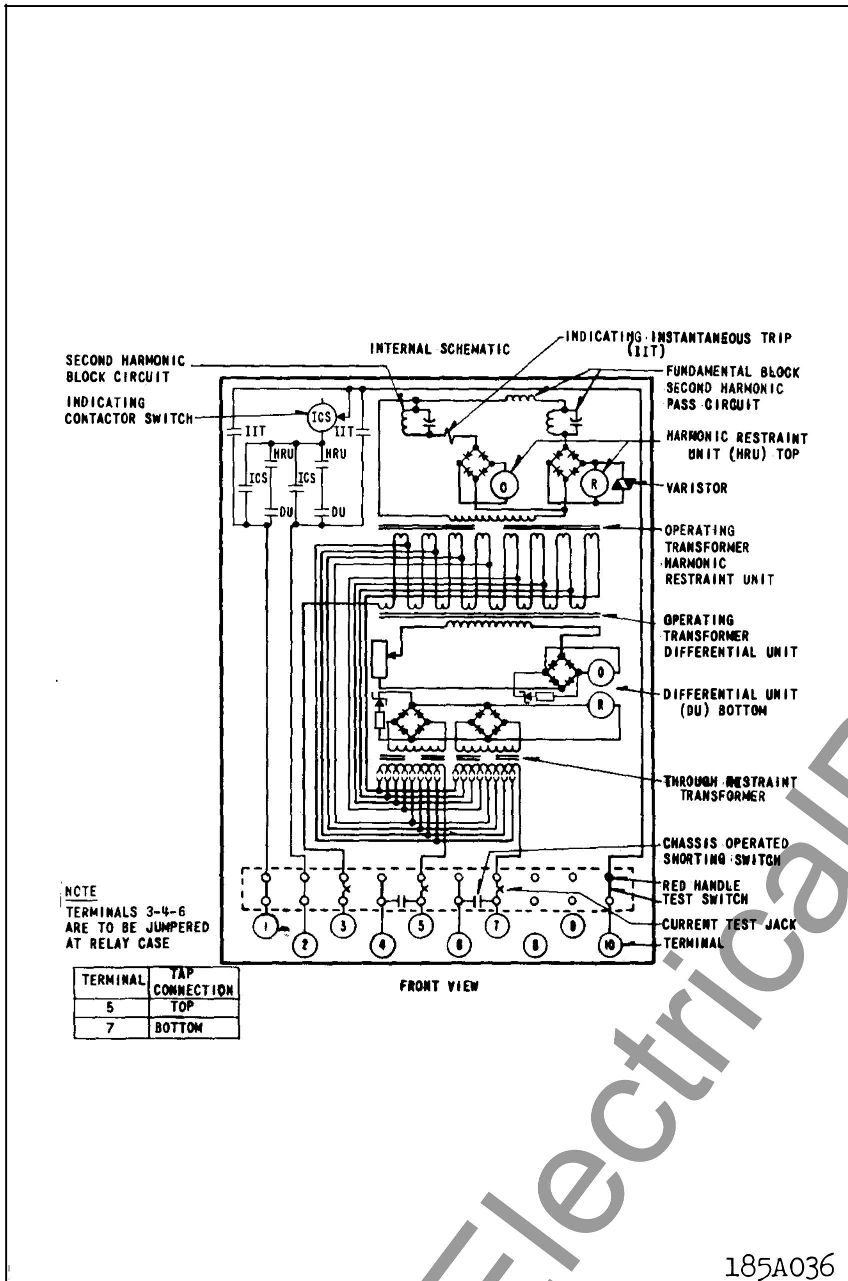


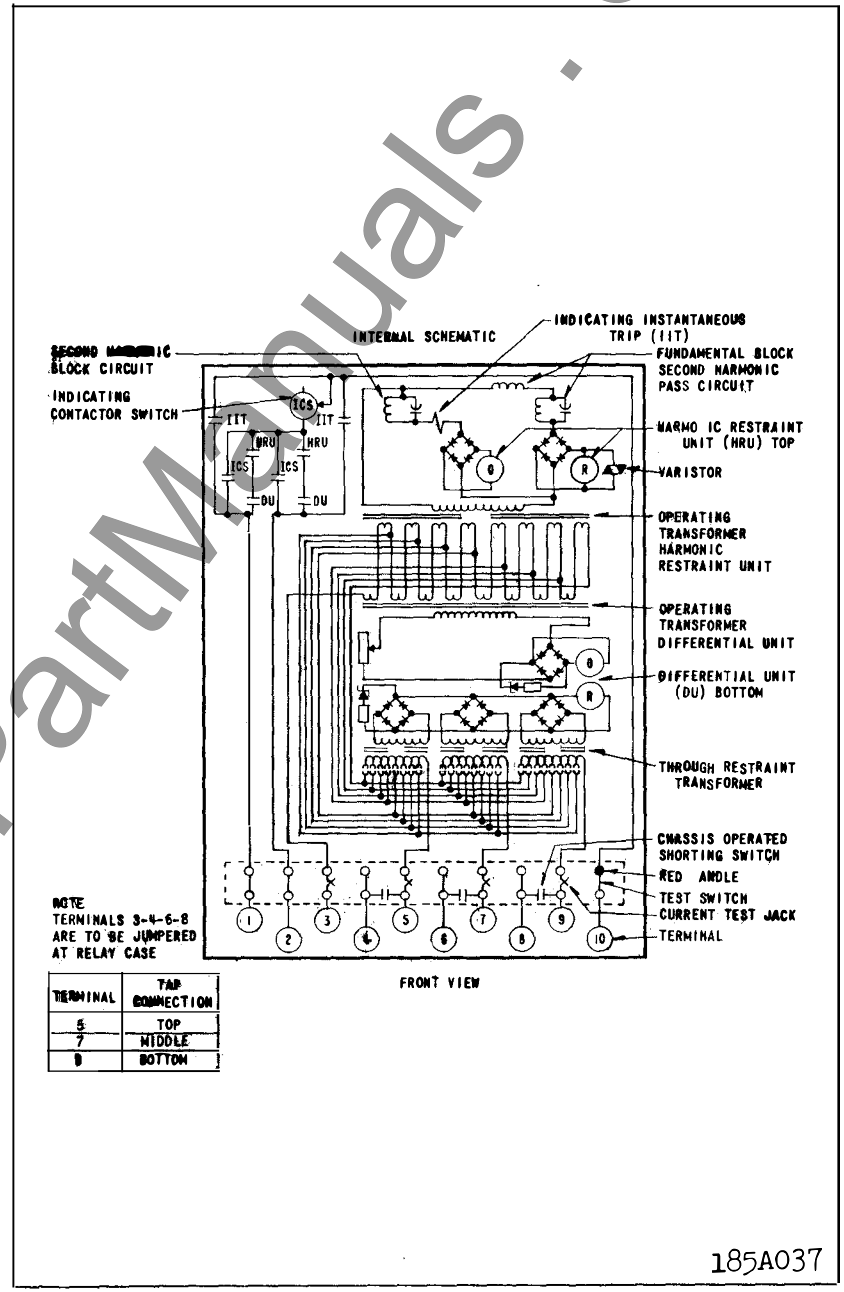
Fig. 1. Type HU-1 Relay – Front View.



* *Fig. 2. Type HU-1 Relay – Rear View.*



* *Fig. 3. Internal Schematic of the Type HU Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted, 184A762.*



* *Fig. 4. Internal Schematic of the Type HU-1 Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted, 184A736.*

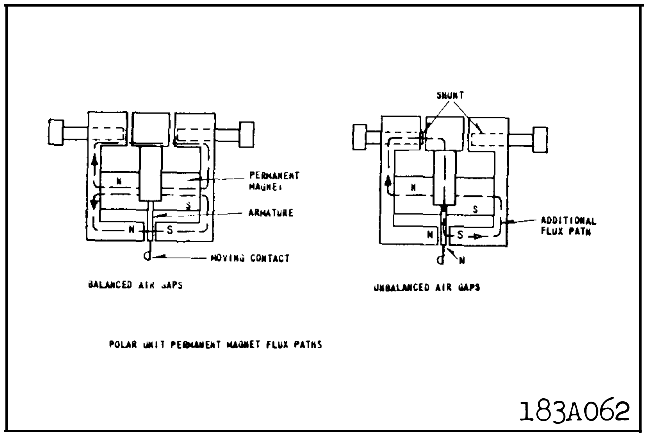


Fig. 5 Polar Unit Permanent Magnet Flux Paths.

magnetic frame, an electromagnet, a permanent magnet, and an armature. The poles of the crescent shaped permanent magnet bridge the magnet frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These non-magnetic joints represent air gaps, which are bridged by two adjustable magnetic shunts. The windings are wound around a magnetic core. The armature is fastened to this core and is free to move in the front air gap. The moving contact is connected to the free end of a leaf spring, which, in turn, is fastened to the armature.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper-type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also, during this operation, two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop.

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

OPERATION

The types HU and HU-1 relays are connected to the protected transformer as shown in Fig. 6. In such a connection, the relays operate to protect the transformer for faults internal to the differential zone of the transformer, but not for faults external to the zone. Neither do the relays operate on magnetizing inrush currents associated with energization of the transformer, even though these currents may appear as an internal fault. To avoid these false operations, each unit of the relay performs a separate function. The differential unit (DU) prevents operation on external faults, while the harmonic-restraint unit (HRU) prevent operations on magnetizing inrush currents. Hence, the operation of the relay can best be described under the headings of external fault current, internal fault currents, and magnetizing inrush currents.

External Fault Currents

The types HU and HU-1 relays have a variable percentage characteristic. This means that the operating current required to close the contact of the differential unit expressed in percent of restraint current varies with the magnitude of the larger restraint current. Fig. 7 and Fig. 8 illustrate this characteristic. To use these curves, divide each restraint current by the appropriate tap and enter the horizontal axis using the larger or largest restraint multiple. Then enter the vertical axis, using the difference of the restraint multiples.

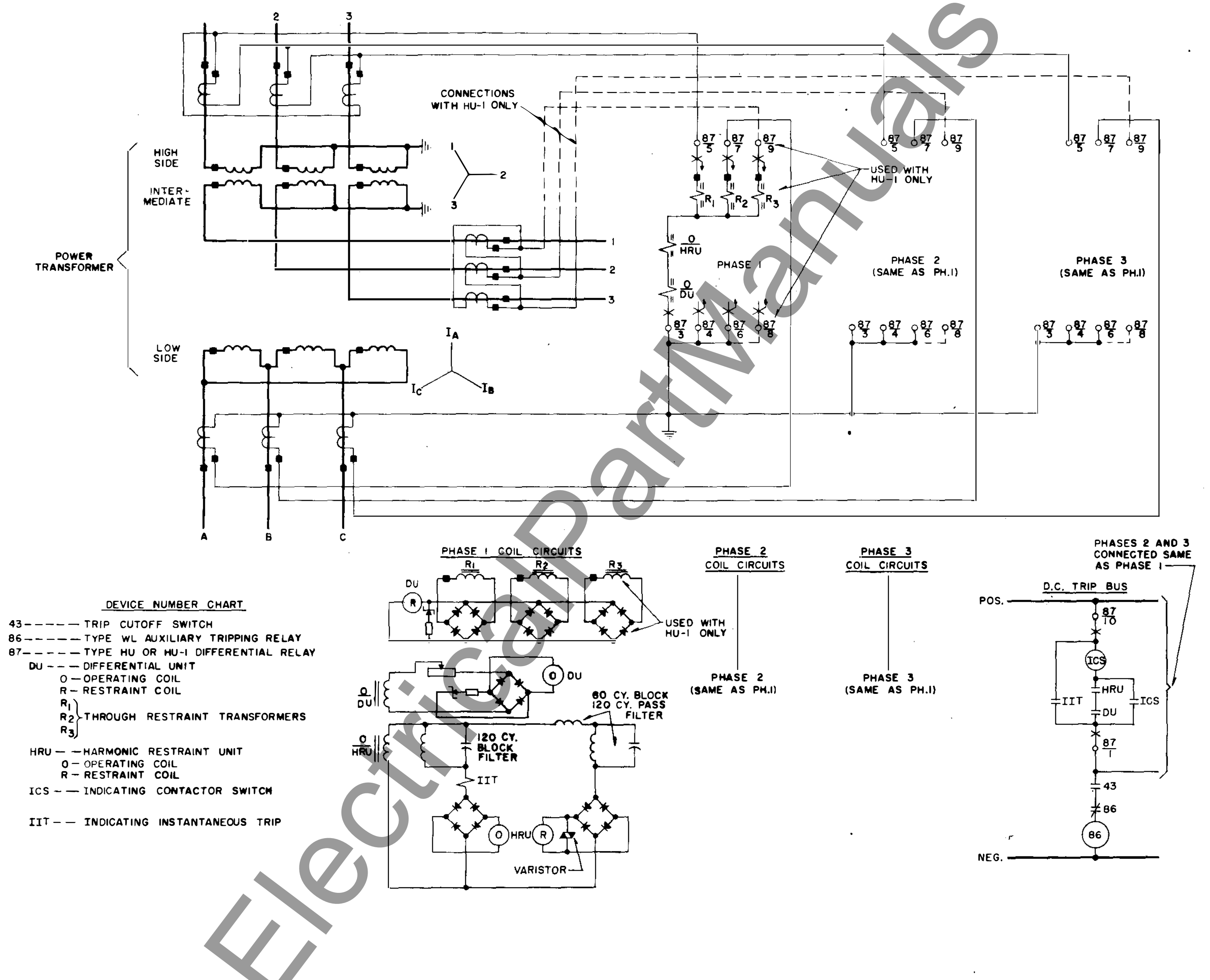
With the relay connected as shown in the schematic diagram of Fig. 9a, an external fault causes currents to flow in the air-gap restraint transformers of the differential unit. If the line current transformers do not saturate and the correct ratio matching taps applied, no effective current flows in the operating transformer of the relay. Hence, only a contact-opening torque is produced on the differential unit.

On heavy external faults where a main current transformer saturates, current flows in the operating circuit of the relay. With such a condition, the harmonic-restraint unit may or may not close its contacts, depending upon the harmonics present in the false operating current. However, operation of the relay is prevented by the variable percentage characteristic of the differential unit, since a large differential current is required to close its contacts during heavy external faults.

Internal Faults

In the case of an internal fault as shown in Fig. 9b, the restraint of the differential unit is proportional to the largest restraint current flowing. The sum of the two restraint currents flows into the operating transformer and produces an excess of operating torque, and the differential unit operates.

In the case of an internal fault fed from one source only, the fault current flows in one restraint



* *Fig. 6. External Schematic of the Type HU and HU-1 Relays.*

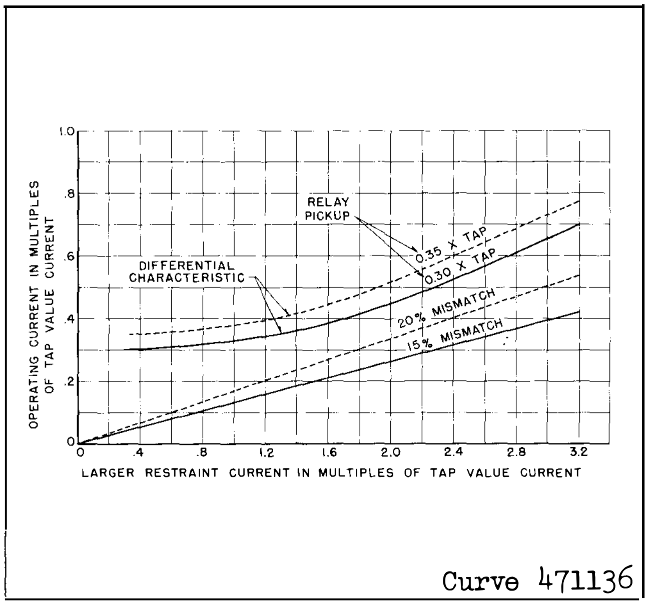


Fig. 7. Differential Characteristic of the DU Unit of the HU and HU-1 Relays at Smaller Values of Current. Actual Operating Current Shown for 15 and 20% Mismatch.

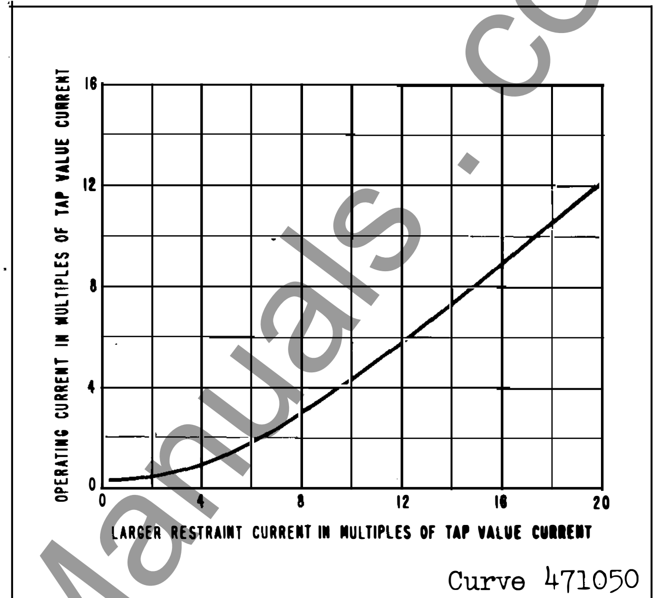


Fig. 8. Differential Characteristic of the Differential Unit (DU) of the HU and HU-1 Relays at Larger Values of Current.

transformer and the operating transformer. An excess of operating torque is produced on the differential unit and it operates.

Faults normally appear as an offset sine wave with a decaying d-c component, and contain very few harmonics. As a result, the harmonic-restraint unit will operate during internal faults to permit tripping of the relay.

For heavy internal faults, the indicating instantaneous trip unit (IIT) will operate before the main unit. Since this unit is connected to an air gap transformer, essentially only the sine wave component of an internal fault is applied to the IIT unit. The d.c. component of the fault is bypassed by the transformer primary. For example, an internal fault with a first peak of 28 times tap value (includes fifty percent d.c.) is reduced to a first peak of approximately 14 times tap value (d.c. component absent) on the secondary of the transformer. The IIT unit will just operate on this wave since it is set to pick up at a peak current of 14.1 times tap (r.m.s. pick-up value = 10 times tap).

The varistor connected across the d.c. side of the restraint rectifier of the harmonic restraint unit prevents excessive voltage peaks from appearing across the rectifiers. These peaks arise through transformer action of the harmonic-restraint polar-unit coils during heavy internal faults. The varistor has a large value of resistance for low voltages, while presenting a low value of resistance for high voltages. This characteristic effectively reduces the voltage spikes on heavy internal faults while not hampering performance during inrush, where the voltage is considerably lower.

Magnetizing Inrush Currents

Magnetizing inrush current waves have various wave shapes. A typical wave appears as a rectified half wave with decaying peaks. In any case, the various wave shapes are rich in harmonics with the second harmonic predominant. Since the second harmonic is always present in inrush waves and not in internal fault waves, this harmonic is used to restrain the harmonic-restraint unit during inrushes. The differential unit may or may not close its contact, depending on the magnitude of the inrush.

When a magnetizing inrush wave is applied to the relay, the d-c component of the wave is by-passed by the air-gap operating transformer. The other components are fed into the filter circuits. The impedance characteristics of these filters are such that the second harmonic component flows into the restraint coil of the polar unit, while the other harmonics flow into the operating coil. The polar unit will not close

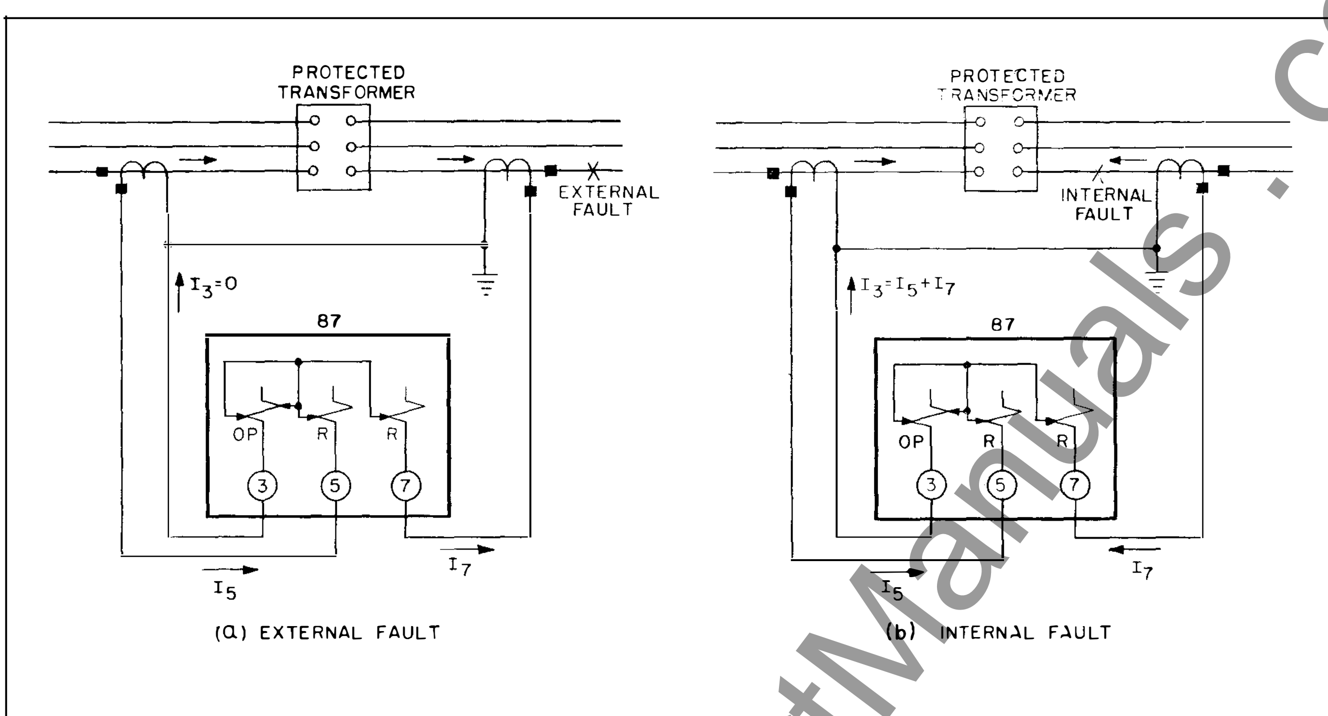


Fig. 9. Simplified Schematic of the Type HU Relay with Current Distribution for (a) External Fault (b) Internal Fault.

its contacts unless the second harmonic content is less than 15 percent of the fundamental component.

The indicating instantaneous trip unit (IIT) will not operate on inrush. The air-gap transformer will bypass the d.c. component of the inrush thereby reducing the magnitude of the wave applied to the IIT unit. If the inrush has an initial peak of 16 times tap-value current, the air-gap transformer will reduce this peak to approximately 8 times tap value on the secondary of the transformer. Since the IIT unit is set for a peak value of 14.1 times tap (r.m.s. pick-up value = 10 times tap), it will not operate on this inrush.

Breaker Maintenance

Before some of the CT's are bypassed for breaker maintenance the trip circuit should be opened, as shown in Fig. 6. Otherwise the false-unbalanced current will cause the relay to trip. It is not necessary to short-circuit the relay operating circuit since it has an adequate continuous-current rating. (See "Energy Requirements").

CHARACTERISTICS

Taps are incorporated in the HU and HU-1 relays to compensate for main current transformer mismatch. These taps are as follows: 2.9, 3.2, 3.5, 3.8, 4.2, 4.6, 5.0, 8.7.

To measure the effective unbalance, a sensitive low-reading voltmeter (5000 ohms per volts) can temporarily be connected across the operating coil resistor (at top of case). With a perfect balance the voltmeter reading will be zero. The reading should not exceed the values indicated by the 15% mismatch curve in Fig. 10 when the relay pickup is 0.30 times tap. If the amount of mismatch is measured or calculated, the measured voltage can be checked against the interpolated value from the curve. For example, assume that the larger restraint current is measured as 1.5 tap multiple and the calculated mismatch is 7%. Then, from Fig. 10 the measured voltage should be approximately 1.0 volts. Use Fig. 11 if the pickup is 0.35 times tap.

Pickup of the harmonic-restraint unit and the differential unit is either 30 or 35% of tap value current. Pickup of the indicating instantaneous trip unit is ten times tap value current.

Components of the harmonic-restraint unit are selected such that 15% second harmonic will prevent operation of the unit. This factor is adequate to prevent false operation on inrushes.

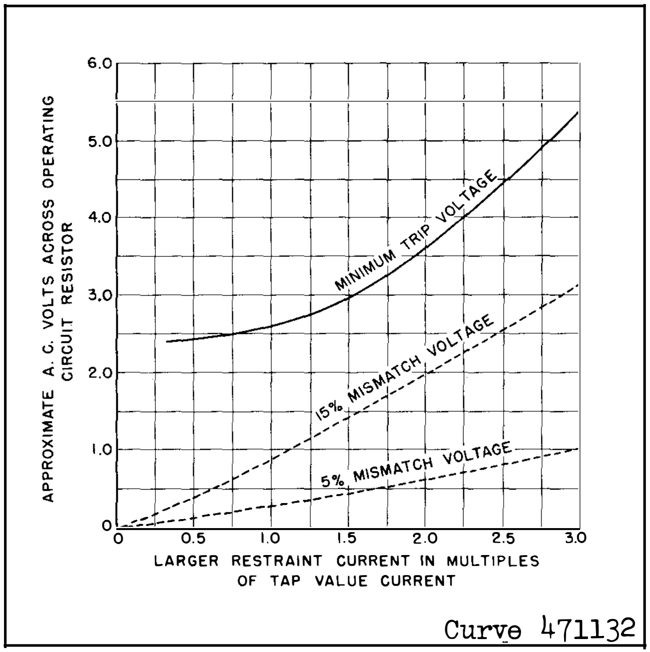


Fig. 10. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.30 Times Tap.

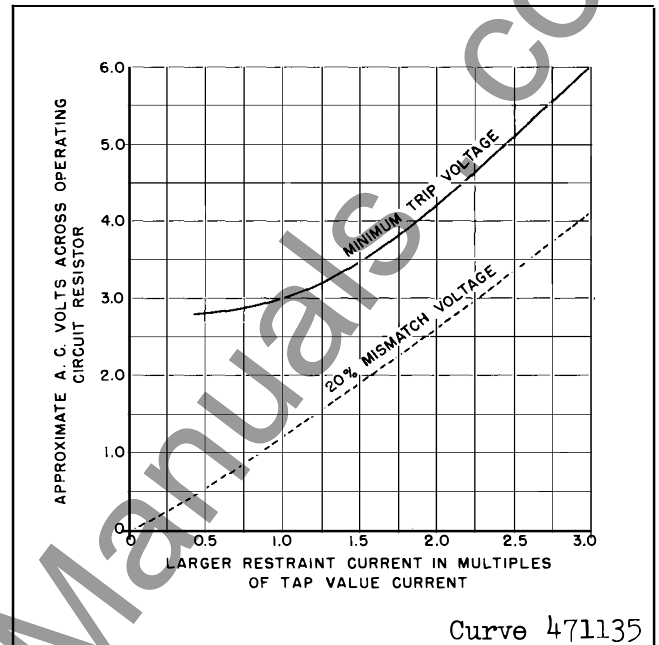


Fig. 11. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.35 Times Tap.

The frequency response of the HU and HU-1 relays is shown in Fig. 13.

Trip Circuit

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

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

SETTING

To set the relay, calculations must be performed as shown under "Setting Calculations". After the correct tap is determined, connections can be made to the relay transformers by placing the connector screws in the various terminal-plate holes in front of the relay. Only one tap screw should be inserted in any horizontal row of taps.

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-or 250-volt d-c type WL relay switch, or equivalent, use the 0.2-ampere tap; for 48 volt DC applications set relay in 2 tap and use Type WL Relay coil S#304C209G01 or equivalent.

Indicating Instantaneous Trip (IIT)

No setting is required on the indicating instantaneous trip unit. This unit is set at the factory to pickup at 10 times tap value current.

SETTING CALCULATIONS

Select the ratio matching taps. There are no other settings. In order to calculate the required tap settings and check current transformer performance the following information is required.

Required Information

1. Maximum transformer power rating $(KVA)_M$
2. Maximum external fault currents
3. Voltage ratings of power transformer (V_H, V_I, V_L)
4. Current transformer ratios, full tap (N_T)
5. Current transformer "10L" accuracy class

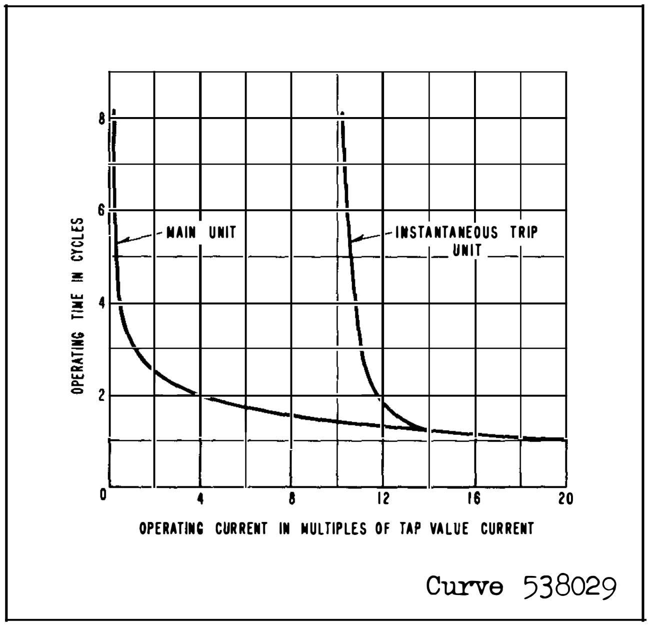


Fig. 12. Typical Tripping Time Characteristic (60 Cycle Currents).

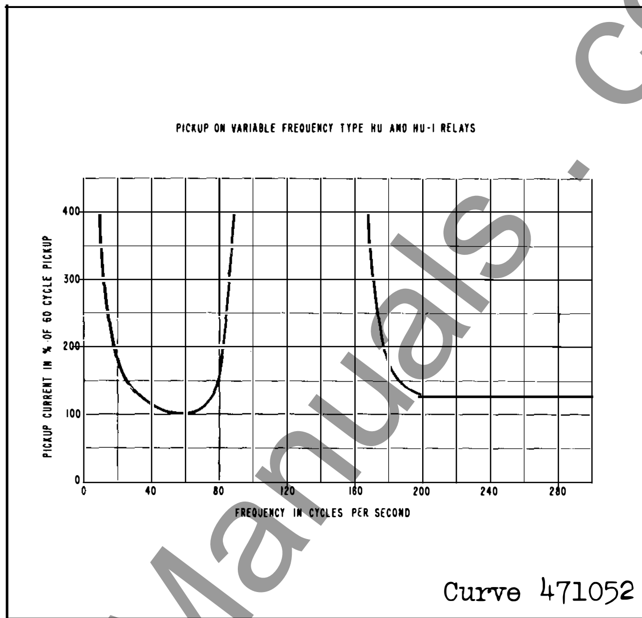


Fig. 13. Typical Frequency Response of the HU and HU-1 Relays.

voltage, (or excitation or ratio-overcurrent curve)

6. One way current transformer lead resistance at 25°C (R_L) (when using excitation curve, include CT winding resistance)

7. Current transformerconnections(wye or delta)

Definitions of Terms

I_P = Primary current at $(KVA)_M$

I_R = Relay input current at $(KVA)_M$

I_{RH}, I_{RL}, I_{RI} are same as I_R except for high, low and intermediate voltage sides respectively.

I_S = CT secondary current at $(KVA)_M$

T_H, T_L, T_I = Relay tap settings for high, low and intermediate voltage windings, respectively.

N = Number of current transformer turns that are in use.

$N_P = N/N_T$ (Proportion of total turns in use)

N_T = Current transformer ratio, full tap

V_{CL} = 10L accuracy class voltage

Z_A = Burden impedance of any devices other than the HU or HU-1 relays, with maximum phase-to-phase or 3-phase current flowing.

Z_T = Total secondary burden in ohms (excluding current transformer winding resistance, except when using excitation curve)

Calculation Procedure

1. *Select current transformer taps,* where multi-ratio types are used.

I_R should be more than 2.9 amperes for high sensitivity and should not exceed the relay continuous rating (see "Energy Requirements"). For determining the required continuous rating of the relay, use the expected two-hour maximum load, since the relay reaches final temperature in this time.

2. *Select relay taps in proportion to the relay currents,* I_R.

I_R should not exceed relay continuous rating. Also the maximum external fault current should not exceed 20 times relay tap.

3. *Determine Mismatch* (Not to exceed 15%)

For 2 winding banks:

$$\% \text{ mismatch} = 100 \frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{S} \quad (1)$$

where S is the smaller of the two terms, (I_{RL}/I_{RH}) or (T_L/T_H)

For 3 winding banks:

$$\% \text{ mismatch} = 100 \frac{(I_{RH}/I_{RI}) - (T_H/T_I)}{S} \quad (2)$$

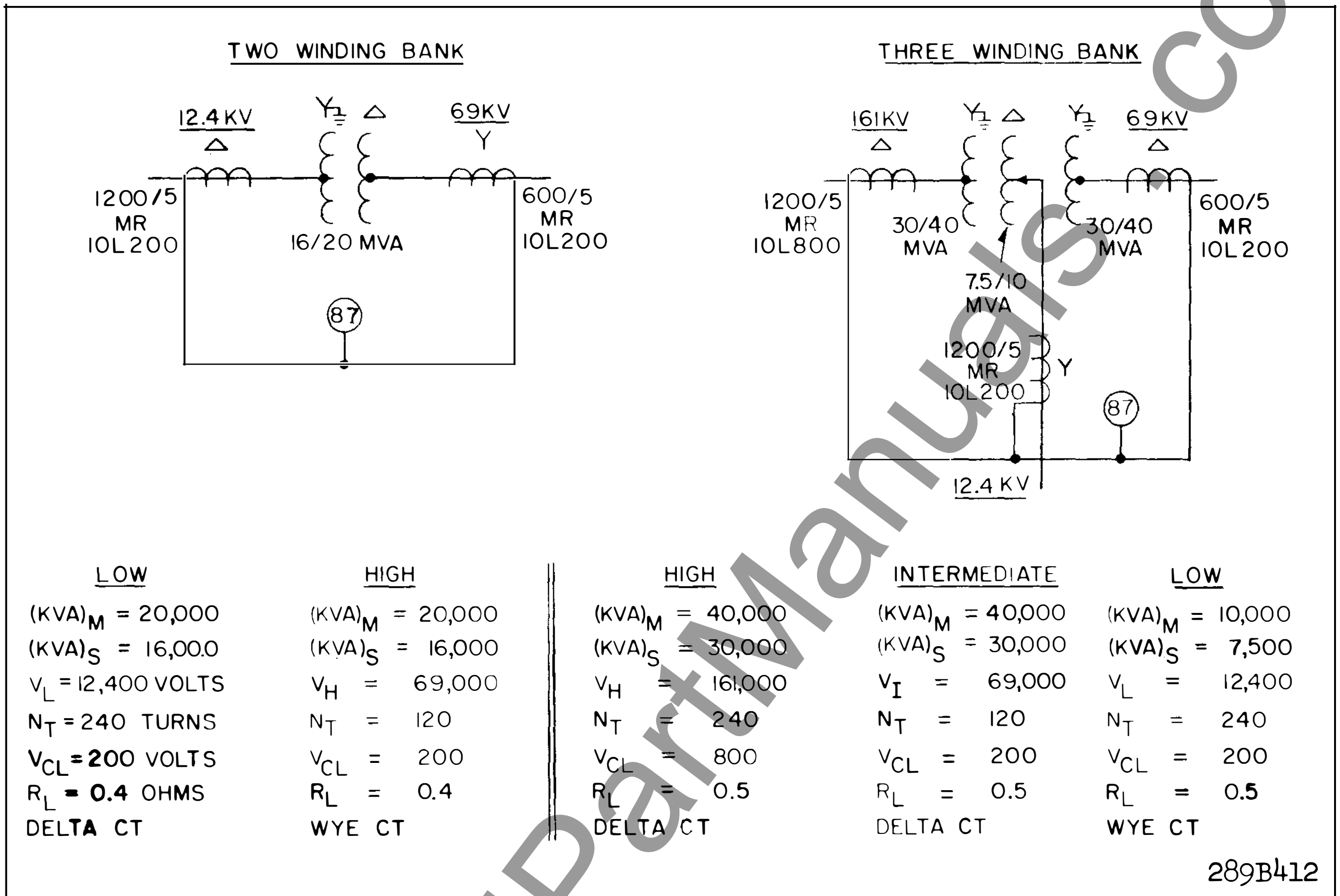


Fig. 14. ***Example for Setting Calculations.***

where "S" is the smaller of the two terms, (I_{RH}/I_{RI}) or (T_H/T_I).

Equations similar to eq. (2) apply for mismatch from the high to low and from the intermediate to low voltage windings.

Where tap changing under load is performed the relays should be set on the basis of the middle or neutral tap position. The total mismatch, including the automatic tap change should not exceed 15% with a 30% sensitivity relay, and 20% with a 35% sensitivity relay. Note from Fig. 7 that an ample safety margin exists at these levels of mismatch.

4. *Check current transformer performance.* Ratio error should not exceed 10% with maximum symmetrical external fault current flowing or with 8 times relay tap current flowing. An accurate method of determining ratio error is to use ratio-correction-factor curves (RCF).

A less accurate, but satisfactory method is to utilize the ASA relaying accuracy classification. If the 10L accuracy is used, performance will be adequate if:

$$\frac{N_P V_{CL}}{100} \text{ is greater than } Z_T \qquad (3)$$

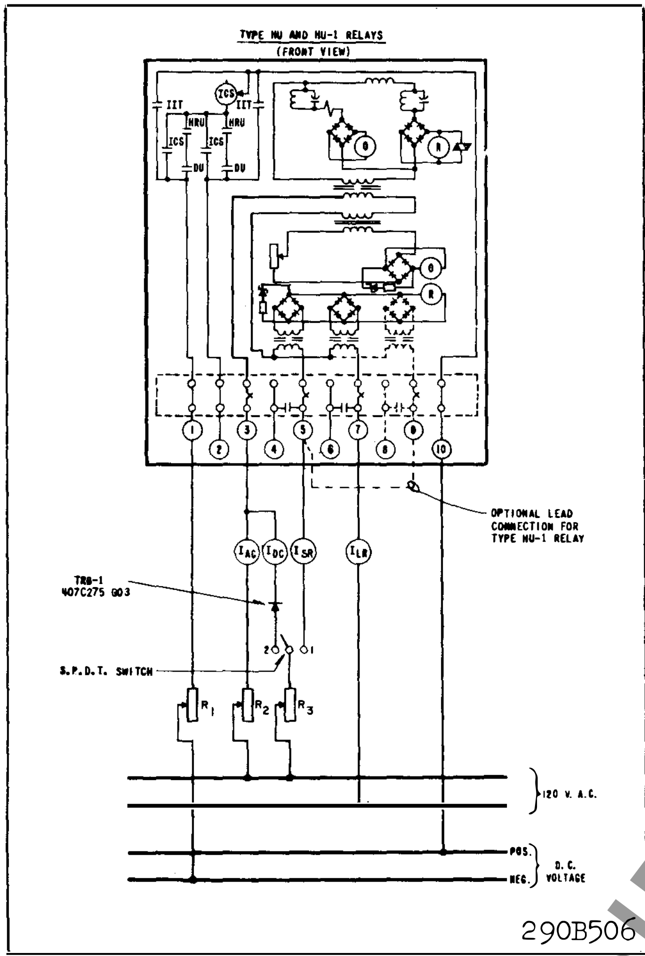
For wye-connected CT:

Z_T = lead resistance + relay burden + Z_A

$$= 1.13\, R_L + \frac{0.15}{T} + Z_A \text{ ohms} \qquad (4)$$

(R_L multiplier, 1.13, is used to account for temperature rise during faults. $\frac{0.15}{T}$ is an approximation, where T = relay tap.

Z_A is any additional burden, when maximum external 3-phase fault current is flowing).



* *Fig. 15. **Test Circuit of the HU and HU-1 Relays.***

For delta-connected CT:

$$Z_T = 3\,(1.13\,R_L + \frac{0.15}{T} + Z_A)\ \text{ohms}$$

$$= 3.4\,R_L + \frac{0.45}{T} + 3Z_A \qquad (5)$$

(The factor of 3 accounts for conditions existing during a phase-to-phase fault. Z_A is any additional burden, when maximum external phase to phase fault current is flowing)

5. *Examples*

Refer to pages 13 and 14 and figure 14 for setting examples. Note in both examples that the 8.7 tap was selected as the first step in selecting relay taps. If a lower tap such as tap 5 had been the first selection, a proper balance would have been impossible. On page 12 for the two winding bank,

$\frac{I_{RL}}{I_{RH}} = \frac{8.05}{4.18} = 1.92$. With tap 5 for the low side the maximum current ratio that can be matched by the taps is $\frac{5}{2.9} = 1.73$. With tap 8.7 selected for the low side, a 3 to 1 current ratio can be matched. On page 13 for the three winding bank,

$$\frac{I_{RL}}{I_{RH}} = 3.02$$

This current ratio can be accommodated by the 8.7 & 2.9 taps without excessive mismatch.

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 to the terminal studs furnished with the relay for thick-panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer.

Acceptance Tests

The following check is recommended to insure that the relay is in proper working order. All checks can best be performed by connecting the relay per the test circuit of Fig. 15. Relay to be tested in case.

1. Minimum Trip Current. With switch open and relay set on 5-ampere tap, apply 1.35 to 1.65 amperes for the 30%-sensitivity relay and 1.6 to 1.9

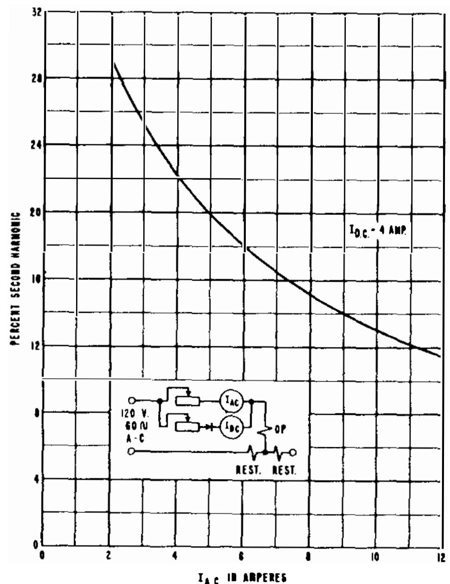
TWO-WINDING TRANSFORMER CALCULATIONS

(See Figure 14)

	LOW	HIGH
1. Select CT Ratio:		
$I_P = \dfrac{(KVA)_M}{\dfrac{V\sqrt{3}}{1000}} =$	$\dfrac{20{,}000}{12.4\sqrt{3}} = 930$ Amp.	$\dfrac{20{,}000}{69\sqrt{3}} = 167$ Amp.
Select Ratio	1000/5 (N = 200)	200/5 (N = 40)
2. Select Relay Taps:		
$I_S = \dfrac{I_P}{N} =$	$\dfrac{930}{200} = 4.65$ Amp.	$\dfrac{167}{40} = 4.18$ Amp.
$I_R =$	$I_{RL} = 4.65\sqrt{3} = 8.05$ Amp.	$I_{RH} = 4.18$ Amp.
Select Tap	$T_L = 8.7$	$T_H = \dfrac{4.18}{8.05} \times 8.7 = 4.64$
Desired Tap		$T_H = 4.6$
3. Determine Mismatch:		
% Mismatch = $100\,\dfrac{(I_{RL}/I_{RH}) - (T_L/T_H)}{T_L/T_H} =$	$100\,\dfrac{(8.05/4.18) - (8.7/4.6)}{8.7/4.6} =$ $100\,\dfrac{1.92 - 1.89}{1.89} =$ 1.6%	
4. Check CT Performance:		
$Z_T =$	$3.4\,R_L + \dfrac{0.45}{T} =$	$1.13\,R_L + \dfrac{0.15}{T} =$
	$3.4 \times 0.4 + \dfrac{0.45}{8.7} = 1.36 + 0.05 =$ 1.41 ohms	$1.13 \times 0.4 + \dfrac{0.15}{4.6} = 0.45 + 0.03 =$ 0.48 ohms
$N_P = \dfrac{N}{N_T} =$	$\dfrac{200}{240} = 0.833$	$\dfrac{40}{120} = 0.333$
$\dfrac{N_P\,V_{CL}}{100} =$	$\dfrac{0.833 \times 200}{100} = 1.67$	$\dfrac{0.333 \times 200}{100} = 0.67$
$(N_P\,V_{CL}/100) > Z_T$	Yes	Yes

THREE-WINDING TRANSFORMER CALCULATIONS
(See Figure 14)

	HIGH	INTERMEDIATE	LOW
1. Select CT Ratio:			
$I_P = \frac{(KVA)_M}{\frac{V\sqrt{3}}{1000}} =$	$\frac{40,000}{161\sqrt{3}} = 143$ Amp.	$\frac{40,000}{69\sqrt{3}} = 334$ Amp.	$\frac{10,000}{12.4\sqrt{3}} = 465$ Amp.
Select Ratio	400/5 (N = 80)	600/5 (N = 120)	1000/5 (N = 200)
2. Select Relay Taps:			
$I_S = \frac{I_P}{N} =$	$\frac{143}{80} = 1.78$ Amp.	$\frac{334}{120} = 2.78$ Amp.	$\frac{465}{200} = 2.32$ Amp. (At 10 MVA)
I_R (At 40 MVA) =	$I_{RH} = 1.78\sqrt{3}$ $= 3.08$ Amp.	$I_{RI} = 2.78\sqrt{3}.$ $= 4.82$ Amp.	$I_{RL} = \frac{40}{10} X\ 2.32$ $= 9.3$ Amp.
Select Tap			$T_L = 8.7$
Desired Tap	$T_H = 8.7\frac{3.08}{9.30}$ $= 2.88$	$T_I = 8.7\frac{4.82}{9.30}$ $= 4.52$	
Select Tap	$T_H = 2.9.$	$T_I = 4.6$	
3. Determine Mismatch			
% Mismatch	$100\frac{(I_{RH}/I_{RI})-(T_H/T_I)}{T_H/T_I} =$ $100\frac{(3.08/4.82)-(2.9/4.6)}{2.9/4.6} =$ $100\ \frac{0.640-0.630}{0.630} =$ 1.6%	$100\frac{(I_{RI}/I_{RL})-(T_I/T_L)}{(I_{RI}/I_{RL})} =$ $100\frac{(4.82/9.30)-(4.6/8.7)}{4.82/9.30} =$ $100\ \frac{0.518-0.528}{0.518} =$ −1.9%	$100\ \frac{(I_{RL}/I_{RH})-(T_L/T_H)}{T_L/T_H} =$ $100\ \frac{(9.3/3.08)-(8.7/2.9)}{8.7/2.9} =$ $100\ \frac{3.02-3.00}{3.00} =$ 0.67%
4. Check CT Performance			
$Z_T =$	$3.4\ R_L + \frac{0.45}{T} =$ $3.4\ X\ 0.5 + \frac{0.45}{2.9} =$ $1.70 + 0.16 =$ 1.86 ohms	$3.4\ R_L + \frac{0.45}{T} =$ $3.4\ X\ 0.5 + \frac{0.45}{4.6} =$ $1.70 + 0.10 =$ 1.80 ohms	$1.13R_L + \frac{0.15}{T} =$ $1.13\ X\ 0.5 + \frac{0.15}{8.7} =$ $0.565 + 0.02 =$ 0.58 ohms
$N_P = \frac{N}{N_T} =$	$\frac{80}{240} = 0.333$	$\frac{120}{120} = 1.0$	$\frac{200}{240} = 0.833$
$\frac{(N_P\ V_{CL})}{100} =$	$\frac{800\ X\ 0.333}{100} = 2.67$	$\frac{200\ X\ 1.0}{100} = 2.0$	$\frac{200\ X\ 0.833}{100} = 1.67$
$(N_P V_{CL}/100) > Z_T$	Yes	Yes	Yes



Curve 471047

Fig. 16 ***Variation of Second Harmonic Content of Test Current.***

amperes for the 35% sensitivity relay. Relay should operate. The upper polar unit may operate for lower currents, but not below 1.0 ampere. This low pickup will not impair its operation on magnetizing inrush currents and should not be disturbed if it is found to be less than the lower polar unit. If a higher pickup is desired, it is suggested that 20 times tap value current be applied to relay terminals 3 & 7. This will cause the upper polar unit to pick up at a current of approximately 1.65 amperes.

2. Indicating instantaneous Trip Pickup. With switch open and relay set on 5 ampere tap, apply 50 amperes to relay. Indicating instantaneous trip should pick up and its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

3. Indicating Contactor Switch. Block Polar unit contacts closed. Pass sufficient direct 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 setting being used. The operation indicator target should drop freely.

The contact gap of the ICS should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

4. Differential Characteristic.

30% Sensitivity relay

a. Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 10 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 12.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 to 2.95 amperes
I_{LR} = 11.8 to 12.8 amperes

b. Reverse leads to restraint transformers and repeat differential test outlined in paragraph 4a. Results should be approximately the same as obtained under paragraph 4a.

35% Sensitivity relay

c. Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 9 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 11.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 amperes
I_{LR} = 10.8 to 11.8 amperes

d. Reverse leads to restraint transformers and repeat differential test outlined in paragraph 4c. Results should be approximately the same as obtained under paragraph 4d.

5. Harmonic Restraint Characteristic. Close switch to position 2. Short out I_{LR} ammeter. Set I_{dc} to 4 amperes and adjust I_{ac} until upper polar unit operates. I_{ac} should read between 6.5 and 9 amperes. As shown in *Fig. 16*, these values of alternating current correspond to 17 percent and 14 percent second harmonic.

In Service Test

Table 1 is to be used as an in-service check of the HU or HU-1 relay using any tap combination. The relay should be connected as shown in fig. 15 with the S.P.O.T. switch in position 1. The ammeter I_{SR} measures the smaller restraint current and should be connected to the terminal associated with the tap block of the smaller setting. The ammeter I_{LR} measures the larger restraint current, and should be connected to the terminal associated with the larger tap block setting. Terminal 5 supplies the upper tap block; terminal 7 supplies the second tap block; and terminal 9 (HU-1 only) supplies the lower tap block (refer to figs. 1 and 4).

Table 1 gives the values of I_{AC} necessary to operate the relay when using a value of I_{SR} equal to 3 times tap value for all taps except the 8.7 tap. A value of I_{SR} equal to 2 times tap value was chosen for the 8.7 tap setting in order to keep the current at a convenient value for testing.

Example (HU Relay)

Upper Tap Block Tap 3.5
Lower Tap Block Tap 5.0

Since the upper tap block has the smaller tap setting I_{SR} should be connected to the upper tap block (Term. 5), and I_{LR} should be connected to Terminal 7. From Table 1 under "Restraint Transformer tap: Larger" = 5.0 "Smaller" = 3.5, set I_{SR} = 10.5 amps. The value of I_{AC} to operate the relay should be between 8.3 and 9.2 amps.

To check the third restraint winding on the HU-1 repeat the above procedure using terminal 9 and either terminal 5 or 7.

TABLE 1

Restraint Transformer Tap	Larger	2.9	3.2	3.5	3.8	4.2	4.6	5.0	8.7
Smaller	CURRENT IN AMPERES								
2.9	ISR	8.7	8.7	8.7	8.7	8.7	8.7	8.7	5.8
	IAC (Min.)	2.6	3.7	5.0	5.8	7.8	9.0	10.4	16.2
	IAC (Max.)	2.8	4.0	5.5	6.4	8.6	10.0	11.6	17.9
3.2	ISR		9.6	9.6	9.6	9.6	9.6	9.6	6.4
	IAC (Min)		2.7	4.0	4.9	6.9	8.1	9.6	15.7
	IAC (Max)		3.1	4.4	5.4	7.6	9.0	10.6	17.3
3.5	ISR			10.5	10.5	10.5	10.5	10.5	7.0
	IAC (Min)			3.0	3.8	5.7	6.9	8.3	14.5
	IAC (Max)			3.3	4.2	6.3	7.7	9.2	16.1
3.8	ISR				11.4	11.4	11.4	11.4	7.6
	IAC (Min)				3.2	5.2	6.5	7.9	14.1
	IAC (Max)				3.6	5.7	7.2	8.7	16.0
4.2	ISR					12.6	12.6	12.6	8.4
	IAC (Min)					3.5	4.7	6.2	12.9
	IAC (Max)					3.9	5.2	6.9	14.2
4.6	ISR						13.8	13.8	9.2
	IAC (Min)						3.9	5.3	12.4
	IAC (Max)						4.3	5.9	13.7
5.0	ISR							15.0	10.0
	IAC (Min)							4.3	11.6
	IAC (Max)							4.8	12.9
8.7	ISR								17.4
	IAC (Min)								5.0
	IAC (Max)								5.5

Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

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 contact.

Calibration (All Relays)

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. All adjustments to be done with relay inside its case. (See "Acceptance Check")

Polar Units

1. Contacts. Place a .060 to .070 inch feeler gage between the right hand pole face and the armature. This gap should be measured near the front of the right hand pole face. Bring up the backstop screw until it just makes with the moving contact. Place gage between moving contact and the stationary contact on the left-hand side of the polar unit. On the upper unit, the gap should be .046 inch and on the lower unit the gap should be .065 to .070 inch. Bring up the stationary contact until it just makes with the gage and lock in place.

2. Minimum Trip Current

   a. Harmonic Restraint Unit (HRU)

Connect the relay per test circuit of Fig. 15. With the switch open, pass I_{ac} = 20 times tap value current into the relay. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right hand shunt on upper polar unit until it trips with I_{ac} = 33% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. Repeat these steps, if necessary, until the unit operates at 33% or slightly lower of tap value current immediately following the application of 20 times tap value current and until the unit resets at a value of current 15% of tap value or greater. After the dropout has been measured, the unit should pick up at 25% or higher of tap value current.

On the application of the high current, the upper polar unit will be biased in the restraining direction and pickup will be greater than the nominal value of 30% of tap value current on the first application of pickup current. If the circuit is deenergized and pickup is measured again, the pickup current will be less than before. However, pickup will be stable after the second application of pickup current. If 20 times tap value current is applied again, the pickup immediately after applying this current will be high. However, measuring the pickup the second time will show that the pickup is again reduced. The variation between these pickups should be between 25% and 33% of tap value current.

The filter circuits are charged by the application of this heavy current and upon the removal of the current, these circuits will discharge their energy. The element will be biased in the restraining direction because the restraint coil has approximately 7 times the number of turns as the operating coil. Upon the application of pickup current, the operating ampere turns will be greater than the restraint ampere turns and the bias will be removed.

If a lower biasing current is used instead of 20 times tap value current, the pickup of the upper unit will be less than before for the first application of pickup current. Pickup will be further reduced with the second application of pickup current, but the current will be stable after this energization. However, this value of pickup will be lower than the limits of 25% and 33% of tap value current. This is in the direction of making the sensitivity of the polar unit lower than 30%, but does not impair the performance of the unit on inrush currents.

   b. Differential Unit (DU)

Set the adjustable resistor at top of the relay in the approximate center of its range. Open the switch and pass I_{ac} = 20 times tap value current. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right-hand shunt of lower polar unit until it trips with I_{ac} = 30% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. If polar unit resets before 15% of tap value current, no adjustments are necessary to the left-hand shunt. Repeat these steps until the lower polar unit will pickup at 30% of tap value current and reset for values of tap value current greater than 15%

Indicating Instantaneous Trip Unit (IIT)

With switch open, pass I_{ac} = 10 times tap value current. Adjust core of the instantaneous trip unit until it picks up. Its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging contact should touch both stationary contacts simultaneously.

Harmonic-Restraint Unit (HRU)

Close switch to position 2. Short out I_{LR} ammeter. Adjust direct current until I_{dc} reads 0.8 times tap setting. Gradually increase alternating current until upper polar unit operates with I_{ac} reading between 1.3 and 1.8 times tap setting. The percent second harmonic in the wave may be derived by the use of the formula:

$$\% \text{ second harmonic} = \frac{47\ I_{dc}}{I_{ac} + 1.11\ I_{dc}}$$

This formula is plotted in curve form in Fig. 16 for I_{dc} = 4 amperes.

Percentage Slope Characteristic (DU)

Close switch to position 1. Set I_{ac} to zero and I_{LR} to 5.5 times tap value current. Then adjust I_{ac} to 4 times tap value current.

Adjust resistor at top of relay until lower polar unit operates. Interchange lead positions to terminals 5 and 7 and repeat the above test. The lower polar unit should operate between the limits of:

I_{ac} = 4 times tap value current

I_{LR} = 9 to 10 times tap value current

Trip condition can best be determined by holding I_{ac} at 4 times tap value current and varying I_{LR}. If I_{LR} is too low the contacts will be closed when the currents are first applied. Hence, I_{LR} should be increased until the contacts open and then decreased until contacts close.

The adjustment of the resistor will have some effect on the pickup of the unit. Hence, recheck the pickup. If necessary readjust shunts to obtain a pickup of 30% of tap value current and dropout of 15% or greater of tap value current. If shunts are changed, check to see that above readings are obtained on the higher restraint currents. If necessary readjust resistor and repeat procedure until the unit operates within the specified limits.

Apply I_{ac} = .56 times tap value and vary I_{LR} until lower polar unit operates. The lower polar unit should operate between following limits.

I_{LR} = 2.36 to 2.56 times tap value current.

Indicating Contactor Switch (ICS)

Block polar unit contacts closed. Pass sufficient direct current through the trip circuit to close the contacts of the ICS. This value of current should be not greater than the particular tap setting being used. The operation-indicator target should drop freely.

The contact gap should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

Calibration (35%-Sensitivity Relays)

The differential unit (DU) should first be calibrated as outlined under "Calibration (All Relays)". Next the right hand shunt of the lower polar unit should be turned out until the relay operates at

I_{ac} = .45 times tap value current

I_{LR} = 1.64 times tap value current

This changes the percentage slope curve of the relay to that shown by the 35 percent sensitivity curve of figure 7. Pickup of the relay is increased from 30% to approximately 35% of tap value current and the curve is changed at low values of restraint current to that shown in figure 7. At large values of restraint current the percentage slope characteristic is essentially the same as shown in figure 8.

As shown in figure 7, the margin of safety between the relay calibrated for a 35% sensitivity and the 20% mismatch curve is the same as that of the relay calibrated for a 30% sensitivity and the 15% mismatch curve. This margin of safety is also shown in the voltage differential characteristic of figure 11 for the 35 percent sensitivity relay.

Electrical Checkpoints

Differential Unit

a. *Restraint Circuit*

Apply two times tap-value current successively to each restraint transformer. This is done by connecting leads to a tap screw and to terminals 5, 7 and 9 in turn (Terminal 9 on HU-1 only). Now measure the a-c voltage across the restraint rectifier bridges (See Fig. 2) using a high-resistance voltmeter (5000 ohms per volt). The voltage should be measured from the left-to the right-hand corners of the bottom set of bridges. A voltage of 2.17 to 2.27 volts should appear only across the appropriate bridge as specified in the following table:

Current in Term.	Associated Rectifier Bridge (Rear View) HU	HU-1
5	Center	Center
7	Right Hand	Left Hand
9	–	Right Hand

b. Operating Circuit

Apply 30 per cent tap-value current to terminal 3 and a tap screw. Using a high-resistance a-c voltmeter measure the voltage on the operating coil bridge across the left-to right-hand corners (See Fig. 2). The voltage should be approximately 2.4 volts. Now, measure the voltage output of the operating transformer (top two coil terminals). The voltage should be about 5.3 volts.

Harmonic Restraint Unit (HRU)

Apply 30 per cent tap-value current to terminal 3 and a tap screw. The following are the approximate voltages that should be obtained using a high-resistance a-c voltmeter (See Fig. 2 for location):

1. Output of operating transformer (top coil terminals)	4.0 volts
2. 4 mfd. capacitor	2.5 volts
3. 0.45 mfd. capacitor	3.9 volts
4. Operating-rectifier bridge (left-to right-hand corners)	2.5 volts
5. Restraint-rectifier bridge (left-to right-hand corners)	0.6 volts
6. Series Filter-Reactor	0.2 volts

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

* APPROXIMATE RESISTANCE VALUES OF COMPONENTS IN HU RELAY

UNIT	CIRCUIT	DESCRIPTION
Harmonic Restraint	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 50 to 70 ohms. Reactor d.c. Resistance 8 to 10 ohms. 4 MFD Capacitor. Rectifier 600 Volts, 1.5 ampere Silicon Diodes Indicating Instantaneous Trip Unit 14 to 16 ohms. Polar Unit Coil d.c. Resistance 80 to 100 ohms.
	Restraint	Series Reactor d.c. Resistance 110 to 130 ohms. Parallel Reactor d.c. Resistance 300 to 360 ohms. .45 MFD Capacitor. Rectifier 600 Volts, 1.5 ampere Silicon Diodes Polar Unit Coil d.c. Resistance 650 to 800 ohms. Varistor 100,000 ±10% at 10 V.D.C. 4000 ±25% at 30 V.D.C.
Differential	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 20 to 30 ohms. Adjustable 3½ inch 280 ohm Resistor Rectifier 600 Volts, 1.5 ampere Silicon Diodes Zener Diode, 200 volts Resistor, 20 ohms, 5% 3W. Polar Unit Coil d.c. Resistance 75 to 100 ohms.
	Restraint	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Rectifier 600 Volts, 1.5 ampere Silicon Diodes Zener Diode, 200 Volts Resistor, 20 ohms, 5% 3W. Polar Unit Coil d.c. Resistance 60 to 110 ohms.
Indicating Contacto Contactor Switch	Trip	0.2 Amp. tap 6,5 ohms d.c. 2.0 Amp. tap 0.15 ohms. d.c.

ENERGY REQUIREMENTS

Burden of Each Restraint Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	volt amperes † at 8 times tap value current	volt amperes † at 20 times tap value current
2.9	10	71	.88	50	191
3.2	12	70	.89	51	211
3.5	13	66	.90	51	203
3.8	14	65	.91	53	220
4.2	15	58	.91	53	235
4.6	16	57.5	.91	55	248
5.0	18	52.5	.92	59.	280
8.7	22	30	1.28	94.	340

Burden of Operating Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	volt amperes † at 8 times tap value current	volt amperes † at 20 times tap value current
2.9	10	35	2.26	76	487
3.2	12	34	2.30	78	499
3.5	13	33	2.30	81	504
3.8	14	33	2.30	83	547
4.2	15	31	2.30	84.	554
4.6	16	30	2.40	88.	598
5.0	18	29	2.50	92.	640
8.7	22	23	3.18	132.	850

θ Degrees current lags voltage at tap value current

† Voltages taken with Rectox type voltmeter

* **Thermal Rating**

One Second — 300 amperes

Thermal capacities for short times other than one second may be calculated on the basis of time being inversely proportional to the square of the current.

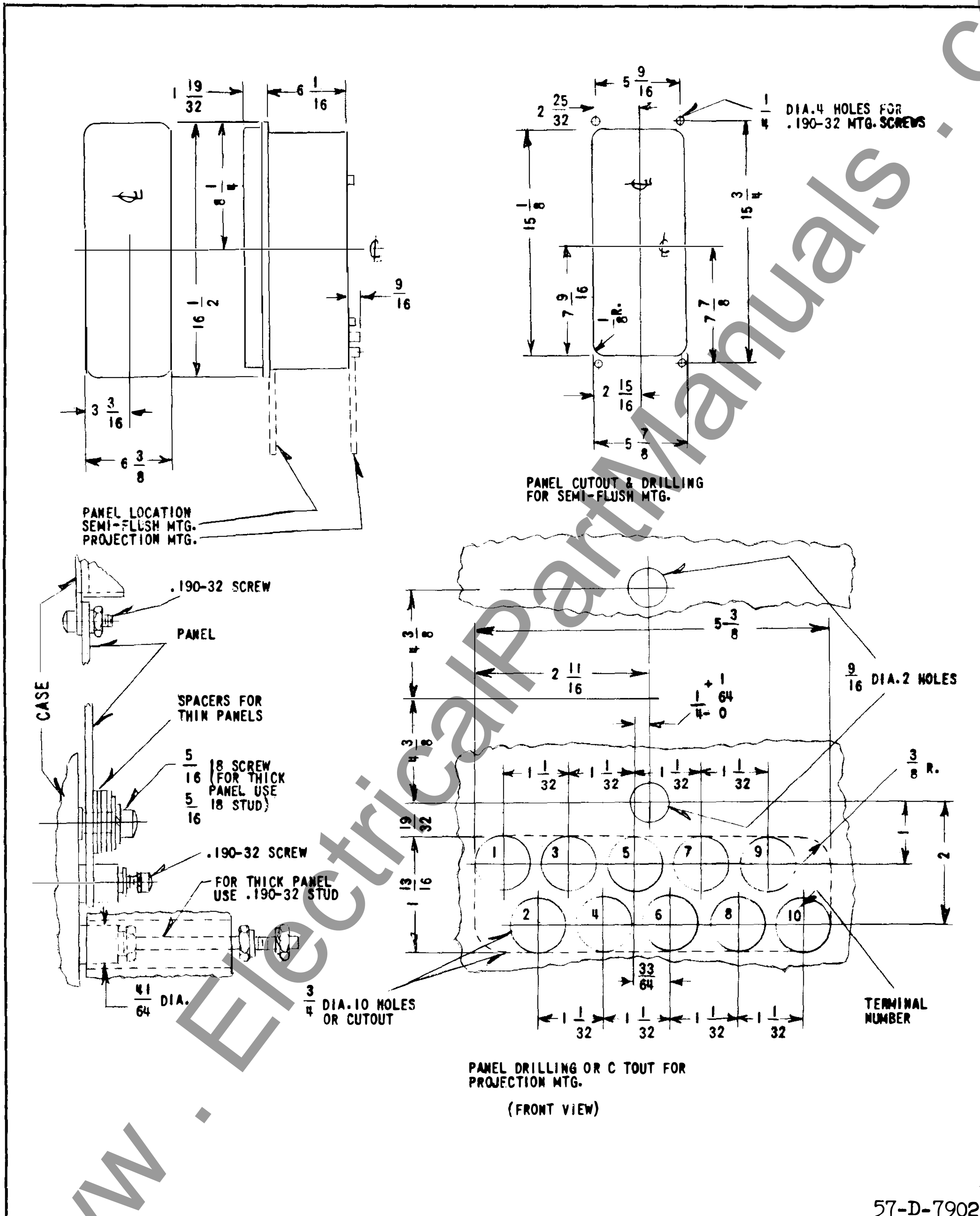


Fig. 17. Outline and Drilling Plan of the Type HU and HU-1 Relays in the FT31 Case.

WESTINGHOUSE ELECTRIC CORPORATION

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

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES HU AND HU-1 TRANSFORMER DIFFERENTIAL RELAYS

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

APPLICATION

The types HU and HU-1 relays are high-speed relays used in the differential protection of transformers. These relays can be applied where the magnetizing inrush current to the transformers is severe.

Current transformer ratio error should not exceed 10% with maximum external fault current flowing, or with eight times relay tap current flowing.

The HU-1 relay has three restraint transformers and associated rows of taps; whereas, the HU relay has one less restraint transformer and two rows of taps. Otherwise the two relays are identical. Three-winding banks normally require the HU-1 relay, although the autotransformer application uses the HU if the tertiary is not loaded.

Both the HU or the HU-1 are available with a sensitivity of either 0.30 or 0.35 times tap. The 30%-sensitivity relay satisfactorily handles up to 15% mismatch (e.g. ±10% transformer tap changing plus 5% CT mismatch). The 35%-sensitivity relay handles as much as 20% mismatch. See Fig. 7 for a comparison of the characteristics of the two sensitivities. Any of the relays may be recalibrated in the field to obtain either characteristic.

Ordinarily the 30%-sensitivity relay will suffice; however, where CT mismatch is abnormally high or where the transformer tap-changing range exceeds ±10%, this calibration may be too sensitive.

CONSTRUCTION

The types HU and HU-1 relays consist of a differential unit (DU), a harmonic-restraint unit (HRU), and an indicating contactor switch (ICS). The principal parts of the relay and their locations are shown in Figs. 1 to 4.

Differential Unit (DU)

The differential unit of the HU relay consists of two air-gap restraint transformers, three full-wave rectifiers, saturating operating-transformer, and a d-c polar unit.

The HU-1 relay, in addition to the above components, has a third air-gap restraint transformer, and a fourth full-wave rectifier.

Each of the restraint transformers and the operating transformer are provided with taps to compensate for mismatch of line current transformers. These taps are incorporated in the relay in such a manner that changing a tap on a restraint transformer automatically changes the same tap on the operating transformer.

Harmonic-Restraint Unit (HRU)

The harmonic-restraint unit of the HU and HU-1 relays consists of an air-gap operating transformer, a second harmonic block filter, a fundamental block-second harmonic pass filter, two full-wave rectifiers, indicating instantaneous trip unit, varistor, and a d-c polar unit.

Taps are also incorporated in this unit to compensate for mismatch of the line current transformers. Changing a tap on the restraint transformer of the differential unit also changes the tap of this unit.

Polar Unit

The polar unit consists of a rectangular shaped

SUPERSEDES I.L. 41-347.1C
*Denotes change from superseded issue

EFFECTIVE DECEMBER 1965

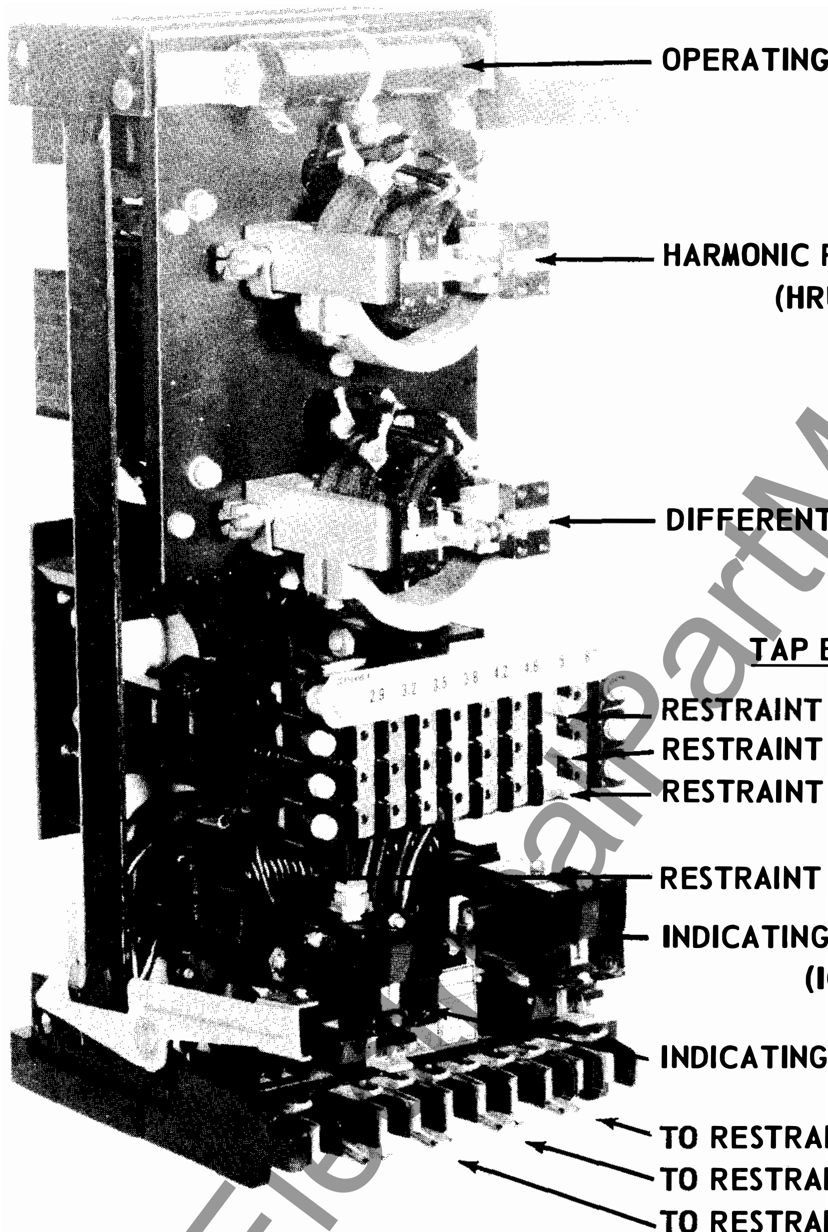


Fig. 1. Type HU-1 Relay – Front View.

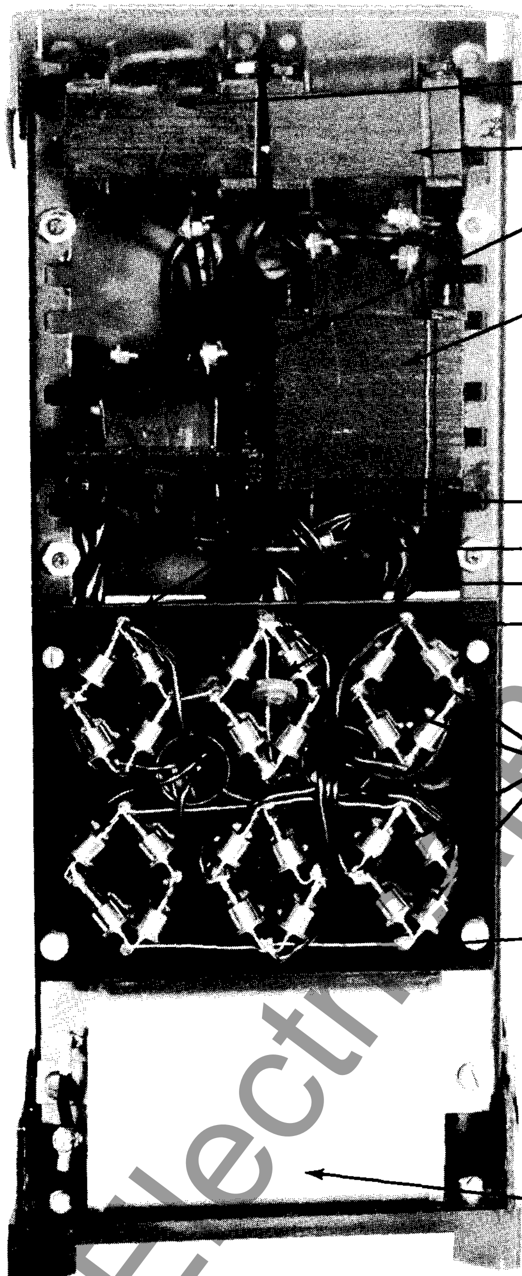


Fig. 2. Type HU-1 Relay – Rear View.

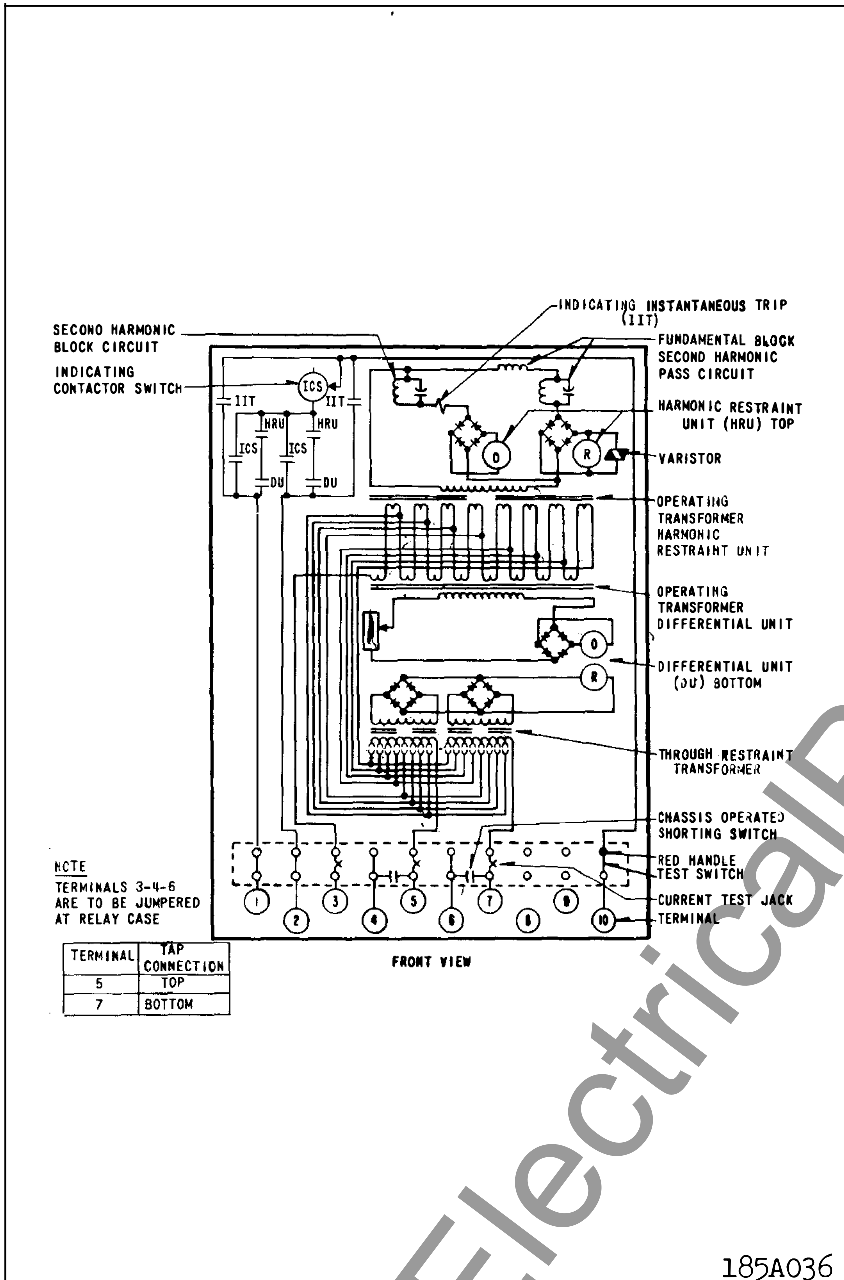


Fig. 3 Internal Schematic of the Type HU Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted.

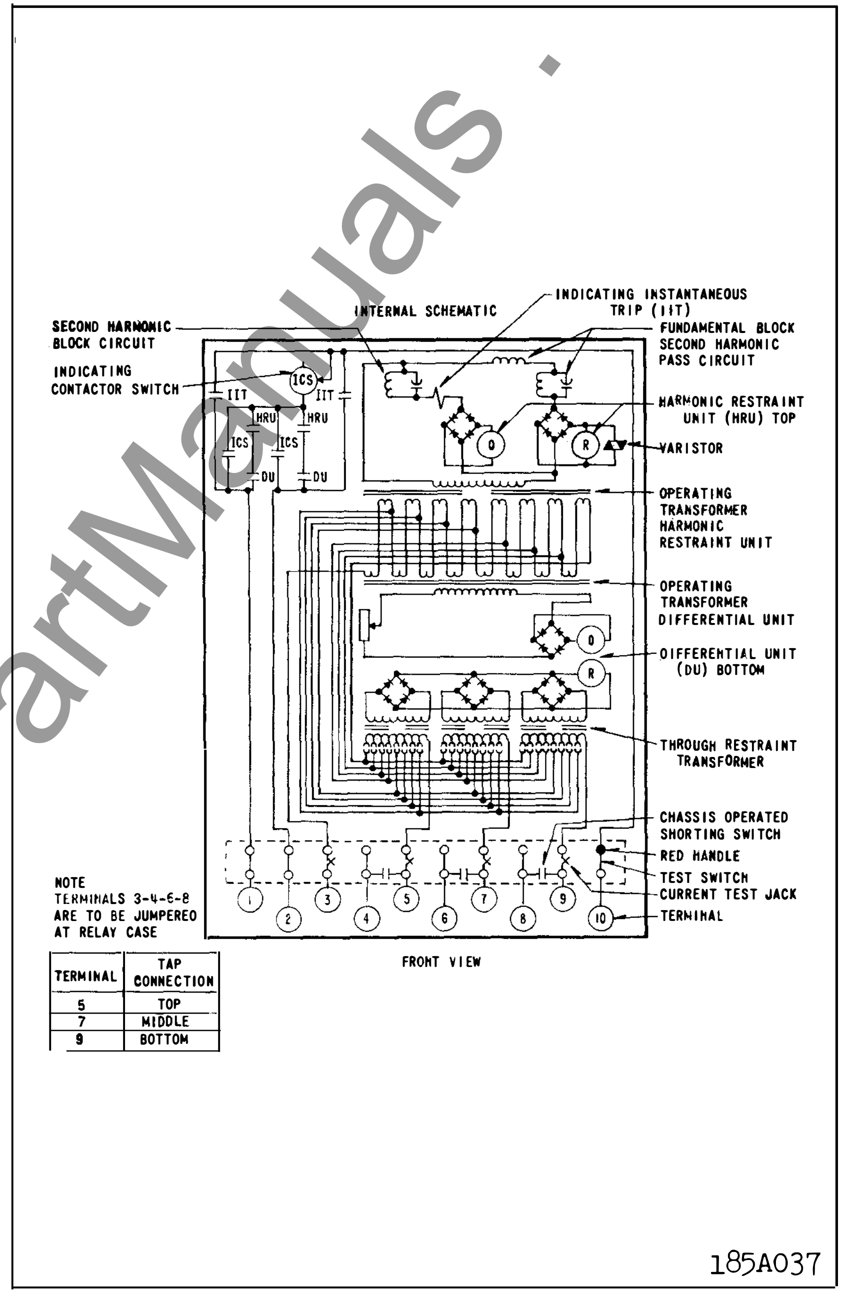


Fig 4. Internal Schematic of the Type HU-1 Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted.

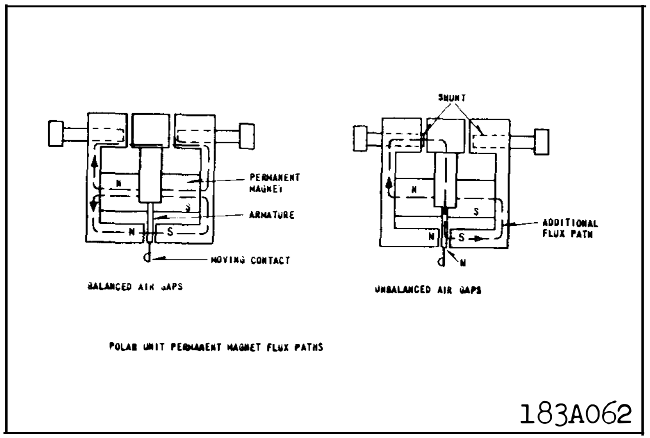


Fig. 5 Polar Unit Permanent Magnet Flux Paths.

magnetic frame, an electromagnet, a permanent magnet, and an armature. The poles of the crescent shaped permanent magnet bridge the magnet frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These non-magnetic joints represent air gaps, which are bridged by two adjustable magnetic shunts. The windings are wound around a magnetic core. The armature is fastened to this core and is free to move in the front air gap. The moving contact is connected to the free end of a leaf spring, which, in turn, is fastened to the armature.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper-type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also, during this operation, two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop.

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

OPERATION

The types HU and HU-1 relays are connected to the protected transformer as shown in Fig. 6. In such a connection, the relays operate to protect the transformer for faults internal to the differential zone of the transformer, but not for faults external to the zone. Neither do the relays operate on magnetizing inrush currents associated with energization of the transformer, even though these currents may appear as an internal fault. To avoid these false operations, each unit of the relay performs a separate function. The differential unit (DU) prevents operation on external faults, while the harmonic-restraint unit (HRU) prevent operations on magnetizing inrush currents. Hence, the operation of the relay can best be described under the headings of external fault current, internal fault currents, and magnetizing inrush currents.

External Fault Currents

The types HU and HU-1 relays have a variable percentage characteristic. This means that the operating current required to close the contact of the differential unit expressed in percent of restraint current varies with the magnitude of the larger restraint current. Fig. 7 and Fig. 8 illustrate this characteristic. To use these curves, divide each restraint current by the appropriate tap and enter the horizontal axis using the larger or largest restraint multiple. Then enter the vertical axis, using the difference of the restraint multiples.

With the relay connected as shown in the schematic diagram of Fig. 9a, an external fault causes currents to flow in the air-gap restraint transformers of the differential unit. If the line current transformers do not saturate and the correct ratio matching taps applied, no effective current flows in the operating transformer of the relay. Hence, only a contact-opening torque is produced on the differential unit.

On heavy external faults where a main current transformer saturates, current flows in the operating circuit of the relay. With such a condition, the harmonic-restraint unit may or may not close its contacts, depending upon the harmonics present in the false operating current. However, operation of the relay is prevented by the variable percentage characteristic of the differential unit, since a large differential current is required to close its contacts during heavy external faults.

Internal Faults

In the case of an internal fault as shown in Fig. 9b, the restraint of the differential unit is proportional to the largest restraint current flowing. The sum of the two restraint currents flows into the operating transformer and produces an excess of operating torque, and the differential unit operates.

In the case of an internal fault fed from one source only, the fault current flows in one restraint

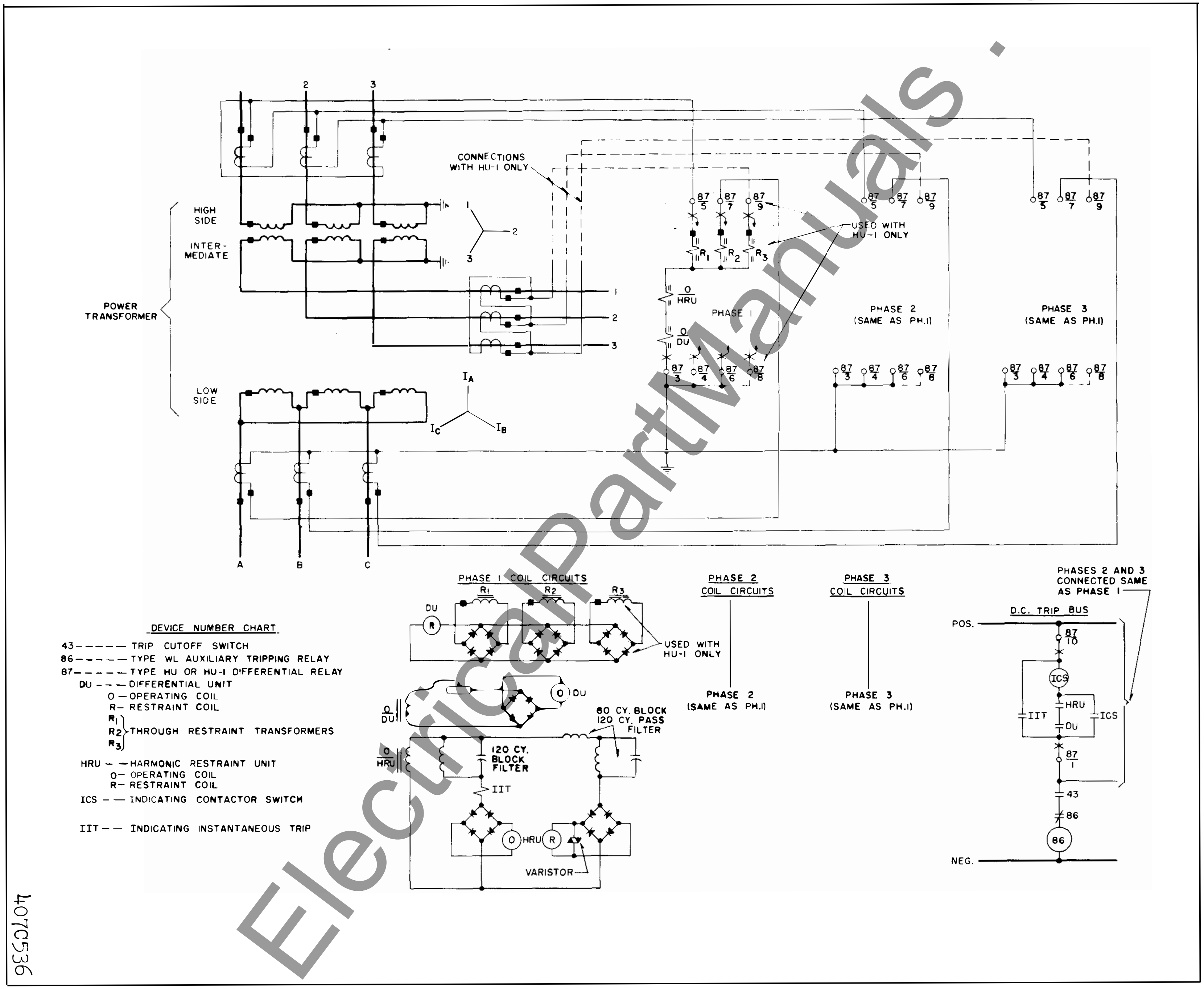


Fig. 6. External Schematic of the Type HU and HU-1 Relays.

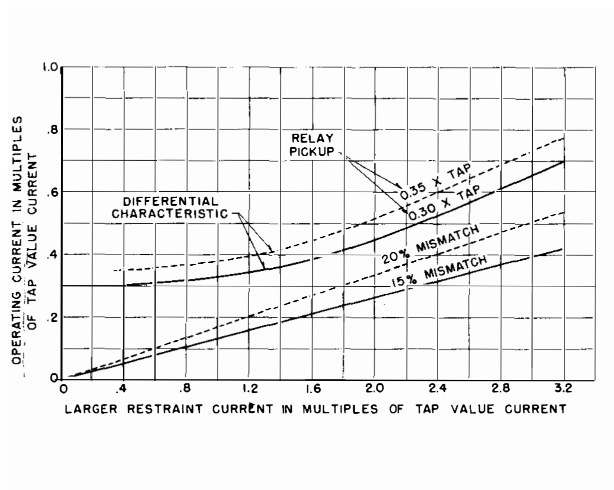


Fig. 7. Differential Characteristic of the DU Unit of the HU and HU-1 Relays at Smaller Values of Current. Actual Operating Current Shown for 15 and 20% Mismatch.

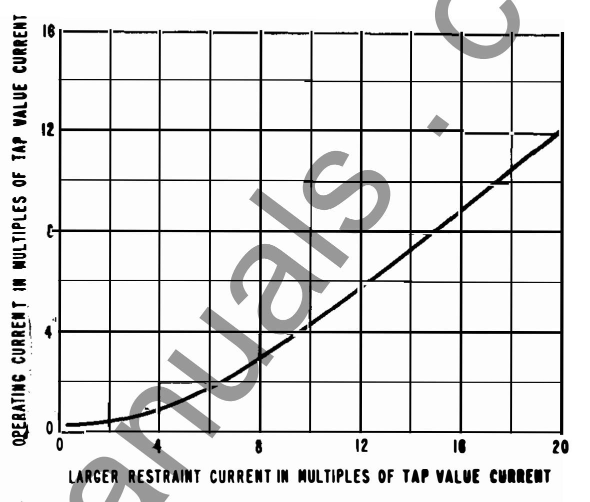


Fig. 8. Differential Characteristic of the Differential Unit (DU) of the HU and HU-1 Relays at Larger Values of Current.

transformer and the operating transformer. An excess of operating torque is produced on the differential unit and it operates.

Faults normally appear as an offset sine wave with a decaying d-c component, and contain very few harmonics. As a result, the harmonic-restraint unit will operate during internal faults to permit tripping of the relay.

For heavy internal faults, the indicating instantaneous trip unit (IIT) will operate before the main unit. Since this unit is connected to an air gap transformer, essentially only the sine wave component of an internal fault is applied to the IIT unit. The d.c. component of the fault is bypassed by the transformer primary. For example, an internal fault with a first peak of 28 times tap value (includes fifty percent d.c.) is reduced to a first peak of approximately 14 times tap value (d.c. component absent) on the secondary of the transformer. The IIT unit will just operate on this wave since it is set to pick up at a peak current of 14.1 times tap (r.m.s. pick-up value = 10 times tap).

The varistor connected across the d.c. side of the restraint rectifier of the harmonic restraint unit prevents excessive voltage peaks from appearing across the rectifiers. These peaks arise through transformer action of the harmonic-restraint polar-unit coils during heavy internal faults. The varistor has a large value of resistance for low voltages, while presenting a low value of resistance for high voltages. This characteristic effectively reduces the voltage spikes on heavy internal faults while not hampering performance during inrush, where the voltage is considerably lower.

Magnetizing Inrush Currents

Magnetizing inrush current waves have various wave shapes. A typical wave appears as a rectified half wave with decaying peaks. In any case, the various wave shapes are rich in harmonics with the second harmonic predominant. Since the second harmonic is always present in inrush waves and not in internal fault waves, this harmonic is used to restrain the harmonic-restraint unit during inrushes. The differential unit may or may not close its contact, depending on the magnitude of the inrush.

When a magnetizing inrush wave is applied to the relay, the d-c component of the wave is by-passed by the air-gap operating transformer. The other components are fed into the filter circuits. The impedance characteristics of these filters are such that the second harmonic component flows into the restraint coil of the polar unit, while the other harmonics flow into the operating coil. The polar unit will not close

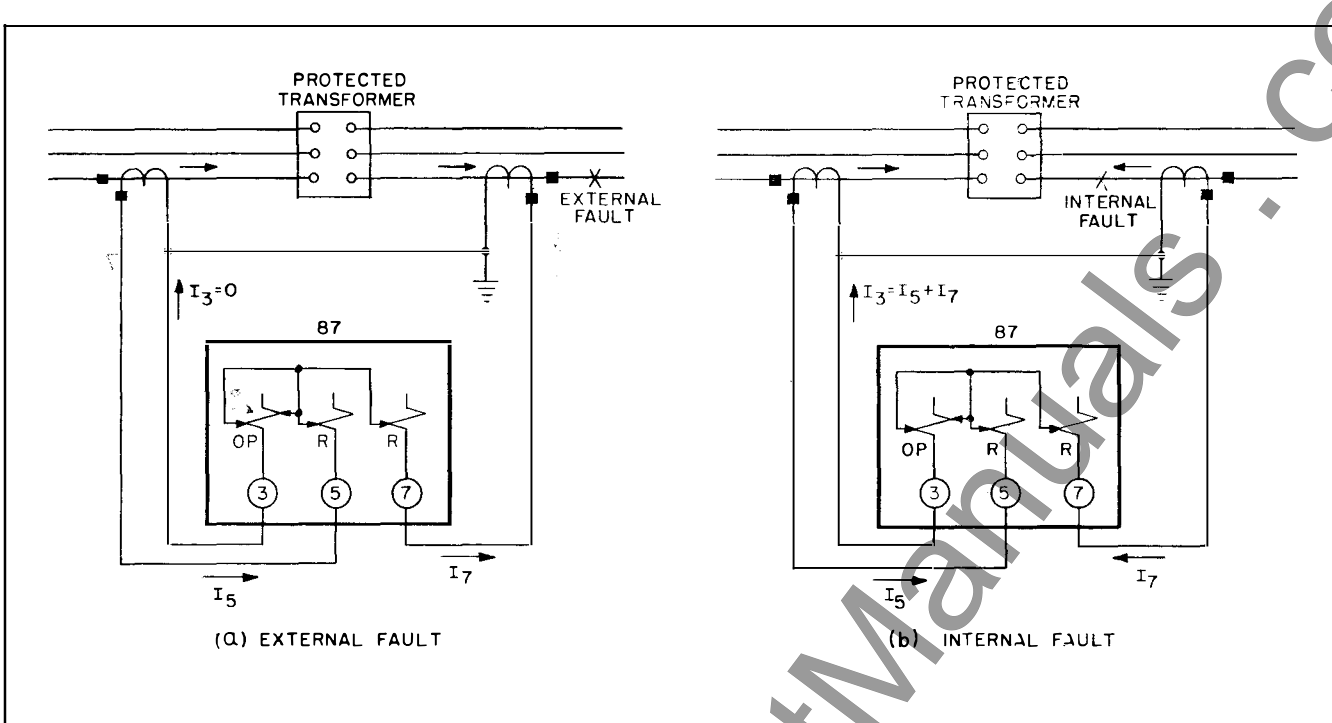


Fig. 9. Simplified Schematic of the Type HU Relay with Current Distribution for (a) External Fault (b) Internal Fault.

its contacts unless the second harmonic content is less than 15 percent of the fundamental component.

The indicating instantaneous trip unit (IIT) will not operate on inrush. The air-gap transformer will bypass the d.c. component of the inrush thereby reducing the magnitude of the wave applied to the IIT unit. If the inrush has an initial peak of 16 times tap-value current, the air-gap transformer will reduce this peak to approximately 8 times tap value on the secondary of the transformer. Since the IIT unit is set for a peak value of 14.1 times tap (r.m.s. pick-up value = 10 times tap), it will not operate on this inrush.

Breaker Maintenance

Before some of the CT's are bypassed for breaker maintenance the trip circuit should be opened, as shown in Fig. 6. Otherwise the false-unbalanced current will cause the relay to trip. It is not necessary to short-circuit the relay operating circuit since it has an adequate continuous-current rating. (See "Energy Requirements").

CHARACTERISTICS

Taps are incorporated in the HU and HU-1 relays to compensate for main current transformer mismatch. These taps are as follows: 2.9, 3.2, 3.5, 3.8, 4.2, 4.6, 5.0, 8.7.

To measure the effective unbalance, a sensitive low-reading voltmeter (5000 ohms per volts) can temporarily be connected across the operating coil resistor (at top of case). With a perfect balance the voltmeter reading will be zero. The reading should not exceed the values indicated by the 15% mismatch curve in Fig. 10 when the relay pickup is 0.30 times tap. If the amount of mismatch is measured or calculated, the measured voltage can be checked against the interpolated value from the curve. For example, assume that the larger restraint current is measured as 1.5 tap multiple and the calculated mismatch is 7%. Then, from Fig. 10 the measured voltage should be approximately 1.0 volts. Use Fig. 11 if the pickup is 0.35 times tap.

Pickup of the harmonic-restraint unit and the differential unit is either 30 or 35% of tap value current. Pickup of the indicating instantaneous trip unit is ten times tap value current.

Components of the harmonic-restraint unit are selected such that 15% second harmonic will prevent operation of the unit. This factor is adequate to prevent false operation on inrushes.

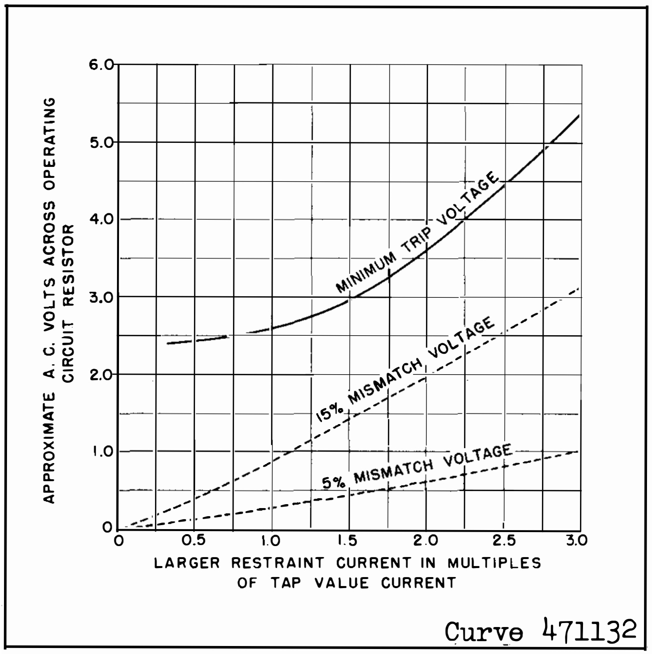


Fig. 10. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.30 Times Tap.

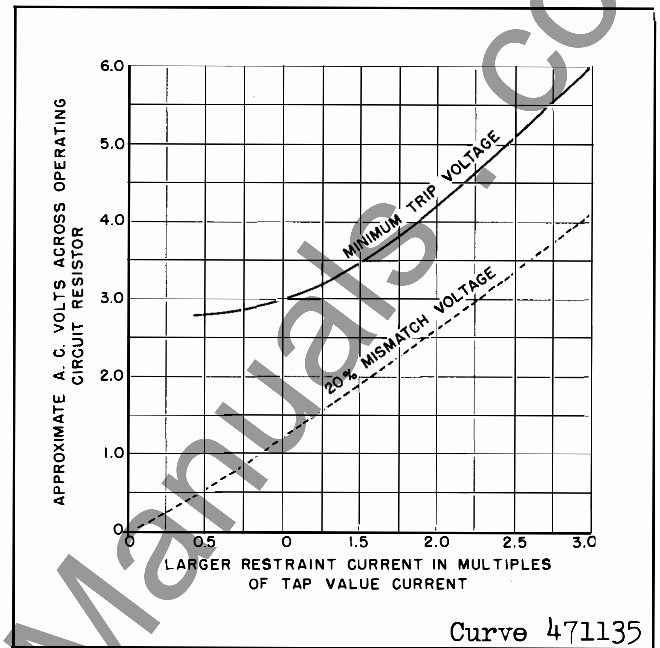


Fig. 11. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.35 Times Tap.

The frequency response of the HU and HU-1 relays is shown in Fig. 13.

Trip Circuit

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

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

SETTING

To set the relay, calculations must be performed as shown under "Setting Calculations". After the correct tap is determined, connections can be made to the relay transformers by placing the connector screws in the various terminal-plate holes in front of the relay. Only one tap screw should be inserted in any horizontal row of taps.

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-or 250-volt d-c type WL relay switch, or equivalent, use the 0.2-ampere tap; for 48 volt DC applications set relay in 2 tap and use Type WL Relay coil S#304C209G01 or equivalent.

Indicating Instantaneous Trip (IIT)

No setting is required on the indicating instantaneous trip unit. This unit is set at the factory to pickup at 10 times tap value current.

SETTING CALCULATIONS

Select the ratio matching taps. There are no other settings. In order to calculate the required tap settings and check current transformer performance the following information is required.

Required Information

1. Maximum transformer power rating $(KVA)_M$
2. Maximum external fault currents
3. Voltage ratings of power transformer (V_H, V_I, V_L)
4. Current transformer ratios, full tap (N_T)
5. Current transformer "10L" accuracy class

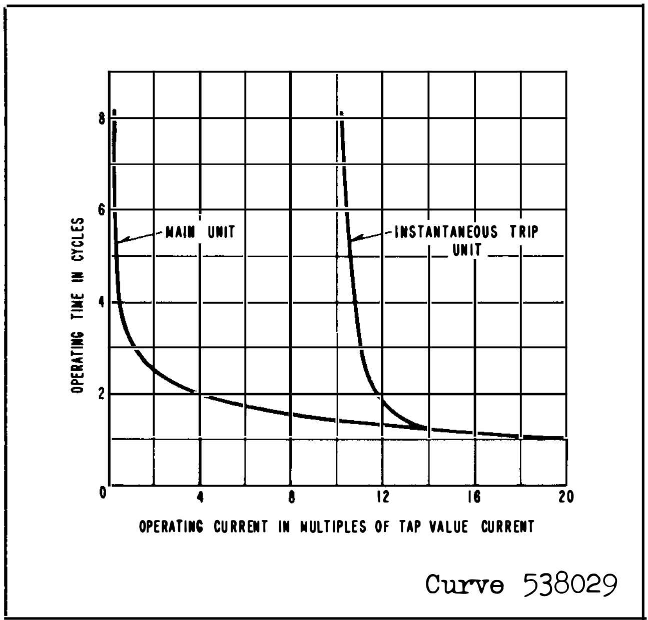


Fig. 12. ***Typical Tripping Time Characteristic (60 Cycle Currents).***

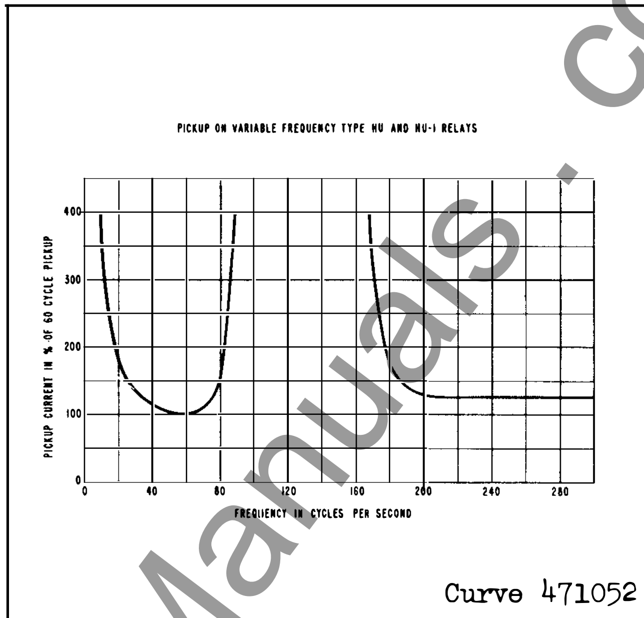


Fig. 13. ***Typical Frequency Response of the HU and HU-1 Relays.***

voltage, (or excitation or ratio-overcurrent curve)

6. One way current transformer lead resistance at 25°C (R_L) (when using excitation curve, include CT winding resistance)
7. Current transformerconnections(wye or delta)

Definitions of Terms

I_P = Primary current at $(KVA)_M$

I_R = Relay input current at $(KVA)_M$

I_{RH}, I_{RL}, I_{RI} are same as I_R except for high, low and intermediate voltage sides respectively.

I_S = CT secondary current at $(KVA)_M$

T_H, T_L, T_I = Relay tap settings for high, low and intermediate voltage windings, respectively.

N = Number of current transformer turns that are in use.

$N_P = N/N_T$ (Proportion of total turns in use)

N_T = Current transformer ratio, full tap

V_{CL} = 10L accuracy class voltage

Z_A = Burden impedance of any devices other than the HU or HU-1 relays, with maximum phase-to-phase or 3-phase current flowing.

Z_T = Total secondary burden in ohms (excluding current transformer winding resistance, except when using excitation curve)

Calculation Procedure

1. *Select current transformer taps,* where multi-ratio types are used.

   I_R should be more than 2.9 amperes for high sensitivity and should not exceed the relay continuous rating (see "Energy Requirements"). For determining the required continuous rating of the relay, use the expected two-hour maximum load, since the relay reaches final temperature in this time.

2. *Select relay taps in proportion to the relay currents,* I_R.

   I_R should not exceed relay continuous rating. Also the maximum external fault current should not exceed 20 times relay tap.

3. *Determine Mismatch* (Not to exceed 15%)

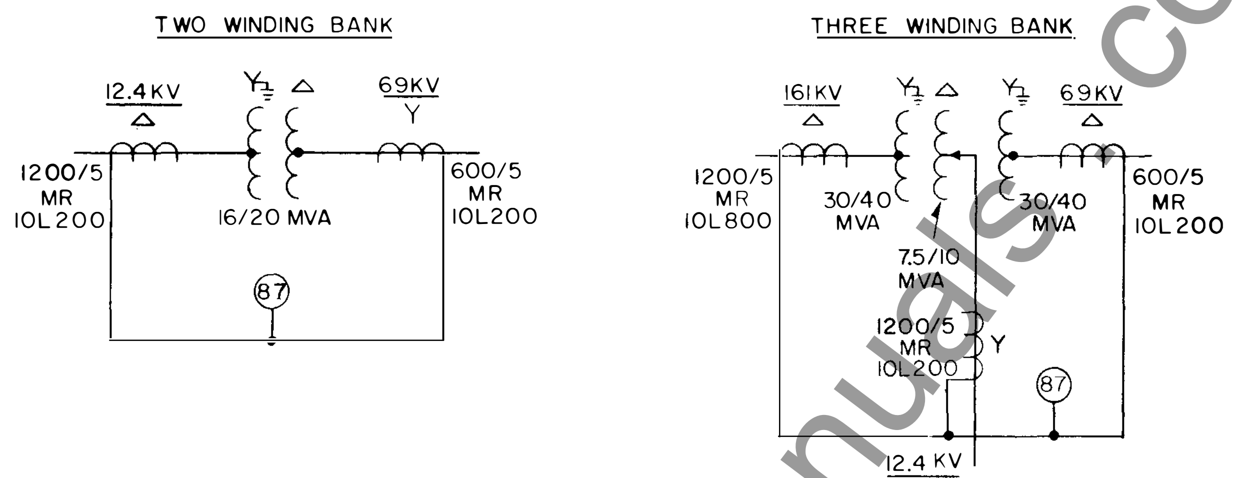
   For 2 winding banks:

$$\% \text{ mismatch} = 100 \frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{S} \qquad (1)$$

where S is the smaller of the two terms, (I_{RL}/I_{RH}) or (T_L/T_H)

For 3 winding banks:

$$\% \text{ mismatch} = 100 \frac{(I_{RH}/I_{RI}) - (T_H/T_I)}{S} \qquad (2)$$



Two winding bank: LOW	Two winding bank: HIGH	Three winding bank: HIGH	Three winding bank: INTERMEDIATE	Three winding bank: LOW
$(KVA)_M$ = 20,000	$(KVA)_M$ = 20,000	$(KVA)_M$ = 40,000	$(KVA)_M$ = 40,000	$(KVA)_M$ = 10,000
$(KVA)_S$ = 16,00.0	$(KVA)_S$ = 16,000	$(KVA)_S$ = 30,000	$(KVA)_S$ = 30,000	$(KVA)_S$ = 7,500
V_L = 12,400 VOLTS	V_H = 69,000	V_H = 161,000	V_I = 69,000	V_L = 12,400
N_T = 240 TURNS	N_T = 120	N_T = 240	N_T = 120	N_T = 240
V_{CL} = 200 VOLTS	V_{CL} = 200	V_{CL} = 800	V_{CL} = 200	V_{CL} = 200
R_L = 0.4 OHMS	R_L = 0.4	R_L = 0.5	R_L = 0.5	R_L = 0.5
DELTA CT	WYE CT	DELTA CT	DELTA CT	WYE CT

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Fig. 14. *Example for Setting Calculations.*

where "S" is the smaller of the two terms, (I_{RH}/I_{RI}) or (T_H/T_I).

Equations similar to eq. (2) apply for mismatch from the high to low and from the intermediate to low voltage windings.

Where tap changing under load is performed the relays should be set on the basis of the middle or neutral tap position. The total mismatch, including the automatic tap change should not exceed 15% with a 30% sensitivity relay, and 20% with a 35% sensitivity relay. Note from Fig. 7 that an ample safety margin exists at these levels of mismatch.

4. *Check current transformer performance.* Ratio error should not exceed 10% with maximum symmetrical external fault current flowing or with 8 times relay tap current flowing. An accurate method of determining ratio error is to use ratio-correction-factor curves (RCF).

A less accurate, but satisfactory method is to utilize the ASA relaying accuracy classification. If the 10L accuracy is used, performance will be adequate if:

$$\frac{N_P V_{CL}}{100} \text{ is greater than } Z_T \qquad (3)$$

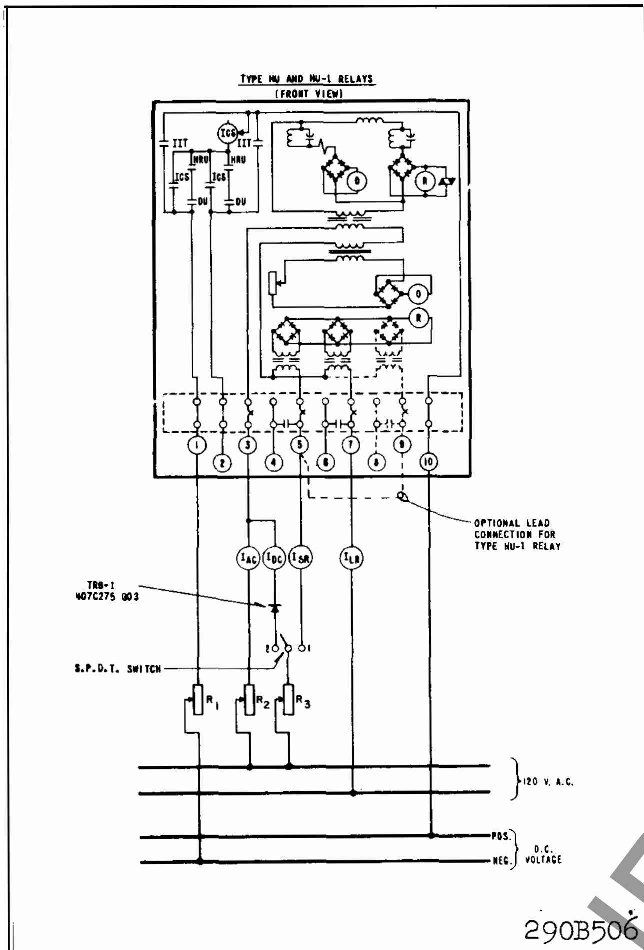
For wye-connected CT:

Z_T = lead resistance + relay burden + Z_A

$$= 1.13\, R_L + \frac{0.15}{T} + Z_A \text{ ohms} \qquad (4)$$

(R_L multiplier, 1.13, is used to account for temperature rise during faults. $\frac{0.15}{T}$ is an approximation, where T = relay tap.

Z_A is any additional burden, when maximum external 3-phase fault current is flowing).



* *Fig. 15. Test Circuit of the HU and HU-1 Relays.*

For delta-connected CT:

$$Z_T = 3\,(1.13\,R_L + \frac{0.15}{T} + Z_A)\ \text{ohms}$$

$$= 3.4\,R_L + \frac{0.45}{T} + 3Z_A \qquad (5)$$

(The factor of 3 accounts for conditions existing during a phase-to-phase fault. Z_A is any additional burden, when maximum external phase to phase fault current is flowing)

5. *Examples*

Refer to pages 13 and 14 and figure 14 for setting examples. Note in both examples that the 8.7 tap was selected as the first step in selecting relay taps. If a lower tap such as tap 5 had been the first selection, a proper balance would have been impossible. On page 12 for the two winding bank,

$$\frac{I_{RL}}{I_{RH}} = \frac{8.05}{4.18} = 1.92.$$ With tap 5 for the low side the maximum current ratio that can be matched by the taps is $\frac{5}{2.9} = 1.73$. With tap 8.7 selected for the low side, a 3 to 1 current ratio can be matched. On page 13 for the three winding bank,

$$\frac{I_{RL}}{I_{RH}} = 3.02$$

This current ratio can be accommodated by the 8.7 & 2.9 taps without excessive mismatch.

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 to the terminal studs furnished with the relay for thick-panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer.

Acceptance Tests

The following check is recommended to insure that the relay is in proper working order. All checks can best be performed by connecting the relay per the test circuit of Fig. 15. Relay to be tested in case.

1. Minimum Trip Current. With switch open and relay set on 5-ampere tap, apply 1.35 to 1.65 amperes for the 30%-sensitivity relay and 1.6 to 1.9

TWO-WINDING TRANSFORMER CALCULATIONS

(See Figure 14)

	LOW	HIGH
1. Select CT Ratio:		
$I_P = \dfrac{\dfrac{(KVA)_M}{V\sqrt{3}}}{1000} =$	$\dfrac{20{,}000}{12.4\sqrt{3}} = 930$ Amp.	$\dfrac{20{,}000}{69\sqrt{3}} = 167$ Amp.
Select Ratio	1000/5 (N = 200)	200/5 (N = 40)
2. Select Relay Taps:		
$I_S = \dfrac{I_P}{N} =$	$\dfrac{930}{200} = 4.65$ Amp.	$\dfrac{167}{40} = 4.18$ Amp.
$I_R =$	$I_{RL} = 4.65\sqrt{3} = 8.05$ Amp.	$I_{RH} = 4.18$ Amp.
Select Tap	$T_L = 8.7$	$T_H = \dfrac{4.18}{8.05} \times 8.7 = 4.64$
Desired Tap		$T_H = 4.6$
3. Determine Mismatch:		
% Mismatch = $100\,\dfrac{(I_{RL}/I_{RH}) - (T_L/T_H)}{T_L/T_H} =$	$100\,\dfrac{(8.05/4.18) - (8.7/4.6)}{8.7/4.6} =$ $100\,\dfrac{1.92 - 1.89}{1.89} =$ 1.6%	
4. Check CT Performance:		
$Z_T =$	$3.4\,R_L + \dfrac{0.45}{T} =$ $3.4 \times 0.4 + \dfrac{0.45}{8.7} = 1.36 + 0.05 =$ 1.41 ohms	$1.13\,R_L + \dfrac{0.15}{T} =$ $1.13 \times 0.4 + \dfrac{0.15}{4.6} = 0.45 + 0.03 =$ 0.48 ohms
$N_P = \dfrac{N}{N_T} =$	$\dfrac{200}{240} = 0.833$	$\dfrac{40}{120} = 0.333$
$\dfrac{N_P\,V_{CL}}{100} =$	$\dfrac{0.833 \times 200}{100} = 1.67$	$\dfrac{0.333 \times 200}{100} = 0.67$
$(N_P\,V_{CL}/100) > Z_T$	Yes	Yes

THREE-WINDING TRANSFORMER CALCULATIONS
(See Figure 14)

	HIGH	INTERMEDIATE	LOW
1. Select CT Ratio:			
$I_P = \frac{(KVA)_M}{\frac{V\sqrt{3}}{1000}} =$	$\frac{40{,}000}{161\sqrt{3}} = 143$ Amp.	$\frac{40{,}000}{69\sqrt{3}} = 334$ Amp.	$\frac{10{,}000}{12.4\sqrt{3}} = 465$ Amp.
Select Ratio	400/5 (N = 80)	600/5 (N = 120)	1000/5 (N = 200)
2. Select Relay Taps:			
$I_S = \frac{I_P}{N} =$	$\frac{143}{80} = 1.78$ Amp.	$\frac{334}{120} = 2.78$ Amp.	$\frac{465}{200} = 2.32$ Amp. (At 10 MVA)
I_R (At 40 MVA) =	$I_{RH} = 1.78\sqrt{3}$ = 3.08 Amp.	$I_{RI} = 2.78\sqrt{3}$. = 4.82 Amp.	$I_{RL} = \frac{40}{10} X\ 2.32$ = 9.3 Amp.
Select Tap			$T_L = 8.7$
Desired Tap	$T_H = 8.7\frac{3.08}{9.30}$ = 2.88	$T_I = 8.7\frac{4.82}{9.30}$ = 4.52	
Select Tap	$T_H = 2.9.$	$T_I = 4.6$	
3. Determine Mismatch			
% Mismatch	$100\frac{(I_{RH}/I_{RI})-(T_H/T_I)}{T_H/T_I} =$	$100\frac{(I_{RI}/I_{RL})-(T_I/T_L)}{(I_{RI}/I_{RL})} =$	$100\frac{(I_{RL}/I_{RH})-(T_L/T_H)}{T_L/T_H} =$
	$100\frac{(3.08/4.82)-(2.9/4.6)}{2.9/4.6} =$	$100\frac{(4.82/9.30)-(4.6/8.7)}{4.82/9.30} =$	$100\frac{(9.3/3.08)-(8.7/2.9)}{8.7/2.9} =$
	$100\frac{0.640-0.630}{0.630} =$	$100\frac{0.518-0.528}{0.518} =$	$100\frac{3.02-3.00}{3.00} =$
	1.6%	−1.9%	0.67%
4. Check CT Performance			
$Z_T =$	$3.4\ R_L + \frac{0.45}{T} =$	$3.4\ R_L + \frac{0.45}{T} =$	$1.13R_L + \frac{0.15}{T} =$
	$3.4 \times 0.5 + \frac{0.45}{2.9} =$	$3.4 \times 0.5 + \frac{0.45}{4.6} =$	$1.13 \times 0.5 + \frac{0.15}{8.7} =$
	1.70 + 0.16 = 1.86 ohms	1.70 + 0.10 = 1.80 ohms	0.565 + 0.02 = 0.58 ohms
$N_P = \frac{N}{N_T} =$	$\frac{80}{240} = 0.333$	$\frac{120}{120} = 1.0$	$\frac{200}{240} = 0.833$
$\frac{(N_P\ V_{CL})}{100} =$	$\frac{800 \times 0.333}{100} = 2.67$	$\frac{200 \times 1.0}{100} = 2.0$	$\frac{200 \times 0.833}{100} = 1.67$
$(N_P\ V_{CL}/100) > Z_T$	Yes	Yes	Yes

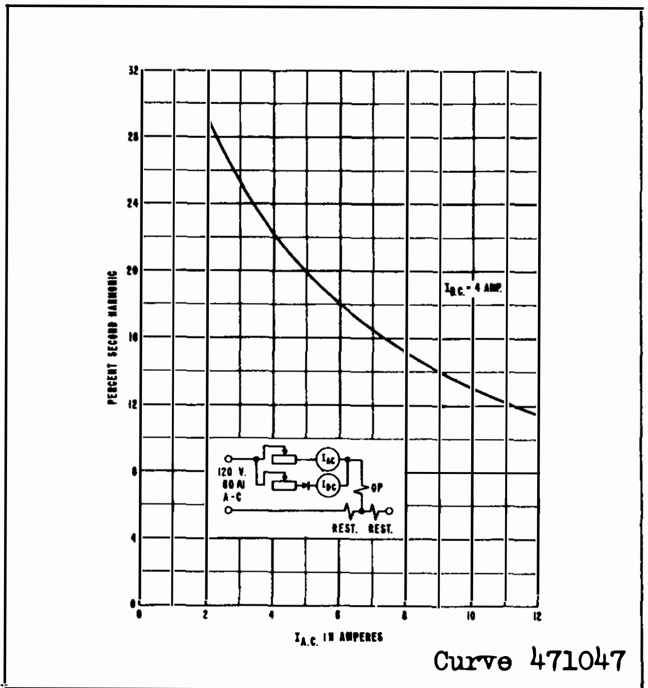


Fig. 16 ***Variation of Second Harmonic Content of Test Current.***

amperes for the 35% sensitivity relay. Relay should operate. The upper polar unit may operate for lower currents, but not below 1.0 ampere. This low pickup will not impair its operation on magnetizing inrush currents and should not be disturbed if it is found to be less than the lower polar unit. If a higher pickup is desired, it is suggested that 20 times tap value current be applied to relay terminals 3 & 7. This will cause the upper polar unit to pick up at a current of approximately 1.65 amperes.

2. Indicating instantaneous Trip Pickup. With switch open and relay set on 5 ampere tap, apply 50 amperes to relay. Indicating instantaneous trip should pick up and its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

3. Indicating Contactor Switch. Block Polar unit contacts closed. Pass sufficient direct 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 setting being used. The operation indicator target should drop freely.

The contact gap of the ICS should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

4. Differential Characteristic.

a. 30% Sensitivity relay

Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 10 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 12.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 to 2.95 amperes
I_{LR} = 11.8 to 12.8 amperes

b. 35% Sensitivity relay

Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 9 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 11.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 amperes
I_{LR} = 10.8 to 11.8 amperes

5. Harmonic Restraint Characteristic. Close switch to position 2. Short out I_{LR} ammeter. Set I_{dc} to 4 amperes and adjust I_{ac} until upper polar unit operates. I_{ac} should read between 6.5 and 9 amperes. As shown in *Fig. 16*, these values of alternating current correspond to 17 percent and 14 percent second harmonic.

*** In Service Test**

Table 1 is to be used as an in-service check of the HU or HU-1 relay using any tap combination. The relay should be connected as shown in fig. 15 with the S.P.O.T. switch in position 1. The ammeter I_{SR} measures the smaller restraint current and should be connected to the terminal associated with the tap block of the smaller setting. The ammeter I_{LR} measures the larger restraint current, and should be connected to the terminal associated with the larger tap block setting. Terminal 5 supplies the upper tap block; terminal 7 supplies the second tap block; and terminal 9 (HU-1 only) supplies the lower tap block (refer to figs. 1 and 4).

Table 1 gives the values of I_{AC} necessary to operate the relay when using a value of I_{SR} equal to 3 times tap value for all taps except the 8.7 tap. A value of I_{SR} equal to 2 times tap value was chosen for the 8.7 tap setting in order to keep the current at a convenient value for testing.

Example (HU Relay)

Upper Tap Block Tap 3.5
Lower Tap Block Tap 5.0

Since the upper tap block has the smaller tap setting I_{SR} should be connected to the upper tap block (Term. 5), and I_{LR} should be connected to Terminal 7. From Table 1 under "Restraint Transformer tap: Larger" = 5.0 "Smaller" = 3.5, set I_{SR} = 10.5 amps. The value of I_{AC} to operate the relay should be between 8.3 and 9.2 amps.

To check the third restraint winding on the HU-1 repeat the above procedure using terminal 9 and either terminal 5 or 7.

TABLE 1

Restraint Transformer Tap	Larger	2.9	3.2	3.5	3.8	4.2	4.6	5.0	8.7
Smaller	CURRENT IN AMPERES								
2.9	ISR	8.7	8.7	8.7	8.7	8.7	8.7	8.7	5.8
	IAC (Min.)	2.6	3.7	5.0	5.8	7.8	9.0	10.4	16.2
	IAC (Max.)	2.8	4.0	5.5	6.4	8.6	10.0	11.6	17.9
3.2	ISR		9.6	9.6	9.6	9.6	9.6	9.6	6.4
	IAC (Min)		2.7	4.0	4.9	6.9	8.1	9.6	15.7
	IAC (Max)		3.1	4.4	5.4	7.6	9.0	10.6	17.3
3.5	ISR			10.5	10.5	10.5	10.5	10.5	7.0
	IAC (Min)			3.0	3.8	5.7	6.9	8.3	14.5
	IAC (Max)			3.3	4.2	6.3	7.7	9.2	16.1
3.8	ISR				11.4	11.4	11.4	11.4	7.6
	IAC (Min)				3.2	5.2	6.5	7.9	14.1
	IAC (Max)				3.6	5.7	7.2	8.7	16.0
4.2	ISR					12.6	12.6	12.6	8.4
	IAC (Min)					3.5	4.7	6.2	12.9
	IAC (Max)					3.9	5.2	6.9	14.2
4.6	ISR						13.8	13.8	9.2
	IAC (Min)						3.9	5.3	12.4
	IAC (Max)						4.3	5.9	13.7
5.0	ISR							15.0	10.0
	IAC (Min)							4.3	11.6
	IAC (Max)							4.8	12.9
8.7	ISR								17.4
	IAC (Min)								5.0
	IAC (Max)								5.5

Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

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 contact.

Calibration (All Relays)

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. All adjustments to be done with relay inside its case. (See "Acceptance Check")

Polar Units

1. Contacts. Place a .060 to .070 inch feeler gage between the right hand pole face and the armature. This gap should be measured near the front of the right hand pole face. Bring up the backstop screw until it just makes with the moving contact. Place gage between moving contact and the stationary contact on the left-hand side of the polar unit. On the upper unit, the gap should be .046 inch and on the lower unit the gap should be .065 to .070 inch. Bring up the stationary contact until it just makes with the gage and lock in place.

2. Minimum Trip Current

a. Harmonic Restraint Unit (HRU)

Connect the relay per test circuit of Fig. 15. With the switch open, pass I_{ac} = 20 times tap value current into the relay. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right hand shunt on upper polar unit until it trips with I_{ac} = 33% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. Repeat these steps, if necessary, until the unit operates at 33% or slightly lower of tap value current immediately following the application of 20 times tap value current and until the unit resets at a value of current 15% of tap value or greater. After the dropout has been measured, the unit should pick up at 25% or higher of tap value current.

On the application of the high current, the upper polar unit will be biased in the restraining direction and pickup will be greater than the nominal value of 30% of tap value current on the first application of pickup current. If the circuit is deenergized and pickup is measured again, the pickup current will be less than before. However, pickup will be stable after the second application of pickup current. If 20 times tap value current is applied again, the pickup immediately after applying this current will be high. However, measuring the pickup the second time will show that the pickup is again reduced. The variation between these pickups should be between 25% and 33% of tap value current.

The filter circuits are charged by the application of this heavy current and upon the removal of the current, these circuits will discharge their energy. The element will be biased in the restraining direction because the restraint coil has approximately 7 times the number of turns as the operating coil. Upon the application of pickup current, the operating ampere turns will be greater than the restraint ampere turns and the bias will be removed.

If a lower biasing current is used instead of 20 times tap value current, the pickup of the upper unit will be less than before for the first application of pickup current. Pickup will be further reduced with the second application of pickup current, but the current will be stable after this energization. However, this value of pickup will be lower than the limits of 25% and 33% of tap value current. This is in the direction of making the sensitivity of the polar unit lower than 30%, but does not impair the performance of the unit on inrush currents.

b. Differential Unit (DU)

Set the adjustable resistor at top of the relay in the approximate center of its range. Open the switch and pass I_{ac} = 20 times tap value current. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right-hand shunt of lower polar unit until it trips with I_{ac} = 30% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. If polar unit resets before 15% of tap value current, no adjustments are necessary to the left-hand shunt. Repeat these steps until the lower polar unit will pickup at 30% of tap value current and reset for values of tap value current greater than 15%

Indicating Instantaneous Trip Unit (IIT)

With switch open, pass I_{ac} = 10 times tap value current. Adjust core of the instantaneous trip unit until it picks up. Its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging contact should touch both stationary contacts simultaneously.

Harmonic-Restraint Unit (HRU)

Close switch to position 2. Short out I_{LR} ammeter. Adjust direct current until I_{dc} reads 0.8 times tap setting. Gradually increase alternating current until upper polar unit operates with I_{ac} reading between 1.3 and 1.8 times tap setting. The percent second harmonic in the wave may be derived by the use of the formula:

$$\% \text{ second harmonic} = \frac{47 I_{dc}}{I_{ac} + 1.11 I_{dc}}$$

This formula is plotted in curve form in Fig. 16 for I_{dc} = 4 amperes.

Percentage Slope Characteristic (DU)

Close switch to position 1. Set I_{ac} to zero and I_{LR} to 5.5 times tap value current. Then adjust I_{ac} to 4 times tap value current.

Adjust resistor at top of relay until lower polar unit operates. Interchange lead positions to terminals 5 and 7 and repeat the above test. The lower polar unit should operate between the limits of:

I_{ac} = 4 times tap value current

I_{LR} = 9 to 10 times tap value current

Trip condition can best be determined by holding I_{ac} at 4 times tap value current and varying I_{LR}. If I_{LR} is too low the contacts will be closed when the currents are first applied. Hence, I_{LR} should be increased until the contacts open and then decreased until contacts close.

The adjustment of the resistor will have some effect on the pickup of the unit. Hence, recheck the pickup. If necessary readjust shunts to obtain a pickup of 30% of tap value current and dropout of 15% or greater of tap value current. If shunts are changed, check to see that above readings are obtained on the higher restraint currents. If necessary readjust resistor and repeat procedure until the unit operates within the specified limits.

Apply I_{ac} = .56 times tap value and vary I_{LR} until lower polar unit operates. The lower polar unit should operate between following limits.

I_{LR} = 2.36 to 2.56 times tap value current.

Indicating Contactor Switch (ICS)

Block polar unit contacts closed. Pass sufficient direct current through the trip circuit to close the contacts of the ICS. This value of current should be not greater than the particular tap setting being used. The operation-indicator target should drop freely.

The contact gap should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

Calibration (35%-Sensitivity Relays)

The differential unit (DU) should first be calibrated as outlined under "Calibration (All Relays)". Next the right hand shunt of the lower polar unit should be turned out until the relay operates at

I_{ac} = .45 times tap value current

I_{LR} = 1.64 times tap value current

This changes the percentage slope curve of the relay to that shown by the 35 percent sensitivity curve of figure 7. Pickup of the relay is increased from 30% to approximately 35% of tap value current and the curve is changed at low values of restraint current to that shown in figure 7. At large values of restraint current the percentage slope characteristic is essentially the same as shown in figure 8.

As shown in figure 7, the margin of safety between the relay calibrated for a 35% sensitivity and the 20% mismatch curve is the same as that of the relay calibrated for a 30% sensitivity and the 15% mismatch curve. This margin of safety is also shown in the voltage differential characteristic of figure 11 for the 35 percent sensitivity relay.

Electrical Checkpoints

Differential Unit

a. *Restraint Circuit*

Apply two times tap-value current successively to each restraint transformer. This is done by connecting leads to a tap screw and to terminals 5, 7 and 9 in turn (Terminal 9 on HU-1 only). Now measure the a-c voltage across the restraint rectifier bridges (See Fig. 2) using a high-resistance voltmeter (5000 ohms per volt). The voltage should be measured from the left-to the right-hand corners of the bottom set of bridges. A voltage of 2.17 to 2.27 volts should appear only across the appropriate bridge as specified in the following table:

Current in Term.	Associated Rectifier Bridge (Rear View) HU	HU-1
5	Center	Center
7	Right Hand	Left Hand
9	—	Right Hand

b. Operating Circuit

Apply 30 per cent tap-value current to terminal 3 and a tap screw. Using a high-resistance a-c voltmeter measure the voltage on the operating coil bridge across the left-to right-hand corners (See Fig. 2). The voltage should be approximately 2.4 volts. Now, measure the voltage output of the operating transformer (top two coil terminals). The voltage should be about 5.3 volts.

Harmonic Restraint Unit (HRU)

Apply 30 per cent tap-value current to terminal 3 and a tap screw. The following are the approximate voltages that should be obtained using a high-resistance a-c voltmeter (See Fig. 2 for location):

1. Output of operating transformer (top coil terminals)	4.0 volts
2. 4 mfd. capacitor	2.5 volts
3. 0.45 mfd. capacitor	3.9 volts
4. Operating-rectifier bridge (left-to right-hand corners)	2.5 volts
5. Restraint-rectifier bridge (left-to right-hand corners)	0.6 volts
6. Series Filter-Reactor	0.2 volts

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

APPROXIMATE RESISTANCE VALUES OF COMPONENTS IN HU RELAY

Unit	Circuit	Description
Harmonic Restraint	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 50 to 70 ohms.
		Reactor d.c. Resistance 8 to 10 ohms.
		4 MFD Capacitor.
		Rectifier 700 Volts, 600 Milliampere Silicon Diodes
		Indicating Instantaneous Trip Unit 14 to 16 ohms.
		Polar Unit Coil d.c. Resistance 80 to 100 ohms.
	Restraint	Series Reactor d.c. Resistance 110 to 130 ohms.
		Parallel Reactor d.c. Resistance 300 to 360 ohms.
		.45 MFD Capacitor.
		Rectifier 200 Volts, 600 Milliampere Silicon Diodes
		Polar Unit Coil d.c. Resistance 650 to 800 ohms.
		Varistor 100,000 ±10% at 10 V.D.C. 4000 ±25% at 30 V.D.C.
Differential	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 20 to 30 ohms.
		Adjustable 3½ inch 280 ohm Resistor
		Rectifier 700 Volts, 600 Milliampere Silicon Diodes
		Polar Unit Coil d.c. Resistance 75 to 100 ohms.
	Restraint	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9)
		Rectifier 200 Volts, 600 Milliampere Silicon Diodes
		Polar Unit Coil d.c. Resistance 60 to 110 ohms.
Indicating Contactor Switch	Trip	0.2 Amp. tap 6.5 ohms d.c.
		2.0 Amp. tap 0.15 ohms.d.c.

ENERGY REQUIREMENTS

Burden of Each Restraint Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	at 8 times tap value current	at 20 times tap value current
2.9	10	71	.88	50	191
3.2	12	70	.89	51	211
3.5	13	66	.90	51	203
3.8	14	65	.91	53	220
4.2	15	58	.91	53	235
4.6	16	57.5	.91	55	248
5.0	18	52.5	.92	59.	280
8.7	22	30	1.28	94.	340

Burden of Operating Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	at 8 times tap value current	at 20 times tap value current
2.9	10	35	2.26	76	487
3.2	12	34	2.30	78	499
3.5	13	33	2.30	81	504
3.8	14	33	2.30	83	547
4.2	15	31	2.30	84.	554
4.6	16	30	2.40	88.	598
5.0	18	29	2.50	92.	640
8.7	22	23	3.18	132.	850

θ Degrees current lags voltage at tap value current

† Voltages taken with Rectox type voltmeter

*** Thermal Rating**

One Second — 300 amperes

Thermal capacities for short times other than one second may be calculated on the basis of time being inversely proportional to the square of the current.

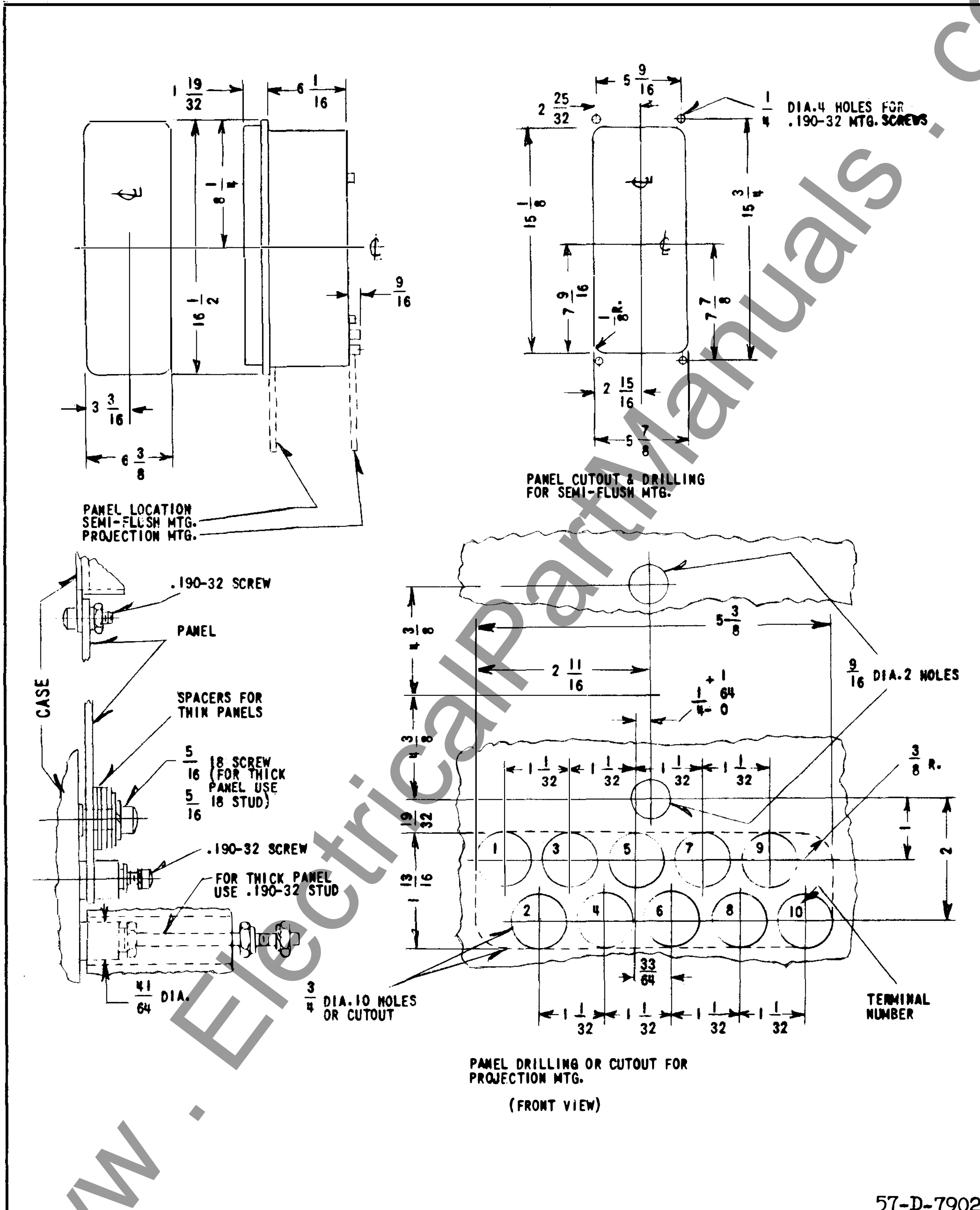


Fig. 17. Outline and Drilling Plan of the Type HU and HU-1 Relays in the FT31 Case.

WESTINGHOUSE ELECTRIC CORPORATION

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

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES HU AND HU-1 TRANSFORMER DIFFERENTIAL RELAYS

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

APPLICATION

The types HU and HU-1 relays are high-speed relays used in the differential protection of transformers. These relays can be applied where the magnetizing inrush current to the transformers is severe.

Current transformer ratio error should not exceed 10% with maximum external fault current flowing, or with eight times relay tap current flowing.

The HU-1 relay has three restraint transformers and associated rows of taps; whereas, the HU relay has one less restraint transformer and two rows of taps. Otherwise the two relays are identical. Three-winding banks normally require the HU-1 relay, although the autotransformer application uses the HU if the tertiary is not loaded.

Both the HU or the HU-1 are available with a sensitivity of either 0.30 or 0.35 times tap. The 30%-sensitivity relay satisfactorily handles up to 15% mismatch (e.g. ±10% transformer tap changing plus 5% CT mismatch). The 35%-sensitivity relay handles as much as 20% mismatch. See Fig. 7 for a comparison of the characteristics of the two sensitivities. Any of the relays may be recalibrated in the field to obtain either characteristic.

Ordinarily the 30%-sensitivity relay will suffice; however, where CT mismatch is abnormally high or where the transformer tap-changing range exceeds ±10%, this calibration may be too sensitive.

CONSTRUCTION

The types HU and HU-1 relays consist of a differential unit (DU), a harmonic-restraint unit (HRU), and an indicating contactor switch (ICS). The principal parts of the relay and their locations are shown in Figs. 1 to 4.

Differential Unit (DU)

The differential unit of the HU relay consists of two air-gap restraint transformers, three full-wave rectifiers, saturating operating-transformer, and a d-c polar unit.

The HU-1 relay, in addition to the above components, has a third air-gap restraint transformer, and a fourth full-wave rectifier.

Each of the restraint transformers and the operating transformer are provided with taps to compensate for mismatch of line current transformers. These taps are incorporated in the relay in such a manner that changing a tap on a restraint transformer automatically changes the same tap on the operating transformer.

Harmonic-Restraint Unit (HRU)

The harmonic-restraint unit of the HU and HU-1 relays consists of an air-gap operating transformer, a second harmonic block filter, a fundamental block-second harmonic pass filter, two full-wave rectifiers, indicating instantaneous trip unit, varistor, and a d-c polar unit.

Taps are also incorporated in this unit to compensate for mismatch of the line current transformers. Changing a tap on the restraint transformer of the differential unit also changes the tap of this unit.

Polar Unit

The polar unit consists of a rectangular shaped

SUPERSEDES I.L. 41-347.1C
*Denotes change from superseded issue

EFFECTIVE DECEMBER 1965

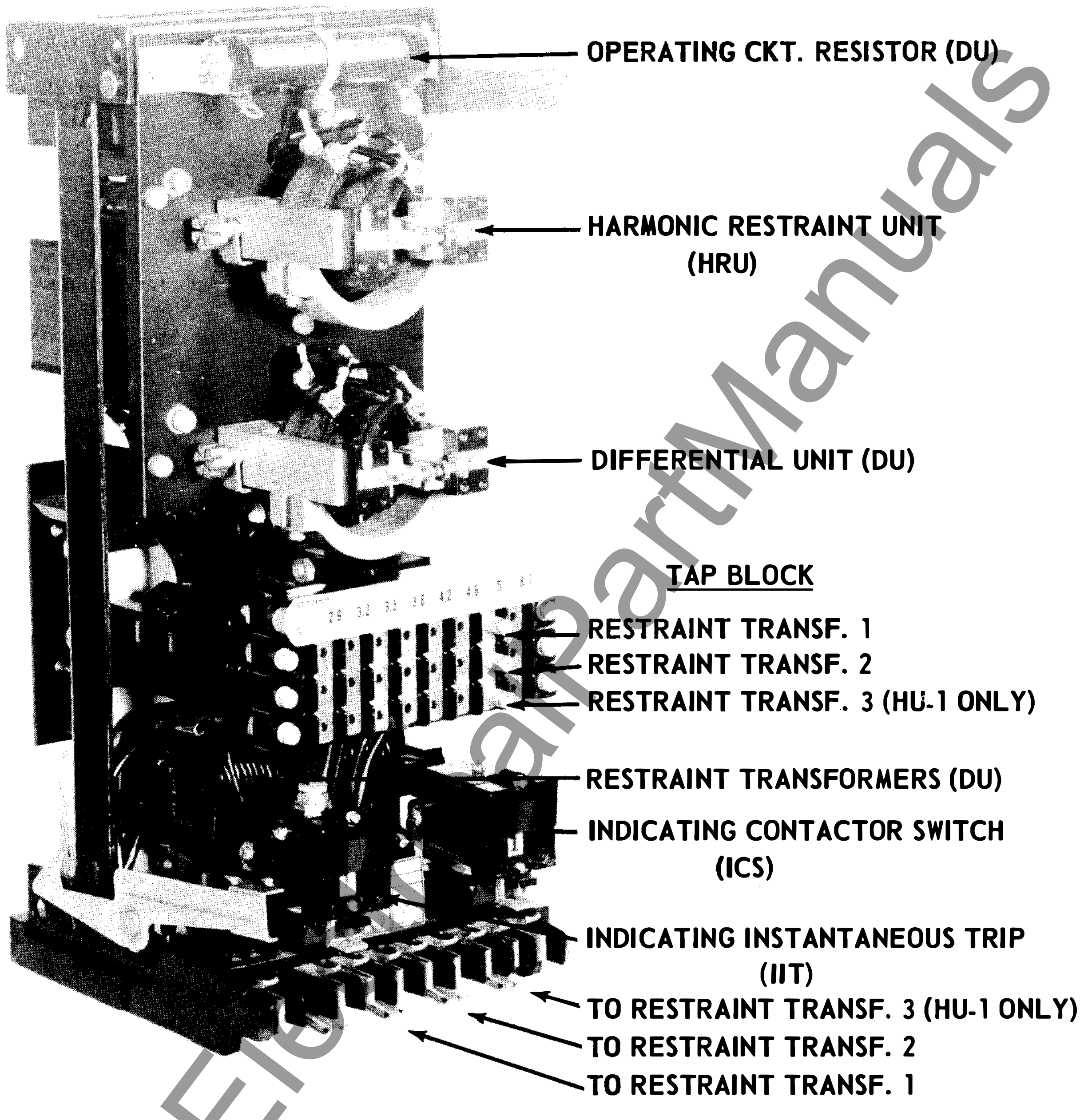


Fig. 1. Type HU-1 Relay – Front View.

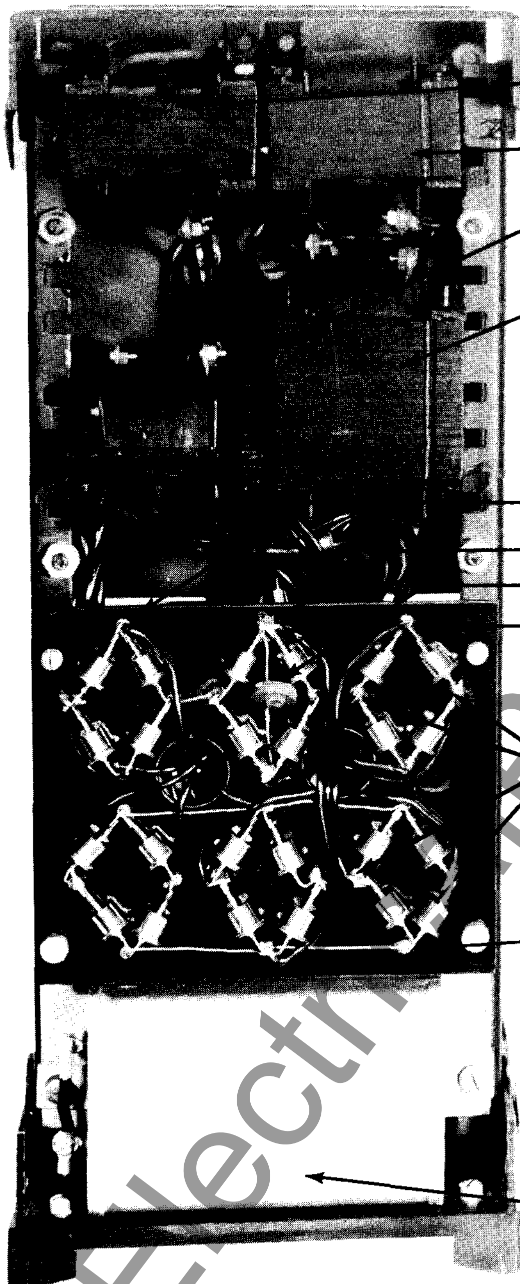
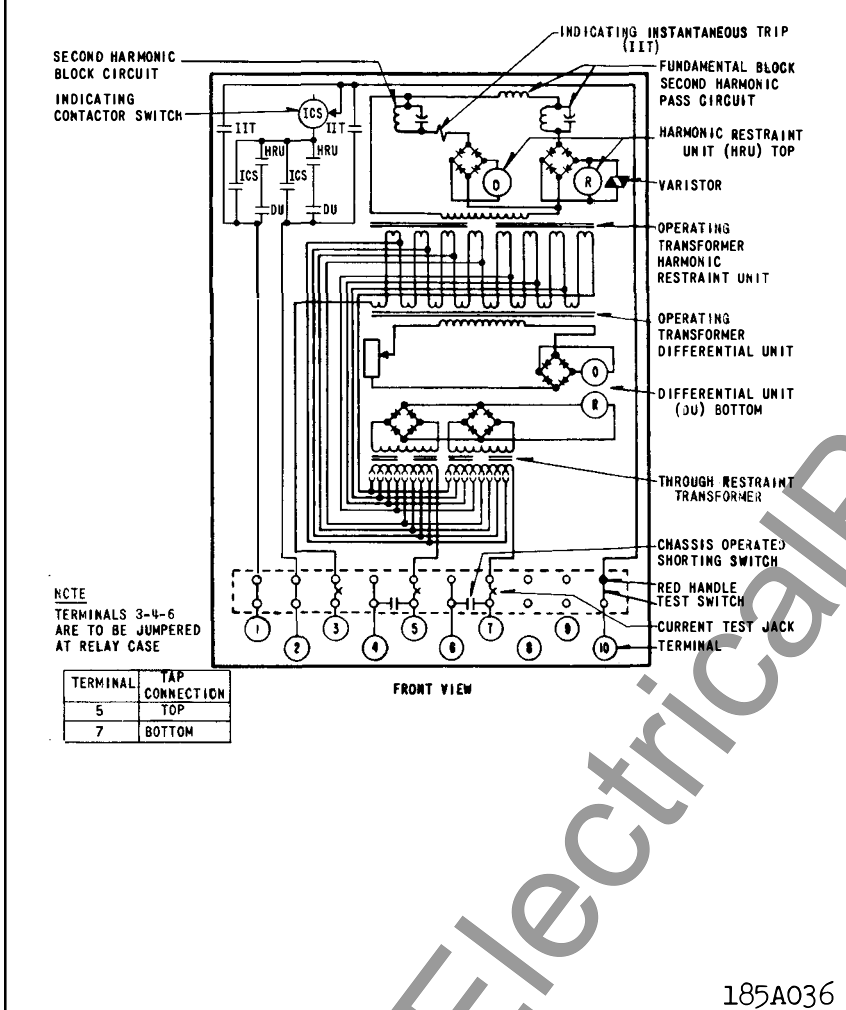
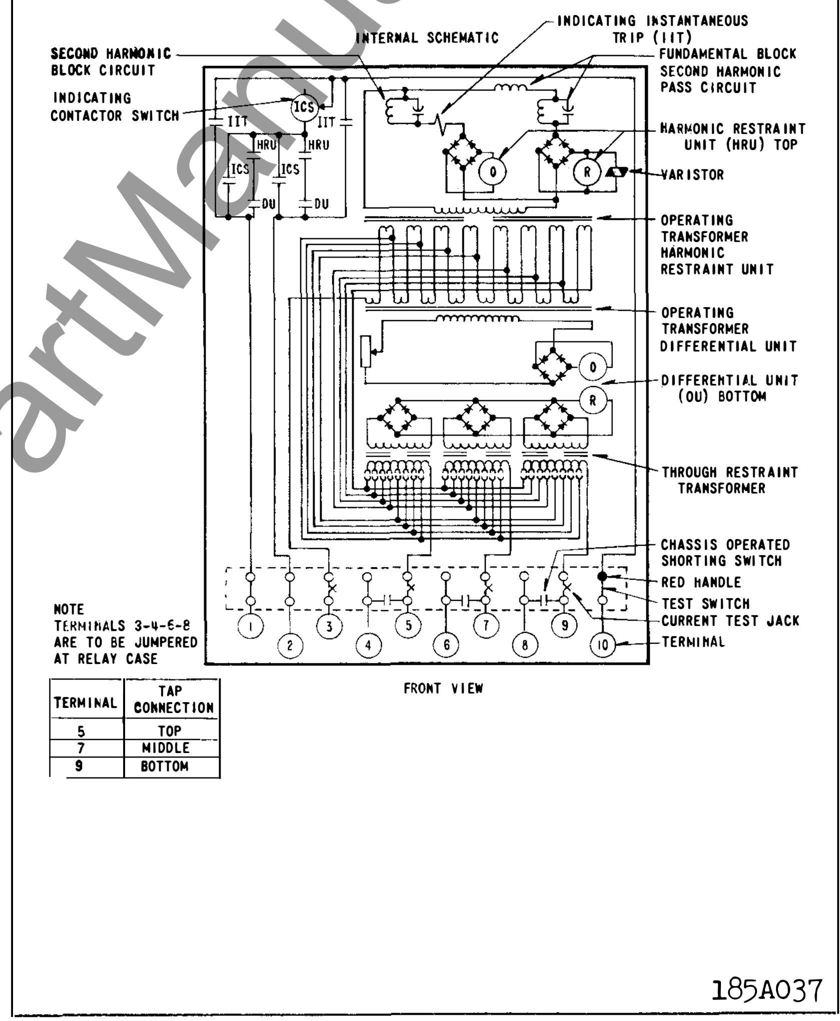


Fig. 2. Type HU-1 Relay – Rear View.



TERMINAL	TAP CONNECTION
5	TOP
7	BOTTOM

Fig. 3 Internal Schematic of the Type HU Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted.



TERMINAL	TAP CONNECTION
5	TOP
7	MIDDLE
9	BOTTOM

Fig 4. Internal Schematic of the Type HU–1 Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted.

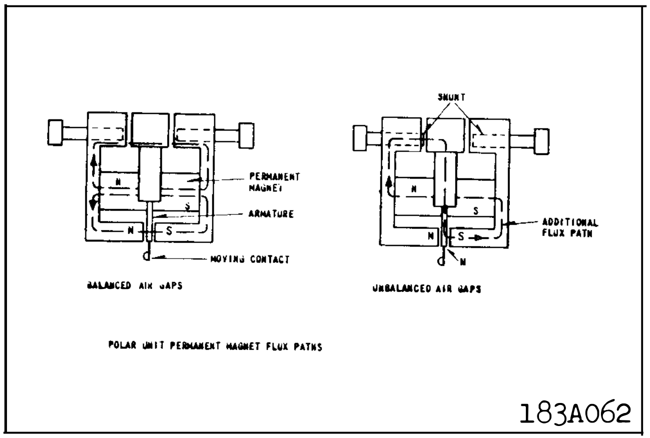


Fig. 5 Polar Unit Permanent Magnet Flux Paths.

magnetic frame, an electromagnet, a permanent magnet, and an armature. The poles of the crescent shaped permanent magnet bridge the magnet frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These non-magnetic joints represent air gaps, which are bridged by two adjustable magnetic shunts. The windings are wound around a magnetic core. The armature is fastened to this core and is free to move in the front air gap. The moving contact is connected to the free end of a leaf spring, which, in turn, is fastened to the armature.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper-type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also, during this operation, two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop.

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

OPERATION

The types HU and HU-1 relays are connected to the protected transformer as shown in Fig. 6. In such a connection, the relays operate to protect the transformer for faults internal to the differential zone of the transformer, but not for faults external to the zone. Neither do the relays operate on magnetizing inrush currents associated with energization of the transformer, even though these currents may appear as an internal fault. To avoid these false operations, each unit of the relay performs a separate function. The differential unit (DU) prevents operation on external faults, while the harmonic-restraint unit (HRU) prevent operations on magnetizing inrush currents. Hence, the operation of the relay can best be described under the headings of external fault current, internal fault currents, and magnetizing inrush currents.

External Fault Currents

The types HU and HU-1 relays have a variable percentage characteristic. This means that the operating current required to close the contact of the differential unit expressed in percent of restraint current varies with the magnitude of the larger restraint current. Fig. 7 and Fig. 8 illustrate this characteristic. To use these curves, divide each restraint current by the appropriate tap and enter the horizontal axis using the larger or largest restraint multiple. Then enter the vertical axis, using the difference of the restraint multiples.

With the relay connected as shown in the schematic diagram of Fig. 9a, an external fault causes currents to flow in the air-gap restraint transformers of the differential unit. If the line current transformers do not saturate and the correct ratio matching taps applied, no effective current flows in the operating transformer of the relay. Hence, only a contact-opening torque is produced on the differential unit.

On heavy external faults where a main current transformer saturates, current flows in the operating circuit of the relay. With such a condition, the harmonic-restraint unit may or may not close its contacts, depending upon the harmonics present in the false operating current. However, operation of the relay is prevented by the variable percentage characteristic of the differential unit, since a large differential current is required to close its contacts during heavy external faults.

Internal Faults

In the case of an internal fault as shown in Fig. 9b, the restraint of the differential unit is proportional to the largest restraint current flowing. The sum of the two restraint currents flows into the operating transformer and produces an excess of operating torque, and the differential unit operates.

In the case of an internal fault fed from one source only, the fault current flows in one restraint

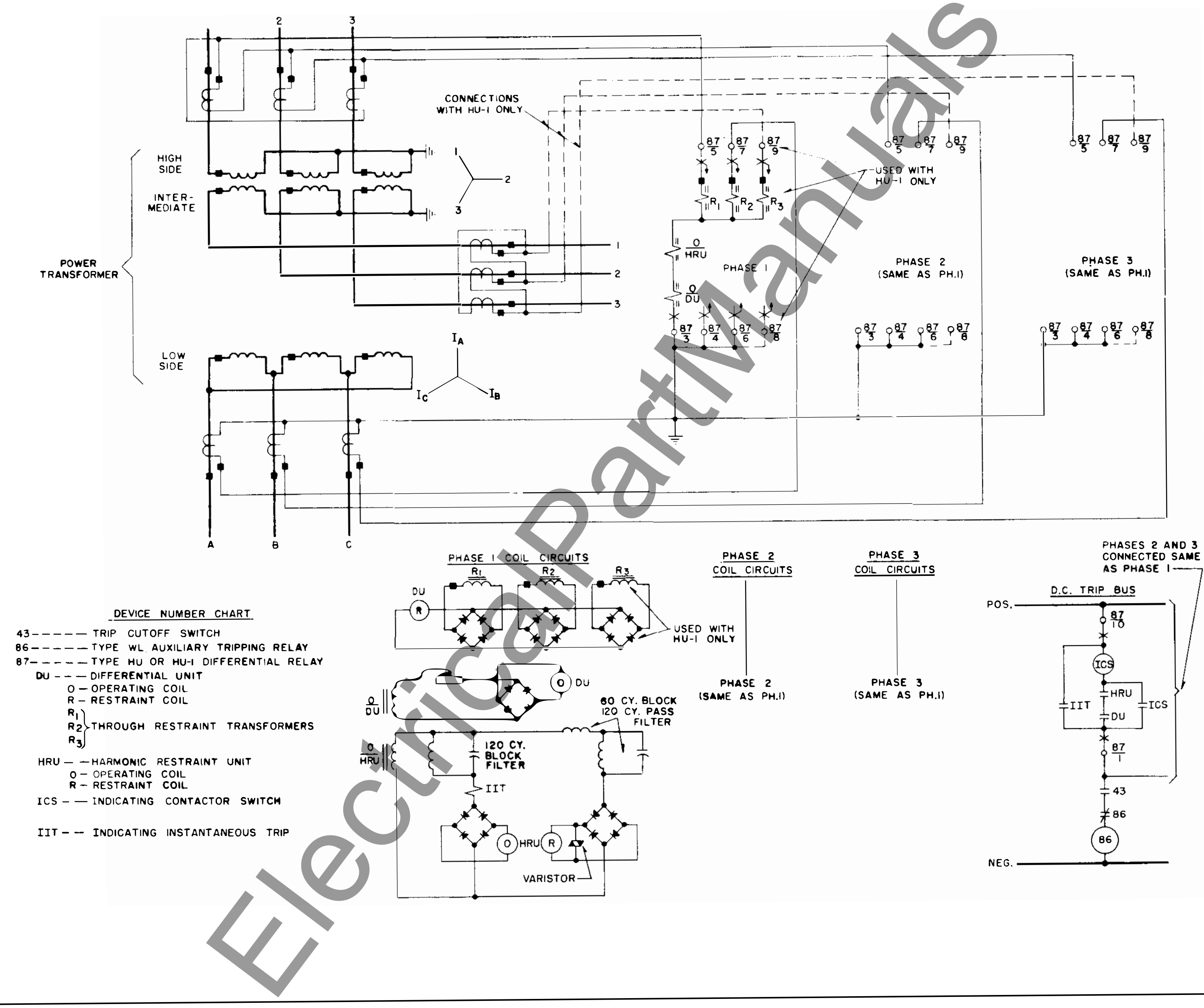
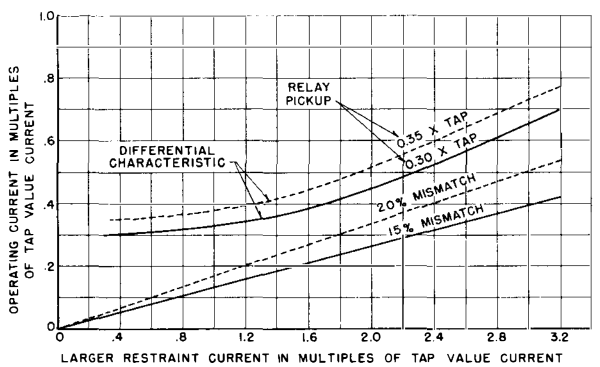
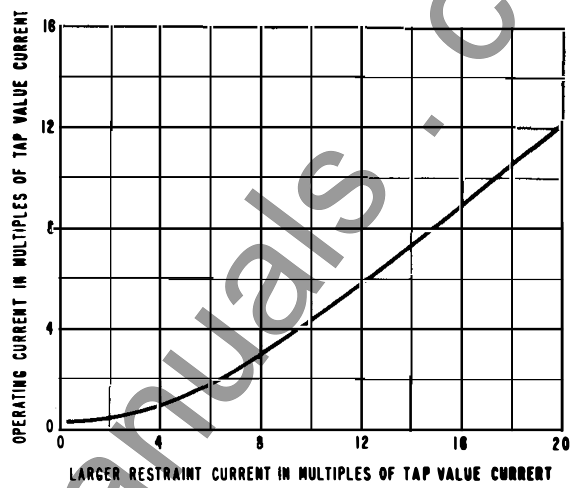


Fig. 6. External Schematic of the Type HU and HU-1 Relays.



Curve 471136

Fig. 7. Differential Characteristic of the DU Unit of the HU and HU-1 Relays at Smaller Values of Current. Actual Operating Current Shown for 15 and 20% Mismatch.



Curve 471050

Fig. 8. Differential Characteristic of the Differential Unit (DU) of the HU and HU-1 Relays at Larger Values of Current.

transformer and the operating transformer. An excess of operating torque is produced on the differential unit and it operates.

Faults normally appear as an offset sine wave with a decaying d-c component, and contain very few harmonics. As a result, the harmonic-restraint unit will operate during internal faults to permit tripping of the relay.

For heavy internal faults, the indicating instantaneous trip unit (IIT) will operate before the main unit. Since this unit is connected to an air gap transformer, essentially only the sine wave component of an internal fault is applied to the IIT unit. The d.c. component of the fault is bypassed by the transformer primary. For example, an internal fault with a first peak of 28 times tap value (includes fifty percent d.c.) is reduced to a first peak of approximately 14 times tap value (d.c. component absent) on the secondary of the transformer. The IIT unit will just operate on this wave since it is set to pick up at a peak current of 14.1 times tap (r.m.s. pick-up value = 10 times tap).

The varistor connected across the d.c. side of the restraint rectifier of the harmonic restraint unit prevents excessive voltage peaks from appearing across the rectifiers. These peaks arise through transformer action of the harmonic-restraint polar-unit coils during heavy internal faults. The varistor has a large value of resistance for low voltages, while presenting a low value of resistance for high voltages. This characteristic effectively reduces the voltage spikes on heavy internal faults while not hampering performance during inrush, where the voltage is considerably lower.

Magnetizing Inrush Currents

Magnetizing inrush current waves have various wave shapes. A typical wave appears as a rectified half wave with decaying peaks. In any case, the various wave shapes are rich in harmonics with the second harmonic predominant. Since the second harmonic is always present in inrush waves and not in internal fault waves, this harmonic is used to restrain the harmonic-restraint unit during inrushes. The differential unit may or may not close its contact, depending on the magnitude of the inrush.

When a magnetizing inrush wave is applied to the relay, the d-c component of the wave is by-passed by the air-gap operating transformer. The other components are fed into the filter circuits. The impedance characteristics of these filters are such that the second harmonic component flows into the restraint coil of the polar unit, while the other harmonics flow into the operating coil. The polar unit will not close

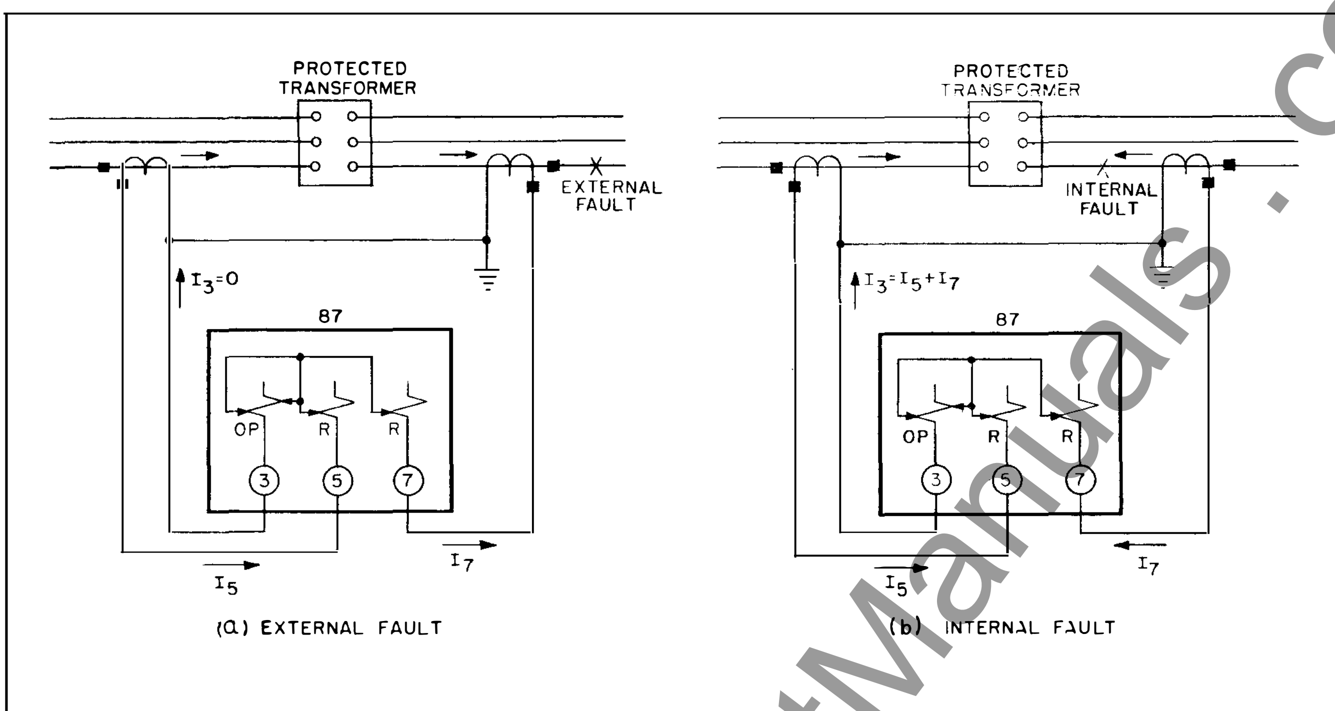


Fig. 9. Simplified Schematic of the Type HU Relay with Current Distribution for (a) External Fault (b) Internal Fault.

its contacts unless the second harmonic content is less than 15 percent of the fundamental component.

The indicating instantaneous trip unit (IIT) will not operate on inrush. The air-gap transformer will bypass the d.c. component of the inrush thereby reducing the magnitude of the wave applied to the IIT unit. If the inrush has an initial peak of 16 times tap-value current, the air-gap transformer will reduce this peak to approximately 8 times tap value on the secondary of the transformer. Since the IIT unit is set for a peak value of 14.1 times tap (r.m.s. pick-up value = 10 times tap), it will not operate on this inrush.

Breaker Maintenance

Before some of the CT's are bypassed for breaker maintenance the trip circuit should be opened, as shown in Fig. 6. Otherwise the false-unbalanced current will cause the relay to trip. It is not necessary to short-circuit the relay operating circuit since it has an adequate continuous-current rating. (See "Energy Requirements").

CHARACTERISTICS

Taps are incorporated in the HU and HU-1 relays to compensate for main current transformer mismatch. These taps are as follows: 2.9, 3.2, 3.5, 3.8, 4.2, 4.6, 5.0, 8.7.

To measure the effective unbalance, a sensitive low-reading voltmeter (5000 ohms per volts) can temporarily be connected across the operating coil resistor (at top of case). With a perfect balance the voltmeter reading will be zero. The reading should not exceed the values indicated by the 15% mismatch curve in Fig. 10 when the relay pickup is 0.30 times tap. If the amount of mismatch is measured or calculated, the measured voltage can be checked against the interpolated value from the curve. For example, assume that the larger restraint current is measured as 1.5 tap multiple and the calculated mismatch is 7%. Then, from Fig. 10 the measured voltage should be approximately 1.0 volts. Use Fig. 11 if the pickup is 0.35 times tap.

Pickup of the harmonic-restraint unit and the differential unit is either 30 or 35% of tap value current. Pickup of the indicating instantaneous trip unit is ten times tap value current.

Components of the harmonic-restraint unit are selected such that 15% second harmonic will prevent operation of the unit. This factor is adequate to prevent false operation on inrushes.

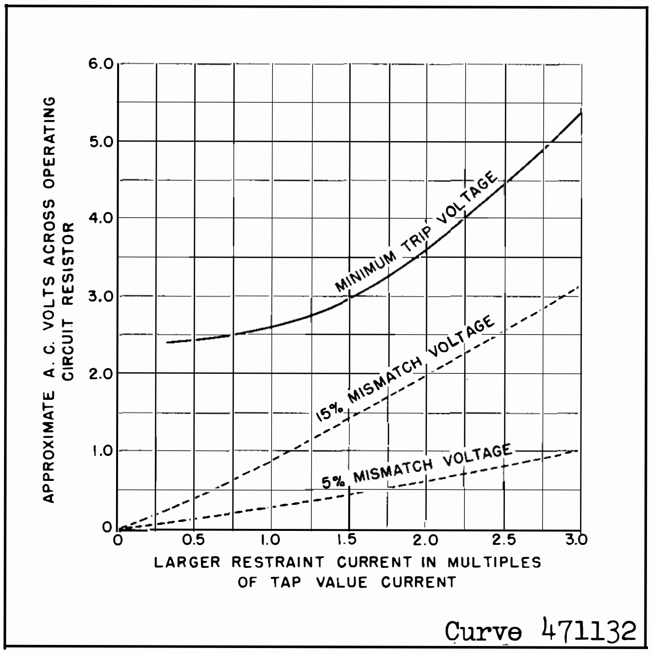


Fig. 10. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.30 Times Tap.

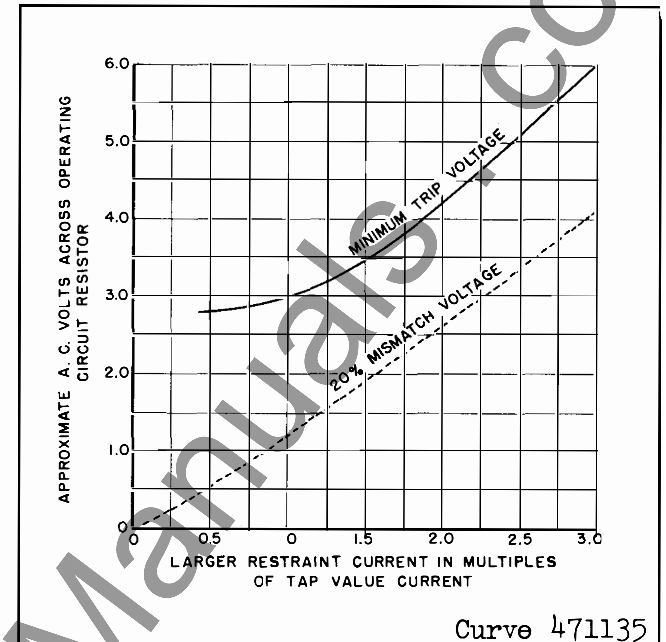


Fig. 11. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.35 Times Tap.

The frequency response of the HU and HU-1 relays is shown in Fig. 13.

Trip Circuit

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

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

SETTING

To set the relay, calculations must be performed as shown under "Setting Calculations". After the correct tap is determined, connections can be made to the relay transformers by placing the connector screws in the various terminal-plate holes in front of the relay. Only one tap screw should be inserted in any horizontal row of taps.

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-or 250-volt d-c type WL relay switch, or equivalent, use the 0.2-ampere tap; for 48 volt DC applications set relay in 2 tap and use Type WL Relay coil S#304C209G01 or equivalent.

Indicating Instantaneous Trip (IIT)

No setting is required on the indicating instantaneous trip unit. This unit is set at the factory to pickup at 10 times tap value current.

SETTING CALCULATIONS

Select the ratio matching taps. There are no other settings. In order to calculate the required tap settings and check current transformer performance the following information is required.

Required Information

1. Maximum transformer power rating $(KVA)_M$
2. Maximum external fault currents
3. Voltage ratings of power transformer (V_H, V_I, V_L)
4. Current transformer ratios, full tap (N_T)
5. Current transformer "10L" accuracy class

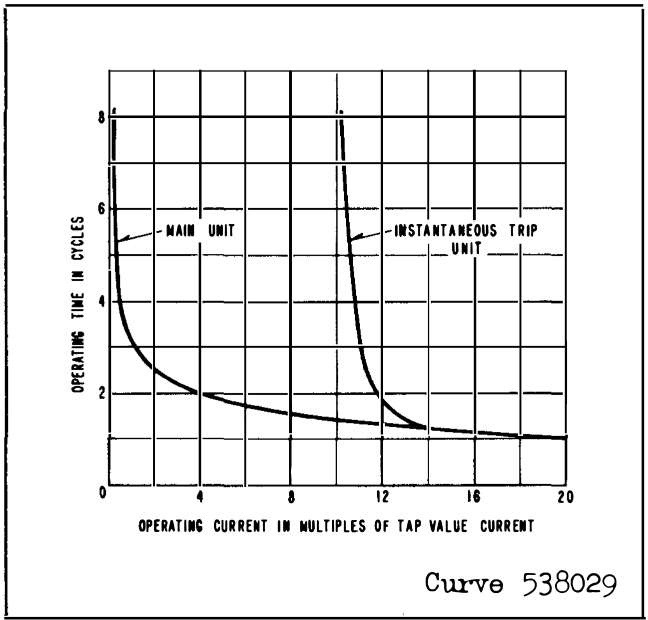


Fig. 12. Typical Tripping Time Characteristic (60 Cycle Currents).

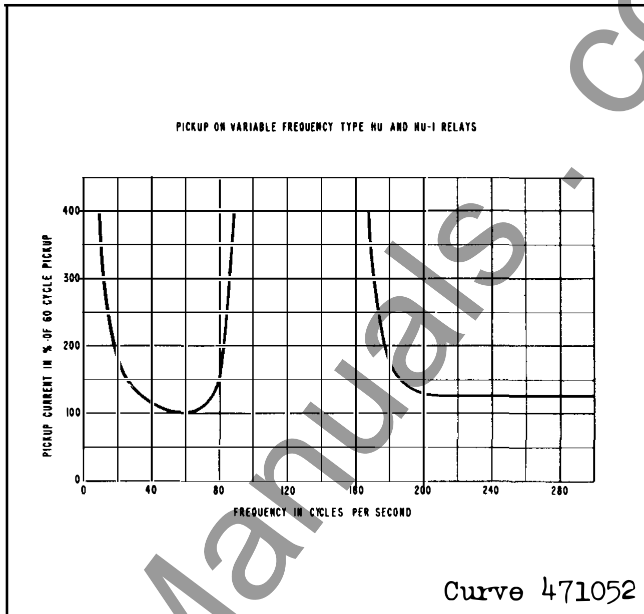


Fig. 13. Typical Frequency Response of the HU and HU-1 Relays.

voltage, (or excitation or ratio-overcurrent curve)

6. One way current transformer lead resistance at 25°C (R_L) (when using excitation curve, include CT winding resistance)
7. Current transformerconnections(wye or delta)

Definitions of Terms

I_P = Primary current at $(KVA)_M$

I_R = Relay input current at $(KVA)_M$

I_{RH}, I_{RL}, I_{RI} are same as I_R except for high, low and intermediate voltage sides respectively.

I_S = CT secondary current at $(KVA)_M$

T_H, T_L, T_I = Relay tap settings for high, low and intermediate voltage windings, respectively.

N = Number of current transformer turns that are in use.

$N_P = N/N_T$ (Proportion of total turns in use)

N_T = Current transformer ratio, full tap

V_{CL} = 10L accuracy class voltage

Z_A = Burden impedance of any devices other than the HU or HU-1 relays, with maximum phase-to-phase or 3-phase current flowing.

Z_T = Total secondary burden in ohms (excluding current transformer winding resistance, except when using excitation curve)

Calculation Procedure

1. *Select current transformer taps,* where multi-ratio types are used.

   I_R should be more than 2.9 amperes for high sensitivity and should not exceed the relay continuous rating (see "Energy Requirements"). For determining the required continuous rating of the relay, use the expected two-hour maximum load, since the relay reaches final temperature in this time.

2. *Select relay taps in proportion to the relay currents,* I_R.

   I_R should not exceed relay continuous rating. Also the maximum external fault current should not exceed 20 times relay tap.

3. *Determine Mismatch* (Not to exceed 15%)

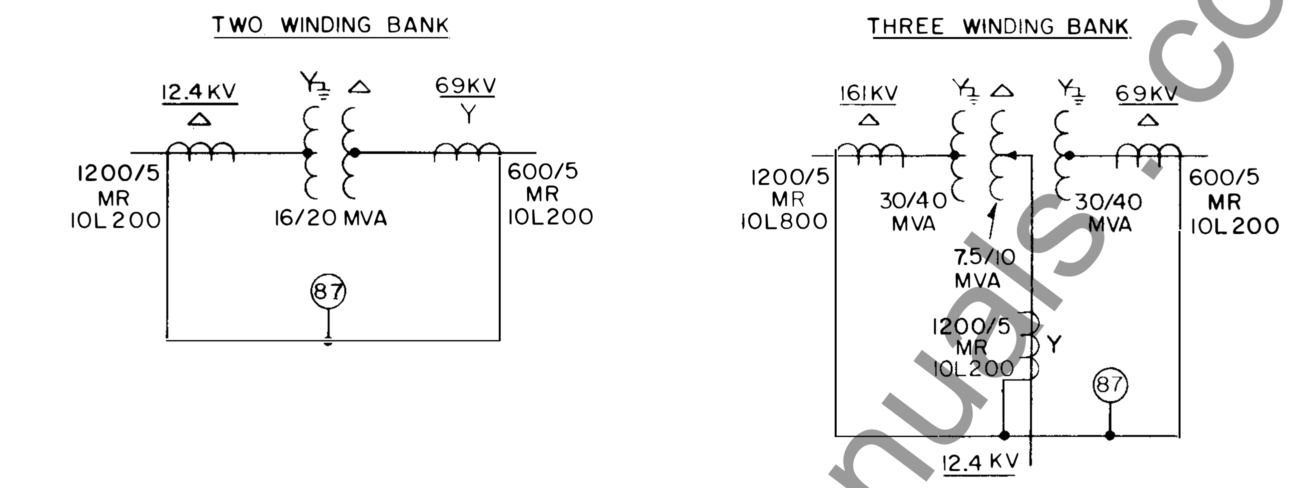
   For 2 winding banks:

$$\% \text{ mismatch} = 100 \frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{S} \quad (1)$$

where S is the smaller of the two terms, (I_{RL}/I_{RH}) or (T_L/T_H)

For 3 winding banks:

$$\% \text{ mismatch} = 100 \frac{(I_{RH}/I_{RI}) - (T_H/T_I)}{S} \quad (2)$$



LOW	HIGH
$(KVA)_M$ = 20,000	$(KVA)_M$ = 20,000
$(KVA)_S$ = 16,000	$(KVA)_S$ = 16,000
V_L = 12,400 VOLTS	V_H = 69,000
N_T = 240 TURNS	N_T = 120
V_{CL} = 200 VOLTS	V_{CL} = 200
R_L = 0.4 OHMS	R_L = 0.4
DELTA CT	WYE CT

HIGH	INTERMEDIATE	LOW
$(KVA)_M$ = 40,000	$(KVA)_M$ = 40,000	$(KVA)_M$ = 10,000
$(KVA)_S$ = 30,000	$(KVA)_S$ = 30,000	$(KVA)_S$ = 7,500
V_H = 161,000	V_I = 69,000	V_L = 12,400
N_T = 240	N_T = 120	N_T = 240
V_{CL} = 800	V_{CL} = 200	V_{CL} = 200
R_L = 0.5	R_L = 0.5	R_L = 0.5
DELTA CT	DELTA CT	WYE CT

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Fig. 14. ***Example for Setting Calculations.***

where "S" is the smaller of the two terms, (I_{RH}/I_{RI}) or (T_H/T_I).

Equations similar to eq. (2) apply for mismatch from the high to low and from the intermediate to low voltage windings.

Where tap changing under load is performed the relays should be set on the basis of the middle or neutral tap position. The total mismatch, including the automatic tap change should not exceed 15% with a 30% sensitivity relay, and 20% with a 35% sensitivity relay. Note from Fig. 7 that an ample safety margin exists at these levels of mismatch.

4. *Check current transformer performance.* Ratio error should not exceed 10% with maximum symmetrical external fault current flowing or with 8 times relay tap current flowing. An accurate method of determining ratio error is to use ratio-correction-factor curves (RCF).

A less accurate, but satisfactory method is to utilize the ASA relaying accuracy classification. If the 10L accuracy is used, performance will be adequate if:

$$\frac{N_P V_{CL}}{100} \text{ is greater than } Z_T \qquad (3)$$

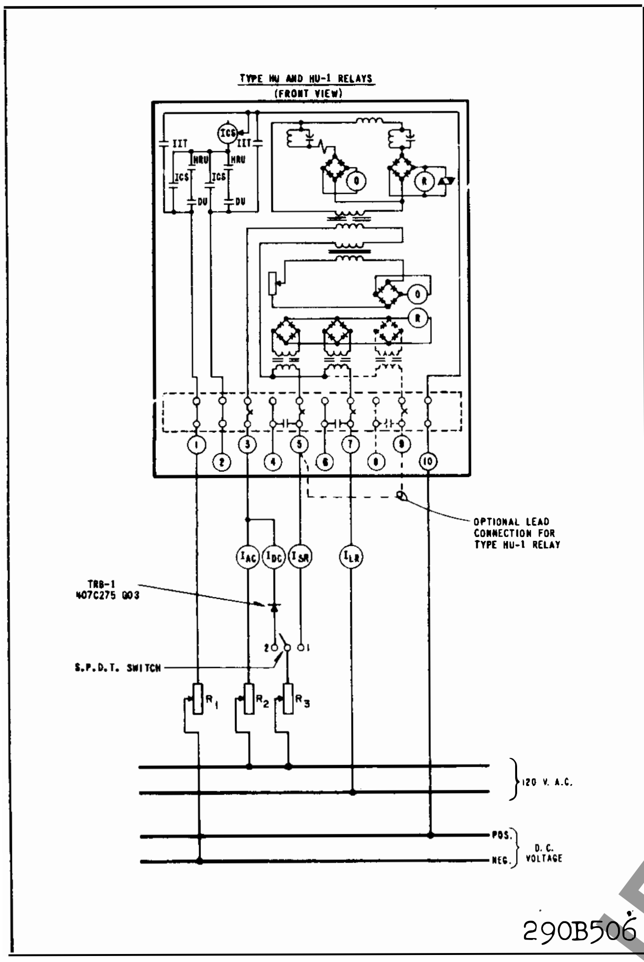
For wye-connected CT:

$$Z_T = \text{lead resistance} + \text{relay burden} + Z_A$$

$$= 1.13\, R_L + \frac{0.15}{T} + Z_A \text{ ohms} \qquad (4)$$

(R_L multiplier, 1.13, is used to account for temperature rise during faults. $\frac{0.15}{T}$ is an approximation, where T = relay tap.

Z_A is any additional burden, when maximum external 3-phase fault current is flowing).



✱ *Fig. 15.* ***Test Circuit of the HU and HU-1 Relays.***

For delta-connected CT:

$$Z_T = 3\,(1.13\ R_L + \frac{0.15}{T} + Z_A)\ \text{ohms}$$

$$= 3.4\ R_L + \frac{0.45}{T} + 3Z_A \qquad (5)$$

(The factor of 3 accounts for conditions existing during a phase-to-phase fault. Z_A is any additional burden, when maximum external phase to phase fault current is flowing)

5. *Examples*

Refer to pages 13 and 14 and figure 14 for setting examples. Note in both examples that the 8.7 tap was selected as the first step in selecting relay taps. If a lower tap such as tap 5 had been the first selection, a proper balance would have been impossible. On page 12 for the two winding bank,

$$\frac{I_{RL}}{I_{RH}} = \frac{8.05}{4.18} = 1.92.$$ With tap 5 for the low side the maximum current ratio that can be matched by the taps is $\frac{5}{2.9} = 1.73$. With tap 8.7 selected for the low side, a 3 to 1 current ratio can be matched. On page 13 for the three winding bank,

$$\frac{I_{RL}}{I_{RH}} = 3.02$$

This current ratio can be accommodated by the 8.7 & 2.9 taps without excessive mismatch.

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 to the terminal studs furnished with the relay for thick-panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer.

Acceptance Tests

The following check is recommended to insure that the relay is in proper working order. All checks can best be performed by connecting the relay per the test circuit of Fig. 15. Relay to be tested in case.

1. Minimum Trip Current. With switch open and relay set on 5-ampere tap, apply 1.35 to 1.65 amperes for the 30%-sensitivity relay and 1.6 to 1.9

TWO-WINDING TRANSFORMER CALCULATIONS

(See Figure 14)

	LOW	HIGH
1. Select CT Ratio:		
$I_P = \dfrac{(KVA)_M}{\dfrac{V\sqrt{3}}{1000}} =$	$\dfrac{20,000}{12.4\sqrt{3}} = 930$ Amp.	$\dfrac{20,000}{69\sqrt{3}} = 167$ Amp.
Select Ratio	1000/5 (N = 200)	200/5 (N = 40)
2. Select Relay Taps:		
$I_S = \dfrac{I_P}{N} =$	$\dfrac{930}{200} = 4.65$ Amp.	$\dfrac{167}{40} = 4.18$ Amp.
$I_R =$	$I_{RL} = 4.65\sqrt{3} = 8.05$ Amp.	$I_{RH} = 4.18$ Amp.
Select Tap	$T_L = 8.7$	$T_H = \dfrac{4.18}{8.05} \times 8.7 = 4.64$
Desired Tap		$T_H = 4.6$

3. Determine Mismatch:

% Mismatch =

$$100\,\frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{T_L/T_H} = 100\,\frac{(8.05/4.18) - (8.7/4.6)}{8.7/4.6} = 100\,\frac{1.92 - 1.89}{1.89} =$$

1.6%

	LOW	HIGH
4. Check CT Performance:		
$Z_T =$	$3.4\,R_L + \dfrac{0.45}{T} =$	$1.13\,R_L + \dfrac{0.15}{T} =$
	$3.4 \times 0.4 + \dfrac{0.45}{8.7} = 1.36 + 0.05 =$	$1.13 \times 0.4 + \dfrac{0.15}{4.6} = 0.45 + 0.03 =$
	1.41 ohms	0.48 ohms
$N_P = \dfrac{N}{N_T} =$	$\dfrac{200}{240} = 0.833$	$\dfrac{40}{120} = 0.333$
$\dfrac{N_P\,V_{CL}}{100} =$	$\dfrac{0.833 \times 200}{100} = 1.67$	$\dfrac{0.333 \times 200}{100} = 0.67$
$(N_P\,V_{CL}/100) > Z_T$	Yes	Yes

THREE-WINDING TRANSFORMER CALCULATIONS

(See Figure 14)

	HIGH	INTERMEDIATE	LOW
1. Select CT Ratio:			
$I_P = \frac{(KVA)_M}{\frac{V\sqrt{3}}{1000}} =$	$\frac{40,000}{161\sqrt{3}} = 143$ Amp.	$\frac{40,000}{69\sqrt{3}} = 334$ Amp.	$\frac{10,000}{12.4\sqrt{3}} = 465$ Amp.
Select Ratio	400/5 (N = 80)	600/5 (N = 120)	1000/5 (N = 200)
2. Select Relay Taps:			
$I_S = \frac{I_P}{N} =$	$\frac{143}{80} = 1.78$ Amp.	$\frac{334}{120} = 2.78$ Amp.	$\frac{465}{200} = 2.32$ Amp. (At 10 MVA)
I_R (At 40 MVA) =	$I_{RH} = 1.78\sqrt{3}$ $= 3.08$ Amp.	$I_{RI} = 2.78\sqrt{3}$. $= 4.82$ Amp.	$I_{RL} = \frac{40}{10} \times 2.32$ $= 9.3$ Amp.
Select Tap			$T_L = 8.7$
Desired Tap	$T_H = 8.7\frac{3.08}{9.30}$ $= 2.88$	$T_I = 8.7\frac{4.82}{9.30}$ $= 4.52$	
Select Tap	$T_H = 2.9.$	$T_I = 4.6$	
3. Determine Mismatch			
% Mismatch	$100\frac{(I_{RH}/I_{RI})-(T_H/T_I)}{T_H/T_I} =$	$100\frac{(I_{RI}/I_{RL})-(T_I/T_L)}{(I_{RI}/I_{RL})} =$	$100\frac{(I_{RL}/I_{RH})-(T_L/T_H)}{T_L/T_H} =$
	$100\frac{(3.08/4.82)-(2.9/4.6)}{2.9/4.6} =$	$100\frac{(4.82/9.30)-(4.6/8.7)}{4.82/9.30} =$	$100\frac{(9.3/3.08)-(8.7/2.9)}{8.7/2.9} =$
	$100\frac{0.640-0.630}{0.630} =$	$100\frac{0.518-0.528}{0.518} =$	$100\frac{3.02-3.00}{3.00} =$
	1.6%	−1.9%	0.67%
4. Check CT Performance			
$Z_T =$	$3.4\,R_L + \frac{0.45}{T} =$	$3.4\,R_L + \frac{0.45}{T} =$	$1.13R_L + \frac{0.15}{T} =$
	$3.4 \times 0.5 + \frac{0.45}{2.9} =$	$3.4 \times 0.5 + \frac{0.45}{4.6} =$	$1.13 \times 0.5 + \frac{0.15}{8.7} =$
	$1.70 + 0.16 =$ 1.86 ohms	$1.70 + 0.10 =$ 1.80 ohms	$0.565 + 0.02 =$ 0.58 ohms
$N_P = \frac{N}{N_T} =$	$\frac{80}{240} = 0.333$	$\frac{120}{120} = 1.0$	$\frac{200}{240} = 0.833$
$\frac{(N_P\ V_{CL})}{100} =$	$\frac{800 \times 0.333}{100} = 2.67$	$\frac{200 \times 1.0}{100} = 2.0$	$\frac{200 \times 0.833}{100} = 1.67$
$(N_P\ V_{CL}/100) > Z_T$	Yes	Yes	Yes

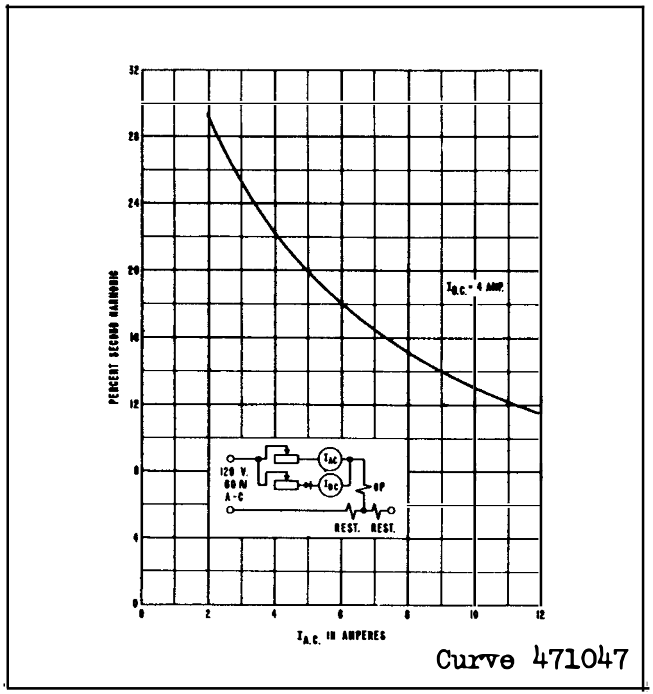


Fig. 16 ***Variation of Second Harmonic Content of Test Current.***

amperes for the 35% sensitivity relay. Relay should operate. The upper polar unit may operate for lower currents, but not below 1.0 ampere. This low pickup will not impair its operation on magnetizing inrush currents and should not be disturbed if it is found to be less than the lower polar unit. If a higher pickup is desired, it is suggested that 20 times tap value current be applied to relay terminals 3 & 7. This will cause the upper polar unit to pick up at a current of approximately 1.65 amperes.

2. Indicating instantaneous Trip Pickup. With switch open and relay set on 5 ampere tap, apply 50 amperes to relay. Indicating instantaneous trip should pick up and its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

3. Indicating Contactor Switch. Block Polar unit contacts closed. Pass sufficient direct 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 setting being used. The operation indicator target should drop freely.

The contact gap of the ICS should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

4. Differential Characteristic.

a. 30% Sensitivity relay

Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 10 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 12.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 to 2.95 amperes
I_{LR} = 11.8 to 12.8 amperes

b. 35% Sensitivity relay

Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 9 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 11.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 amperes
I_{LR} = 10.8 to 11.8 amperes

5. Harmonic Restraint Characteristic. Close switch to position 2. Short out I_{LR} ammeter. Set I_{dc} to 4 amperes and adjust I_{ac} until upper polar unit operates. I_{ac} should read between 6.5 and 9 amperes. As shown in *Fig. 16*, these values of alternating current correspond to 17 percent and 14 percent second harmonic.

*** In Service Test**

Table 1 is to be used as an in-service check of the HU or HU-1 relay using any tap combination. The relay should be connected as shown in fig. 15 with the S.P.O.T. switch in position 1. The ammeter I_{SR} measures the smaller restraint current and should be connected to the terminal associated with the tap block of the smaller setting. The ammeter I_{LR} measures the larger restraint current, and should be connected to the terminal associated with the larger tap block setting. Terminal 5 supplies the upper tap block; terminal 7 supplies the second tap block; and terminal 9 (HU-1 only) supplies the lower tap block (refer to figs. 1 and 4).

Table 1 gives the values of I_{AC} necessary to operate the relay when using a value of I_{SR} equal to 3 times tap value for all taps except the 8.7 tap. A value of I_{SR} equal to 2 times tap value was chosen for the 8.7 tap setting in order to keep the current at a convenient value for testing.

Example (HU Relay)

Upper Tap Block Tap 3.5
Lower Tap Block Tap 5.0

Since the upper tap block has the smaller tap setting I_{SR} should be connected to the upper tap block (Term. 5), and I_{LR} should be connected to Terminal 7. From Table 1 under "Restraint Transformer tap: Larger" = 5.0 "Smaller" = 3.5, set I_{SR} = 10.5 amps. The value of I_{AC} to operate the relay should be between 8.3 and 9.2 amps.

To check the third restraint winding on the HU-1 repeat the above procedure using terminal 9 and either terminal 5 or 7.

TABLE 1

Restraint Transformer Tap	Larger	2.9	3.2	3.5	3.8	4.2	4.6	5.0	8.7
Smaller	CURRENT IN AMPERES								
2.9	ISR	8.7	8.7	8.7	8.7	8.7	8.7	8.7	5.8
	IAC (Min.)	2.6	3.7	5.0	5.8	7.8	9.0	10.4	16.2
	IAC (Max.)	2.8	4.0	5.5	6.4	8.6	10.0	11.6	17.9
3.2	ISR		9.6	9.6	9.6	9.6	9.6	9.6	6.4
	IAC (Min)		2.7	4.0	4.9	6.9	8.1	9.6	15.7
	IAC (Max)		3.1	4.4	5.4	7.6	9.0	10.6	17.3
3.5	ISR			10.5	10.5	10.5	10.5	10.5	7.0
	IAC (Min)			3.0	3.8	5.7	6.9	8.3	14.5
	IAC (Max)			3.3	4.2	6.3	7.7	9.2	16.1
3.8	ISR				11.4	11.4	11.4	11.4	7.6
	IAC (Min)				3.2	5.2	6.5	7.9	14.1
	IAC (Max)				3.6	5.7	7.2	8.7	16.0
4.2	ISR					12.6	12.6	12.6	8.4
	IAC (Min)					3.5	4.7	6.2	12.9
	IAC (Max)					3.9	5.2	6.9	14.2
4.6	ISR						13.8	13.8	9.2
	IAC (Min)						3.9	5.3	12.4
	IAC (Max)						4.3	5.9	13.7
5.0	ISR							15.0	10.0
	IAC (Min)							4.3	11.6
	IAC (Max)							4.8	12.9
8.7	ISR								17.4
	IAC (Min)								5.0
	IAC (Max)								5.5

Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

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 contact.

Calibration (All Relays)

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. All adjustments to be done with relay inside its case. (See "Acceptance Check")

Polar Units

1. Contacts. Place a .060 to .070 inch feeler gage between the right hand pole face and the armature. This gap should be measured near the front of the right hand pole face. Bring up the backstop screw until it just makes with the moving contact. Place gage between moving contact and the stationary contact on the left-hand side of the polar unit. On the upper unit, the gap should be .046 inch and on the lower unit the gap should be .065 to .070 inch. Bring up the stationary contact until it just makes with the gage and lock in place.

2. Minimum Trip Current

a. Harmonic Restraint Unit (HRU)

Connect the relay per test circuit of Fig. 15. With the switch open, pass I_{ac} = 20 times tap value current into the relay. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right hand shunt on upper polar unit until it trips with I_{ac} = 33% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. Repeat these steps, if necessary, until the unit operates at 33% or slightly lower of tap value current immediately following the application of 20 times tap value current and until the unit resets at a value of current 15% of tap value or greater. After the dropout has been measured, the unit should pick up at 25% or higher of tap value current.

On the application of the high current, the upper polar unit will be biased in the restraining direction and pickup will be greater than the nominal value of 30% of tap value current on the first application of pickup current. If the circuit is deenergized and pickup is measured again, the pickup current will be less than before. However, pickup will be stable after the second application of pickup current. If 20 times tap value current is applied again, the pickup immediately after applying this current will be high. However, measuring the pickup the second time will show that the pickup is again reduced. The variation between these pickups should be between 25% and 33% of tap value current.

The filter circuits are charged by the application of this heavy current and upon the removal of the current, these circuits will discharge their energy. The element will be biased in the restraining direction because the restraint coil has approximately 7 times the number of turns as the operating coil. Upon the application of pickup current, the operating ampere turns will be greater than the restraint ampere turns and the bias will be removed.

If a lower biasing current is used instead of 20 times tap value current, the pickup of the upper unit will be less than before for the first application of pickup current. Pickup will be further reduced with the second application of pickup current, but the current will be stable after this energization. However, this value of pickup will be lower than the limits of 25% and 33% of tap value current. This is in the direction of making the sensitivity of the polar unit lower than 30%, but does not impair the performance of the unit on inrush currents.

b. Differential Unit (DU)

Set the adjustable resistor at top of the relay in the approximate center of its range. Open the switch and pass I_{ac} = 20 times tap value current. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right-hand shunt of lower polar unit until it trips with I_{ac} = 30% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. If polar unit resets before 15% of tap value current, no adjustments are necessary to the left-hand shunt. Repeat these steps until the lower polar unit will pickup at 30% of tap value current and reset for values of tap value current greater than 15%

Indicating Instantaneous Trip Unit (IIT)

With switch open, pass I_{ac} = 10 times tap value current. Adjust core of the instantaneous trip unit until it picks up. Its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging contact should touch both stationary contacts simultaneously.

Harmonic-Restraint Unit (HRU)

Close switch to position 2. Short out I_{LR} ammeter. Adjust direct current until I_{dc} reads 0.8 times tap setting. Gradually increase alternating current until upper polar unit operates with I_{ac} reading between 1.3 and 1.8 times tap setting. The percent second harmonic in the wave may be derived by the use of the formula:

$$\% \text{ second harmonic} = \frac{47 I_{dc}}{I_{ac} + 1.11 I_{dc}}$$

This formula is plotted in curve form in Fig. 16 for I_{dc} = 4 amperes.

Percentage Slope Characteristic (DU)

Close switch to position 1. Set I_{ac} to zero and I_{LR} to 5.5 times tap value current. Then adjust I_{ac} to 4 times tap value current.

Adjust resistor at top of relay until lower polar unit operates. Interchange lead positions to terminals 5 and 7 and repeat the above test. The lower polar unit should operate between the limits of:

I_{ac} = 4 times tap value current

I_{LR} = 9 to 10 times tap value current

Trip condition can best be determined by holding I_{ac} at 4 times tap value current and varying I_{LR}. If I_{LR} is too low the contacts will be closed when the currents are first applied. Hence, I_{LR} should be increased until the contacts open and then decreased until contacts close.

The adjustment of the resistor will have some effect on the pickup of the unit. Hence, recheck the pickup. If necessary readjust shunts to obtain a pickup of 30% of tap value current and dropout of 15% or greater of tap value current. If shunts are changed, check to see that above readings are obtained on the higher restraint currents. If necessary readjust resistor and repeat procedure until the unit operates within the specified limits.

Apply I_{ac} = .56 times tap value and vary I_{LR} until lower polar unit operates. The lower polar unit should operate between following limits.

I_{LR} = 2.36 to 2.56 times tap value current.

Indicating Contactor Switch (ICS)

Block polar unit contacts closed. Pass sufficient direct current through the trip circuit to close the contacts of the ICS. This value of current should be not greater than the particular tap setting being used. The operation-indicator target should drop freely.

The contact gap should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

Calibration (35%-Sensitivity Relays)

The differential unit (DU) should first be calibrated as outlined under "Calibration (All Relays)". Next the right hand shunt of the lower polar unit should be turned out until the relay operates at

I_{ac} = .45 times tap value current

I_{LR} = 1.64 times tap value current

This changes the percentage slope curve of the relay to that shown by the 35 percent sensitivity curve of figure 7. Pickup of the relay is increased from 30% to approximately 35% of tap value current and the curve is changed at low values of restraint current to that shown in figure 7. At large values of restraint current the percentage slope characteristic is essentially the same as shown in figure 8.

As shown in figure 7, the margin of safety between the relay calibrated for a 35% sensitivity and the 20% mismatch curve is the same as that of the relay calibrated for a 30% sensitivity and the 15% mismatch curve. This margin of safety is also shown in the voltage differential characteristic of figure 11 for the 35 percent sensitivity relay.

Electrical Checkpoints

Differential Unit

a. *Restraint Circuit*

Apply two times tap-value current successively to each restraint transformer. This is done by connecting leads to a tap screw and to terminals 5, 7 and 9 in turn (Terminal 9 on HU-1 only). Now measure the a-c voltage across the restraint rectifier bridges (See Fig. 2) using a high-resistance voltmeter (5000 ohms per volt). The voltage should be measured from the left-to the right-hand corners of the bottom set of bridges. A voltage of 2.17 to 2.27 volts should appear only across the appropriate bridge as specified in the following table:

Current in Term.	Associated Rectifier Bridge (Rear View) HU	HU-1
5	Center	Center
7	Right Hand	Left Hand
9	—	Right Hand

b. Operating Circuit

Apply 30 per cent tap-value current to terminal 3 and a tap screw. Using a high-resistance a-c voltmeter measure the voltage on the operating coil bridge across the left-to right-hand corners (See Fig. 2). The voltage should be approximately 2.4 volts. Now, measure the voltage output of the operating transformer (top two coil terminals). The voltage should be about 5.3 volts.

Harmonic Restraint Unit (HRU)

Apply 30 per cent tap-value current to terminal 3 and a tap screw. The following are the approximate voltages that should be obtained using a high-resistance a-c voltmeter (See Fig. 2 for location):

1. Output of operating transformer (top coil terminals)	4.0 volts
2. 4 mfd. capacitor	2.5 volts
3. 0.45 mfd. capacitor	3.9 volts
4. Operating-rectifier bridge (left-to right-hand corners)	2.5 volts
5. Restraint-rectifier bridge (left-to right-hand corners)	0.6 volts
6. Series Filter-Reactor	0.2 volts

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

APPROXIMATE RESISTANCE VALUES OF COMPONENTS IN HU RELAY

Unit	Circuit	Description
Harmonic Restraint	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 50 to 70 ohms.
		Reactor d.c. Resistance 8 to 10 ohms.
		4 MFD Capacitor.
		Rectifier 700 Volts, 600 Milliampere Silicon Diodes
		Indicating Instantaneous Trip Unit 14 to 16 ohms.
		Polar Unit Coil d.c. Resistance 80 to 100 ohms.
	Restraint	Series Reactor d.c. Resistance 110 to 130 ohms.
		Parallel Reactor d.c. Resistance 300 to 360 ohms.
		.45 MFD Capacitor.
		Rectifier 200 Volts, 600 Milliampere Silicon Diodes
		Polar Unit Coil d.c. Resistance 650 to 800 ohms.
		Varistor 100,000 ±10% at 10 V.D.C. 4000 ±25% at 30 V.D.C.
Differential	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 20 to 30 ohms.
		Adjustable 3½ inch 280 ohm Resistor
		Rectifier 700 Volts, 600 Milliampere Silicon Diodes
		Polar Unit Coil d.c. Resistance 75 to 100 ohms.
	Restraint	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9)
		Rectifier 200 Volts, 600 Milliampere Silicon Diodes
		Polar Unit Coil d.c. Resistance 60 to 110 ohms.
Indicating Contactor Switch	Trip	0.2 Amp. tap 6.5 ohms d.c.
		2.0 Amp. tap 0.15 ohms.d.c.

ENERGY REQUIREMENTS

Burden of Each Restraint Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	volt amperes † at 8 times tap value current	volt amperes † at 20 times tap value current
2.9	10	71	.88	50	191
3.2	12	70	.89	51	211
3.5	13	66	.90	51	203
3.8	14	65	.91	53	220
4.2	15	58	.91	53	235
4.6	16	57.5	.91	55	248
5.0	18	52.5	.92	59.	280
8.7	22	30	1.28	94.	340

Burden of Operating Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	volt amperes † at 8 times tap value current	volt amperes † at 20 times tap value current
2.9	10	35	2.26	76	487
3.2	12	34	2.30	78	499
3.5	13	33	2.30	81	504
3.8	14	33	2.30	83	547
4.2	15	31	2.30	84.	554
4.6	16	30	2.40	88.	598
5.0	18	29	2.50	92.	640
8.7	22	23	3.18	132.	850

θ Degrees current lags voltage at tap value current

† Voltages taken with Rectox type voltmeter

*** Thermal Rating**

One Second — 300 amperes

Thermal capacities for short times other than one second may be calculated on the basis of time being inversely proportional to the square of the current.

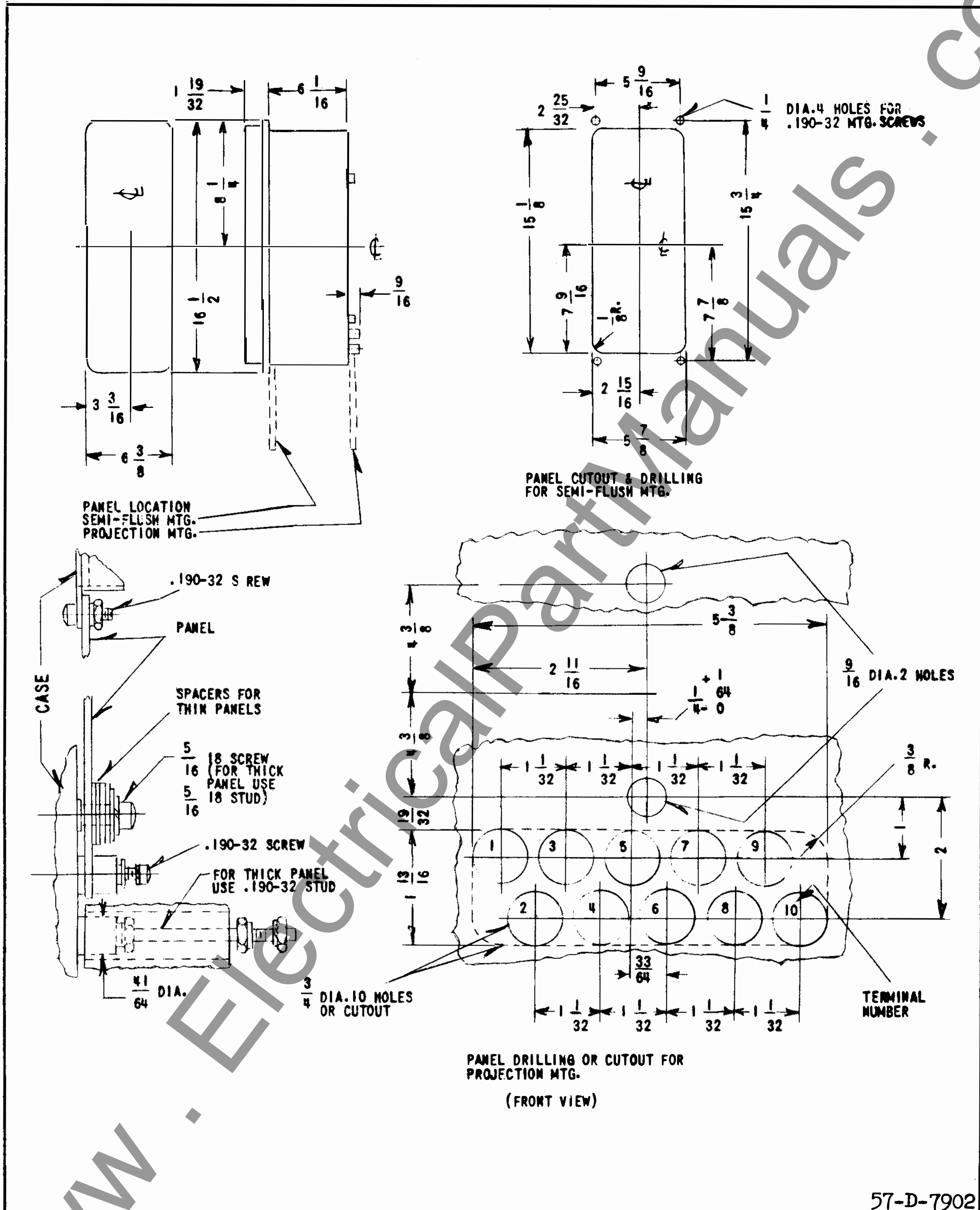


Fig. 17. Outline and Drilling Plan of the Type HU and HU-1 Relays in the FT31 Case.

WESTINGHOUSE ELECTRIC CORPORATION

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

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES HU AND HU-1 TRANSFORMER DIFFERENTIAL RELAYS

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

APPLICATION

* The types HU and HU-1 relays are high-speed single phase relays used in the differential protection of transformers. These relays can be applied where the magnetizing inrush current to the transformers is severe.

Current transformer ratio error should not exceed 10% with maximum external fault current flowing, or with eight times relay tap current flowing.

The HU-1 relay has three restraint transformers and associated rows of taps; whereas, the HU relay has one less restraint transformer and two rows of taps. Otherwise the two relays are identical. Three-winding banks normally require the HU-1 relay, although the autotransformer application uses the HU if the tertiary is not loaded.

Both the HU or the HU-1 are available with a sensitivity of either 0.30 or 0.35 times tap. The 30%-sensitivity relay satisfactorily handles up to 15% mismatch (e.g. ± 10% transformer tap changing plus 5% CT mismatch). The 35%-sensitivity relay handles as much as 20% mismatch. See Fig. 7 for a comparison of the characteristics of the two sensitivities. Any of the relays may be recalibrated in the field to obtain either characteristic.

Ordinarily the 30%-sensitivity relay will suffice; however, where CT mismatch is abnormally high or where the transformer tap-changing range exceeds ± 10%, this calibration may be too sensitive.

CONSTRUCTION

The types HU and HU-1 relays consist of a differential unit (DU), a harmonic-restraint unit (HRU), and an indicating contactor switch (ICS). The principal parts of the relay and their locations are shown in Figs. 1 to 4.

Differential Unit (DU)

The differential unit of the HU relay consists of two air-gap restraint transformers, three full-wave rectifiers, saturating operating-transformer, and a d-c polar unit.

The HU-1 relay, in addition to the above components, has a third air-gap restraint transformer, and a fourth full-wave rectifier.

Each of the restraint transformers and the operating transformer are provided with taps to compensate for mismatch of line current transformers. These taps are incorporated in the relay in such a manner that changing a tap on a restraint transformer automatically changes the same tap on the operating transformer.

Harmonic-Restraint Unit (HRU)

The harmonic-restraint unit of the HU and HU-1 relays consists of an air-gap operating transformer, a second harmonic block filter, a fundamental block-second harmonic pass filter, two full-wave rectifiers, indicating instantaneous trip unit, varistor, and a d-c polar unit.

Taps are also incorporated in this unit to compensate for mismatch of the line current transformers. Changing a tap on the restraint transformer of the differential unit also changes the tap of this unit.

Polar Unit

The polar unit consists of a rectangular shaped

SUPERSEDES I.L. 41-347.1G
*Denotes change from superseded issue.

EFFECTIVE NOVEMBER 1968

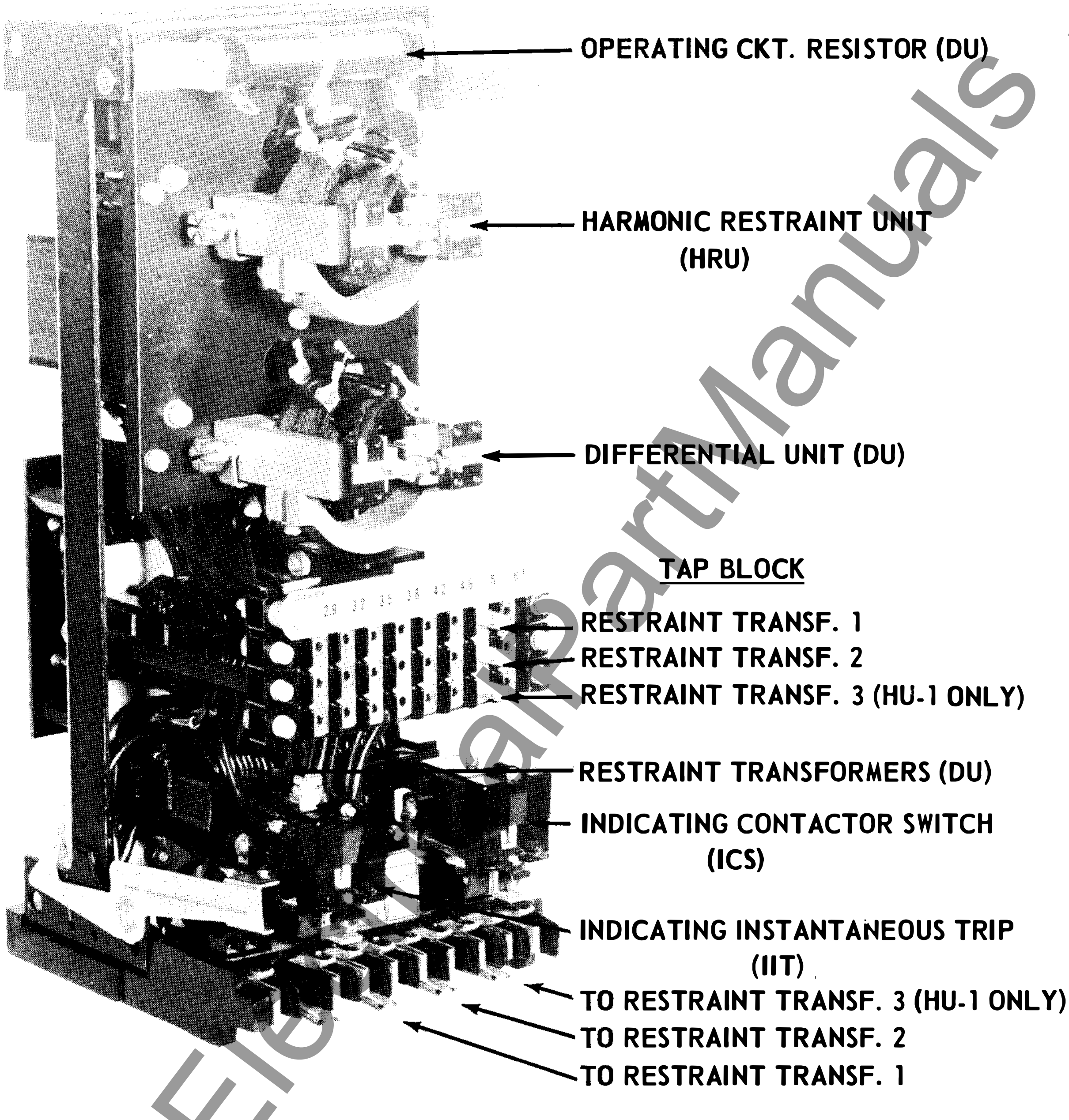


Fig. 1. Type HU-1 Relay – Front View.

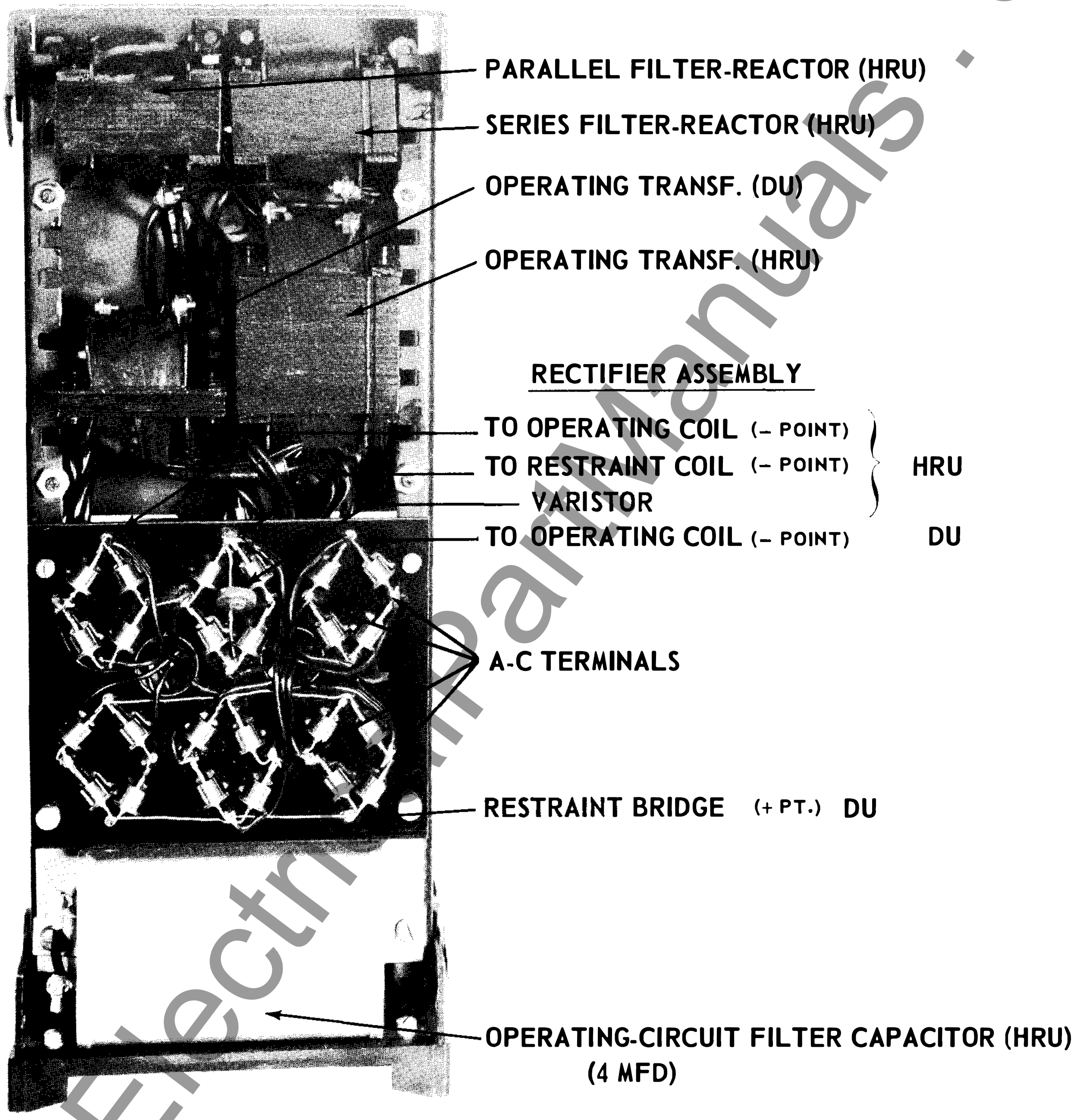
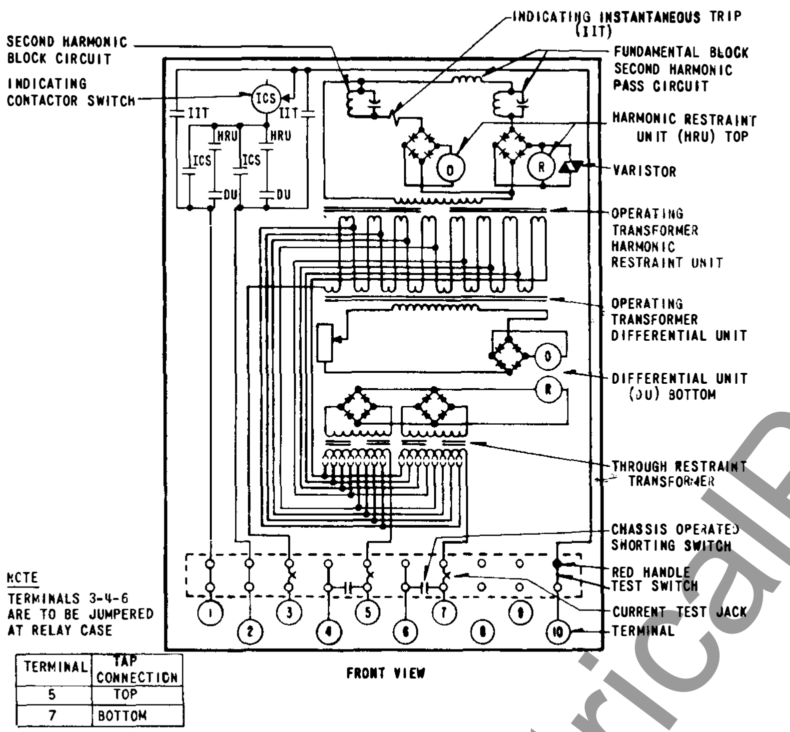
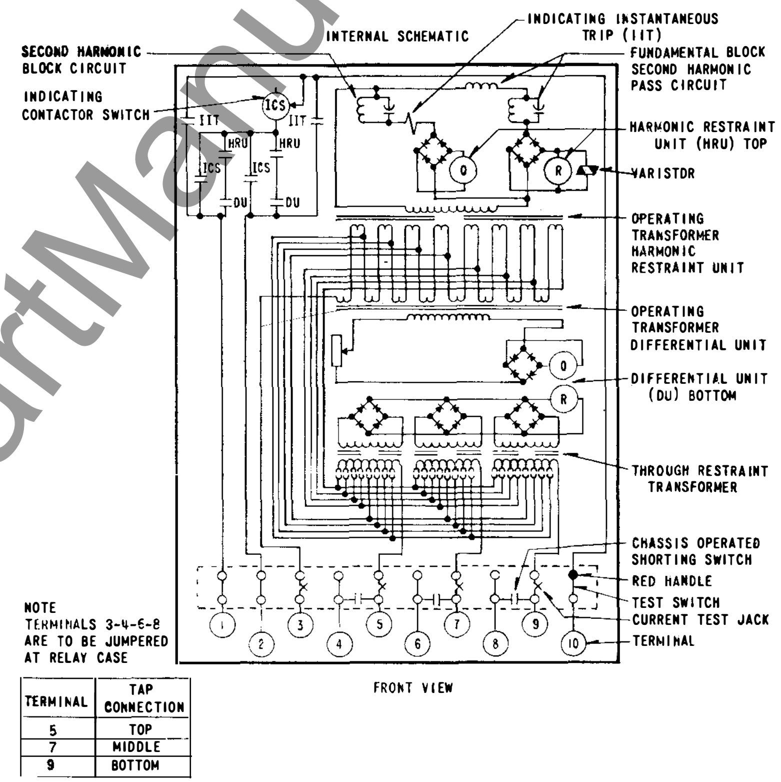


Fig. 2. Type HU-1 Relay — Rear View.



TERMINAL	TAP CONNECTION
5	TOP
7	BOTTOM

Fig. 3. Internal Schematic of the Type HU Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted, 184A762.



TERMINAL	TAP CONNECTION
5	TOP
7	MIDDLE
9	BOTTOM

Fig. 4. Internal Schematic of the Type HU-1 Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted, 184A736.

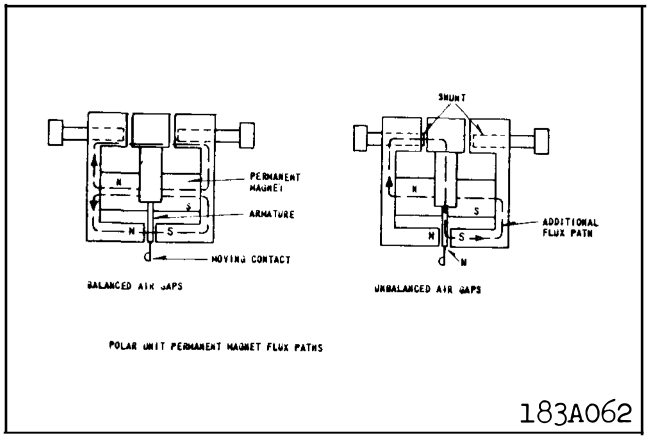


Fig. 5 Polar Unit Permanent Magnet Flux Paths.

magnetic frame, an electromagnet, a permanent magnet, and an armature. The poles of the crescent shaped permanent magnet bridge the magnet frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These non-magnetic joints represent air gaps, which are bridged by two adjustable magnetic shunts. The windings are wound around a magnetic core. The armature is fastened to this core and is free to move in the front air gap. The moving contact is connected to the free end of a leaf spring, which, in turn, is fastened to the armature.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper-type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also, during this operation, two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop.

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

OPERATION

The types HU and HU-1 relays are connected to the protected transformer as shown in Fig. 6. In such a connection, the relays operate to protect the transformer for faults internal to the differential zone of the transformer, but not for faults external to the zone. Neither do the relays operate on magnetizing inrush currents associated with energization of the transformer, even though these currents may appear as an internal fault. To avoid these false operations, each unit of the relay performs a separate function. The differential unit (DU) prevents operation on external faults, while the harmonic-restraint unit (HRU) prevent operations on magnetizing inrush currents. Hence, the operation of the relay can best be described under the headings of external fault current, internal fault currents, and magnetizing inrush currents.

External Fault Currents

The types HU and HU-1 relays have a variable percentage characteristic. This means that the operating current required to close the contact of the differential unit expressed in percent of restraint current varies with the magnitude of the larger restraint current. Fig. 7 and Fig. 8 illustrate this characteristic. To use these curves, divide each restraint current by the appropriate tap and enter the horizontal axis using the larger or largest restraint multiple. Then enter the vertical axis, using the difference of the restraint multiples.

With the relay connected as shown in the schematic diagram of Fig. 9a, an external fault causes currents to flow in the air-gap restraint transformers of the differential unit. If the line current transformers do not saturate and the correct ratio matching taps applied, no effective current flows in the operating transformer of the relay. Hence, only a contact-opening torque is produced on the differential unit.

On heavy external faults where a main current transformer saturates, current flows in the operating circuit of the relay. With such a condition, the harmonic-restraint unit may or may not close its contacts, depending upon the harmonics present in the false operating current. However, operation of the relay is prevented by the variable percentage characteristic of the differential unit, since a large differential current is required to close its contacts during heavy external faults.

Internal Faults

In the case of an internal fault as shown in Fig. 9b, the restraint of the differential unit is proportional to the largest restraint current flowing. The sum of the two restraint currents flows into the operating transformer and produces an excess of operating torque, and the differential unit operates.

In the case of an internal fault fed from one source only, the fault current flows in one restraint

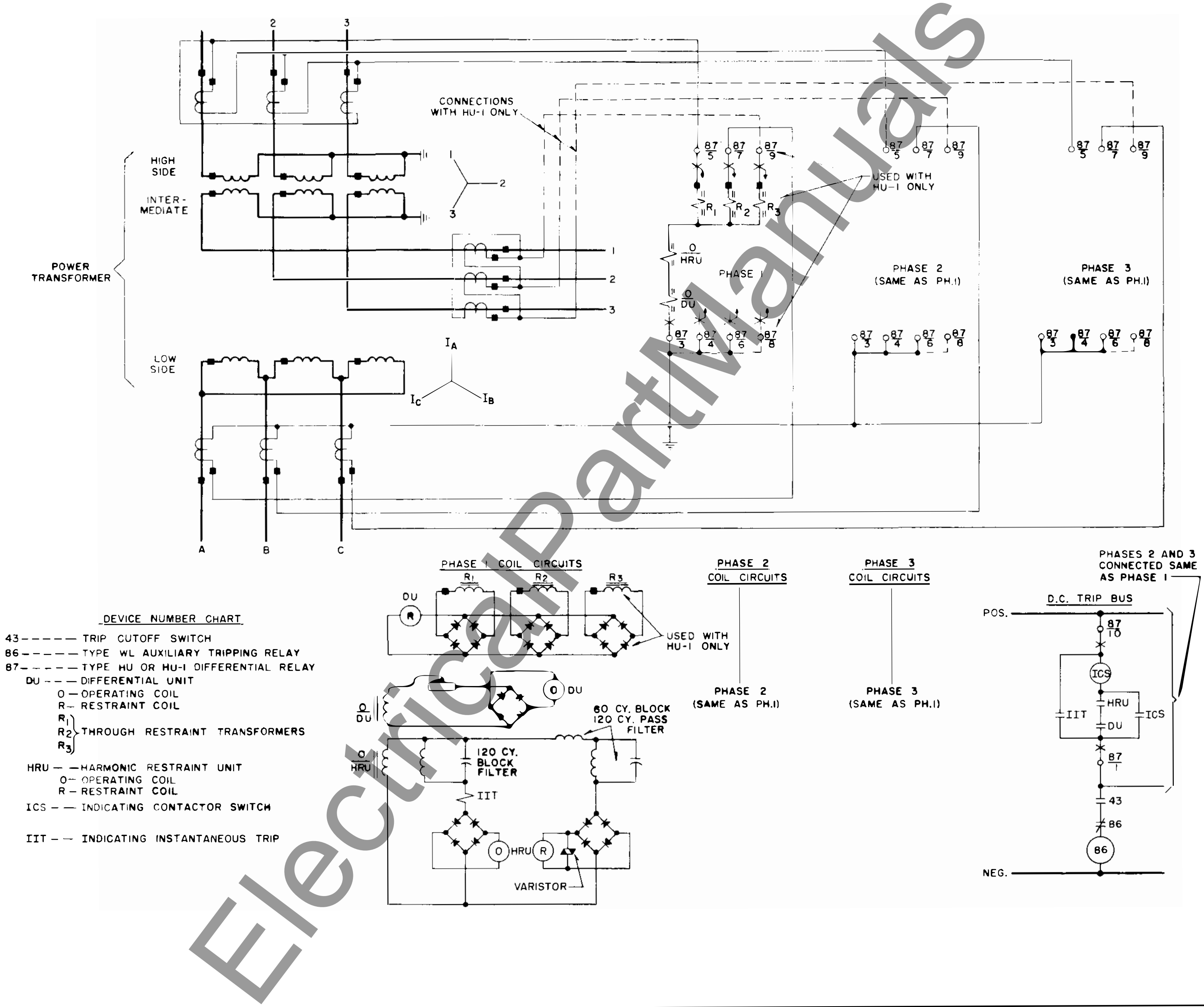


Fig. 6. External Schematic of the Type HU and HU-1 Relays.

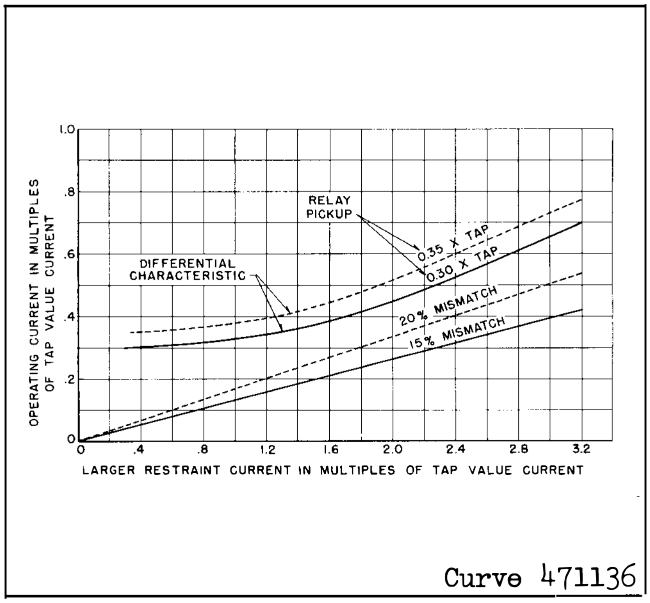


Fig. 7. Differential Characteristic of the DU Unit of the HU and HU-1 Relays at Smaller Values of Current. Actual Operating Current Shown for 15 and 20% Mismatch.

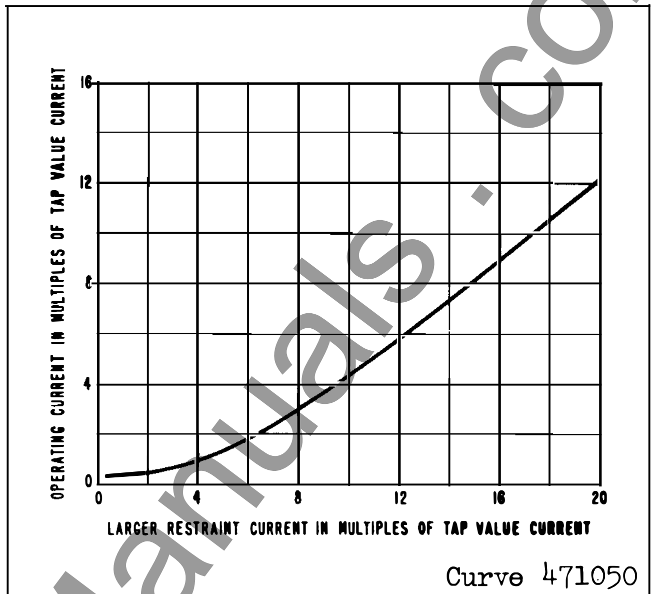


Fig. 8. Differential Characteristic of the Differential Unit (DU) of the HU and HU-1 Relays at Larger Values of Current.

transformer and the operating transformer. An excess of operating torque is produced on the differential unit and it operates.

Faults normally appear as an offset sine wave with a decaying d-c component, and contain very few harmonics. As a result, the harmonic-restraint unit will operate during internal faults to permit tripping of the relay.

For heavy internal faults, the indicating instantaneous trip unit (IIT) will operate before the main unit. Since this unit is connected to an air gap transformer, essentially only the sine wave component of an internal fault is applied to the IIT unit. The d.c. component of the fault is bypassed by the transformer primary. For example, an internal fault with a first peak of 28 times tap value (includes fifty percent d.c.) is reduced to a first peak of approximately 14 times tap value (d.c. component absent) on the secondary of the transformer. The IIT unit will just operate on this wave since it is set to pick up at a peak current of 14.1 times tap (r.m.s. pick-up value = 10 times tap).

The varistor connected across the d.c. side of the restraint rectifier of the harmonic restraint unit prevents excessive voltage peaks from appearing across the rectifiers. These peaks arise through transformer action of the harmonic-restraint polar-unit coils during heavy internal faults. The varistor has a large value of resistance for low voltages, while presenting a low value of resistance for high voltages. This characteristic effectively reduces the voltage spikes on heavy internal faults while not hampering performance during inrush, where the voltage is considerably lower.

Magnetizing Inrush Currents

Magnetizing inrush current waves have various wave shapes. A typical wave appears as a rectified half wave with decaying peaks. In any case, the various wave shapes are rich in harmonics with the second harmonic predominant. Since the second harmonic is always present in inrush waves and not in internal fault waves, this harmonic is used to restrain the harmonic-restraint unit during inrushes. The differential unit may or may not close its contact, depending on the magnitude of the inrush.

When a magnetizing inrush wave is applied to the relay, the d-c component of the wave is by-passed by the air-gap operating transformer. The other components are fed into the filter circuits. The impedance characteristics of these filters are such that the second harmonic component flows into the restraint coil of the polar unit, while the other harmonics flow into the operating coil. The polar unit will not close

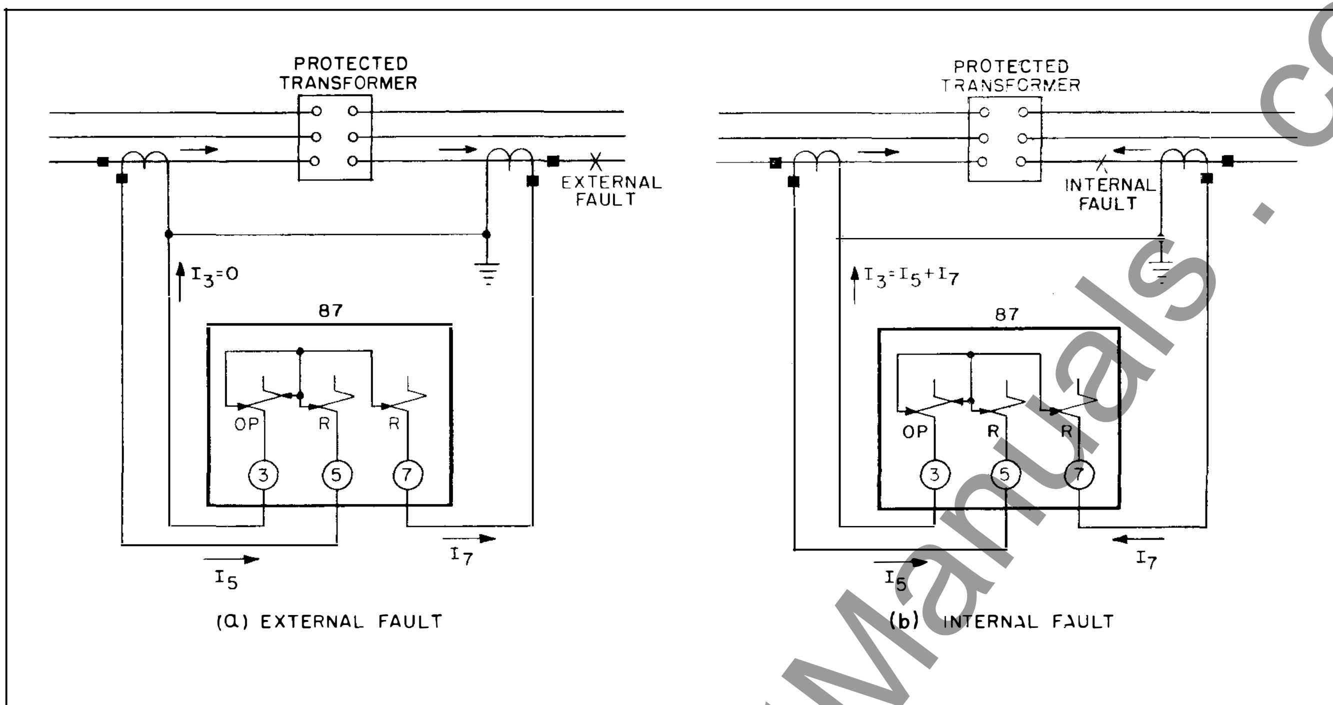


Fig. 9. Simplified Schematic of the Type HU Relay with Current Distribution for (a) External Fault (b) Internal Fault.

its contacts unless the second harmonic content is less than 15 percent of the fundamental component.

The indicating instantaneous trip unit (IIT) will not operate on inrush. The air-gap transformer will bypass the d.c. component of the inrush thereby reducing the magnitude of the wave applied to the IIT unit. If the inrush has an initial peak of 16 times tap-value current, the air-gap transformer will reduce this peak to approximately 8 times tap value on the secondary of the transformer. Since the IIT unit is set for a peak value of 14.1 times tap (r.m.s. pick-up value = 10 times tap), it will not operate on this inrush.

Breaker Maintenance

Before some of the CT's are bypassed for breaker maintenance the trip circuit should be opened, as shown in Fig. 6. Otherwise the false-unbalanced current will cause the relay to trip. It is not necessary to short-circuit the relay operating circuit since it has an adequate continuous-current rating. (See "Energy Requirements").

CHARACTERISTICS

Taps are incorporated in the HU and HU-1 relays to compensate for main current transformer mismatch. These taps are as follows: 2.9, 3.2, 3.5, 3.8, 4.2, 4.6, 5.0, 8.7.

To measure the effective unbalance, a sensitive low-reading voltmeter (5000 ohms per volts) can temporarily be connected across the operating coil resistor (at top of case). With a perfect balance the voltmeter reading will be zero. The reading should not exceed the values indicated by the 15% mismatch curve in Fig. 10 when the relay pickup is 0.30 times tap. If the amount of mismatch is measured or calculated, the measured voltage can be checked against the interpolated value from the curve. For example, assume that the larger restraint current is measured as 1.5 tap multiple and the calculated mismatch is 7%. Then, from Fig. 10 the measured voltage should be approximately 1.0 volts. Use Fig. 11 if the pickup is 0.35 times tap.

Pickup of the harmonic-restraint unit and the differential unit is either 30 or 35% of tap value current. Pickup of the indicating instantaneous trip unit is ten times tap value current.

Components of the harmonic-restraint unit are selected such that 15% second harmonic will prevent operation of the unit. This factor is adequate to prevent false operation on inrushes.

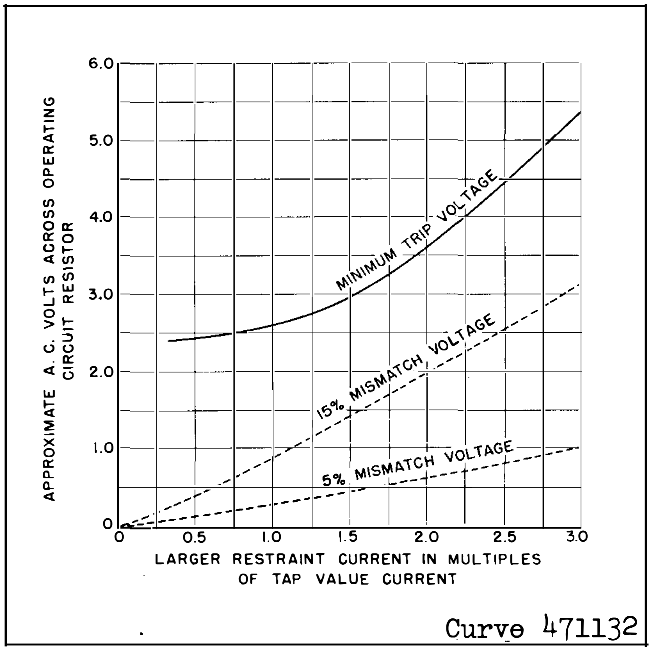


Fig. 10. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.30 Times Tap.

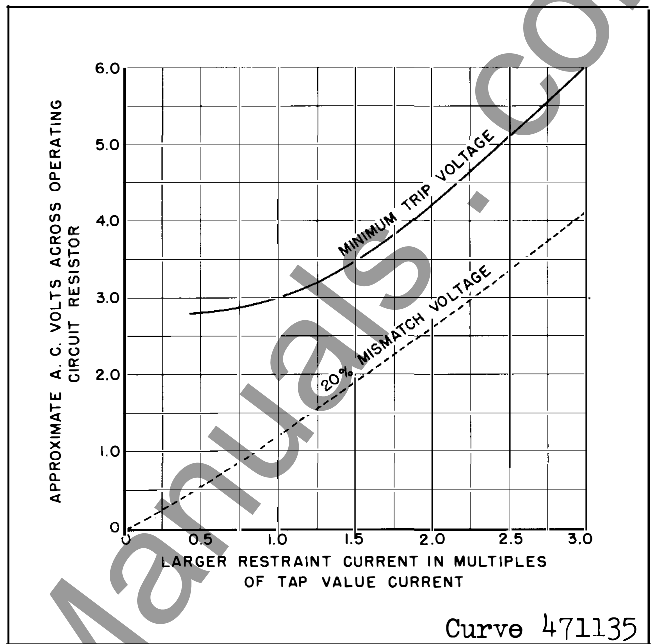


Fig. 11. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.35 Times Tap.

The frequency response of the HU and HU-1 relays is shown in Fig. 13.

Trip Circuit

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

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

SETTING

To set the relay, calculations must be performed as shown under "Setting Calculations". After the correct tap is determined, connections can be made to the relay transformers by placing the connector screws in the various terminal-plate holes in front of the relay. Only one tap screw should be inserted in any horizontal row of taps.

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-or 250-volt d-c type WL relay switch, or equivalent, use the 0.2-ampere tap; for 48 volt DC applications set relay in 2 tap and use Type WL Relay coil S#304C209G01 or equivalent.

Indicating Instantaneous Trip (IIT)

No setting is required on the indicating instantaneous trip unit. This unit is set at the factory to pickup at 10 times tap value current.

SETTING CALCULATIONS

Select the ratio matching taps. There are no other settings. In order to calculate the required tap settings and check current transformer performance the following information is required.

Required Information

1. Maximum transformer power rating $(KVA)_M$
2. Maximum external fault currents
3. Voltage ratings of power transformer (V_H, V_I, V_L)
4. Current transformer ratios, full tap (N_T)
5. Current transformer "10L" accuracy class

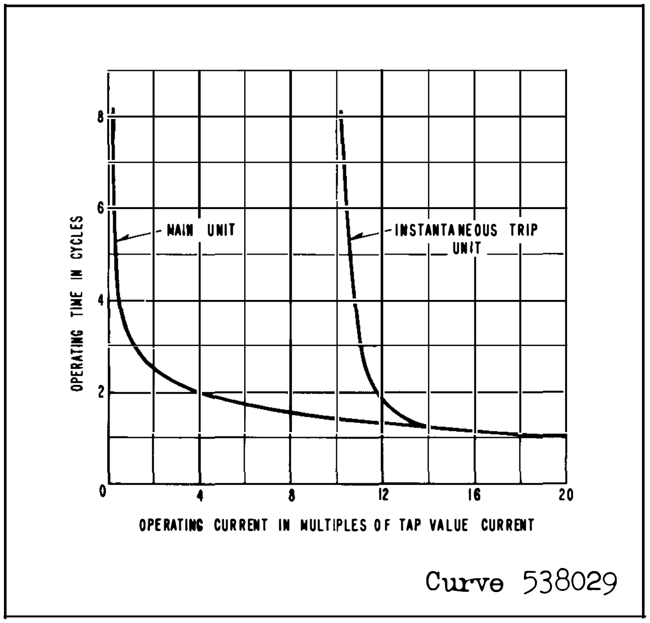


Fig. 12. Typical Tripping Time Characteristic (60 Cycle Currents).

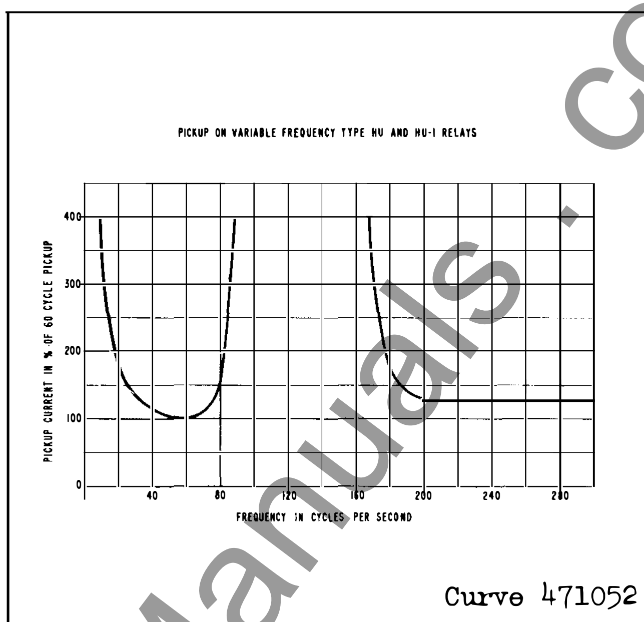


Fig. 13. Typical Frequency Response of the HU and HU-1 Relays.

voltage, (or excitation or ratio-overcurrent curve)

6. One way current transformer lead resistance at 25°C (R_L) (when using excitation curve, include CT winding resistance)
7. Current transformerconnections(wye or delta)

Definitions of Terms

I_P = Primary current at $(KVA)_M$

I_R = Relay input current at $(KVA)_M$

I_{RH}, I_{RL}, I_{RI} are same as I_R except for high, low and intermediate voltage sides respectively.

I_S = CT secondary current at $(KVA)_M$

T_H, T_L, T_I = Relay tap settings for high, low and intermediate voltage windings, respectively.

N = Number of current transformer turns that are in use.

$N_P = N/N_T$ (Proportion of total turns in use)

N_T = Current transformer ratio, full tap

V_{CL} = 10L accuracy class voltage

Z_A = Burden impedance of any devices other than the HU or HU-1 relays, with maximum phase-to-phase or 3-phase current flowing.

Z_T = Total secondary burden in ohms (excluding current transformer winding resistance, except when using excitation curve)

Calculation Procedure

1. *Select current transformer taps,* where multi-ratio types are used.

   I_R should be more than 2.9 amperes for high sensitivity and should not exceed the relay continuous rating (see "Energy Requirements"). For determining the required continuous rating of the relay, use the expected two-hour maximum load, since the relay reaches final temperature in this time.

2. *Select relay taps in proportion to the relay currents,* I_R.

   I_R should not exceed relay continuous rating. Also the maximum external fault current should not exceed 20 times relay tap.

3. *Determine Mismatch* (Not to exceed 15%)

   For 2 winding banks:

$$\%\ \text{mismatch} = 100\ \frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{S} \qquad (1)$$

   where S is the smaller of the two terms, (I_{RL}/I_{RH}) or (T_L/T_H)

   For 3 winding banks:

$$\%\ \text{mismatch} = 100\ \frac{(I_{RH}/I_{RI}) - (T_H/T_I)}{S} \qquad (2)$$

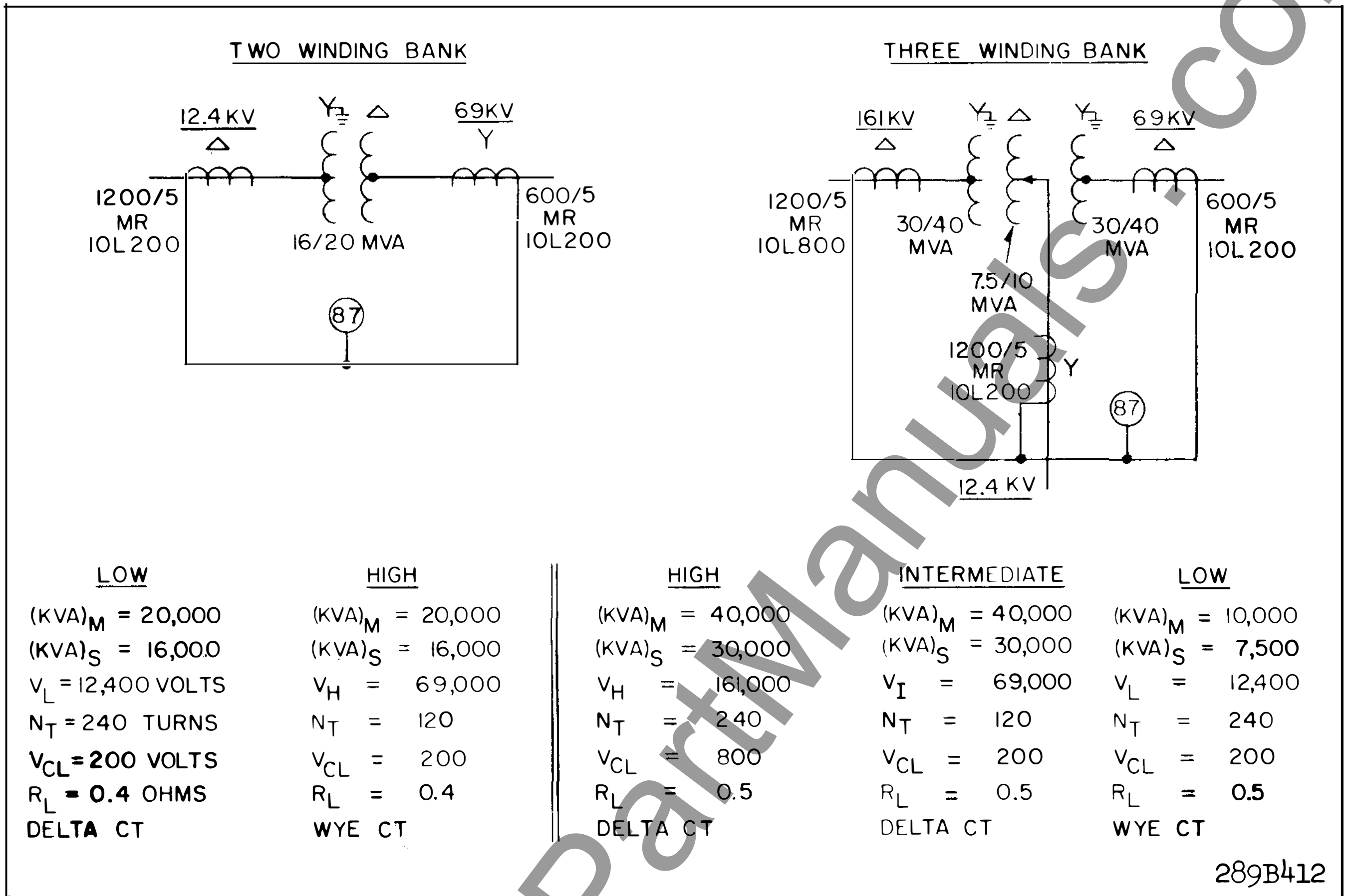


Fig. 14. ***Example for Setting Calculations.***

where "S" is the smaller of the two terms, (I_{RH}/I_{RI}) or (T_H/T_I).

Equations similar to eq. (2) apply for mismatch from the high to low and from the intermediate to low voltage windings.

Where tap changing under load is performed the relays should be set on the basis of the middle or neutral tap position. The total mismatch, including the automatic tap change should not exceed 15% with a 30% sensitivity relay, and 20% with a 35% sensitivity relay. Note from Fig. 7 that an ample safety margin exists at these levels of mismatch.

4. *Check current transformer performance.* Ratio error should not exceed 10% with maximum symmetrical external fault current flowing or with 8 times relay tap current flowing. An accurate method of determining ratio error is to use ratio-correction-factor curves (RCF).

A less accurate, but satisfactory method is to utilize the ASA relaying accuracy classification. If the 10L accuracy is used, performance will be adequate if:

$$\frac{N_P V_{CL}}{100} \text{ is greater than } Z_T \qquad (3)$$

For wye-connected CT:

Z_T = lead resistance + relay burden + Z_A

$$= 1.13\ R_L + \frac{0.15}{T} + Z_A \text{ ohms} \qquad (4)$$

(R_L multiplier, 1.13, is used to account for temperature rise during faults. $\frac{0.15}{T}$ is an approximation, where T = relay tap.

Z_A is any additional burden, when maximum external 3-phase fault current is flowing).

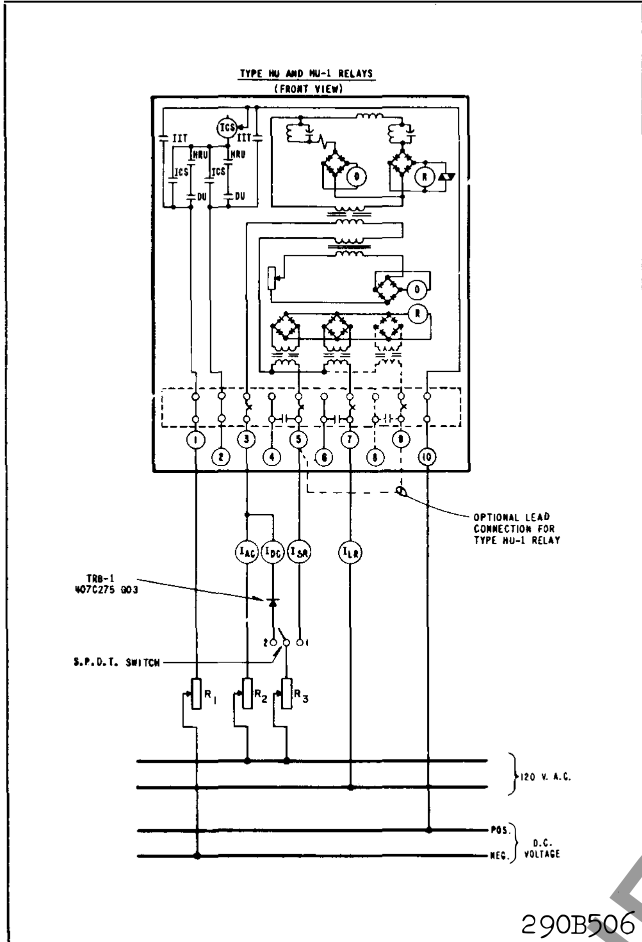


Fig. 15. Test Circuit of the HU and HU-1 Relays.

For delta-connected CT:

$$Z_T = 3\,(1.13\,R_L + \frac{0.15}{T} + Z_A)\text{ ohms}$$

$$= 3.4\,R_L + \frac{0.45}{T} + 3Z_A \qquad (5)$$

(The factor of 3 accounts for conditions existing during a phase-to-phase fault. Z_A is any additional burden, when maximum external phase to phase fault current is flowing)

5. *Examples*

Refer to pages 13 and 14 and figure 14 for setting examples. Note in both examples that the 8.7 tap was selected as the first step in selecting relay taps. If a lower tap such as tap 5 had been the first selection, a proper balance would have been impossible. On page 12 for the two winding bank,

$$\frac{I_{RL}}{I_{RH}} = \frac{8.05}{4.18} = 1.92.$$ With tap 5 for the low side the maximum current ratio that can be matched by the taps is $\frac{5}{2.9} = 1.73$. With tap 8.7 selected for the low side, a 3 to 1 current ratio can be matched. On page 13 for the three winding bank,

$$\frac{I_{RL}}{I_{RH}} = 3.02$$

This current ratio can be accommodated by the 8.7 & 2.9 taps without excessive mismatch.

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 to the terminal studs furnished with the relay for thick-panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer.

Acceptance Tests

The following check is recommended to insure that the relay is in proper working order. All checks can best be performed by connecting the relay per the test circuit of Fig. 15. Relay to be tested in case.

1. Minimum Trip Current. With switch open and relay set on 5-ampere tap, apply 1.35 to 1.65 amperes for the 30%-sensitivity relay and 1.6 to 1.9

TWO-WINDING TRANSFORMER CALCULATIONS

(See Figure 14)

	LOW	HIGH
1. Select CT Ratio:		
$I_P = \dfrac{(KVA)_M}{\frac{V\sqrt{3}}{1000}} =$	$\dfrac{20{,}000}{12.4\sqrt{3}} = 930$ Amp.	$\dfrac{20{,}000}{69\sqrt{3}} = 167$ Amp.
Select Ratio	1000/5 (N = 200)	200/5 (N = 40)
2. Select Relay Taps:		
$I_S = \dfrac{I_P}{N} =$	$\dfrac{930}{200} = 4.65$ Amp.	$\dfrac{167}{40} = 4.18$ Amp.
$I_R =$	$I_{RL} = 4.65\sqrt{3} = 8.05$ Amp.	$I_{RH} = 4.18$ Amp.
Select Tap	$T_L = 8.7$	$T_H = \dfrac{4.18}{8.05} \times 8.7 = 4.64$
Desired Tap		$T_H = 4.6$
3. Determine Mismatch: % Mismatch = $100\,\dfrac{(I_{RL}/I_{RH}) - (T_L/T_H)}{T_L/T_H} =$	$100\,\dfrac{(8.05/4.18) - (8.7/4.6)}{8.7/4.6} =$ $100\,\dfrac{1.92 - 1.89}{1.89} =$ 1.6%	
4. Check CT Performance:		
$Z_T =$	$3.4\,R_L + \dfrac{0.45}{T} =$ $3.4 \times 0.4 + \dfrac{0.45}{8.7} = 1.36 + 0.05 =$ 1.41 ohms	$1.13\,R_L + \dfrac{0.15}{T} =$ $1.13 \times 0.4 + \dfrac{0.15}{4.6} = 0.45 + 0.03 =$ 0.48 ohms
$N_P = \dfrac{N}{N_T} =$	$\dfrac{200}{240} = 0.833$	$\dfrac{40}{120} = 0.333$
$\dfrac{N_P\,V_{CL}}{100} =$	$\dfrac{0.833 \times 200}{100} = 1.67$	$\dfrac{0.333 \times 200}{100} = 0.67$
$(N_P\,V_{CL}/100) > Z_T$	Yes	Yes

THREE-WINDING TRANSFORMER CALCULATIONS
(See Figure 14)

	HIGH	INTERMEDIATE	LOW
1. Select CT Ratio:			
$I_P = \frac{(KVA)_M}{\frac{V\sqrt{3}}{1000}} =$	$\frac{40,000}{161\sqrt{3}} = 143$ Amp.	$\frac{40,000}{69\sqrt{3}} = 334$ Amp.	$\frac{10,000}{12.4\sqrt{3}} = 465$ Amp.
Select Ratio	400/5 (N = 80)	600/5 (N = 120)	1000/5 (N = 200)
2. Select Relay Taps:			
$I_S = \frac{I_P}{N} =$	$\frac{143}{80} = 1.78$ Amp.	$\frac{334}{120} = 2.78$ Amp.	$\frac{465}{200} = 2.32$ Amp. (At 10 MVA)
I_R (At 40 MVA) =	$I_{RH} = 1.78\sqrt{3}$ $= 3.08$ Amp.	$I_{RI} = 2.78\sqrt{3}$. $= 4.82$ Amp.	$I_{RL} = \frac{40}{10} \text{ X } 2.32$ $= 9.3$ Amp.
Select Tap			$T_L = 8.7$
Desired Tap	$T_H = 8.7\frac{3.08}{9.30}$ $= 2.88$	$T_I = 8.7\frac{4.82}{9.30}$ $= 4.52$	
Select Tap	$T_H = 2.9.$	$T_I = 4.6$	
3. Determine Mismatch			
% Mismatch	$100\frac{(I_{RH}/I_{RI})-(T_H/T_I)}{T_H/T_I} =$ $100\frac{(3.08/4.82)-(2.9/4.6)}{2.9/4.6} =$ $100\frac{0.640-0.630}{0.630} =$ 1.6%	$100\frac{(I_{RI}/I_{RL})-(T_I/T_L)}{(I_{RI}/I_{RL})} =$ $100\frac{(4.82/9.30)-(4.6/8.7)}{4.82/9.30} =$ $100\frac{0.518-0.528}{0.518} =$ −1.9%	$100\frac{(I_{RL}/I_{RH})-(T_L/T_H)}{T_L/T_H} =$ $100\frac{(9.3/3.08)-(8.7/2.9)}{8.7/2.9} =$ $100\frac{3.02-3.00}{3.00} =$ 0.67%
4. Check CT Performance			
$Z_T =$	$3.4 R_L + \frac{0.45}{T} =$ $3.4 \text{ X } 0.5 + \frac{0.45}{2.9} =$ $1.70 + 0.16 =$ 1.86 ohms	$3.4 R_L + \frac{0.45}{T} =$ $3.4 \text{ X } 0.5 + \frac{0.45}{4.6} =$ $1.70 + 0.10 =$ 1.80 ohms	$1.13 R_L + \frac{0.15}{T} =$ $1.13 \text{ X } 0.5 + \frac{0.15}{8.7} =$ $0.565 + 0.02 =$ 0.58 ohms
$N_P = \frac{N}{N_T} =$	$\frac{80}{240} = 0.333$	$\frac{120}{120} = 1.0$	$\frac{200}{240} = 0.833$
$\frac{(N_P \ V_{CL})}{100} =$	$\frac{800 \text{ X } 0.333}{100} = 2.67$	$\frac{200 \text{ X } 1.0}{100} = 2.0$	$\frac{200 \text{ X } 0.833}{100} = 1.67$
$(N_P \ V_{CL}/100) > Z_T$	Yes	Yes	Yes

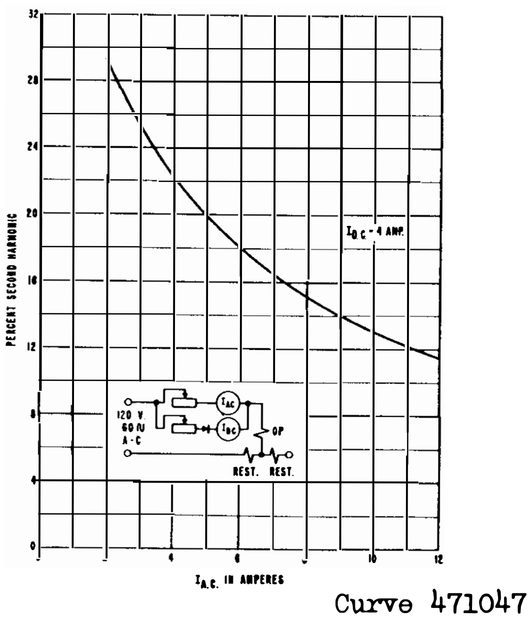


Fig. 16 ***Variation of Second Harmonic Content of Test Current.***

amperes for the 35% sensitivity relay. Relay should operate. The upper polar unit may operate for lower currents, but not below 1.0 ampere. This low pickup will not impair its operation on magnetizing inrush currents and should not be disturbed if it is found to be less than the lower polar unit. If a higher pickup is desired, it is suggested that 20 times tap value current be applied to relay terminals 3 & 7. This will cause the upper polar unit to pick up at a current of approximately 1.65 amperes.

2. Indicating instantaneous Trip Pickup. With switch open and relay set on 5 ampere tap, apply 50 amperes to relay. Indicating instantaneous trip should pick up and its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

3. Indicating Contactor Switch. Block Polar unit contacts closed. Pass sufficient direct 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 setting being used. The operation indicator target should drop freely.

The contact gap of the ICS should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

4. Differential Characteristic.

30% Sensitivity relay

* a. Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 10 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 12.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 to 2.95 amperes
I_{LR} = 11.8 to 12.8 amperes

b. Reverse leads to restraint transformers and repeat differential test outlined in paragraph 4a. Results should be approximately the same as obtained under paragraph 4a.

35% Sensitivity relay

* c. Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 9 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 11.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 amperes
I_{LR} = 10.8 to 11.8 amperes

* d. Reverse leads to restraint transformers and repeat differential test outlined in paragraph 4c. Results should be approximately the same as obtained under paragraph 4d.

5. Harmonic Restraint Characteristic. Close switch to position 2. Short out I_{LR} ammeter. Set I_{dc} to 4 amperes and adjust I_{ac} until upper polar unit operates. I_{ac} should read between 6.5 and 9 amperes. As shown in *Fig. 16*, these values of alternating current correspond to 17 percent and 14 percent second harmonic.

In Service Test

Table 1 is to be used as an in-service check of the HU or HU-1 relay using any tap combination. The relay should be connected as shown in fig. 15 with the S.P.O.T. switch in position 1. The ammeter I_{SR} measures the smaller restraint current and should be connected to the terminal associated with the tap block of the smaller setting. The ammeter I_{LR} measures the larger restraint current, and should be connected to the terminal associated with the larger tap block setting. Terminal 5 supplies the upper tap block; terminal 7 supplies the second tap block; and terminal 9 (HU-1 only) supplies the lower tap block (refer to figs. 1 and 4).

Table 1 gives the values of I_{AC} necessary to operate the relay when using a value of I_{SR} equal to 3 times tap value for all taps except the 8.7 tap. A value of I_{SR} equal to 2 times tap value was chosen for the 8.7 tap setting in order to keep the current at a convenient value for testing.

Example (HU Relay)

Upper Tap Block Tap 3.5
Lower Tap Block Tap 5.0

Since the upper tap block has the smaller tap setting I_{SR} should be connected to the upper tap block (Term. 5), and I_{LR} should be connected to Terminal 7. From Table 1 under "Restraint Transformer tap: Larger" = 5.0 "Smaller" = 3.5, set I_{SR} = 10.5 amps. The value of I_{AC} to operate the relay should be between 8.3 and 9.2 amps.

To check the third restraint winding on the HU-1 repeat the above procedure using terminal 9 and either terminal 5 or 7.

TABLE 1

Restraint Transformer Tap	Larger	2.9	3.2	3.5	3.8	4.2	4.6	5.0	8.7
Smaller	CURRENT IN AMPERES								
2.9	ISR	8.7	8.7	8.7	8.7	8.7	8.7	8.7	5.8
	IAC (Min.)	2.6	3.7	5.0	5.8	7.8	9.0	10.4	16.2
	IAC (Max.)	2.8	4.0	5.5	6.4	8.6	10.0	11.6	17.9
3.2	ISR		9.6	9.6	9.6	9.6	9.6	9.6	6.4
	IAC (Min)		2.7	4.0	4.9	6.9	8.1	9.6	15.7
	IAC (Max)		3.1	4.4	5.4	7.6	9.0	10.6	17.3
3.5	ISR			10.5	10.5	10.5	10.5	10.5	7.0
	IAC (Min)			3.0	3.8	5.7	6.9	8.3	14.5
	IAC (Max)			3.3	4.2	6.3	7.7	9.2	16.1
3.8	ISR				11.4	11.4	11.4	11.4	7.6
	IAC (Min)				3.2	5.2	6.5	7.9	14.1
	IAC (Max)				3.6	5.7	7.2	8.7	16.0
4.2	ISR					12.6	12.6	12.6	8.4
	IAC (Min)					3.5	4.7	6.2	12.9
	IAC (Max)					3.9	5.2	6.9	14.2
4.6	ISR						13.8	13.8	9.2
	IAC (Min)						3.9	5.3	12.4
	IAC (Max)						4.3	5.9	13.7
5.0	ISR							15.0	10.0
	IAC (Min)							4.3	11.6
	IAC (Max)							4.8	12.9
8.7	ISR								17.4
	IAC (Min)								5.0
	IAC (Max)								5.5

Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

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 contact.

Calibration (All Relays)

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. All adjustments to be done with relay inside its case. (See "Acceptance Check")

Polar Units

1. Contacts. Place a .060 to .070 inch feeler gage between the right hand pole face and the armature. This gap should be measured near the front of the right hand pole face. Bring up the backstop screw until it just makes with the moving contact. Place gage between moving contact and the stationary contact on the left-hand side of the polar unit. On the upper unit, the gap should be .046 inch and on the lower unit the gap should be .065 to .070 inch. Bring up the stationary contact until it just makes with the gage and lock in place.

2. Minimum Trip Current

a. Harmonic Restraint Unit (HRU)

Connect the relay per test circuit of Fig. 15. With the switch open, pass I_{ac} = 20 times tap value current into the relay. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right hand shunt on upper polar unit until it trips with I_{ac} = 33% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. Repeat these steps, if necessary, until the unit operates at 33% or slightly lower of tap value current immediately following the application of 20 times tap value current and until the unit resets at a value of current 15% of tap value or greater. After the dropout has been measured, the unit should pick up at 25% or higher of tap value current.

On the application of the high current, the upper polar unit will be biased in the restraining direction and pickup will be greater than the nominal value of 30% of tap value current on the first application of pickup current. If the circuit is deenergized and pickup is measured again, the pickup current will be less than before. However, pickup will be stable after the second application of pickup current. If 20 times tap value current is applied again, the pickup immediately after applying this current will be high. However, measuring the pickup the second time will show that the pickup is again reduced. The variation between these pickups should be between 25% and 33% of tap value current.

The filter circuits are charged by the application of this heavy current and upon the removal of the current, these circuits will discharge their energy. The element will be biased in the restraining direction because the restraint coil has approximately 7 times the number of turns as the operating coil. Upon the application of pickup current, the operating ampere turns will be greater than the restraint ampere turns and the bias will be removed.

If a lower biasing current is used instead of 20 times tap value current, the pickup of the upper unit will be less than before for the first application of pickup current. Pickup will be further reduced with the second application of pickup current, but the current will be stable after this energization. However, this value of pickup will be lower than the limits of 25% and 33% of tap value current. This is in the direction of making the sensitivity of the polar unit lower than 30%, but does not impair the performance of the unit on inrush currents.

b. Differential Unit (DU)

Set the adjustable resistor at top of the relay in the approximate center of its range. Open the switch and pass I_{ac} = 20 times tap value current. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right-hand shunt of lower polar unit until it trips with I_{ac} = 30% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. If polar unit resets before 15% of tap value current, no adjustments are necessary to the left-hand shunt. Repeat these steps until the lower polar unit will pickup at 30% of tap value current and reset for values of tap value current greater than 15%

Indicating Instantaneous Trip Unit (IIT)

With switch open, pass I_{ac} = 10 times tap value current. Adjust core of the instantaneous trip unit until it picks up. Its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging contact should touch both stationary contacts simultaneously.

Harmonic-Restraint Unit (HRU)

Close switch to position 2. Short out I_{LR} ammeter. Adjust direct current until I_{dc} reads 0.8 times tap setting. Gradually increase alternating current until upper polar unit operates with I_{ac} reading between 1.3 and 1.8 times tap setting. The percent second harmonic in the wave may be derived by the use of the formula:

$$\% \text{ second harmonic} = \frac{47\, I_{dc}}{I_{ac} + 1.11\, I_{dc}}$$

This formula is plotted in curve form in Fig. 16 for I_{dc} = 4 amperes.

Percentage Slope Characteristic (DU)

Close switch to position 1. Set I_{ac} to zero and I_{LR} to 5.5 times tap value current. Then adjust I_{ac} to 4 times tap value current.

Adjust resistor at top of relay until lower polar unit operates. Interchange lead positions to terminals 5 and 7 and repeat the above test. The lower polar unit should operate between the limits of:

I_{ac} = 4 times tap value current

I_{LR} = 9 to 10 times tap value current

Trip condition can best be determined by holding I_{ac} at 4 times tap value current and varying I_{LR}. If I_{LR} is too low the contacts will be closed when the currents are first applied. Hence, I_{LR} should be increased until the contacts open and then decreased until contacts close.

The adjustment of the resistor will have some effect on the pickup of the unit. Hence, recheck the pickup. If necessary readjust shunts to obtain a pickup of 30% of tap value current and dropout of 15% or greater of tap value current. If shunts are changed, check to see that above readings are obtained on the higher restraint currents. If necessary readjust resistor and repeat procedure until the unit operates within the specified limits.

Apply I_{ac} = .56 times tap value and vary I_{LR} until lower polar unit operates. The lower polar unit should operate between following limits.

I_{LR} = 2.36 to 2.56 times tap value current.

Indicating Contactor Switch (ICS)

Block polar unit contacts closed. Pass sufficient direct current through the trip circuit to close the contacts of the ICS. This value of current should be not greater than the particular tap setting being used. The operation-indicator target should drop freely.

The contact gap should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

Calibration (35%-Sensitivity Relays)

The differential unit (DU) should first be calibrated as outlined under "Calibration (All Relays)". Next the right hand shunt of the lower polar unit should be turned out until the relay operates at

I_{ac} = .45 times tap value current

I_{LR} = 1.64 times tap value current

This changes the percentage slope curve of the relay to that shown by the 35 percent sensitivity curve of figure 7. Pickup of the relay is increased from 30% to approximately 35% of tap value current and the curve is changed at low values of restraint current to that shown in figure 7. At large values of restraint current the percentage slope characteristic is essentially the same as shown in figure 8.

As shown in figure 7, the margin of safety between the relay calibrated for a 35% sensitivity and the 20% mismatch curve is the same as that of the relay calibrated for a 30% sensitivity and the 15% mismatch curve. This margin of safety is also shown in the voltage differential characteristic of figure 11 for the 35 percent sensitivity relay.

Electrical Checkpoints

Differential Unit

a. Restraint Circuit

Apply two times tap-value current successively to each restraint transformer. This is done by connecting leads to a tap screw and to terminals 5, 7 and 9 in turn (Terminal 9 on HU-1 only). Now measure the a-c voltage across the restraint rectifier bridges (See Fig. 2) using a high-resistance voltmeter (5000 ohms per volt). The voltage should be measured from the left-to the right-hand corners of the bottom set of bridges. A voltage of 2.17 to 2.27 volts should appear only across the appropriate bridge as specified in the following table:

Current in Term.	Associated Rectifier Bridge (Rear View) HU	HU-1
5	Center	Center
7	Right Hand	Left Hand
9	—	Right Hand

b. Operating Circuit

Apply 30 per cent tap-value current to terminal 3 and a tap screw. Using a high-resistance a-c voltmeter measure the voltage on the operating coil bridge across the left-to right-hand corners (See Fig. 2). The voltage should be approximately 2.4 volts. Now, measure the voltage output of the operating transformer (top two coil terminals). The voltage should be about 5.3 volts.

Harmonic Restraint Unit (HRU)

Apply 30 per cent tap-value current to terminal 3 and a tap screw. The following are the approximate voltages that should be obtained using a high-resistance a-c voltmeter (See Fig. 2 for location):

1. Output of operating transformer (top coil terminals) — 4.0 volts
2. 4 mfd. capacitor — 2.5 volts
3. 0.45 mfd. capacitor — 3.9 volts
4. Operating-rectifier bridge (left-to right-hand corners) — 2.5 volts
5. Restraint-rectifier bridge (left-to right-hand corners) — 0.6 volts
6. Series Filter-Reactor — 0.2 volts

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

APPROXIMATE RESISTANCE VALUES OF COMPONENTS IN HU RELAY

Unit	Circuit	Description
Harmonic Restraint	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 50 to 70 ohms.
		Reactor d.c. Resistance 8 to 10 ohms.
		4 MFD Capacitor.
		Rectifier 700 Volts, 600 Milliampere Silicon Diodes
		Indicating Instantaneous Trip Unit 14 to 16 ohms.
		Polar Unit Coil d.c. Resistance 80 to 100 ohms.
	Restraint	Series Reactor d.c. Resistance 110 to 130 ohms.
		Parallel Reactor d.c. Resistance 300 to 360 ohms.
		.45 MFD Capacitor.
	*	Rectifier 700 Volts, 600 Milliampere Silicon Diodes
		Polar Unit Coil d.c. Resistance 650 to 800 ohms.
		Varistor 100,000 ±10% at 10 V.D.C. 4000 ± 25% at 30 V.D.C.
Differential	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3,8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 20 to 30 ohms.
		Adjustable 3½ inch 280 ohm Resistor
		Rectifier 700 Volts, 600 Milliampere Silicon Diodes
		Polar Unit Coil d.c. Resistance 75 to 100 ohms.
	Restraint	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9)
	*	Rectifier 700 Volts, 600 Milliampere Silicon Diodes
		Polar Unit Coil d.c. Resistance 60 to 110 ohms.
Indicating Contactor Switch	Trip	0.2 Amp. tap 6.5 ohms d.c.
		2.0 Amp. tap 0.15 ohms.d.c.

ENERGY REQUIREMENTS

Burden of Each Restraint Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	at 8 times tap value current	at 20 times tap value current
2.9	10	71	.88	50	191
3.2	12	70	.89	51	211
3.5	13	66	.90	51	203
3.8	14	65	.91	53	220
4.2	15	58	.91	53	235
4.6	16	57.5	.91	55	248
5.0	18	52.5	.92	59.	280
8.7	22	30	1.28	94.	340

Burden of Operating Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	at 8 times tap value current	at 20 times tap value current
2.9	10	35	2.26	76	487
3.2	12	34	2.30	78	499
3.5	13	33	2.30	81	504
3.8	14	33	2.30	83	547
4.2	15	31	2.30	84.	554
4.6	16	30	2.40	88.	598
5.0	18	29	2.50	92.	640
8.7	22	23	3.18	132.	850

θ Degrees current lags voltage at tap value current

† Voltages taken with Rectox type voltmeter

* **Thermal Rating**

One Second — 300 amperes

Thermal capacities for short times other than one second may be calculated on the basis of time being inversely proportional to the square of the current.

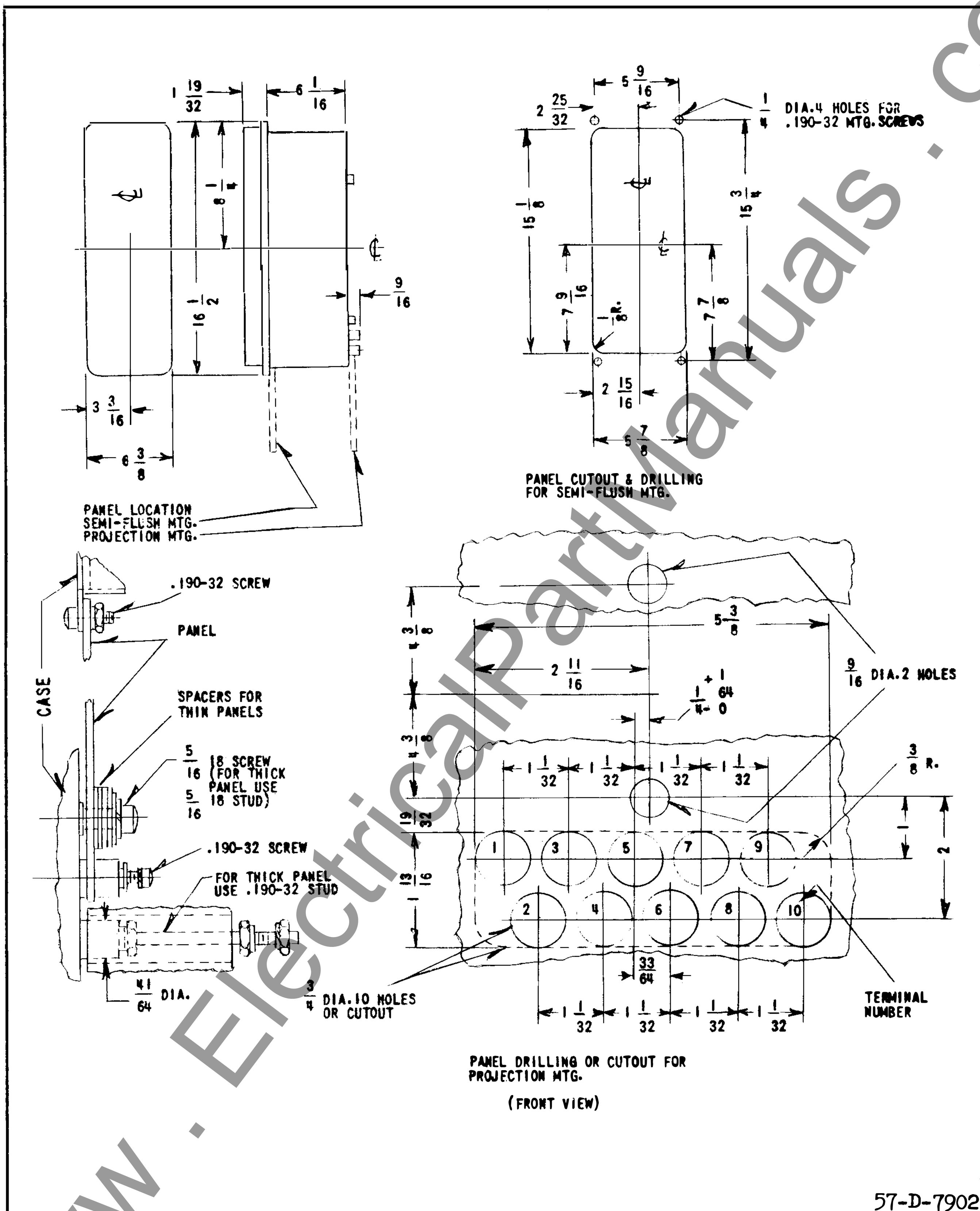


Fig. 17. Outline and Drilling Plan of the Type HU and HU-1 Relays in the FT31 Case.

WESTINGHOUSE ELECTRIC CORPORATION

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

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE HRU INSTANTANEOUS OVERCURRENT RELAY WITH HARMONIC RESTRAINT

CAUTION Before putting 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 proply, and operate the relay to check the settings and electrical connections.

APPLICATION

The type HRU relay is a high speed relay used in the differential protection of transformers. These relays can be applied where the magnetizing inrush current to the transformer is severe.

This relay is not intended to be used in applications where saturation of current transformers occurs on asymmetrical and symmetrical faults external to the protected transformer. For such applications the type HU relay should be applied.

CONSTRUCTION

The type HRU relay consists of an instantaneous trip unit, a harmonic restraint unit, and an indicating contactor switch. The principal component parts of the relay are shown in Fig. 1.

Harmonic Restraint Unit (HRU)

The harmonic restraint unit consists of an air-gap transformer, a second harmonic block filter, a fundamental block-second harmonic pass filter, two full-wave rectifiers, a varistor, and a d-c polar unit.

Polar Unit

The polar unit consists of a rectangular shaped magnetic frame, an electromagnet, a permanent magnet, and an armature. The poles of the crescent shaped permanent magnet bridge the magnet frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These non-magnetic joints represent air gaps, which are bridged by two adjustable magnetic shunts. The windings are wound around a magnetic core. The armature is fastened to this core, and is free to move in the front air gap. The moving contact is connected to the free end of a leaf spring, which, in turn, is fastened to the armature.

Instantaneous Trip Unit (IT)

The instantaneous trip unit is a small a-c operated 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. A core screw accessible from the top of the switch provides the adjustable pickup range. The minimum and maximum pickup points are indicated on the scale, which is located to the rear of the core screw.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper-type device. A magnetic armature to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also, during this operation, two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop.

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

OPERATION

The type HRU relay is connected to operate for faults internal to the differential zone of the transformer but not on magnetizing inrush currents associated with energization of the transformer. This is accomplished by supervising the contacts of an instantaneous trip unit with the contacts of a harmonic restraint unit.

Magnetizing Inrush Currents

Magnetizing inrush current waves have various wave

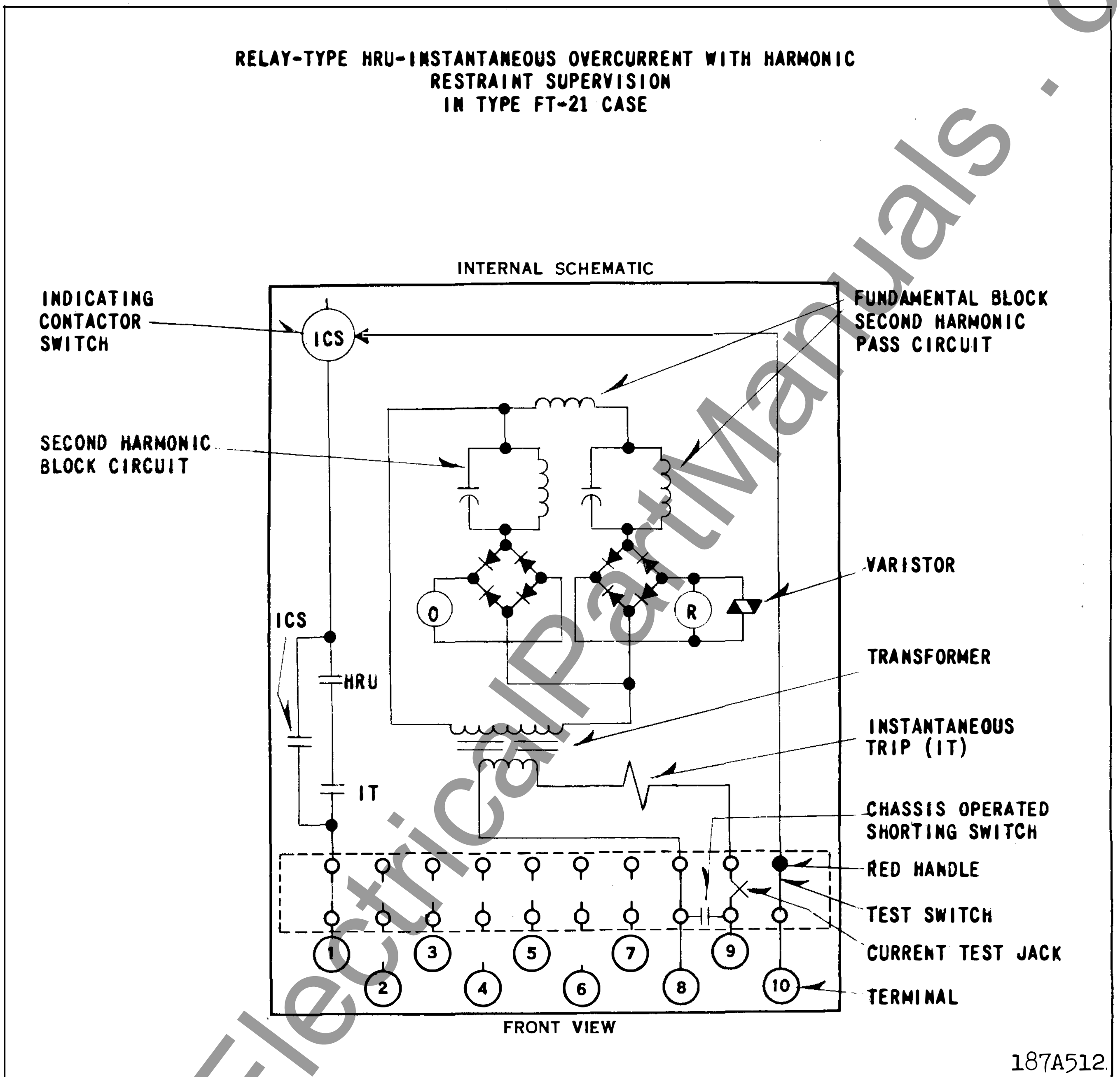


Fig. 1 Internal Schematic

shapes. A typical wave appears as a rectified half wave with decaying peaks. In any case, the various wave shapes are rich in harmonics with the second harmonic predominant. Since the second harmonic is always present in inrush waves and not in internal fault waves, this harmonic is used to restrain the harmonic-restraint unit during inrushes. The instantaneous trip unit may or may not close its contact, depending on the magnitude of the inrush.

When a magnetizing inrush wave is applied to the relay, the d-c component of the wave is by-passed by the air-gap operating transformer. The other components are fed into the filter circuits. The impedance characteristics of these filters are such that the second harmonic component flows into the restraint coil of the polar unit, while the other harmonics flow into the operating coil. The polar unit will not close its contacts unless the second harmonic content is less than 15 percent of the fundamental component.

Internal Faults

Faults normally appear as an offset sine wave with a decaying d-c component, and contain very few harmonics. As a result, the harmonic-restraint unit and instantaneous trip will operate during internal faults to permit tripping of the relay.

The varistor connected across the d-c side of the restraint rectifier of the harmonic restraint unit prevents excessive voltage peaks from appearing across the rectifiers. These peaks arise through transformer action of the harmonic-restraint polar-unit coils during heavy internal faults. The varistor has a large value of resistance for low voltages, while presenting a low value of resistance for high voltages. This characteristic effectively reduces the voltage spikes on heavy internal faults while not hampering performance during inrush, where the voltage is considerably lower.

SETTINGS

Harmonic Restraint Unit (HRU)

No settings are required on the harmonic restraint unit. If desired, pickup may be varied by adjusting the right hand shunt (front view).

Indicating Contactor Switch (ICS)

No setting required on the ICS unit except the selection of the 0.2 or 2.0 amperes 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 or 250 volt d-c type WL relay switch or equivalent, use the 0.2 ampere tap; for 48 volt d-c applications set relay in the 2.0 amp. tap and use WL relay coil S#304C209G01 or equivalent.

Instantaneous Trip (IT)

The core screw must be adjusted to the value of pickup current desired.

The nameplate data will furnish the actual current range that may be obtained from the IT unit.

INSTALLATION

The relays should be mounted on a switchboard panel 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 mount- or to the terminal studs furnished with the relay for thick panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

For detailed FT case information, refer to (I.L. 41-076).

ADJUSTMENTS AND MAINTENANCE

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

Acceptance Tests

The following check is recommended to insure that the relay is in proper working order. Use test circuit of Fig. 2.

1. Minimum Trip Circuit – With the switch open, apply current to terminals 8 and 9 of the relay. The polar unit should operate at rated current. The polar unit may operate for lower currents,

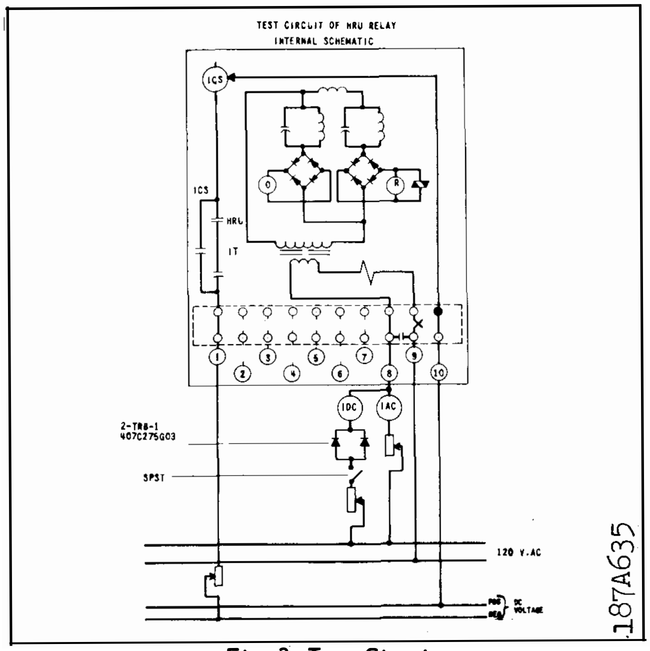


Fig. 2 Test Circuit

but not below value of Table I. This low pickup will not impair its operation on magnetizing inrush, and should not be disturbed if it is found to be less than rated current. However, if a higher pickup is desired, it is suggested that 100 amperes be applied to relay terminals 8 and 9. This will cause the polar unit to pickup at approximately rated current.

2. Harmonic Restraint Characteristic — Close switch of test circuit and set I_{dc} per Table 2 and adjust I_{ac} until the polar unit operates. I_{ac} should be as indicated in Table 2. These values of alternating current corresponds to 17 per cent and 14 per cent second harmonic.

3. Instantaneous Unit (IT)

   The core screw which is adjustable from the top of the trip unit determines the pickup value. The trip unit has a nominal ratio of adjustment of 1 to 4 and an accuracy within the limits of 10%.

   Position the stationary contact for a minimum of 1/32 inch wipe. The bridging moving contact should touch both stationary contacts simultaneously. Apply sufficient current to operate the IT.

4. Indicating Contactor Switch (ICS)

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

   The contact gap should be approximately .047 inches between the bridging moving contact and and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

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 contact.

Calibration

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. (See ''Acceptance Check.'')

Polar Unit

1. Contacts — Place a .060 to .070 inch feeler gage between the right hand pole face and the armature. This gap should be measured near the front of the right hand pole face. Bring up the backstop screw until it just makes with the moving contact. Place gage between moving contact and stationary contact on the left hand side of the polar unit. Bring up the stationary contact until it just makes with the gage and lock in place.

2. Minimum Trip Current — Harmonic Restraint Unit (HRU)

   Connect the relay to the test circuit of Fig. 2.

   With the switch open, pass I_{ac} = 100 amperes into the relay. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust the right hand shunt on the polar unit until it trips with I_{ac} = Rated Current. Lower I_{ac} gradually to 50% rated current, unit should reset, if not, adjust left hand shunt until the unit resets.

If additional adjustments are necessary, apply 100 amperes and adjust the right hand shunt until the unit operates at rated current. Lower I_{ac} gradually to 50% rated current and adjust the left hand shunt until the contacts reset. Repeat these steps until the unit will operate at rated current, lower immediately following the application of 100 amperes, and until the unit will drop out at 50% rated current or greater. After the dropout has been measured, the unit should pick up at .94 times rated current.

On the application of the high current, the polar unit will be biased in the restraining direction and pickup will be rated current on the first application of pickup current. If the current is de-energized and pickup is measured again, the pickup current will be less than before. However, pickup will be stable after the second application of pickup current. If 100 amperes is applied again, the pickup immediately after applying this current will be rated current. However, measuring the pickup the second time will show that the pickup is again reduced. The variation between .94 and 1 times rated current.

The filter circuits are charged by the application of this heavy current and upon the removal of the current, these circuits will discharge their energy. The element will be biased in the restraining direction because the restraint coil has approximately 7 times the number of turns as the operating coil. Upon the application of pickup current, the operating ampere turns will be greater than the restraint ampere turns and the bias will be removed.

If a lower biasing current is used instead of 100 amperes, the pickup of the unit will be less than before for the application of pickup current. Pickup will be further reduced with the second application of pickup current, but the current will be stable after this energization. However, this value of pickup will be lower than the limit of .94 times rated current. This is in the direction of making the sensitivity of the polar unit lower than rated current but does not impair the performance of the unit on inrush current.

If a pickup other than rated current is desired, the right hand shunt can be screwed inward to give the desired pickup. This adjustment should be done after the application of 100 amperes.

3. Harmonic-Restraint Characteristics

Close switch of test circuit in Fig. 2. Adjust direct current I_{dc} per Table 2. Gradually increase alternating current until the polar unit operates with I_{ac} as indicated in Table 2. The per cent second harmonic in the wave may be derived by the use of the formula:

$$\% \text{ second harmonic} = \frac{47\ I_{dc}}{I_{ac} + 1.11\ I_{ac}}$$

Indicating Contactor Switch (ICS)

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

Instantaneous Trip (IT)

The core screw which is adjustable from the top of the trip unit determines the pickup value. The trip unit has a nominal ratio of adjustment of 1 to 4 and an accuracy within the limits of 10%.

Apply sufficient current to operate the IT.

Electrical Checkpoints

Apply rated current to terminals 8 and 9. The following are the approximate voltages that should be obtained using a high-resistance a-c voltmeter:

1.	Output of operating transformer (Top Coil Terminals)	4.0 volts
2.	4 mfd. capacitor	2.5 volts
3.	0.45 mfd. capacitor	3.9 volts
4.	Operating-rectifier bridge	2.5 volts
5.	Restraint-rectifier bridge	0.6 volts
6.	Series filter-reactor	0.2 volts

APPROXIMATE RESISTANCE VALUES OF COMPONENTS IN HRU RELAY

Unit	Circuit	Description
Harmonic Restraint	Operating	Transformer Secondary d-c resistance 50 to 70 ohms.
		Reactor d-c resistance 8 to 10 ohms.
		4 mfd. capacitor
		Rectifier 700 volts, 600 milliamperes silicon diodes.
		Polar unit coil d-c resistance 80 to 100 ohms.
	Restraint	Series reactor d-c resistance 100 to 130 ohms.
		Parallel reactor d-c resistance 300 to 360 ohms.
		.45 mfd. capacitor
		Rectifier 200 volts, 600 milliamperes silicon diodes.
		Polar unit coil d.c resistance 650 to 800 ohms
		Varistor 100,000 ± 10% at 10 VDC 4000 ± 25% at 30 VDC.
Indicating Contactor Switch	Trip	0.2 amp. tap 6.5 ohms d-c 2.0 amp. tap 0.15 ohms d-c

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

TABLE 1

Polar Unit Min. Trip Values

Rated Current	Lower Current Limit
.87	.6
2.0	1.35
4.0	2.7

TABLE 2

Harmonic Restraint Values

Rated Current	I_{dc}	I_{ac}
.87	2.3	3.8 – 5.3
2.0	6.0	10.0 – 13.5
4.0	12.0	19.9 – 27.0

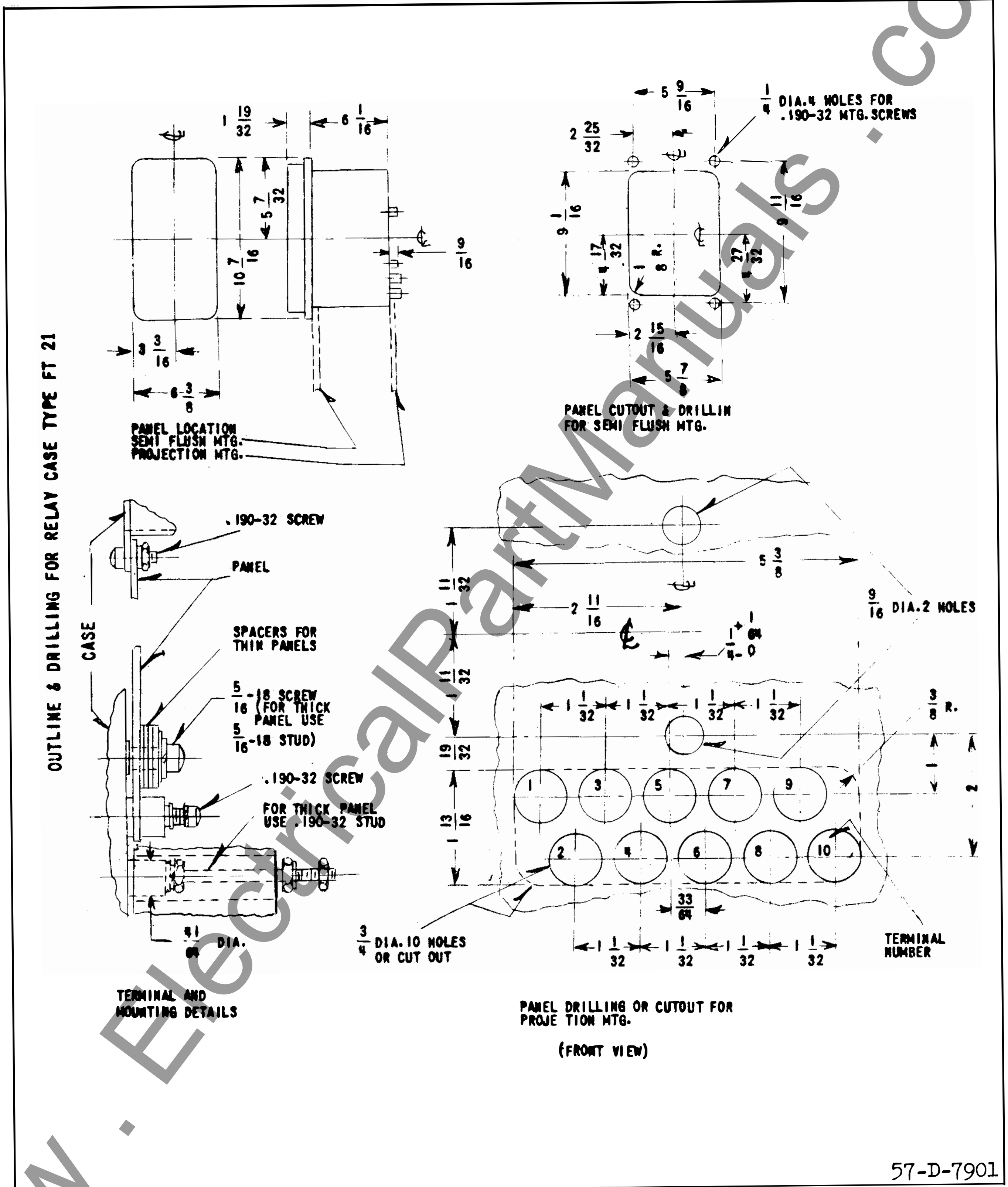


Fig. 3 Outline & Drilling For FT21

WESTINGHOUSE ELECTRIC CORPORATION
RELAY-INSTRUMENT DIVISION NEWARK, N. J.
Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPES HU AND HU-1 TRANSFORMER DIFFERENTIAL RELAYS

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

APPLICATION

The types HU and HU-1 relays are high-speed relays used in the differential protection of transformers. These relays can be applied where the magnetizing inrush current to the transformers is severe.

* Current transformer ratio error should not exceed 10% with maximum symmetrical external fault current flowing and the maximum symmetrical error current which is flowing in the differential circuit on external faults should not exceed 10 times relay tap setting.

The HU-1 relay has three restraint transformers and associated rows of taps; whereas, the HU relay has one less restraint transformer and two rows of taps. Otherwise the two relays are identical. Three-winding banks normally require the HU-1 relay, although the autotransformer application uses the HU if the tertiary is not loaded.

* Both the HU or the HU-1 are available with a sensitivity of either 30% or 35% times tap. The 30%-sensitivity relay satisfactorily handles up to 15% mismatch (e.g. ± 10% transformer tap changing plus 5% CT mismatch). The 35%-sensitivity relay handles as much as 20% mismatch. See Fig. 7 for a comparison of the characteristics of the two sensitivities. Any of the relays may be recalibrated in the field to obtain either characteristic.

Ordinarily the 30%-sensitivity relay will suffice; however, where CT mismatch is abnormally high or where the transformer tap-changing range exceeds ± 10%, this calibration may be too sensitive.

CONSTRUCTION

* The types HU and HU-1 relays consist of a differential unit (DU), a harmonic-restraint unit (HRU), an indicating instantaneous trip unit (ITT) and an indicating contactor switch (ICS). The principal parts of the relay and their locations are shown in Figs. 1 to 4.

Differential Unit (DU)

The differential unit of the HU relay consists of two air-gap restraint transformers, three full-wave rectifiers, saturating operating-transformer, and a d-c polar unit.

The HU-1 relay, in addition to the above components, has a third air-gap restraint transformer, and a fourth full-wave rectifier.

Each of the restraint transformers and the operating transformer are provided with taps to compensate for mismatch of line current transformers. These taps are incorporated in the relay in such a manner that changing a tap on a restraint transformer automatically changes the same tap on the operating transformer.

Harmonic-Restraint Unit (HRU)

The harmonic-restraint unit of the HU and HU-1 relays consists of an air-gap operating transformer, a second harmonic block filter, a fundamental block-second harmonic pass filter, two full-wave rectifiers, indicating instantaneous trip unit, varistor, and a d-c polar unit.

Taps are also incorporated in this unit to compensate for mismatch of the line current transformers. Changing a tap on the restraint transformer of the differential unit also changes the tap of this unit.

Polar Unit

The polar unit consists of a rectangular shaped

SUPERSEDES I.L. 41-347.1K
*Denotes change from superseded issue.

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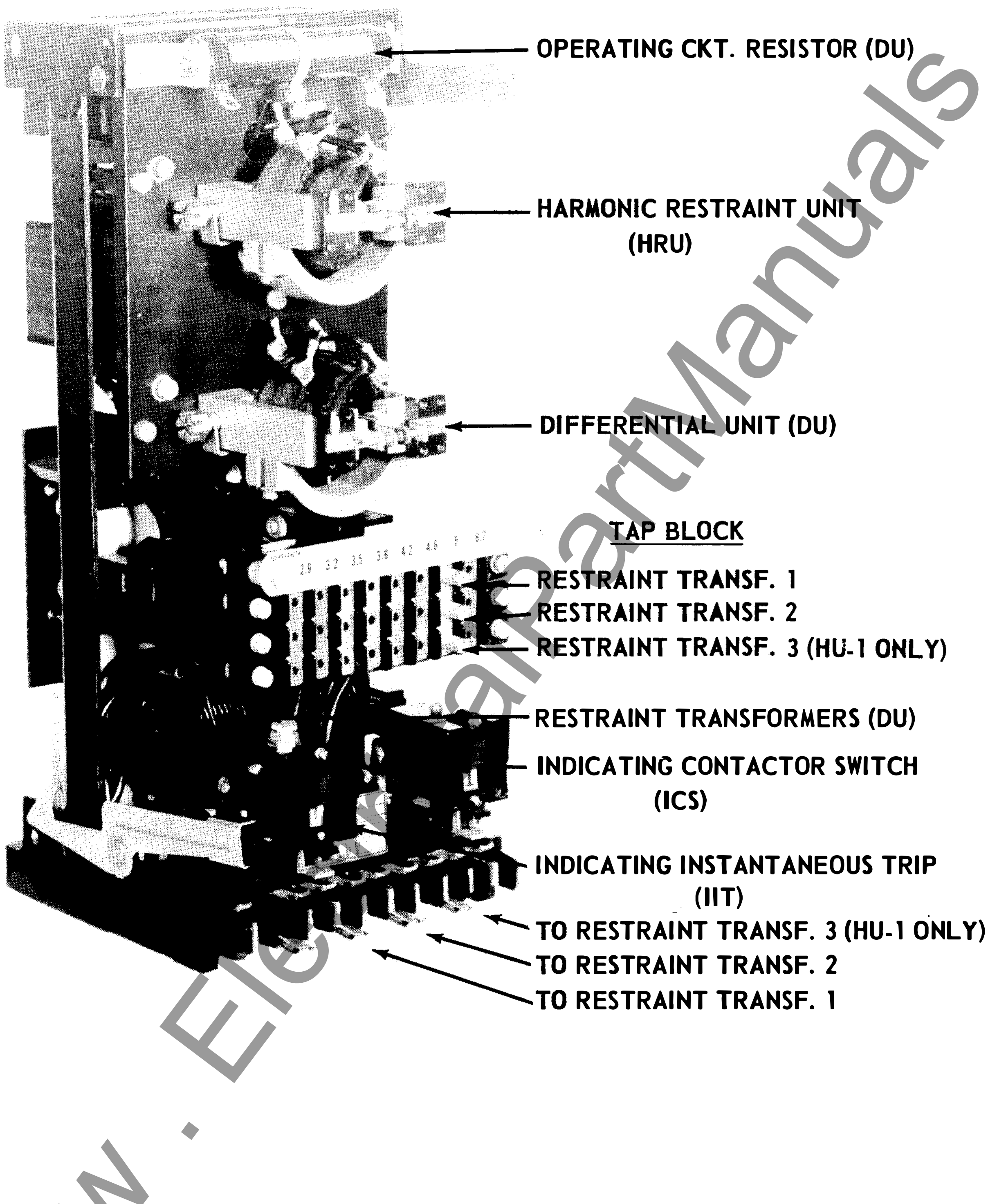
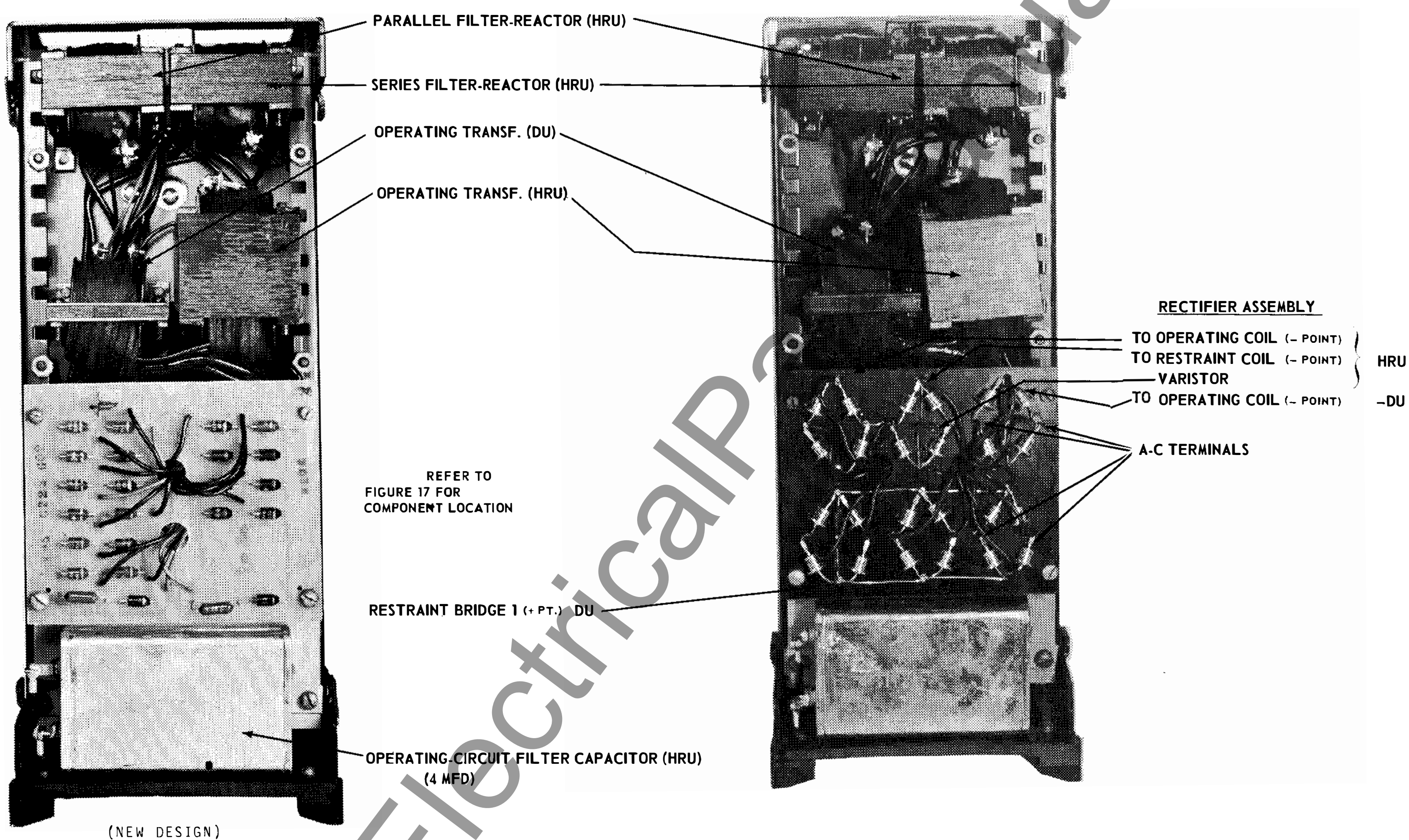
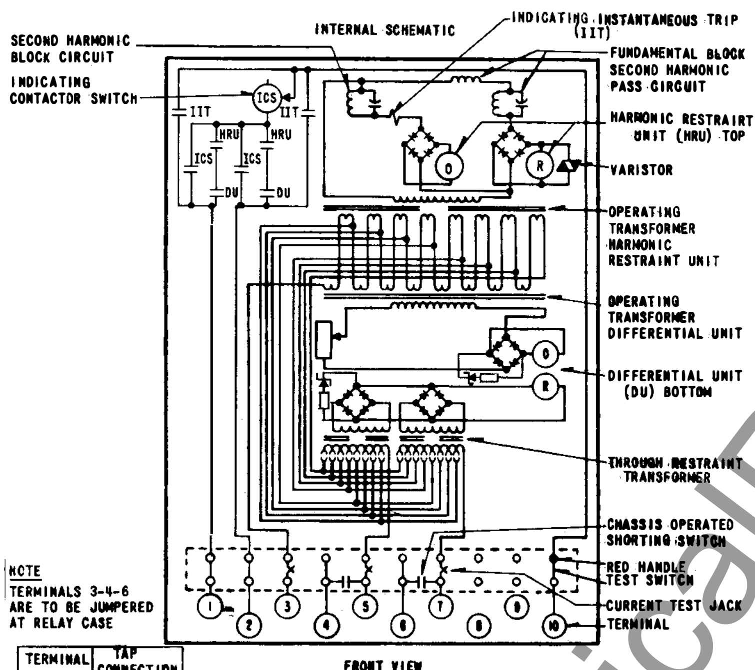


Fig. 1. Type HU-1 Relay – Front View.



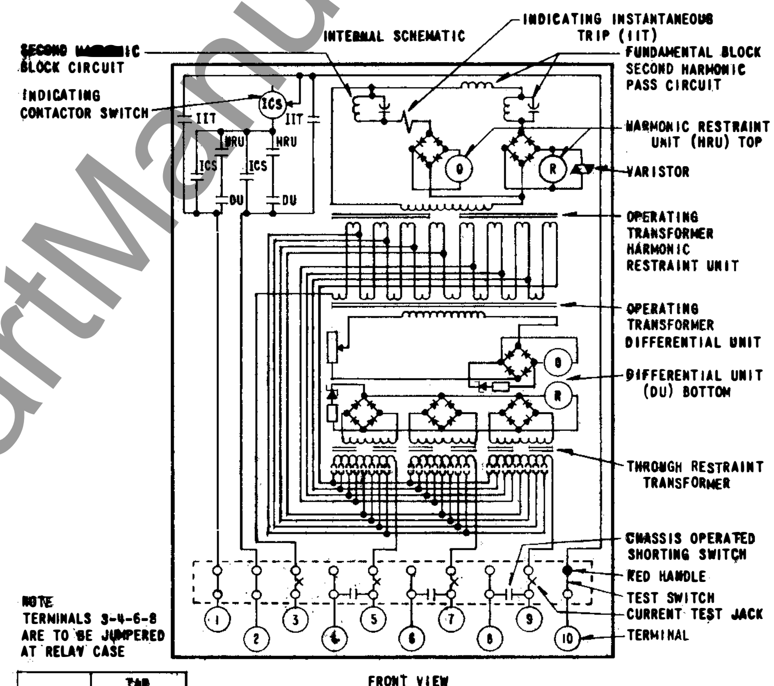
* *Fig. 2. Type HU-1 Relay – Rear View.*



TERMINAL	TAP CONNECTION
5	TOP
7	BOTTOM

185A036

Fig. 3. Internal Schematic of the Type HU Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted, 184A762.



TERMINAL	TAP CONNECTION
5	TOP
7	MIDDLE
9	BOTTOM

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Fig. 4. Internal Schematic of the Type HU-1 Relay in FT31 Case. For Single Trip Relays the Circuit Associated with Terminal 2 is Omitted, 184A736.

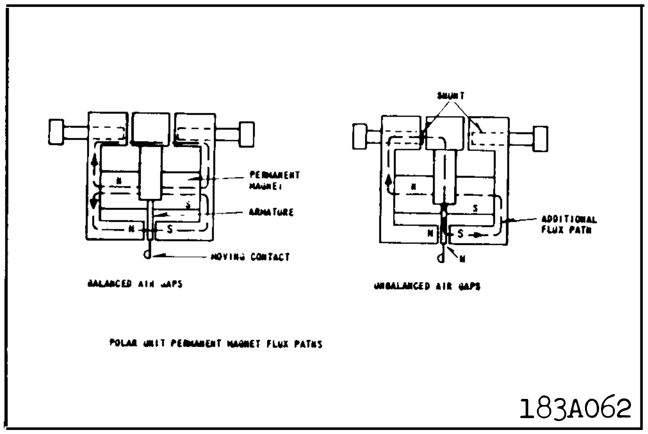


Fig. 5 Polar Unit Permanent Magnet Flux Paths.

magnetic frame, an electromagnet, a permanent magnet, and an armature. The poles of the crescent shaped permanent magnet bridge the magnet frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These non-magnetic joints represent air gaps, which are bridged by two adjustable magnetic shunts. The windings are wound around a magnetic core. The armature is fastened to this core and is free to move in the front air gap. The moving contact is connected to the free end of a leaf spring, which, in turn, is fastened to the armature.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper-type device. A magnetic armature, to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also, during this operation, two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop.

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

Indicating Instantaneous Trip Unit (IIT)

The instantaneous trip unit is a small a-c operated 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 bridge two stationary contacts completing the trip circuit. Also, during the operation, two fingers on the armature deflect a spring located on the front of the switch which allows the operation indicator target to drop.

A core screw accessible from the top of the switch provides the adjustable pickup range.

OPERATION

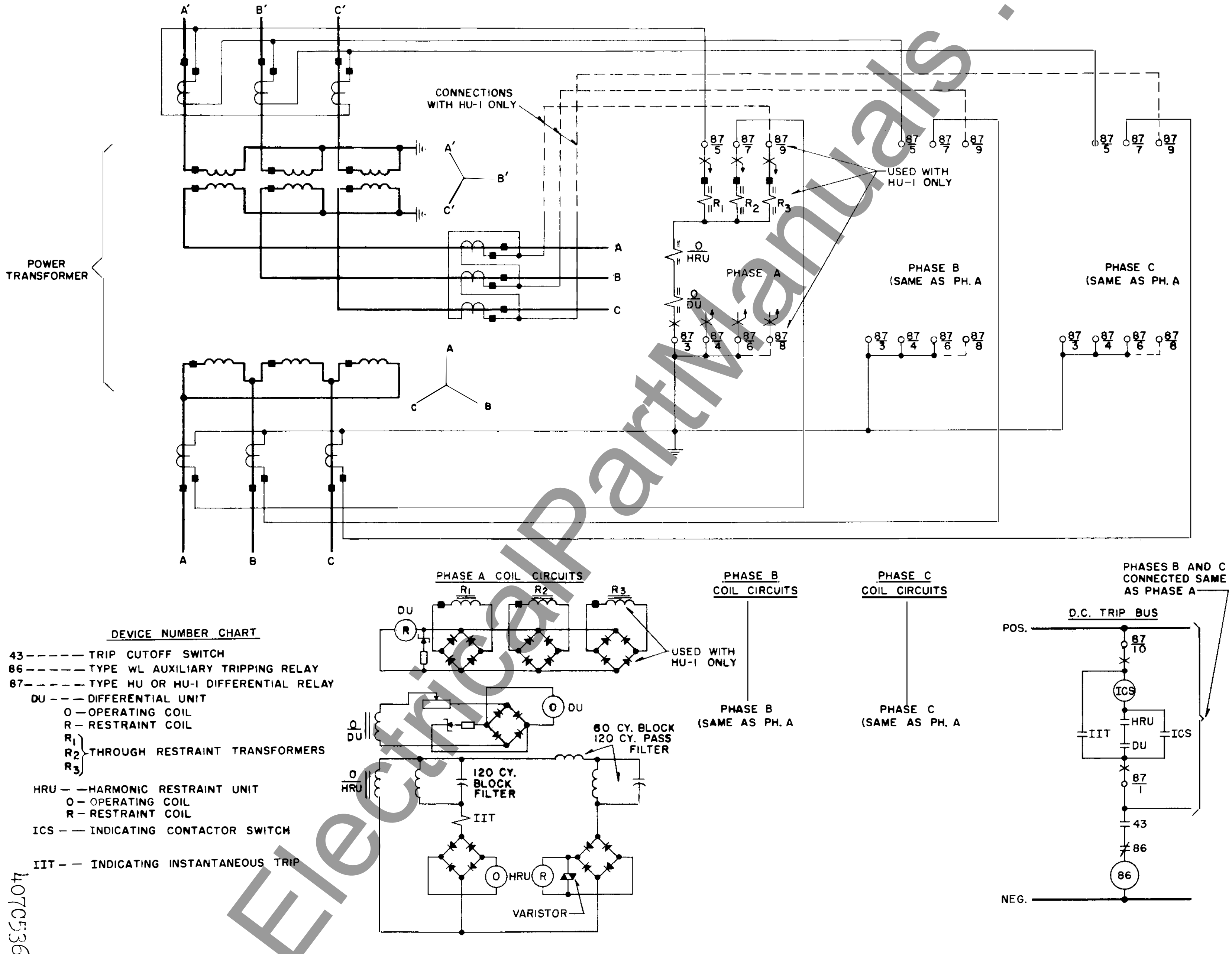
The types HU and HU-1 relays are connected to the protected transformer as shown in Fig. 6. In such a connection, the relays operate to protect the transformer for faults internal to the differential zone of the transformer, but not for faults external to the zone. Neither do the relays operate on magnetizing inrush currents associated with energization of the transformer, even though these currents may appear as an internal fault. To avoid these false operations, each unit of the relay performs a separate function. The differential unit (DU) prevents operation on external faults, while the harmonic-restraint unit (HRU) prevent operations on magnetizing inrush currents. Hence, the operation of the relay can best be described under the headings of external fault current, internal fault currents, and magnetizing inrush currents.

External Fault Currents

The types HU and HU-1 relays have a variable percentage characteristic. This means that the operating current required to close the contact of the differential unit expressed in percent of restraint current varies with the magnitude of the larger restraint current. Fig. 7 and Fig. 8 illustrate this characteristic. To use these curves, divide each restraint current by the appropriate tap and enter the horizontal axis using the larger or largest restraint multiple. Then enter the vertical axis, using the difference of the restraint multiples.

With the relay connected as shown in the schematic diagram of Fig. 9a, an external fault causes currents to flow in the air-gap restraint transformers of the differential unit. If the line current transformers do not saturate and the correct ratio matching taps applied, no effective current flows in the operating transformer of the relay. Hence, only a contact-opening torque is produced on the differential unit.

On heavy external faults where a main current transformer saturates, current flows in the operating circuit of the relay. With such a condition, the harmonic-restraint unit may or may not close its contacts, depending upon the harmonics present in the false operating current. However, operation of the



* *Fig. 6. External Schematic of the Type HU and HU-1 Relays.*

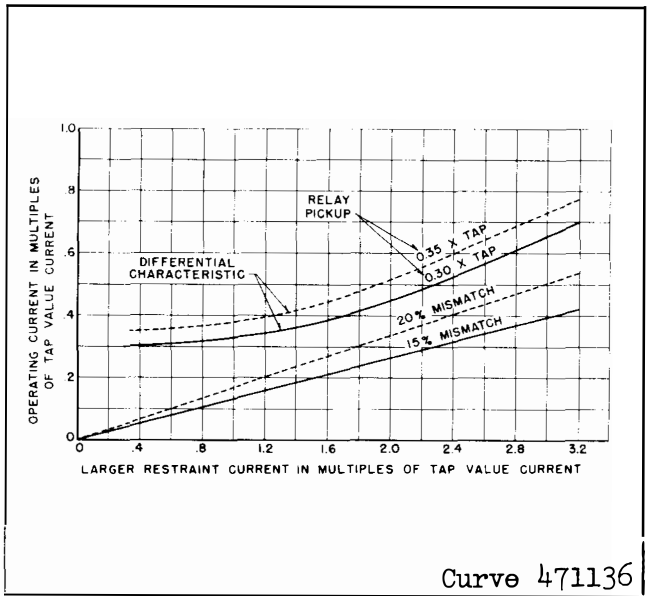


Fig. 7. Differential Characteristic of the DU Unit of the HU and HU-1 Relays at Smaller Values of Current. Actual Operating Current Shown for 15 and 20% Mismatch.

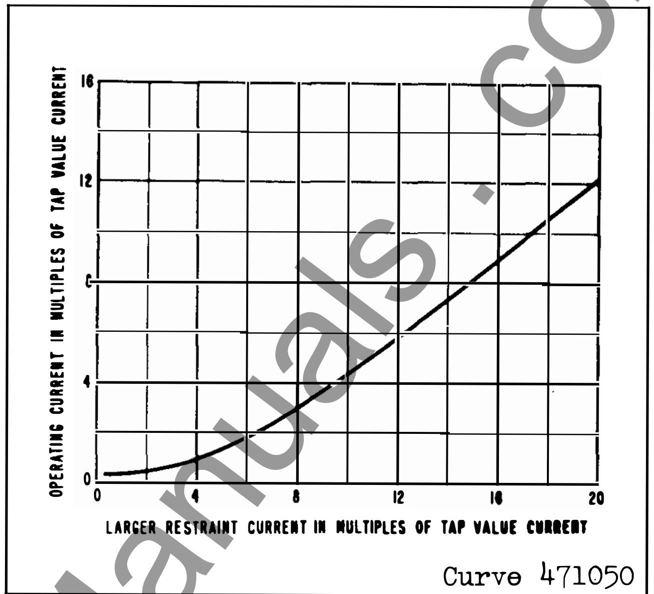


Fig. 8. Differential Characteristic of the Differential Unit (DU) of the HU and HU-1 Relays at Larger Values of Current.

relay is prevented by the variable percentage characteristic of the differential unit, since a large differential current is required to close its contacts during heavy external faults.

Internal Faults

In the case of an internal fault as shown in Fig. 9b, the restraint of the differential unit is proportional to the largest restraint current flowing. The sum of the two restraint currents flows into the operating transformer and produces an excess of operating torque, and the differential unit operates.

In the case of an internal fault fed from one source only, the fault current flows in one restraint transformer and the operating transformer. An excess of operating torque is produced on the differential unit and it operates.

Faults normally appear as an offset sine wave with a decaying d-c component, and contain very few harmonics. As a result, the harmonic-restraint unit will operate during internal faults to permit tripping of the relay.

For heavy internal faults, the indicating instantaneous trip unit (IIT) will operate. Since this unit is connected to an air gap transformer, essentially only the sine wave component of an internal fault is applied to the IIT unit. The d-c component of the fault is bypassed by the transformer primary. For example, an internal fault with a first peak of 28 times tap value (includes fifty percent d.c.) is reduced to a first peak of approximately 14 times tap value (d.c. component absent) on the secondary transformer. The IIT unit will just operate on this wave since it is set to pick up at a peak current of 14.1 times tap (r.m.s. pick-up value = 10 times tap).

The varistor connected across the d.c. side of the restraint rectifier of the harmonic restraint unit prevents excessive voltage peaks from appearing across the rectifiers. These peaks arise through transformer action of the harmonic-restraint polar-unit coils during heavy internal faults. The varistor has a large value of resistance for low voltages, while presenting a low value of resistance for high voltages. This characteristic effectively reduces the voltage spikes on heavy internal faults while not hampering performance during inrush, where the voltage is considerably lower.

Magnetizing Inrush Currents

Magnetizing inrush current waves have various wave shapes. A typical wave appears as a rectified half wave with decaying peaks. In any case, the various wave shapes are rich in harmonics with the second harmonic predominant. Since the second harmonic is always present in inrush waves and not in internal fault waves, this harmonic is used to restrain the harmonic-restraint unit during inrushes.

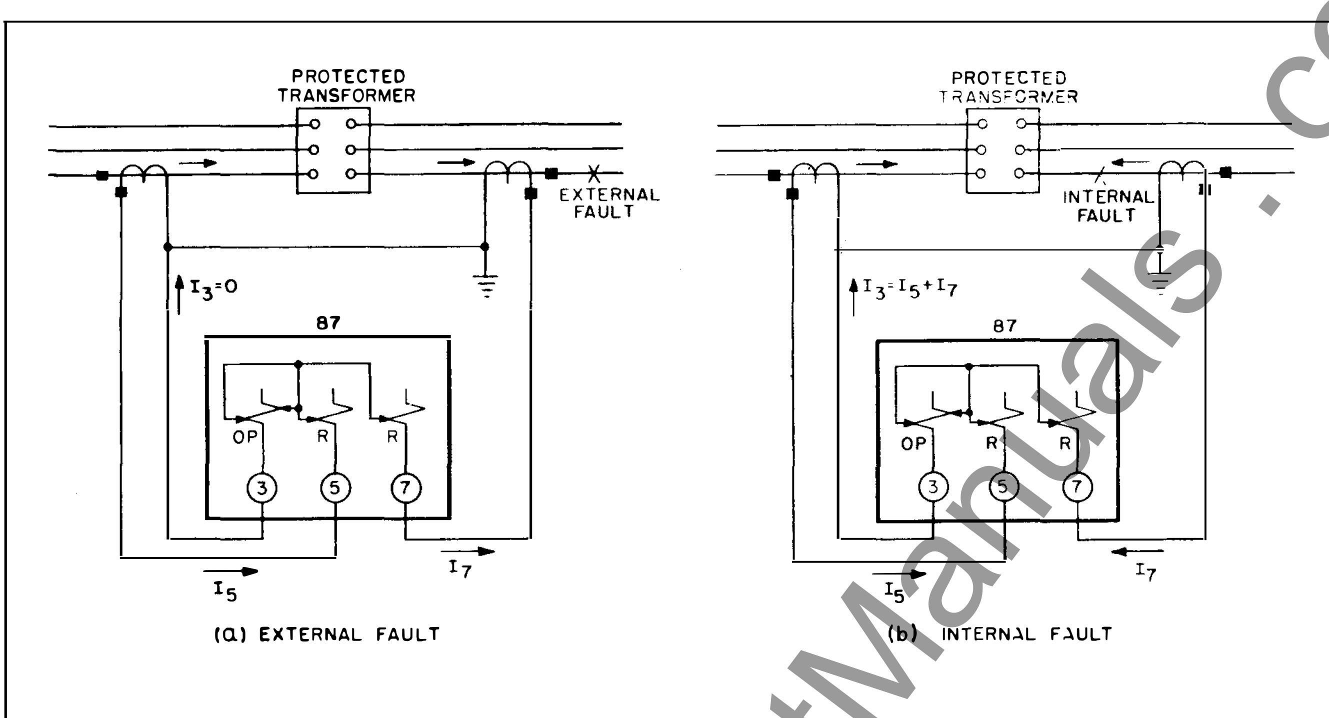


Fig. 9. Simplified Schematic of the Type HU Relay with Current Distribution for (a) External Fault (b) Internal Fault.

The differential unit may or may not close its contact, depending on the magnitude of the inrush.

When a magnetizing inrush wave is applied to the relay, the d-c component of the wave is by-passed by the air-gap operating transformer. The other components are fed into the filter circuits. The impedance characteristics of these filters are such that the second harmonic component flows into the restraint coil of the polar unit, while the other harmonics flow into the operating coil. The polar unit will not close its contacts unless the second harmonic content is less than 15 percent of the fundamental component.

The indicating instantaneous trip unit (IIT) will not operate on inrush. The air-gap transformer will bypass the d.c. component of the inrush thereby reducing the magnitude of the wave applied to the IIT unit. If the inrush has an initial peak of 16 times tap-value current, the air-gap transformer will reduce this peak to approximately 8 times tap value on the secondary of the transformer. Since the IIT unit is set for a peak value of 14.1 times tap (r.m.s. pick-up value = 10 times tap), it will not operate on this inrush.

Breaker Maintenance

Before some of the CT's are bypassed for breaker maintenance the trip circuit should be opened, as shown in Fig. 6. Otherwise the false-unbalanced current will cause the relay to trip. It is not necessary to short-circuit the relay operating circuit since it has an adequate continuous-current rating. (See "Energy Requirements").

CHARACTERISTICS

Taps are incorporated in the HU and HU-1 relays to compensate for main current transformer mismatch. These taps are as follows: 2.9, 3.2, 3.5, 3.8, 4.2, 4.6, 5.0, 8.7.

To measure the effective unbalance, a sensitive low-reading voltmeter (5000 ohms per volts) can temporarily be connected across the operating coil resistor (at top of case). With a perfect balance the voltmeter reading will be zero. The reading should not exceed the values indicated by the 15% mismatch curve in Fig. 10 when the relay pickup is 0.30 times tap. If the amount of mismatch is measured or calculated, the measured voltage can be checked against the interpolated value from the curve. For example, assume that the larger restraint current is measured as 1.5 tap multiple and the calculated mismatch is 7%. Then, from Fig. 10 the measured voltage should be approximately 1.0 volts. Use Fig. 11 if the pickup is 0.35 times tap.

Pickup of the harmonic-restraint unit and the

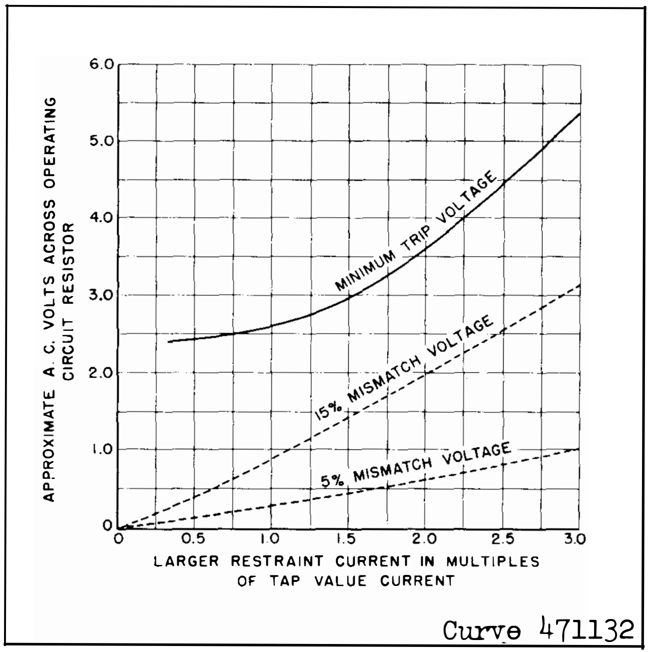


Fig. 10. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.30 Times Tap.

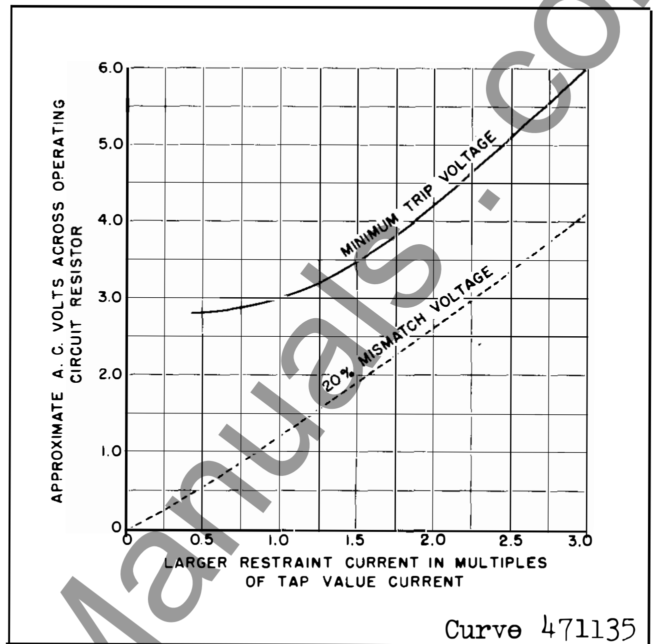


Fig. 11. Differential Voltage Characteristic of the DU Unit of the HU and HU-1 Relays with a Pickup of 0.35 Times Tap.

differential unit is either 30 or 35% of tap value current. Pickup of the indicating instantaneous trip unit is ten times tap value current.

Components of the harmonic-restraint unit are selected such that 15% second harmonic will prevent operation of the unit. This factor is adequate to prevent false operation on inrushes.

The frequency response of the HU and HU-1 relays is shown in Fig. 13.

Trip Circuit

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

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

SETTING

To set the relay, calculations must be performed as shown under "Setting Calculations". After the correct tap is determined, connections can be made to the relay transformers by placing the connector screws in the various terminal-plate holes in front of the relay. Only one tap screw should be inserted in any horizontal row of taps.

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-or 250-volt d-c type WL relay switch, or equivalent, use the 0.2-ampere tap; for 48 volt DC applications set relay in 2 tap and use Type WL Relay coil S#304C209G01 or equivalent.

Indicating Instantaneous Trip (IIT)

No setting is required on the indicating instantaneous trip unit. This unit is set at the factory to pickup at 10 times tap value current.

SETTING CALCULATIONS

Select the ratio matching taps. There are no other settings. In order to calculate the required tap settings and check current transformer performance the following information is required.

Required Information

1. Maximum transformer power rating $(KVA)_M$

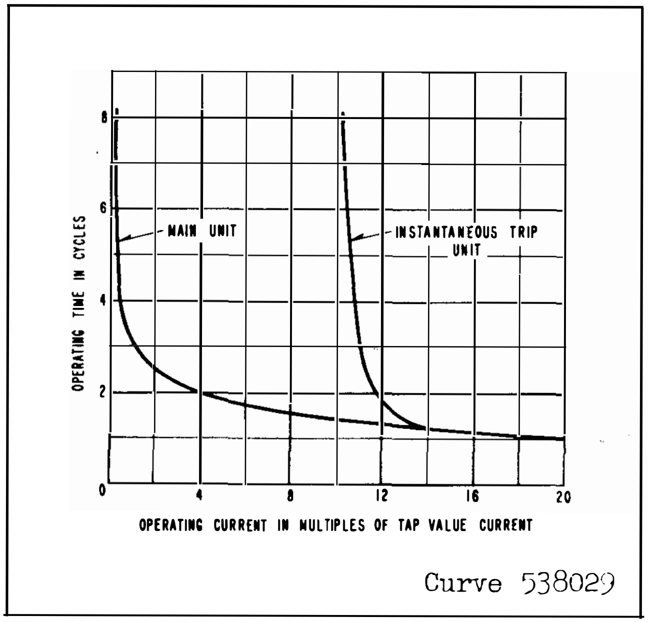


Fig. 12. ***Typical Tripping Time Characteristic (60 Cycle Currents).***

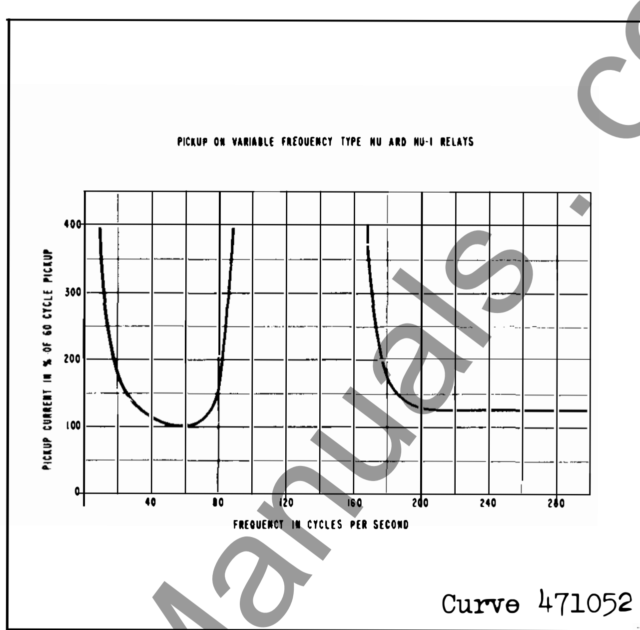


Fig. 13. ***Typical Frequency Response of the HU and HU-1 Relays.***

2. Maximum external fault currents
3. Voltage ratings of power transformer (V_H, V_I, V_L)
4. Current transformer ratios, full tap (N_T)

* 5. Current transformer "C" accuracy class voltage, (or excitation or ratio correction factor curve)

* 6. One way current transformer lead resistance at 25°C (RL) (when using excitation curve, include ct winding resistance)

7. Current transformer connections (wye or delta)

* 8. ct secondary winding resistance, R_S.

Definitions of Terms

I_P = Primary current at $(KVA)_M$

I_R = Relay input current at $(KVA)_M$

I_{RH}, I_{RL}, I_{RI} are same as I_R except for high, low and intermediate voltage sides respectively.

* I_S = ct secondary current at $(KVA)_M$

* T = relay tap setting.

* T_H, T_L, T_I, = are same as T except for high, low and intermediate voltage windings, respectively.

N = Number of current transformer turns that are in use.

$N_P = N/N_T$ (Proportion of total turns in use)

N_T = Current transformer ratio, full tap

* V_{CL} = "C" accuracy class voltage

Z_A = Burden impedance of any devices other than the HU or HU-1 relays, with maximum external fault current flowing.

* $I_{ext.}$ = max. symmetrical external fault current in secondary RMS amperes.

Z_T = Total secondary burden in ohms (excluding
* current transformer winding resistance.)

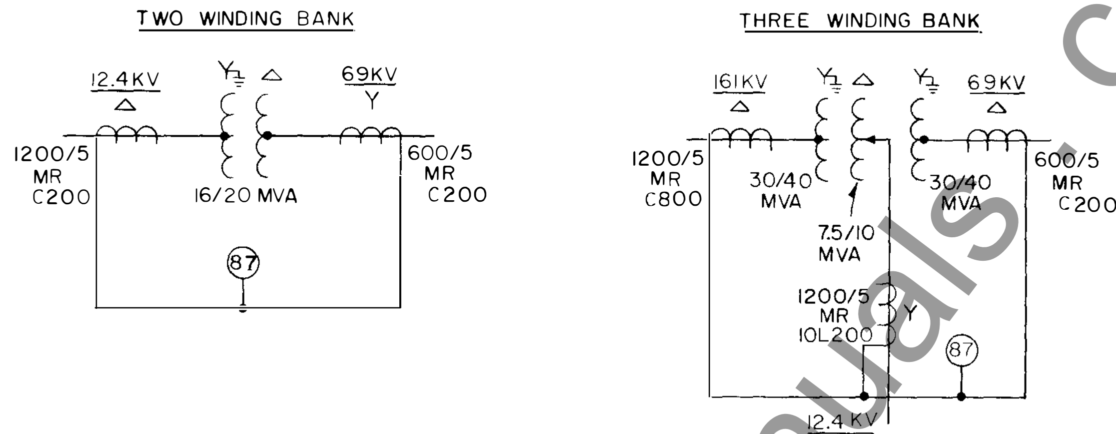
Calculation Procedure

* 1. *Select current transformer taps,* where multi-ratio types are used.

Select a tap to give approximately 5 amperes at maximum load. This will provide good sensitivity and will produce no thermal problem to the ct., the leads or the relay. Better sensitivity can be achieved by selecting a tap to give more than 5 amperes if a careful check is made of the ct, the leads and the relay capability. For determing the required continuous rating of the relay, use the expected two-hour maximum load, since the relay reaches final temperature in this time.

* 2. *Select relay taps in proportion to the relay currents, I_R.*

I_R should not exceed relay continuous rating. Also, to avoid IIT operation due to dissimilar ct saturation the maximum symmet-



Two winding bank

LOW	HIGH
$(KVA)_M = 20{,}000$	$(KVA)_M = 20{,}000$
$(KVA)_S = 16{,}000$	$(KVA)_S = 16{,}000$
$V_L = 12{,}400$ VOLTS	$V_H = 69{,}000$
$N_T = 240$ TURNS	$N_T = 120$
$V_{CL} = 200$ VOLTS	$V_{CL} = 200$
$R_L = 0.4$ OHMS	$R_L = 0.4$
DELTA CT	WYE CT
$I_{ext} \leq 100A$	

Three winding bank

HIGH	INTERMEDIATE	LOW
$(KVA)_M = 40{,}000$	$(KVA)_M = 40{,}000$	$(KVA)_M = 10{,}000$
$(KVA)_S = 30{,}000$	$(KVA)_S = 30{,}000$	$(KVA)_S = 7{,}500$
$V_H = 161{,}000$	$V_I = 69{,}000$	$V_L = 12{,}400$
$N_T = 240$	$N_T = 120$	$N_T = 240$
$V_{CL} = 800$	$V_{CL} = 200$	$V_{CL} = 200$
$R_L = 0.5$	$R_L = 0.5$	$R_L = 0.5$
DELTA CT	DELTA CT	WYE CT
$I_{ext} \leq 100A$		

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* Fig. 14. *Example for Setting Calculations.*

rical error current which is flowing in the differential circuit on external fault current should not exceed 10 times relay tap.

3. *Determine Mismatch*

For 2 winding banks:

$$\% \text{ mismatch} = 100 \frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{S} \quad (1)$$

where S is the smaller of the two terms, (I_{RL}/I_{RH}) or (T_L/T_H)

For 3 winding banks:

$$\% \text{ mismatch} = 100 \frac{(I_{RH}/I_{RI}) - (T_H/T_I)}{S} \quad (2)$$

where "S" is the smaller of the two terms, (I_{RH}/I_{RI}) or (T_H/T_I).

Equations similar to eq. (2) apply for mismatch from the high to low and from the intermediate to low voltage windings.

Where tap changing under load is performed the relays should be set on the basis of the middle or neutral tap position. The total mismatch, including the automatic tap change should not exceed 15% with a 30% sensitivity relay, and 20% with a 35% sensitivity relay. Note from Fig. 7 that an ample safety margin exists at these levels of mismatch.

* 4. *Check current transformer performance.* Ratio error should not exceed 10% with maximum symmetrical external fault current flowing. An accurate method of determing ratio error is to use ratio-correction-factor curves (RCF). A less accurate, but satisfactory method is utilize the ASA relaying accuracy classification. If the "C" accuracy is used, performance will be adequate if:

$[N_p V_{cl} - (I_{ext} - 100) R_S] / I_{ext}$
is greater than Z_T (3)

Note: let $I_{ext} = 100$
when maximum external fault current is less than 100A.

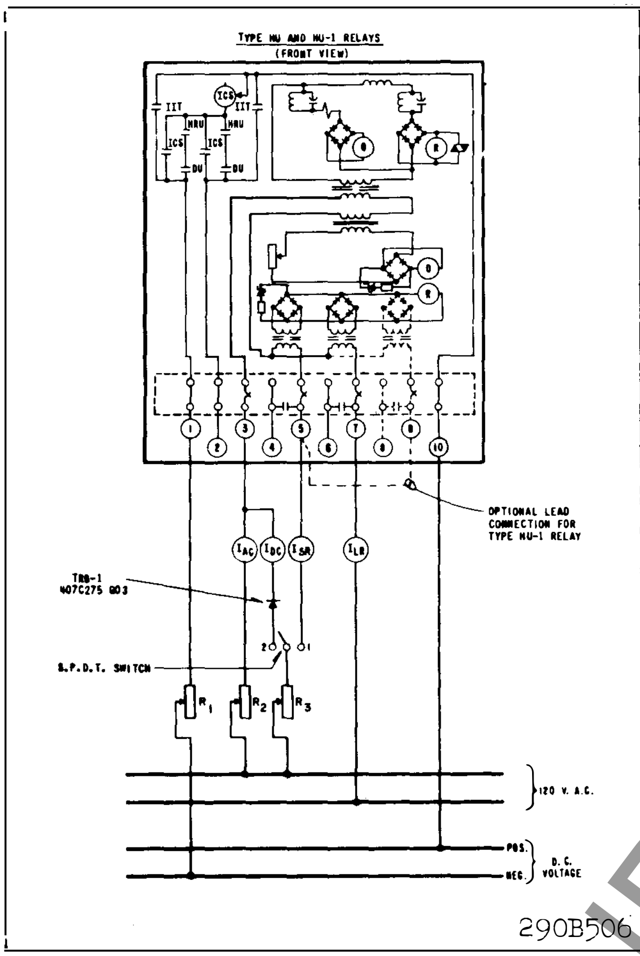


Fig. 15. Test Circuit of the HU and HU-1 Relays.

For wye-connected ct:

$$Z_T = \text{lead resistance} + \text{relay burden} + Z_A$$

$$= 1.13\, R_L + \frac{0.15}{T} + Z_A \text{ ohms} \qquad (4)$$

(R_L multiplier, 1.13, is used to account for temperature rise during faults. $\frac{0.15}{T}$ is an approximation. Use 2 way lead resistance for single phase to ground fault.)

For delta-connected ct:

$$Z_T = 3\,(1.13\, R_L + \frac{0.15}{T} + Z_A) \text{ ohms}$$

$$= 3.4\, R_L + \frac{0.45}{T} + 3Z_A \qquad (5)$$

* (The factor of 3 accounts for conditions existing during a phase fault.)

5. *Examples*

Refer to pages 13 and 14 and figure 14 for setting examples.

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 to the terminal studs furnished with the relay for thick-panel mounting. The terminal studs may be easily removed or inserted by locking two nuts on the stud and then turning the proper nut with a wrench.

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

ADJUSTMENTS AND MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer.

Acceptance Tests

The following check is recommended to insure that the relay is in proper working order. All checks can best be performed by connecting the relay per the test circuit of Fig. 15. Relay to be tested in case.

1. Minimum Trip Current. With switch open and relay set on 5-ampere tap, apply 1.35 to 1.65 amperes for the 30%-sensitivity relay and 1.6 to 1.9

* TWO-WINDING TRANSFORMER CALCULATIONS

(See Figure 14)

	LOW	HIGH
1. Select ct Ratio:		
$I_P = \dfrac{(KVA)_M}{\dfrac{V\sqrt{3}}{1000}} =$	$\dfrac{20{,}000}{12.4\sqrt{3}} = 930$ Amp.	$\dfrac{20{,}000}{69\sqrt{3}} = 167$ Amp.
Select Ratio	1000/5 (N = 200)	200/5 (N = 40)
2. Select Relay Taps:		
$I_S = \dfrac{I_P}{N} =$	$\dfrac{930}{200} = 4.65$ Amp.	$\dfrac{167}{40} = 4.18$ Amp.
$I_R =$	$I_{RL} = 4.65\sqrt{3} = 8.05$ Amp.	$I_{RH} = 4.18$ Amp.
Select Tap	$T_L = 8.7$	$T_H = \dfrac{4.18}{8.05} X\ 8.7 = 4.64$
Desired Tap		$T_H = 4.6$

3. Determine Mismatch:

% Mismatch =

$$100\ \frac{(I_{RL}/I_{RH}) - (T_L/T_H)}{T_L/T_H} =$$

$$100\ \frac{(8.05/4.18) - (8.7/4.6)}{8.7/4.6} =$$

$$100\ \frac{1.92 - 1.89}{1.89} =$$

1.6%

	LOW	HIGH
4. Check ct Performance:		
$Z_T =$	$3.4\ R_L + \dfrac{0.45}{T} =$	$1.13\ R_L + \dfrac{0.15}{T} =$
	$3.4\ X\ 0.4 + \dfrac{0.45}{8.7} = 1.36 + 0.05 =$	$1.13\ X\ 0.4 + \dfrac{0.15}{4.6} = 0.45 + 0.03 =$
	1.41 ohms	0.48 ohms
$N_P = \dfrac{N}{N_T} =$	$\dfrac{200}{240} = 0.833$	$\dfrac{40}{120} = 0.333$
$\dfrac{N_P\ V_{CL}}{100} =$	$\dfrac{0.833\ X\ 200}{100} = 1.67$	$\dfrac{0.333\ X\ 200}{100} = 0.67$
$(N_P\ V_{CL}/100) > Z_T$	Yes	Yes

* THREE-WINDING TRANSFORMER CALCULATIONS
(See Figure 14)

	HIGH	INTERMEDIATE	LOW
1. Select ct Ratio:			
$I_P = \frac{(KVA)_M}{\frac{V\sqrt{3}}{1000}} =$	$\frac{40,000}{161\sqrt{3}} = 143$ Amp.	$\frac{40,000}{69\sqrt{3}} = 334$ Amp.	$\frac{10,000}{12.4\sqrt{3}} = 465$ Amp.
Select Ratio	400/5 (N = 80)	600/5 (N = 120)	1000/5 (N = 200)
2. Select Relay Taps:			
$I_S = \frac{I_P}{N} =$	$\frac{143}{80} = 1.78$ Amp.	$\frac{334}{120} = 2.78$ Amp.	$\frac{465}{200} = 2.32$ Amp. (At 10 MVA)
I_R (At 40 MVA) =	$I_{RH} = 1.78\sqrt{3}$ = 3.08 Amp.	$I_{RI} = 2.78\sqrt{3}$ = 4.82 Amp.	$I_{RL} = \frac{40}{10} X\ 2.32$ = 9.3 Amp.
Select Tap			$T_L = 8.7$
Desired Tap	$T_H = 8.7\frac{3.08}{9.30}$ = 2.88	$T_I = 8.7\frac{4.82}{9.30}$ = 4.52	
Select Tap	$T_H = 2.9$	$T_I = 4.6$	
3. Determine Mismatch			
% Mismatch	$100\frac{(I_{RH}/I_{RI})-(T_H/T_I)}{T_H/T_I} =$	$100\frac{(I_{RI}/I_{RL})-(T_I/T_L)}{(I_{RI}/I_{RL})} =$	$100\frac{(I_{RL}/I_{RH})-(T_L/T_H)}{T_L/T_H} =$
	$100\frac{(3.08/4.82)-(2.9/4.6)}{2.9/4.6} =$	$100\frac{(4.82/9.30)-(4.6/8.7)}{4.82/9.30} =$	$100\frac{(9.3/3.08)-(8.7/2.9)}{8.7/2.9} =$
	$100\frac{0.640-0.630}{0.630} =$	$100\frac{0.518-0.528}{0.518} =$	$100\frac{3.02-3.00}{3.00} =$
	1.6%	−1.9%	0.67%
4. Check ct Performance			
$Z_T =$	$3.4\ R_L + \frac{0.45}{T} =$	$3.4\ R_L + \frac{0.45}{T} =$	$1.13R_L + \frac{0.15}{T} =$
	$3.4 X 0.5 + \frac{0.45}{2.9} =$	$3.4 X 0.5 + \frac{0.45}{4.6} =$	$1.13 X 0.5 + \frac{0.15}{8.7} =$
	1.70 + 0.16 = 1.86 ohms	1.70 + 0.10 = 1.80 ohms	0.565 + 0.02 = 0.58 ohms
$N_P = \frac{N}{N_T} =$	$\frac{80}{240} = 0.333$	$\frac{120}{120} = 1.0$	$\frac{200}{240} = 0.833$
$\frac{(N_P\ V_{CL})}{100} =$	$\frac{800 X 0.333}{100} = 2.67$	$\frac{200 X 1.0}{100} = 2.0$	$\frac{200 X 0.833}{100} = 1.67$
$(N_P\ V_{CL}/100) > Z_T$	Yes	Yes	Yes

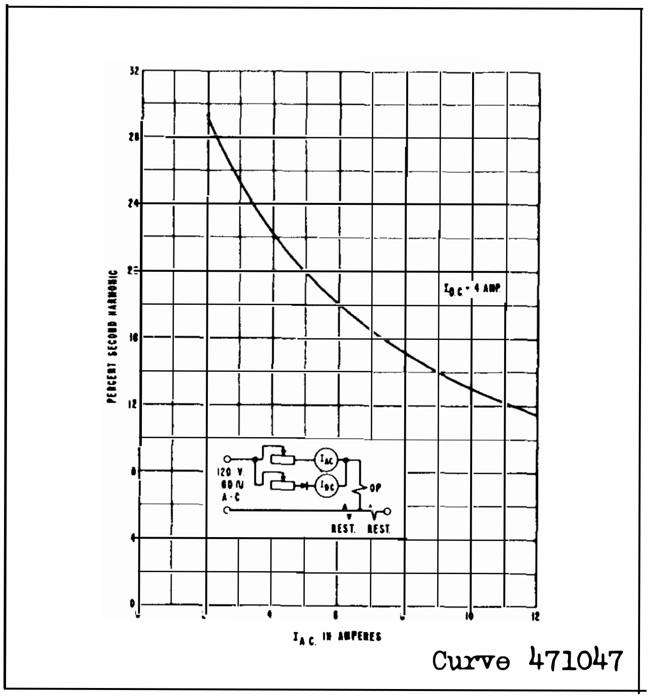


Fig. 16 ***Variation of Second Harmonic Content of Test Current.***

amperes for the 35% sensitivity relay. Relay should operate. The upper polar unit may operate for lower currents, but not below 1.0 ampere. This low pickup will not impair its operation on magnetizing inrush currents and should not be disturbed if it is found to be less than the lower polar unit. If a higher pickup is desired, it is suggested that 20 times tap value current be applied to relay terminals 3 & 7. This will cause the upper polar unit to pick up at a current of approximately 1.65 amperes.

2. Indicating instantaneous Trip Pickup. With switch open and relay set on 5 ampere tap, apply 50 amperes to relay. Indicating instantaneous trip should pick up and its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

3. Indicating Contactor Switch. Block Polar unit contacts closed. Pass sufficient direct 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 setting being used. The operation indicator target should drop freely.

The contact gap of the ICS should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

4. Differential Characteristic.

30% Sensitivity relay

a. Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 10 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 12.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 to 2.95 amperes
I_{LR} = 11.8 to 12.8 amperes

b. Reverse leads to restraint transformers and repeat differential test outlined in paragraph 4 a. Results should be approximately the same as obtained under paragraph 4 a.

35% Sensitivity relay

c. Close switch to position 1. Set I_{ac} to zero and adjust I_{LR} to 9 amperes. Increase I_{ac} to 2.8 amperes. If the lower polar unit does not operate with I_{ac} = 2.8 amperes and I_{LR} = 11.8 amperes, lower I_{LR} current. The lower polar unit should operate between the following limits:

I_{ac} = 2.8 amperes
I_{LR} = 10.8 to 11.8 amperes

d. Reverse leads to restraint transformers and repeat differential test outlined in paragraph 4 c. Results should be approximately the same as obtained under paragraph 4c.

5. Harmonic Restraint Characteristic.

Close switch to position 2. Short out I_{LR} ammeter. Set I_{dc} to 4 amperes and adjust I_{ac} until upper polar unit operates. I_{ac} should read between 6.5 and 9 amperes.

As shown in Fig. 16, these values of alternating current correspond to 17 percent and 14 percent second harmonic.

6. Diodes

Check for open or shorted diodes using electrical checkpoints under relay calibration section.

In Service Test

Table 1 is to be used as an in-service check of the HU or HU-1 relay using any tap combination. This test also checks against reversed tap connections. The relay should be connected as shown in fig. 15 with the S.P.D.T. switch in position 1. The ammeter I_{SR} measures the smaller restraint current and should be connected to the terminal associated with the tap block of the smaller setting. The ammeter I_{LR} measures the larger restraint current, and should be connected to the terminal associated with the larger tap block setting. Terminal 5 supplies the upper tap block; terminal 7 supplies the second tap block; and terminal 9 (HU-1 only) supplies the lower tap block (refer to figs. 1 and 4).

* Table 1 gives the values of I_{AC} necessary to operate the relay when using a value of I_{SR} equal to 3 times tap value for all taps except the 8.7 tap. A value of I_{SR} equal to 2 times tap value was chosen for the 8.7 tap setting in order to keep the current at a convenient value for testing. Table I refers to a 30% relay. For a 35% relay, values of I_{ac} will be .1 to .2 amperes higher.

Example (HU Relay)
Upper Tap Block Tap 3.5
Lower Tap Block Tap 5.0

Since the upper tap block has the smaller tap setting I_{SR} should be connected to the upper tap block (Term. 5), and I_{LR} should be connected to

TABLE 1

Restraint Transformer Tap	Larger	2.9	3.2	3.5	3.8	4.2	4.6	5.0	8.7
Smaller	CURRENT IN AMPERES								
2.9	ISR	8.7	8.7	8.7	8.7	8.7	8.7	8.7	5.8
	IAC (Min.)	2.6	3.7	5.0	5.8	7.8	9.0	10.4	16.2
	IAC (Max.)	2.8	4.0	5.5	6.4	8.6	10.0	11.6	17.9
3.2	ISR		9.6	9.6	9.6	9.6	9.6	9.6	6.4
	IAC (Min)		2.7	4.0	4.9	6.9	8.1	9.6	15.7
	IAC (Max)		3.1	4.4	5.4	7.6	9.0	10.6	17.3
3.5	ISR			10.5	10.5	10.5	10.5	10.5	7.0
	IAC (Min)			3.0	3.8	5.7	6.9	8.3	14.5
	IAC (Max)			3.3	4.2	6.3	7.7	9.2	16.1
3.8	ISR				11.4	11.4	11.4	11.4	7.6
	IAC (Min)				3.2	5.2	6.5	7.9	14.1
	IAC (Max)				3.6	5.7	7.2	8.7	16.0
4.2	ISR					12.6	12.6	12.6	8.4
	IAC (Min)					3.5	4.7	6.2	12.9
	IAC (Max)					3.9	5.2	6.9	14.2
4.6	ISR						13.8	13.8	9.2
	IAC (Min)						3.9	5.3	12.4
	IAC (Max)						4.3	5.9	13.7
5.0	ISR							15.0	10.0
	IAC (Min)							4.3	11.6
	IAC (Max)							4.8	12.9
8.7	ISR								17.4
	IAC (Min)								5.0
	IAC (Max)								5.5

Terminal 7. From Table 1 under "Restraint Transformer tap: Larger" = 5.0 "Smaller" = 3.5, set I_{SR} = 10.5 amps. The value of I_{AC} to operate the relay should be between 8.3 and 9.2 amps.

To check the third restraint winding on the HU-1 repeat the above procedure using terminal 9 and either terminal 5 or 7.

Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

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 contact.

Calibration (All Relays)

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. All adjustments to be done with relay inside its case. (See "Acceptance Check")

Polar Units

1. Contacts. Place a .060 to .070 inch feeler gage between the right hand pole face and the armature. This gap should be measured near the front of the right hand pole face. Bring up the backstop screw until it just makes with the moving contact. Place gage between moving contact and the stationary contact on the left-hand side of the polar unit. On the upper unit, the gap should be .046 inch and on the lower unit the gap should be .065 to .070 inch. Bring up the stationary contact until it just makes with the gage and lock in place.

2. Minimum Trip Current

a. Harmonic Restraint Unit (HRU)

Connect the relay per test circuit of Fig. 15. With the switch open, pass I_{ac} = 20 times tap value current into the relay. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right hand shunt on upper polar unit until it trips with I_{ac} = 33% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. Repeat these steps, if necessary, until the unit operates at 33% or slightly lower of tap value current immediately following the application of 20 times tap value current and until the unit resets at a value of current 15% of tap value or greater. After the dropout has been measured, the unit should pick up at 25% or higher of tap value current.

On the application of the high current the upper polar unit will be biased in the restraining direction and pickup will be greater than the nominal value of 30% of tap value current on the first application of pickup current. If the circuit is deenergized and pickup is measured again, the pickup current will be less than before. However, pickup will be stable after the second application of pickup current. If 20 times tap value current is applied again, the pickup immediately after applying this current will be high. However, measuring the pickup the second time will show that the pickup is again reduced. The variation between these pickups should be between 25% and 33% of tap value current.

The filter circuits are charged by the application of this heavy current and upon the removal of the current, these circuits will discharge their energy. The element will be biased in the restraining direction because the restraint coil has approximately 7 times the number of turns as the operating coil. Upon the application of pickup current, the operating ampere turns will be greater than the restraint ampere turns and the bias will be removed.

If a lower biasing current is used instead of 20 times tap value current, the pickup of the upper unit will be less than before for the first application of pickup current. Pickup will be further reduced with the second application of pickup current, but the current will be stable after this energization. However, this value of pickup will be lower than the limits of 25% and 33% of tap value current. This is in the direction of making the sensitivity of the polar unit lower than 30%, but does not impair the performance of the unit on inrush currents.

b. Differential Unit (DU)

Set the adjustable resistor at top of the relay in the approximate center of its range. Open the switch and pass I_{ac} = 20 times tap value current. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust right-hand shunt of lower polar unit until it trips with I_{ac} = 30% of tap value amperes. Lower I_{ac} gradually to 15% of tap value current and adjust left-hand shunt until unit resets. If polar unit resets before 15% of tap value current, no adjustments are necessary to the left-hand shunt. Repeat these steps until the lower polar unit will pickup at 30% of tap value current and reset for values of tap value current greater than 15%

Indicating Instantaneous Trip Unit (IIT)

With switch open, pass I_{ac} = 10 times tap value current. Adjust core of the instantaneous trip unit until it picks up. Its target should drop freely.

The contact gap should be approximately 0.094 inch between the bridging moving contact and the adjustable stationary contacts. The bridging contact should touch both stationary contacts simultaneously.

Harmonic-Restraint Unit (HRU)

Close switch to position 2. Short out I_{LR} ammeter. Adjust direct current until I_{dc} reads 0.8 times tap setting. Gradually increase alternating current until upper polar unit operates with I_{ac} reading between 1.3 and 1.8 times tap setting. The percent second harmonic in the wave may be derived by the use of the formula:

$$\% \text{ second harmonic} = \frac{47\ I_{dc}}{I_{ac} + 1.11\ I_{dc}}$$

This formula is plotted in curve form in Fig. 16 for I_{dc} = 4 amperes.

Percentage Slope Characteristic (DU)

Close switch to position 1. Set I_{ac} to zero and I_{SR} to 5.5 times tap value current. Then adjust I_{ac} to 4 times tap value current.

Adjust resistor at top of relay until lower polar unit operates. Interchange lead positions to terminals 5 and 7 and repeat the above test. The lower polar unit should operate between the limits of:

I_{ac} = 4 times tap value current

I_{LR} = 9 to 10 times tap value current

Trip condition can best be determined by holding I_{ac} at 4 times tap value current and varying I_{LR}. If I_{LR} is too low the contacts will be closed when the currents are first applied. Hence, I_{LR} should be increased until the contacts open and then decreased until contacts close.

The adjustment of the resistor will have some effect on the pickup of the unit. Hence, recheck the pickup. If necessary readjust shunts to obtain a pickup of 30% of tap value current and dropout of 15% or greater of tap value current. If shunts are changed, check to see that above readings are obtained on the higher restraint currents. If necessary readjust resistor and repeat procedure until the unit operates within the specified limits.

Apply I_{ac} = .56 times tap value and vary I_{LR} until lower polar unit operates. The lower polar unit should operate between following limits.

I_{LR} = 2.36 to 2.56 times tap value current.

Indicating Contactor Switch (ICS)

Block polar unit contacts closed. Pass sufficient direct current through the trip circuit to close the contacts of the ICS. This value of current should be not greater than the particular tap setting being used. The operation-indicator target should drop freely.

The contact gap should be approximately 0.047 inch between the bridging moving contact and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

Calibration (35%-Sensitivity Relays)

The differential unit (DU) should first be calibrated as outlined under "Calibration (All Relays)". Next the right hand shunt of the lower polar unit should be turned out until the relay operates at

I_{ac} = .45 times tap value current

I_{LR} = 1.64 times tap value current

This changes the percentage slope curve of the relay to that shown by the 35 percent sensitivity curve of figure 7. Pickup of the relay is increased from 30% to approximately 35% of tap value current and the curve is changed at low values of restraint current to that shown in figure 7. At large values of restraint current the percentage slope characteristic is essentially the same as shown in figure 8.

As shown in figure 7, the margin of safety between the relay calibrated for a 35% sensitivity and the 20% mismatch curve is the same as that of the relay calibrated for a 30% sensitivity and the 15% mismatch curve. This margin of safety is also shown in the voltage differential characteristic of figure 11 for the 35 percent sensitivity relay.

* Electrical Checkpoints

Differential Unit (DU)

a. Restraint Circuit

Apply two times tap - value current successively to each restraint transformer. This is done by connecting leads to a tap screw and to terminals 5, 7 and 9 (HU-1 only) in turn. The a-c voltage across the appropriate restraint rectifier bridge using a high resistance voltmeter (5000 ohms per volt) should be 2.25 ±5% volts.

Location at the appropriate bridge is shown in the following table for Relays having a diode board as shown in Figure 2 and in Figure 17 for Relays using a printed circuit module.

Current in Term	Associated Rectifier Bridge (Rear View - Bottom)	
	HU	HU-1
5 (Restraint 1)	Center	Center
7 (Restraint 2)	Right hand	Left hand
9 (Restraint 3)	–	Right hand

b. Operating Circuit

Apply 30 per-cent tap-value current to terminal 3 and a tap screw. Using a high-resistance voltmeter, the a-c voltage across the operating coil bridge should be 2.8 ±5% volts (Refer to Fig. 2 or 17 for bridge location depending on diode board used). The a-c voltage output of the operating transformer (top two coil terminals) should be 5.2 ± 15% volts.

* Harmonic Restraint Unit (HRU)

Apply 30 percent tap-value current to terminal 3 and a tap screw. The following are the voltages that should be obtained using a high resistance a-c voltmeter. (Refer to Fig. 2 or 17 for location depending on diode board used.)

1.	Output of operating transformer (top coil terminals)	4.35±10% volts
2.	4 MFD capacitor	2.5 ± 15% volts
3.	0.45 MFD capacitor	3.8 ± 15% volts
4.	Operating - rectifier bridge	2.6 ± 10% volts
5.	Restraint - rectifier bridge	less than 1 volt
6.	Series-Filter Reactor	less than 0.5 volt

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

* APPROXIMATE RESISTANCE VALUES OF COMPONENTS IN HU RELAY

UNIT	CIRCUIT	DESCRIPTION
Harmonic Restraint	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 50 to 70 ohms. Reactor d.c. Resistance 8 to 10 ohms. 4 MFD Capacitor. Rectifier 500 Volts, 1.5 ampere Silicon Diodes Indicating Instantaneous Trip Unit 14 to 16 ohms. Polar Unit Coil d.c. Resistance 80 to 100 ohms.
	Restraint	Series Reactor d.c. Resistance 110 to 130 ohms. Parallel Reactor d.c. Resistance 300 to 360 ohms. .45 MFD Capacitor. Rectifier 500 Volts, 1.5 ampere Silicon Diodes Polar Unit Coil d.c. Resistance 650 to 800 ohms. Varistor 150K±50% at 10 V.D.C. 4000 ±25% at 30 V.D.C.
Differential	Operating	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Secondary d.c. Resistance 20 to 30 ohms. Adjustable 3½ inch 280 ohm Resistor Rectifier 500 Volts, 1.5 ampere Silicon Diodes Zener Diode, 200 volts Resistor, 20 ohms, 5% 3W. Polar Unit Coil d.c. Resistance 75 to 100 ohms.
	Restraint	Transformer (Primary taps 8.7, 5, 4.6, 4.2, 3.8, 3.5, 3.2, 2.9) Rectifier 500 Volts, 1.5 ampere Silicon Diodes Zener Diode, 200 Volts Resistor, 20 ohms, 5% 3W. Polar Unit Coil d.c. Resistance 60 to 110 ohms.
Indicating Contactor Switch	Trip	0.2 Amp. tap 6,5 ohms d.c. 2.0 Amp. tap 0.15 ohms. d.c.

ENERGY REQUIREMENTS

Burden of Each Restraint Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	at 8 times tap value current	at 20 times tap value current
2.9	10	71	.88	50	191
3.2	12	70	.89	51	211
3.5	13	66	.90	51	203
3.8	14	65	.91	53	220
4.2	15	58	.91	53	235
4.6	16	57.5	.91	55	248
5.0	18	52.5	.92	59.	280
8.7	22	30	1.28	94.	340

Burden of Operating Circuit

Tap	Continuous Rating	Power Factor Angle θ	volt amperes † at tap value current	at 8 times tap value current	at 20 times tap value current
2.9	10	35	2.26	76	487
3.2	12	34	2.30	78	499
3.5	13	33	2.30	81	504
3.8	14	33	2.30	83	547
4.2	15	31	2.30	84.	554
4.6	16	30	2.40	88.	598
5.0	18	29	2.50	92.	640
8.7	22	23	3.18	132.	850

θ Degrees current lags voltage at tap value current

† Voltages taken with Rectox type voltmeter

* **Thermal Rating**

One Second — 300 amperes

Thermal capacities for short times other than one second may be calculated on the basis of time being inversely proportional to the square of the current.

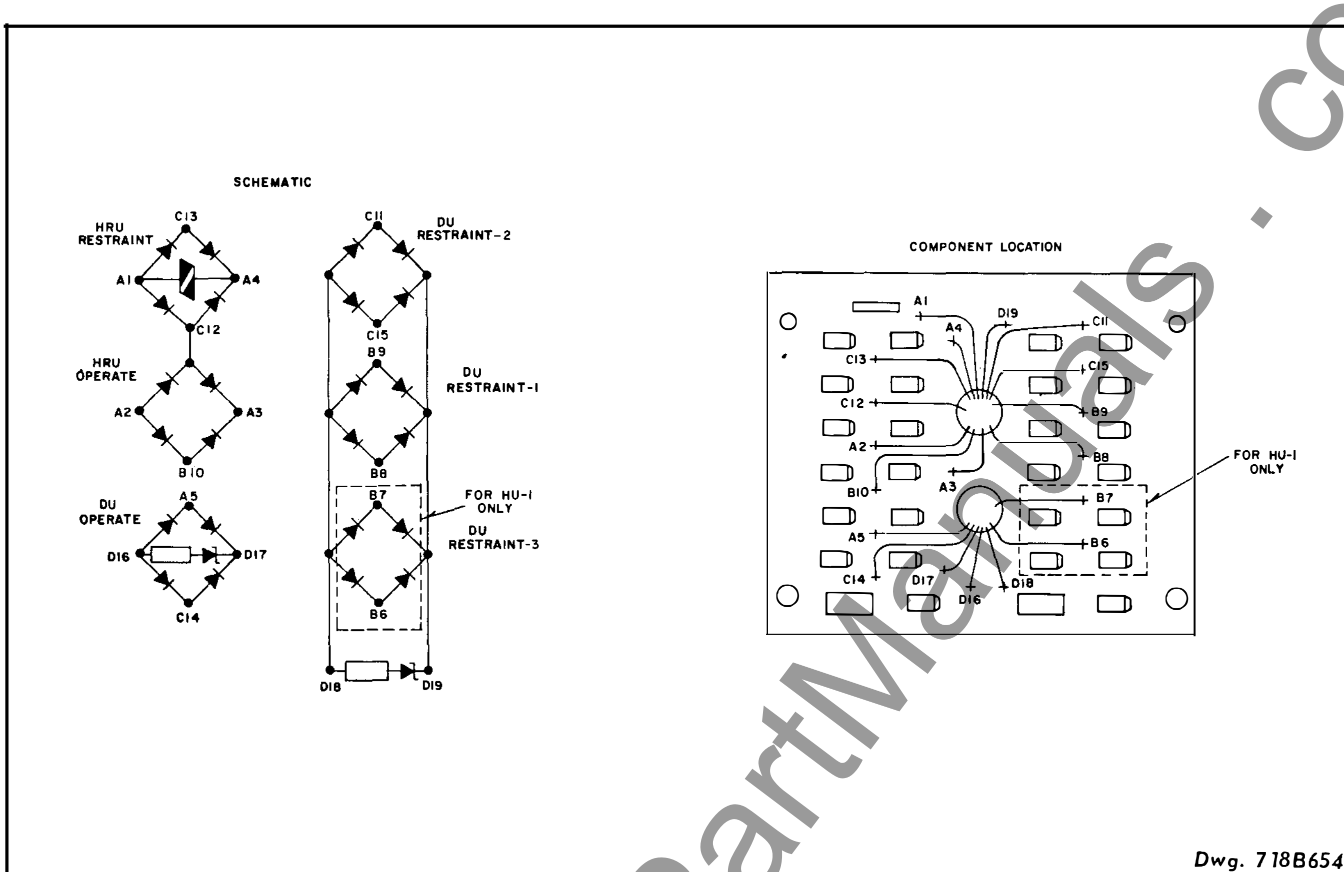


Fig. 17. HU, HU-1, Diode Board Module – Component Location.

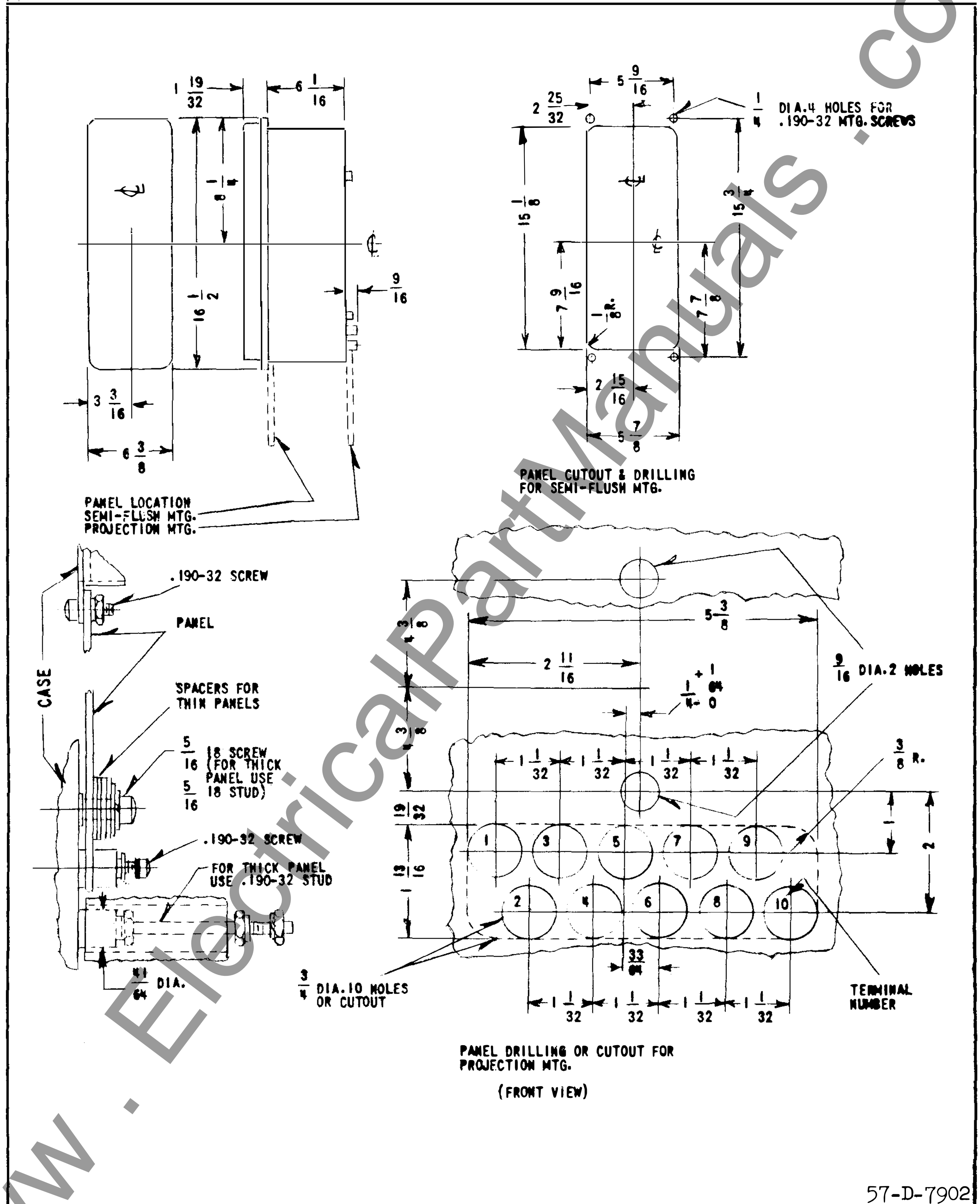


Fig. 18. Outline and Drilling Plan of the Type HU and HU-1 Relays in the FT31 Case.

WESTINGHOUSE ELECTRIC CORPORATION

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

Printed in U.S.A.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE HRU INSTANTANEOUS OVERCURRENT RELAY WITH HARMONIC RESTRAINT

CAUTION Before putting 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 proply, and operate the relay to check the settings and electrical connections.

* APPLICATION

The type HRU harmonic restraint relay is a high speed relay used for supervising overcurrent, differential or pilot relays to avoid magnetizing inrush tripping. There are single phase and 3-phase units available as shown in Fig. 1 to Fig. 4.

The 3-phase HRU relay may be added to an existing induction-disc differential relay installation per Fig. 5 should inrush tripping become a problem.

Fig. 6 shows the scheme using a 3-phase HRU relay to supervise the HCB or HCB-1 relay for preventing magnetizing inrush tripping.

Fig. 7 shows the use of single phase HRU relays to provide sensitive instantaneous overcurrent protection for rectifier transformers, where there are no selectivity requirements with low-side protective devices. This scheme is not recommended where transformer loads are not supervised by individual local breakers, since this always involves load pick up with transformer energization.

This relay is not intended to be used in applications where saturation of current transformers occurs on asymmetrical and symmetrical faults external to the protected transformer. For such applications the type HU relay should be applied.

CONSTRUCTION

The single phase HRU relays consist of an instantaneous trip unit, a harmonic restraint unit, and an indicating contactor switch. The principal component parts of the relay are shown in Fig. 1 and Fig. 2.

* The 3-phase HRU relay consists of the same parts in the single phase HRU relays, except with a mixing transformer, as shown in Fig. 3 and 4.

Harmonic Restraint Unit (HRU)

The harmonic restraint unit consists of an air-gap transformer, a second harmonic block filter, a fundamental block-second harmonic pass filter, two full-wave rectifiers, a varistor, and a d-c polar unit.

Polar Unit

The polar unit consists of a rectangular shaped magnetic frame, an electromagnet, a permanent magnet, and an armature. The poles of the crescent shaped permanent magnet bridge the magnet frame. The magnetic frame consists of three pieces joined in the rear with two brass rods and silver solder. These non-magnetic joints represent air gaps, which are bridged by two adjustable magnetic shunts. The windings are wound around a magnetic core. The armature is fastened to this core, and is free to move in the front air gap. The moving contact is connected to the free end of a leaf spring, which, in turn, is fastened to the armature.

Instantaneous Trip Unit (IT)

The instantaneous trip unit is a small a-c operated 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. A core screw accessible from the top of the switch provides the adjustable pickup range. The minimum and maximum pickup points are indicated on the scale, which is located to the rear of the core screw.

Indicating Contactor Switch Unit (ICS)

The d-c indicating contactor switch is a small clapper-type device. A magnetic armature to which leaf-spring mounted contacts are attached, is attracted to the magnetic core upon energization of the switch. When the switch closes, the moving contacts bridge two stationary contacts, completing the trip circuit. Also, during this operation, two fingers on the arma-

SUPERSEDES I.L. 41-347.3
*Denotes change from superseded issue.

EFFECTIVE SEPTEMBER 1972

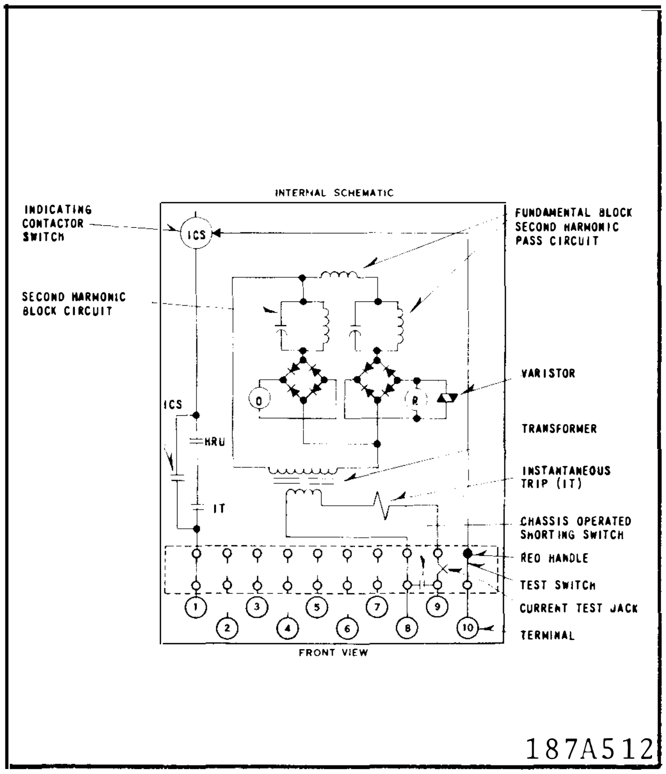


Fig. 1 Internal Schematic of Single Phase HRU Relay

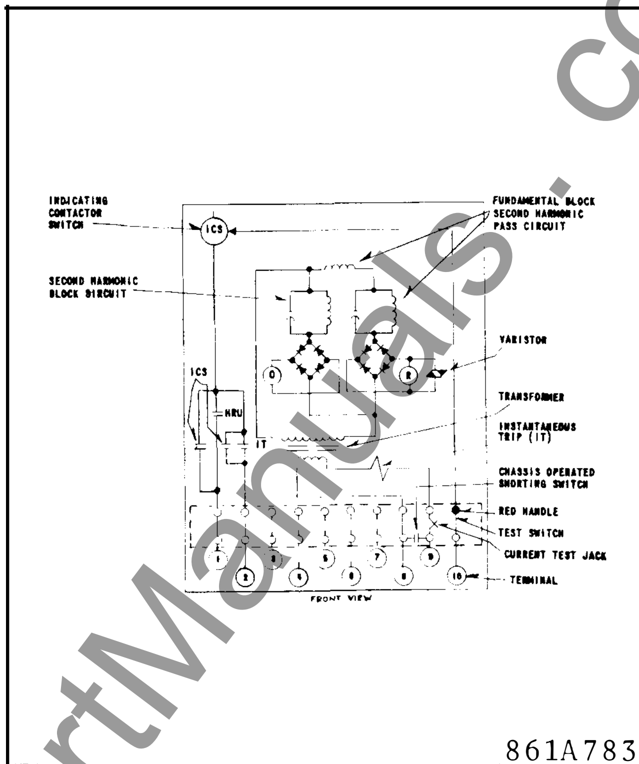


Fig. 2 Internal Schematic of Single Phase HRU Relay

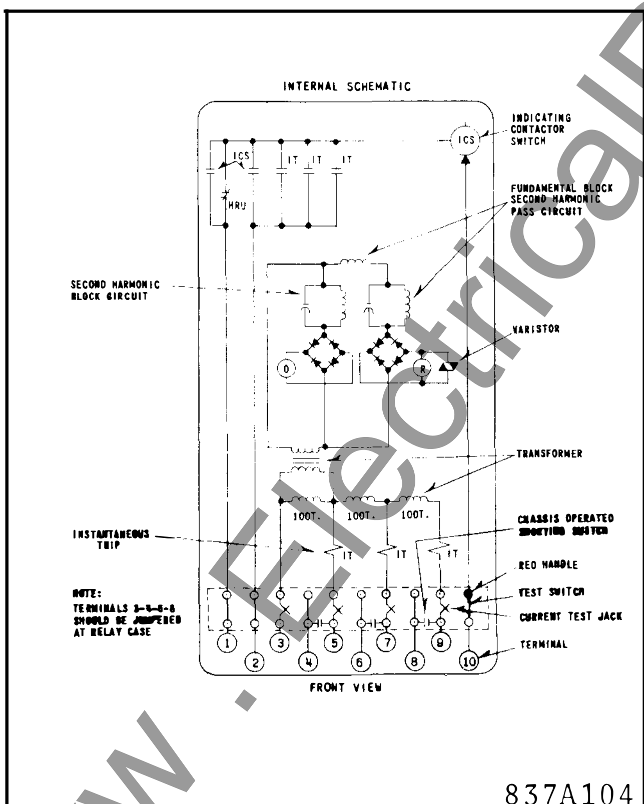
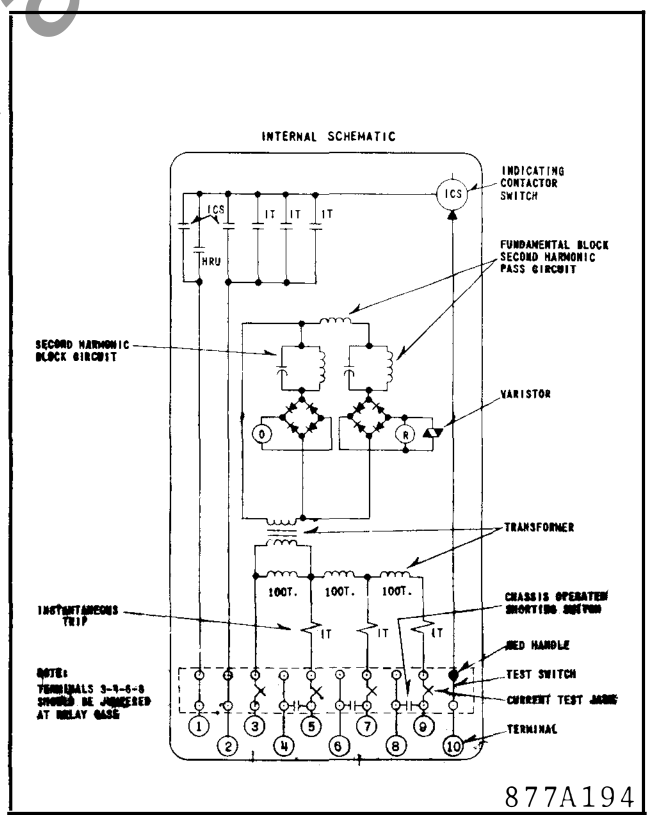


Fig. 3 Internal Schematic of 3-Phase HRU Relay



* *Fig. 4 Internal Schematic 3-Phase HRU Relay*

ture deflect a spring located on the front of the switch, which allows the operation indicator target to drop.

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

OPERATION

The type HRU relay is connected to operate for faults internal to the differential zone of the transformer but not on magnetizing inrush currents associated with energization of the transformer.

Magnetizing Inrush Currents

Magnetizing inrush current waves have various wave shapes. A typical wave appears as a rectified half wave with decaying peaks. In any case, the various wave shapes are rich in harmonics with the second harmonic predominant. Since the second harmonic is always present in inrush waves and not in internal fault waves, this harmonic is used to restrain the harmonic-restraint unit during inrushes. The instantaneous trip unit may or may not close its contact, depending on the magnitude of the inrush.

When a magnetizing inrush wave is applied to the relay, the d-c component of the wave is by-passed by the air-gap operating transformer. The other components are fed into the filter circuits. The impedance characteristics of these filters are such that the second harmonic component flows into the restraint coil of the polar unit, while the other harmonics flow into the operating coil. The polar unit will not close its contacts unless the second harmonic content is less than 15 percent of the fundamental component.

Internal Faults

Faults normally appear as an offset sine wave with a decaying d-c component, and contain very few harmonics. As a result, the harmonic-restraint unit and instantaneous trip will operate during internal faults to permit tripping of the relay.

The varistor connected across the d-c side of the restraint rectifier of the harmonic restraint unit prevents excessive voltage peaks from appearing across the rectifiers. These peaks arise through transformer action of the harmonic-restraint polar-unit coils during heavy internal faults. The varistor has a large value of resistance for low voltages, while presenting a low value of resistance for high voltages. This characteristic effectively reduces the voltage spikes on heavy internal faults while not hampering performance during inrush, where the voltage is considerably lower.

SETTINGS

Harmonic Restraint Unit (HRU)

No settings are required on the harmonic restraint unit. If desired, pickup may be varied by adjusting the right hand shunt (front view).

Indicating Contactor Switch (ICS)

No setting required on the ICS unit except the selection of the 0.2 or 2.0 amperes 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 or 250 volt d-c type WL relay switch or equivalent, use the 0.2 ampere tap; for 48 volt d-c applications set relay in the 2.0 amp. tap and use WL relay coil S*304C209G01 or equivalent.

Instantaneous Trip (IT)

The core screw must be adjusted to the value of pickup current desired.

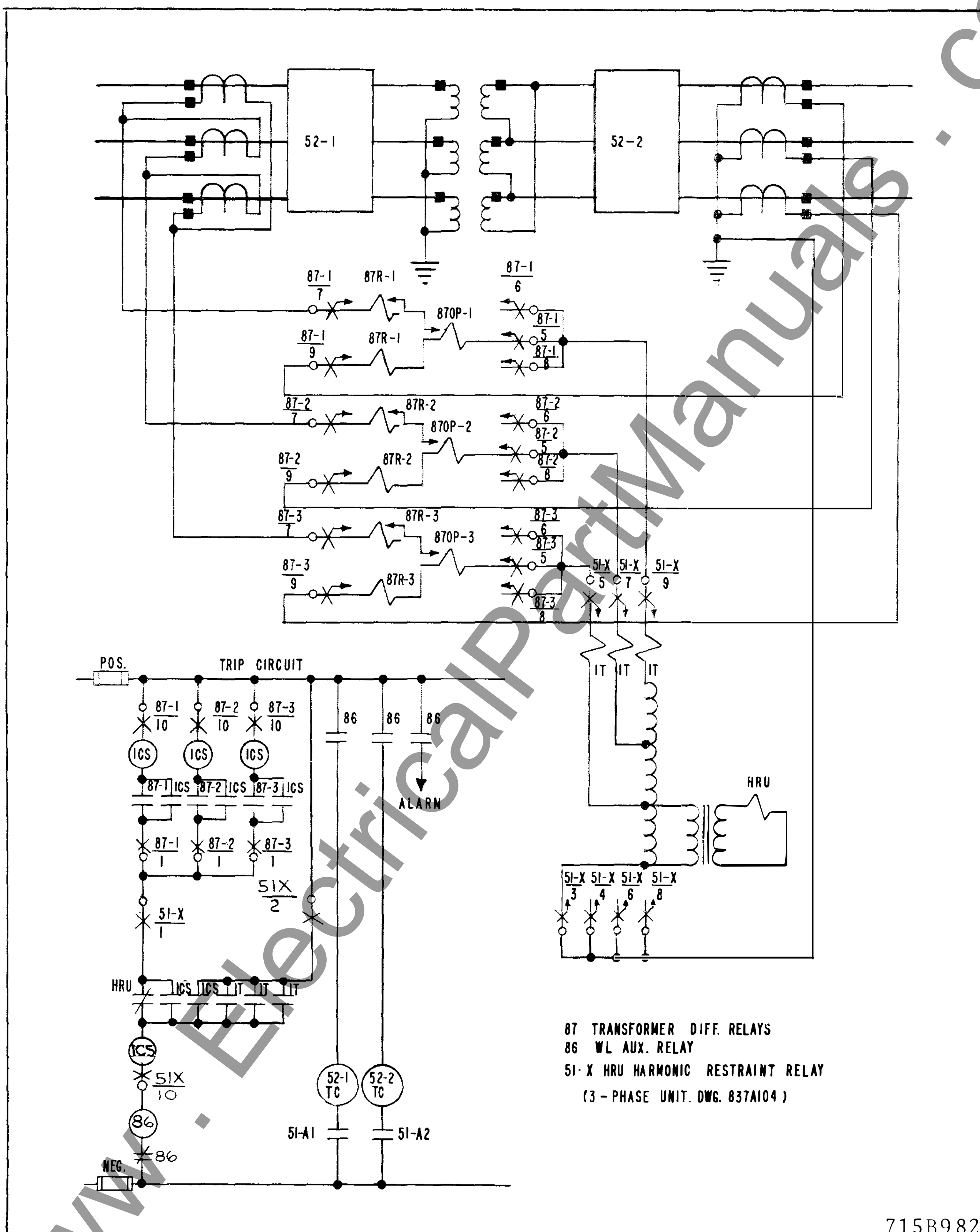
* The IT unit should be set above the maximum inrush expected, if its contact is in parallel with the normally open HRU contact.

The nameplate data will furnish the actual current range that may be obtained from the IT unit.

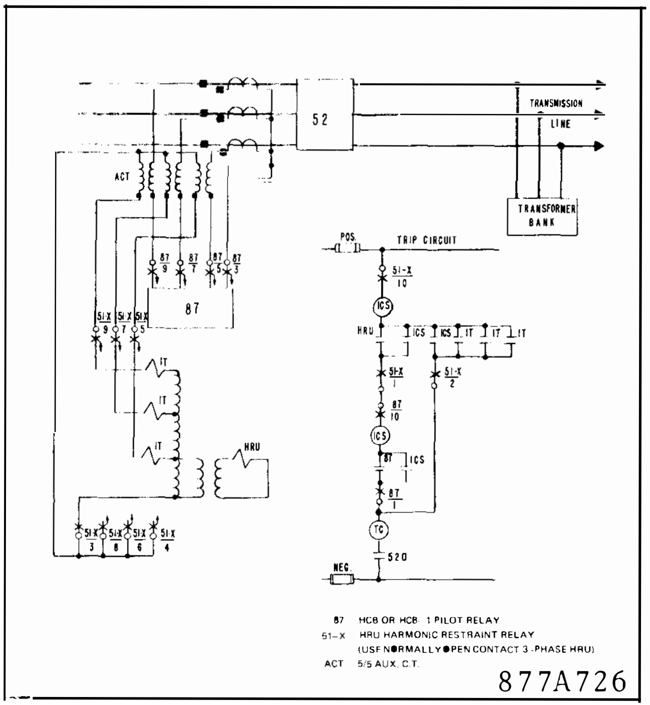
INSTALLATION

The relays should be mounted on a switchboard panel 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 mount- or to 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.

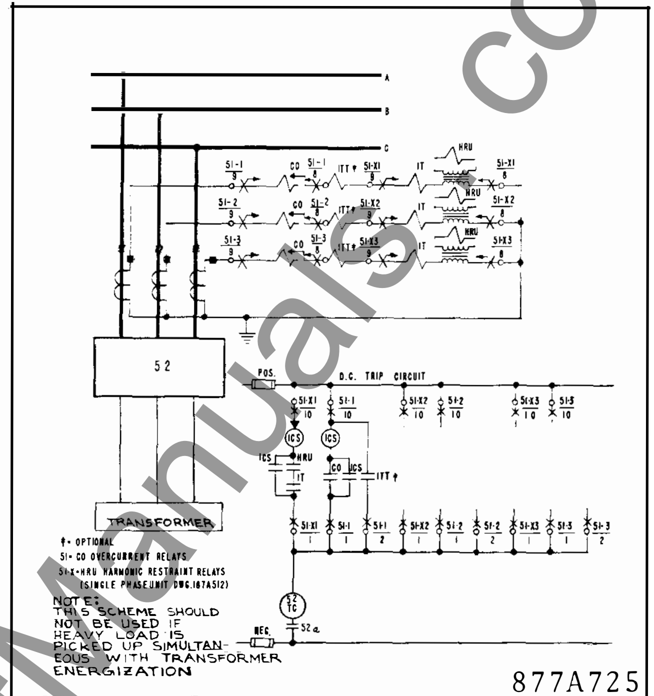
For detailed FT case information, refer to (I.L. 41-076).


52-1
52-2
87-1 7
87R-1
87-1 6
87OP-1
87-1 5
87-1 9
87-1 8
87-2 7
87R-2
87-2 6
87OP-2
87-2 5
87-2 9
87-2 8
87-3 7
87R-3
87-3 6
87OP-3
87-3 5
87-3 9
87-3 8
51-X 5
51-X 7
51-X 9
IT
POS.
TRIP CIRCUIT
87-1 10
87-2 10
87-3 10
ICS
86
ALARM
87-1 1
87-2 1
87-3 1
51X 2
51-X 1
HRU
51-X 3
51-X 4
51-X 6
51-X 8
IT
51X 10
52-1 TC
52-2 TC
51-A1
51-A2
NEG.
87 TRANSFORMER DIFF. RELAYS
86 WL AUX. RELAY
51-X HRU HARMONIC RESTRAINT RELAY
(3-PHASE UNIT. DWG. 837A104)
715B982

* *Fig. 5*



* Fig. 6



* Fig. 7

ADJUSTMENTS AND MAINTENANCE

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

Acceptance Tests

* The following check is recommended to insure that the relay is in proper working order. Use test circuit of Fig. 8 (single phase HRU) or Fig. 9 (3-phase HRU).

1. Minimum Trip Circuit

   A. Single Phase HRU Relays

   With the switch open, apply current to terminals 8 and 9 of the relay. The polar unit should operate at rated current. The polar unit may operate for lower currents, but not below value of Table I. This low pickup will not impair its operation on magnetizing inrush, and should not be disturbed if it is found to be less than rated current. However, if a higher pickup is desired, it is suggested that 100 amperes be momentarily applied to relay terminals 8 and 9. This will cause the polar unit to pickup at approximately rated current.

   * B. 3 Phase HRU Relays (Normally Open Contact)

   Use single phase test for all 3 phases.

* 2. Harmonic Restraint Characteristic

   A. Single Phase HRU Relays or 3 Phase Relay with normally open contact.

   Close switch of test circuit and set I_{dc} per Table 2 and adjust I_{ac} until the polar unit operates. I_{ac} should be as indicated in Table 2. These values of alternating current corresponds to 17 per cent and 14 per cent second harmonic. For 3 phase relay, check all three phases.

   * B. 3-Phase HRU Relays (Normally closed contact).

   In de-energized position, HRV contact should be closed to left.

   Energize relay with an Iac of approximately 5 amps. Close switch of test circuit and set I_{dc} per Table 2. Check to see that the polar unit contacts move to the right when I_{ac} is decreased to approximately 3.5 amps. Momentarily apply 100 amps I_{ac} to polarize unit, then set I_{dc} again per Table 2. The polar unit contacts move to the left when I_{ac} is increased to approximately 3.8 amps. All 3 phases should be acceptance tested as per Figure 9 and the above procedure.

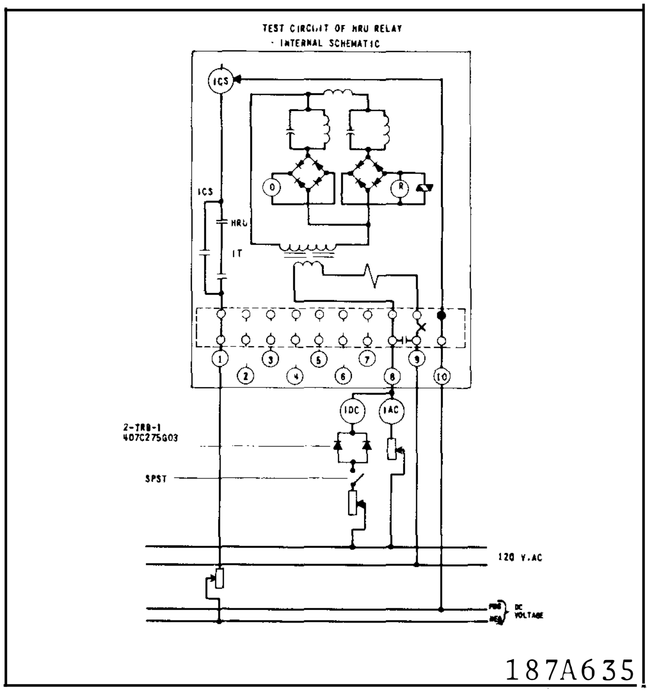


Fig. 8 Test Circuit (Single Phase HRU Relay).

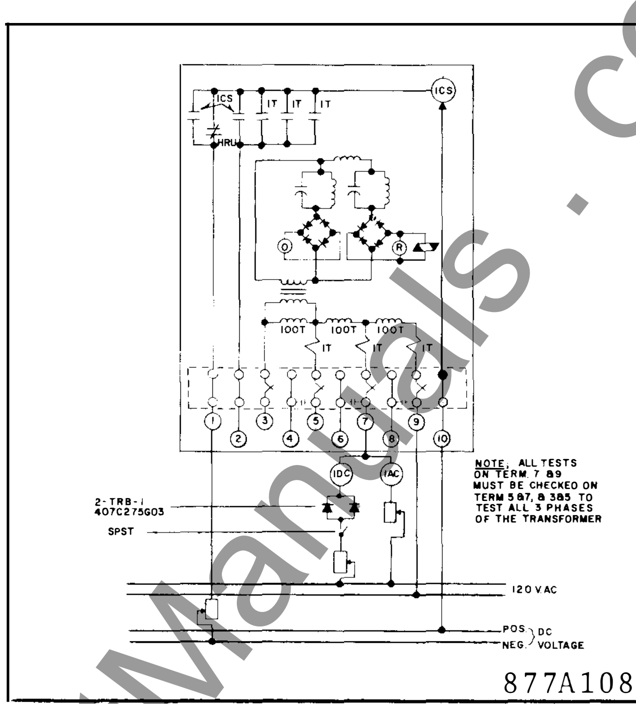


Fig. 9 Test Circuit (3-Phase HRU Relay)

3. Instantaneous Unit (IT)

The core screw which is adjustable from the top of the trip unit determines the pickup value. The trip unit has a nominal ratio of adjustment of 1 to 4 and an accuracy within the limits of 10%.

Position the stationary contact for a minimum of 1/32 inch wipe. The bridging moving contact should touch both stationary contacts simultaneously. Apply sufficient current to operate the IT.

4. Indicating Contactor Switch (ICS)

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

The contact gap should be approximately .047 inches between the bridging moving contact and and the adjustable stationary contacts. The bridging moving contact should touch both stationary contacts simultaneously.

Routine Maintenance

All relays should be checked at least once every year or at such other time intervals as may be dictated by experience to be suitable to the particular application.

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 contact.

Calibration

Use the following procedure for calibrating the relay if the relay has been taken apart for repairs or the adjustments disturbed. This procedure should not be used until it is apparent that the relay is not in proper working order. (See "Acceptance Check.")

Polar Unit

1. Contacts – Place a .060 to .070 inch feeler gage between the right hand pole face and the armature. This gap should be measured near the front of the right hand pole face. Bring up the backstop screw until it just makes with the moving contact. Place gage between moving contact and stationary contact on the left hand side of the polar-unit. Bring up the stationary contact until it just makes with the gage and lock in place.

2. Minimum Trip Current – Harmonic Restraint Unit (HRU)

* Connect the relay to the test circuit of Fig. 8 or Fig. 9. Test all three phases on 3-phase units.

With the switch open, pass I_{ac}= 100 amperes into the relay. This current should be applied for a very short period of time and it should be suddenly interrupted. Adjust the right hand shunt on the polar unit until it trips with I_{ac} = Rated Current. Lower I_{ac} gradually to 50% rated current, unit should reset, if not, adjust left hand shunt until the unit resets.

If additional adjustments are necessary, apply 100 amperes and adjust the right hand shunt until the unit operates at rated current. Lower I_{ac} gradually to 50% rated current and adjust the left hand shunt until the contacts reset. Repeat these steps until the unit will operate at rated current, lower immediately following the application of 100 amperes, and until the unit will drop out at 50% rated current or greater. After the dropout has been measured, the unit should pick up at .94 times rated current.

On the application of the high current, the polar unit will be biased in the restraining direction and pickup will be rated current on the first application of pickup current. If the current is deenergized and pickup is measured again, the pickup current will be less than before. However, pickup will be stable after the second application of pickup current. If 100 amperes is applied again, the pickup immediately after applying this current will be rated current. However, measuring the pickup the second time will show that the pickup is again reduced. The variation between .94 and 1 times rated current.

The filter circuits are charged by the application of this heavy current and upon the removal of the current, these circuits will discharge their energy. The element will be biased in the restraining direction because the restraint coil has approximately 7 times the number of turns as the operating coil. Upon the application of pickup current, the operating ampere turns will be greater than the restraint ampere turns and the bias will be removed.

If a lower biasing current is used instead of 100 amperes, the pickup of the unit will be less than before for the application of pickup current. Pickup will be further reduced with the second application of pickup current, but the current will be stable after this energization. However, this value of pickup will be lower than the limit of .94 times rated current. This is in the direction of making the sensitivity of the polar unit lower than rated current but does not impair the performance of the unit on inrush current.

If a pickup other than rated current is desired, the right hand shunt can be screwed inward to give the desired pickup. This adjustment should be done after the application of 100 amperes.

* 3. Harmonic-Restraint Characteristics

* A. Single Phase and 3 Phase HRU Relays (Normally Open contact)

Close switch of test circuit in Fig. 8 or 9. Adjust direct current I_{dc} per Table 2. Gradually increase alternating current until the polar unit operates with I_{ac} as indicated in Table 2. The per cent second harmonic in the wave may be derived by the use of the formula. Check all three phases for the 3-phase HRU.

$$\% \text{ second harmonic} = \frac{47\, I_{dc}}{I_{ac} + 1.11\, I_{ac}}$$

* B. 3-Phase Relays (Normally closed HRU contact)

De-energize relay and move the right-hand shunt (approximately 3 slots in) to make the contacts normally closed to the left. Reenergize the relay, close test switch and set I_{dc} per Table 2. Check that the polar unit contacts move to the right when Iac is decreased to approximately 3.5 amps.

Momentarily apply 100 amps I_{ac} to polarize unit, then set I_{dc} again per Table 2. The polar unit contacts should move to the left when Iac is increased to approximately 3.8 amps.

Check all 3 phases for pickup and dropout as per above test.

Indicating Contactor Switch (ICS)

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

Instantaneous Trip (IT)

The core screw which is adjustable from the top of the trip unit determines the pickup value. The trip unit has a nominal ratio of adjustment of 1 to 4 and an accuracy within the limits of 10%.

Apply sufficient current to operate the IT.

Electrical Checkpoints

Apply rated current to terminals 8 and 9. The following are the approximate voltages that should be obtained using a high-resistance a-c voltmeter:

1.	Output of operating transformer (Top Coil Terminals)	4.0 volts
2.	4 mfd. capacitor	2.5 volts
3.	0.45 mfd. capacitor	3.9 volts
4.	Operating-rectifier bridge	2.5 volts
5.	Restraint-rectifier bridge	0.6 volts
6.	Series filter-reactor	0.2 volts

TABLE 1

Polar Unit Min. Trip Values

Rated Current	Lower Current Limit
.87	.6
2.0	1.35
4.0	2.7

TABLE 2

Harmonic Restraint Values

Rated Current	I_{dc}	I_{ac}
.87	2.3	3.8 – 5.3
2.0	6.0	10.0 – 13.5
4.0	12.0	19.9 – 27.0

APPROXIMATE RESISTANCE VALUES OF COMPONENTS IN HRU RELAY

Unit	Circuit	Description
Harmonic Restraint	Operating	Transformer Secondary d-c resistance 50 to 70 ohms.
		Reactor d-c resistance 8 to 10 ohms.
		4 mfd. capacitor
		Rectifier 700 volts, 600 milliamperes silicon diodes.
		Polar unit coil d-c resistance 80 to 100 ohms.
	Restraint	Series reactor d-c resistance 100 to 130 ohms.
		Parallel reactor d-c resistance 300 to 360 ohms.
		.45 mfd. capacitor
		Rectifier 700 volts, 600 milliamperes silicon diodes.
		Polar unit coil d.c resistance 650 to 800 ohms
		Varistor 100,000 ohms ± 10% at 10 VDC 4000 ohms ± 25% at 30 VDC.
Indicating Contactor Switch	Trip	0.2 amp. tap 6.5 ohms d-c 2.0 amp. tap 0.15 ohms d-c

* ENERGY REQUIREMENTS

Rated Current	Continuous Relay	1 sec.	Burden At Top Value	Burden At 8X
.87	10 amps	300 amps	2.26	76
2.0	18 amps	300 amps	2.50	92
4.0	22 amps	300 amps	3.18 greater than	132

Continuous rating of 3 phase HRU-5.75 amps.

RENEWAL PARTS

Repair work can be done most satisfactorily at the factory. However, interchangeable parts can be furnished to customers who are equipped for doing repair work. When ordering parts, always give the complete nameplate data.

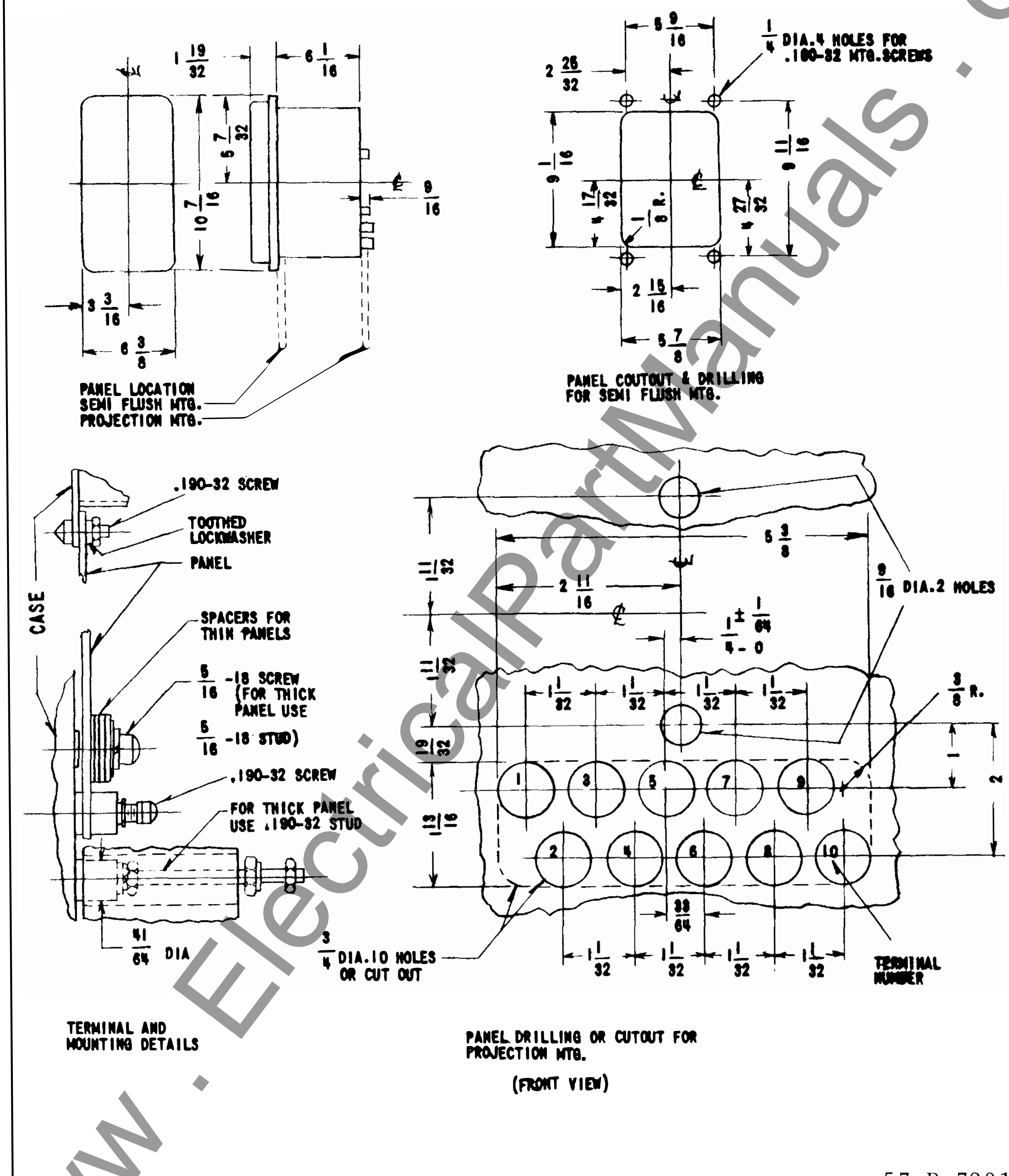


Fig. 10 Outline & Drilling For FT21.

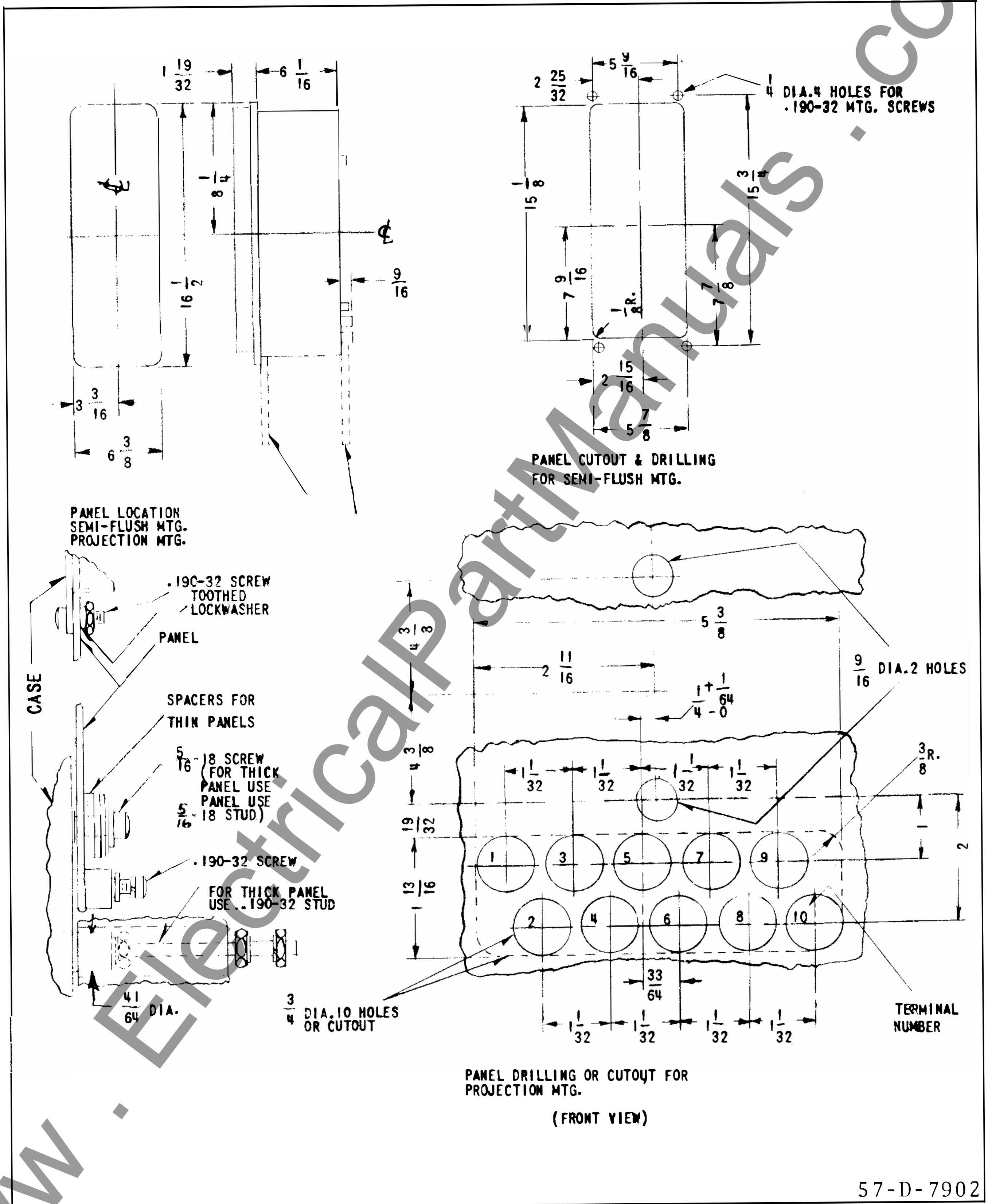


Fig. 11 Outline & Drilling For FT31.

WESTINGHOUSE ELECTRIC CORPORATION

RELAY-INSTRUMENT DIVISION NEWARK, N. J.

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