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(I) Denotes Change Since Previous Issue.

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Type CA Percentage Differential Relay for Transformer Protection (50 and 60 Hertz)

⚠ 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.

1.0 APPLICATION

The type CA percentage differential relay for transformer protection is designed for the protection of power transformer. This relay can be applied where the magnetizing inrush current to the transformer is not severe.

Current transformer ratio error should not exceed 10% with maximum symmetrical external fault current flowing. The sensitivity of type CA relay for transformer protection is 50%. It satisfactorily handles up to 35% of mismatch (transformer tap-changing under load plus ct mismatch)

2.0 CONSTRUCTION

The type CA relay consists of a percentage differential unit and an indicating contactor switch. The principle component parts of the relay and their locations are shown in Figures 1 through 3.

2.1 PERCENTAGE DIFFERENTIAL UNIT

This unit is an induction disc unit with an electro-magnet that has poles above and below the disc as shown in Figure 2. Two restraint coils are placed on the lower left-hand pole (front view) and an operating coil is wound on the lower right-hand pole.

A transformer winding is supplied on both the left and right hand poles and these are connected in parallel to supply current to the upper pole windings. The upper pole current generates a flux which is in quadrature with the lower pole resultant flux, and the two fluxes react to produce a torque on the disc. If the operating winding is energized, this torque is in the contact closing direction, if current flows through the two restraining windings in the same direction a contact opening torque is produced.

2.2 INDICATING CONTACTOR SWITCH UNIT (ICS)

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

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

All possible contingencies which may arise during installation, operation or maintenance, and all details and variations of this equipment do not purport to be covered by these instructions. If further information is desired by purchaser regarding this particular installation, operation or maintenance of this equipment, the local ABB Power T&D Company Inc. representative should be contacted.
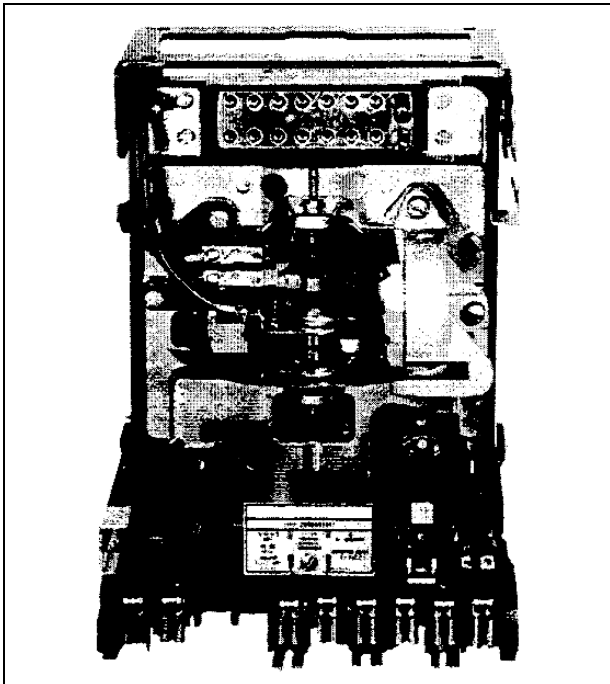
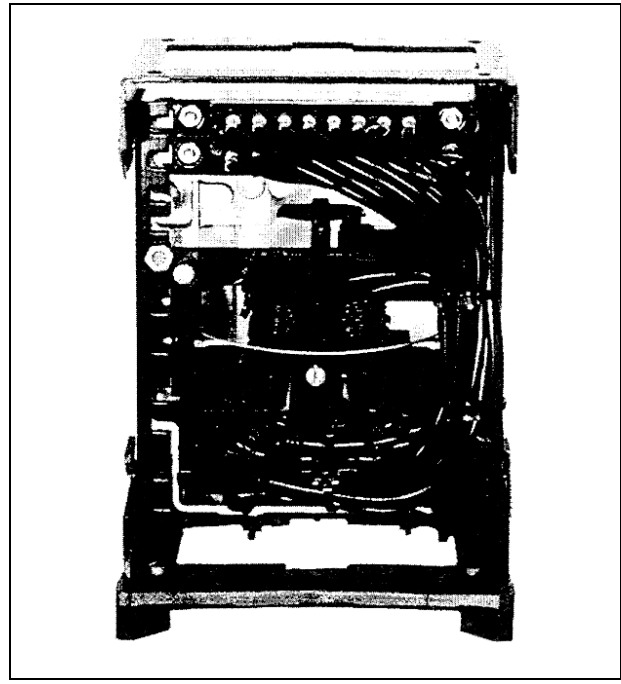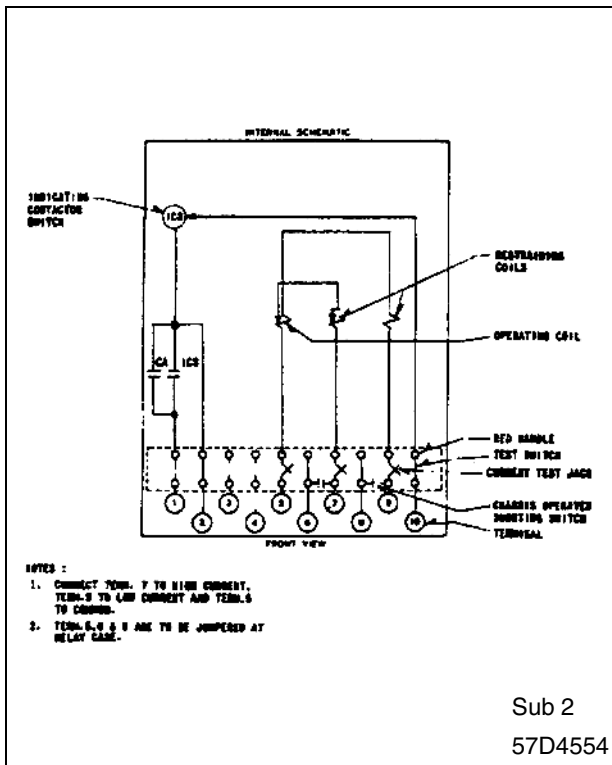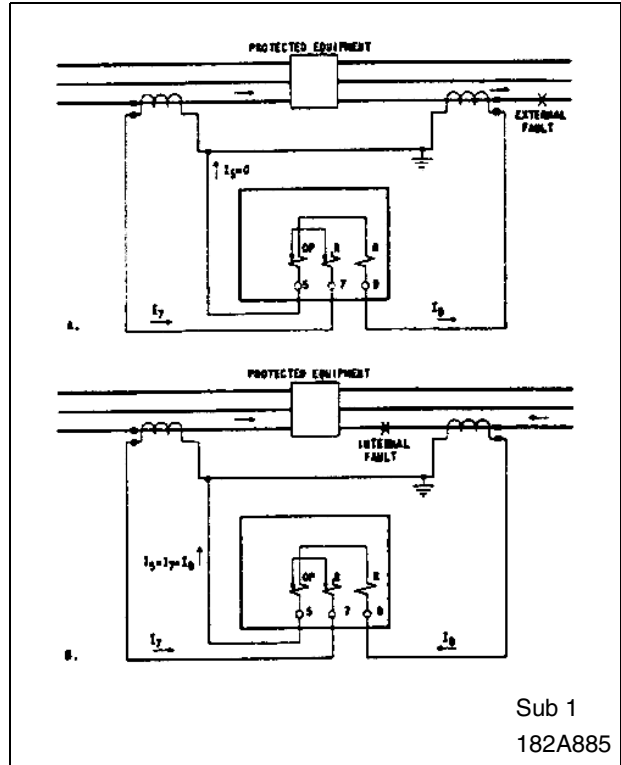Figure 1. Type CA Transformer Relay (Front View).

Figure 2. Type CA Transformer Relay (Rear View).

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Figure 3.   Internal Schematic of the Type CA Transformer Relay in The Type FT-21 Case.

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Figure 4.   Schematic Diagrams of the Percentage Differential Relays:
(A) Fault Current Distribution for an External Fault.
(B) Distribution for an Internal Fault.

3.0 OPERATION

With the relay connected as in the schematic diagram, Figure 4.(A), a through fault causes currents to flow through two restraint windings in the same direction. If the current transformers operate properly, these restraining currents are equal, or effectively equal if appropriate auto balance taps are used to compensate for mismatch in current transformer ratios and no effective current flows in the operating coil winding and hence only contact opening torque is produced. If the currents in the two restraining windings are effectively unequal, the effective difference must flow in the operating coil. The operating coil current required to overcome the restraining torque and close the relay contacts is a function of restraining current.

In the case of heavy internal fault, when an external source feeds current into the fault, the restraining currents are in opposite directions and restraining torque tends to cancel out as illustrated in Figure 4.(B). When the currents fed from the two sides are equal or effectively equal because of the taps used, the restraint is totally cancelled. When effectively unequal currents flow in from the two sides, the restraint is equivalent to the difference in the two effective currents, divided by two, but since the more sensitive operating coil is energized by the sum of the two currents, the restraint in this case is inconsequential, and a large amount of contact closing torque is produced.

4.0 CHARACTERISTICS

The operating characteristics of the relay for normal through load current and through fault current are shown in Figures 5 and 6. When the currents flowing into and out of the relay are plotted on these curves, if the point falls outside of the inoperative area, the relay will close its contacts.

In Figures 5 and 6, the two curves going with the 5-5 tap are tied together with a bracket to indicate that these two curves go together. Similarly, the two curves for the 5-10 tap are also tied together with a bracket. The center lines between pairs of curves are shown for all taps. The paired curves, bounding the inoperative areas, are not shown for taps 5-5.5 through

5-9. These curves may be determined approximately by means of the following formulas:

For the upper curve: $I_9 = I_7 * K_1/T + 1.8$ (1)

For the lower curve: $I_7 = I_9 * K2 * T + C_2$ (2)

The relations between T, K_1, K_2, and C_2 are given in the following table:

T	K_1	K_2	C_2
5	7.28	.276	2.5
5.5	7.32	.274	2.65
6	7.36	.272	2.8
6.6	7.41	.27	2.98
7.3	7.46	.268	3.19
8	7.52	.265	3.4
9	7.6	.262	3.7
10	7.67	.258	4

In these formulas, T is the larger number of the tap pair. For example, if the relay is used on the 5–7.3 tap, then T = 7.3.

As an example of the degree of accuracy of the formula consider the point $I_7 = 43.5$, and $I_9 = 30$, read from the lower curve for the 5–5 tap, Figure 4. Applying the formula, Equation (2) the calculated value of I_7 is found to be 45 amperes, which is fairly close to the curve value, $I_7 = 43.5$.

The derivations of Equations (1) and (2) are given in Figure 7, which has been included to illustrate the meaning of these equations.

Typical time-of-operation curves are shown in Figure 9.

Figure 8 shows the operating curves for the relay with the restraining currents 180° out-of-phase. These curves also apply where current flows in only one restraining winding and the operating coil.

4.1 TRIP CIRCUIT

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

The indicating contactor switch has two taps that provide a pick-up setting of 0.2 or 2 amperes. To change taps require connecting the lead located in front of the
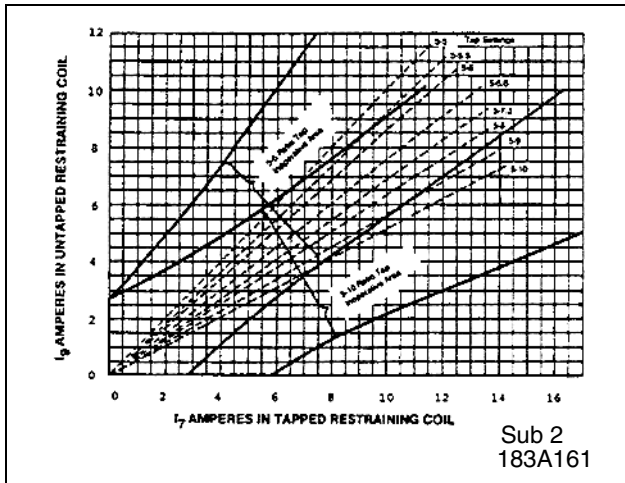
Figure 5. *Typical Operating Curves for Low Values of Current.*

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tap block to the desired setting by means of a screw connection.

4.2 TRIP CIRCUIT CONSTANT

Indicating Contactor Switch (ICS)

0.2 Ampere Tap 6.5 Ohms dc Resistance
2.0 Ampere Tap 0.15 Ohms dc Resistance

4.3 ENERGY REQUIREMENTS

The 60 Hz burdens of the type CA relay are best given in curve formulas illustrated and given by the curves, Figures 10, 11, and 12.

The burden data of the 50 Hz relay can be approximately estimated by using the following equations.

$$\theta_2 = \text{arc Tan}\left(\frac{5}{6} \text{ Tan } \theta_1\right)$$

$$V_2 \bullet I_2 = V_1 \bullet I_1 \sqrt{\cos^2\theta_1 + \frac{25}{36}\sin^2\theta_1}$$

Where the $V_1 \bullet I_1$ & θ_1 and $V_2 \bullet I_2$ & θ_2 are the VA and

angles for the 60 and 50 Hz relays respectively.

Figure 10, gives the 60 Hz VA burdens only. The 50 Hz equivalent curves can be obtained by using the 60 Hz curve times a factor of 0.88.

The restraining windings of the relay have a continuous rating of 10 amperes. The operating coil has a continuous rating of 5 amperes. However, it is best not to allow more than 5 amperes in the untapped restraining winding in order to keep from over-loading a portion of the operating winding. For example, currents of 10 and 6.85 amperes would be in the proper
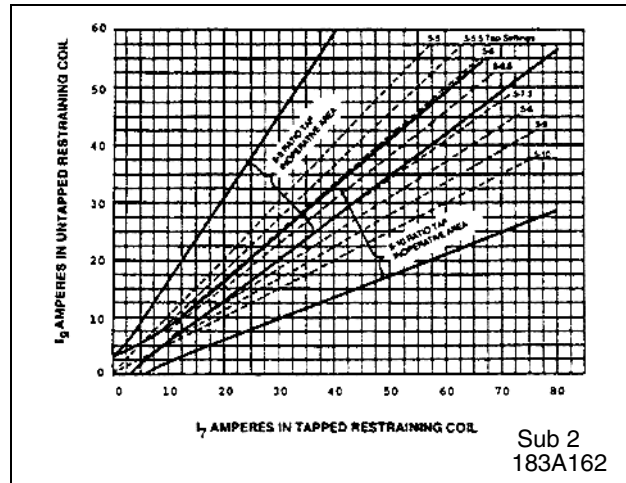

Figure 6. *Typical Operating Curves for High Values of Current.*

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ratio of the 5-7.3 taps, but when these taps are used, 6.85 amperes would flow in a portion of the 5 ampere operating coil.

5.0 SETTINGS

⚠ **CAUTION**

Since the tap block screw carries operating current, be sure that the screws are turned tight.

In order to avoid opening current transformer circuits when changing taps under load, the relay must be first removed from the case. Chassis operating shorting switches on the case will short the secondary of the current transformer. The taps should then be changed with the relay outside of the case and then reinserted into the case.

5.1 PERCENTAGE DIFFERENTIAL UNIT

The transformer relay is detailed in Figure 4. When the relay is correctly set, one screw must be in the lower row of holes at the correct tap value and the other must be in the hole directly above.

To determine the correct tap setting, calculate the currents delivered to the relay at full load on the transformer bank, taking into consideration not only the current transformer ratios, but also any delta connections which may be used. These currents will be in a certain ratio and the taps on the relay should be chosen to match that ratio as closely as possible. For example, assume that the currents are 7.8 and 4.6 amperes, with the relay properly connected so that the higher current, 7.8 amperes, flows in the tapped
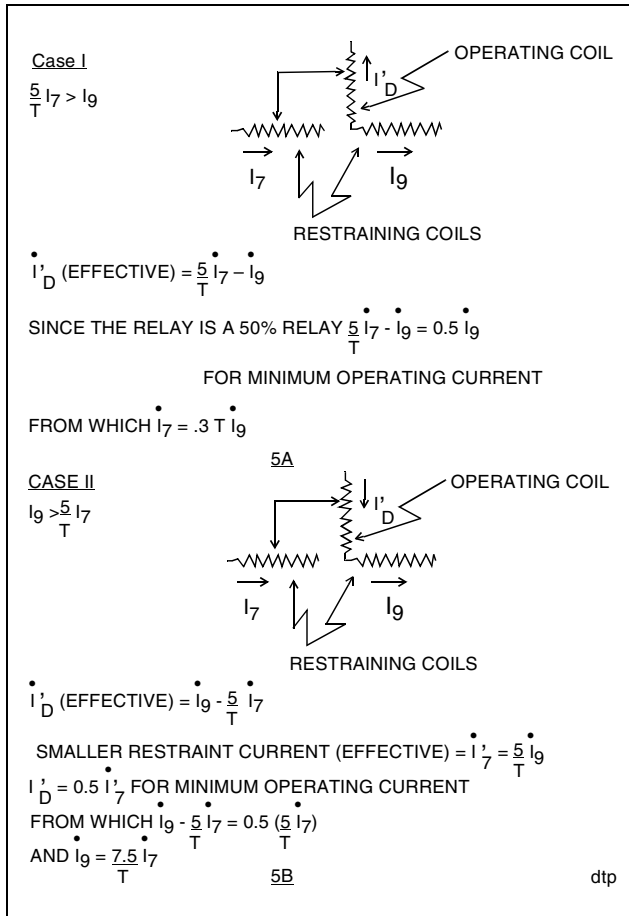
Figure 7. Fundamental Relationships in the Type CA Electromagnet.

Case I

$$\frac{5}{T} I_7 > I_9$$

OPERATING COIL

I_7 I_9

RESTRAINING COILS

$$\dot{I}'_D \text{ (EFFECTIVE)} = \frac{5}{T}\dot{I}_7 - \dot{I}_9$$

SINCE THE RELAY IS A 50% RELAY $\frac{5}{T}\dot{I}_7 - \dot{I}_9 = 0.5\,\dot{I}_9$

FOR MINIMUM OPERATING CURRENT

FROM WHICH $\dot{I}_7 = .3\,T\,\dot{I}_9$

CASE II

$$I_9 > \frac{5}{T} I_7$$

5A

OPERATING COIL

I_7 I_9

RESTRAINING COILS

$$\dot{I}'_D \text{ (EFFECTIVE)} = \dot{I}_9 - \frac{5}{T}\dot{I}_7$$

SMALLER RESTRAINT CURRENT (EFFECTIVE) $= \dot{I}'_7 = \frac{5}{T}\dot{I}_9$

$\dot{I}'_D = 0.5\,\dot{I}'_7$ FOR MINIMUM OPERATING CURRENT

FROM WHICH $I_9 - \frac{5}{T}I_7 = 0.5\,(\frac{5}{T}I_7)$

AND $I_9 = \frac{7.5}{T}I_7$

5B

dtp

restraining winding. The ratio 4.6/7.8 is equal to 5/8.48. The nearest tap ratio on the relay is 5/8, and this pair of taps should be used.

The time dial should be set on the number 1 position.

5.2   INDICATING CONTACTOR SWITCH

For the ICS unit, the selection of the 0.2 or 2.0 amp tap setting must be 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 dc type WL relay switch, or equivalent, use the 0.2 ampere tap; for 48 Vdc applications set relay in 2 ampere and use WL relay coil S#304C209G01 or equivalent. For direct tripping of a circuit breaker use the 2 ampere tap.

6.0   INSTALLATION

6.1   MOUNTING

The relays should be mounted on switchboard panels or their equivalent in a location free from dirt,
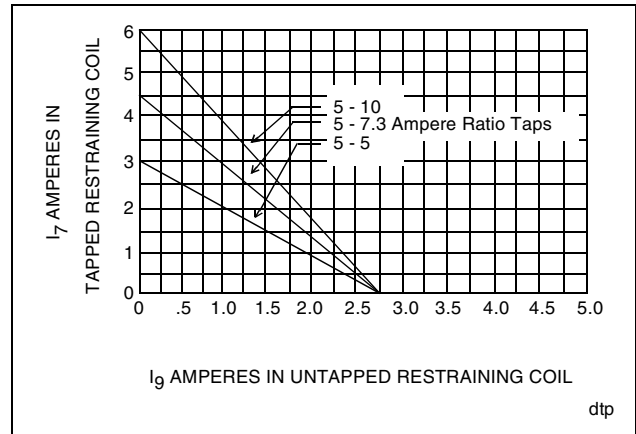

Figure 8.   Typical Sensitivity Characteristics of the Type CA Transformer Relay.

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 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.

6.2   CONNECTION

Figure 14 shows the connections for a delta-wye transformer with the delta on the high voltage side. The current transformer connections must be different from this when the delta is on the low voltage side because the phase relationships between high and low currents is different.

7.0   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.

7.1   PERFORMANCE TESTS

The following check is recommended to verify that the relay is in proper working order.
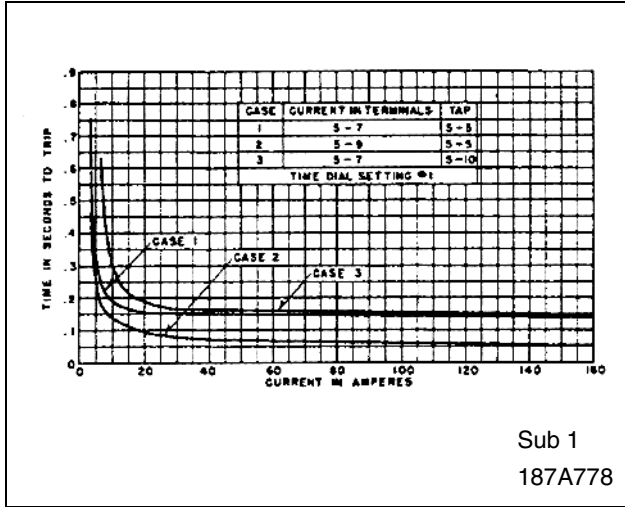
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Figure 9. Typical Time Curves for the Type CA transformer Relay.

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Figure 10. Typical 60 Hertz Saturation Curves for the Type CA Transformer Relay.

7.1.1 Contact

The index mark on the movement frame will coincide with the "O" mark on the time dial when the stationary contact has moved through approximately one-half of its normal deflection. Therefore, with the stationary contact resting against the backstop, the index mark is offset to the right of the "O" mark by approximately.020 inch. The placement of the one time dial position in line with the index will give operating times as shown on the respective time-current curves. For double trip relays, the follow on the stationary contacts should be approximately 1/32 inch.

7.1.2 Minimum Trip Current

With the relay set on the 5-5 tap, the contacts should close within the following limits with current applied to the specified terminals:

Terminal 9 and 5 ....2.7 to 2.8 amperes
Terminal 7 and 5 ....2.9 to 3.2 amperes

7.1.3 Differential Characteristics

Connect the relay per the test circuit of Figure 13 (**normal connection**). Set the relay on the 5-5 tap and apply 20 amperes to terminal 9. The relay should just operate when the current from terminal 7 is between the limits of 28.5 to 31.5 amperes.
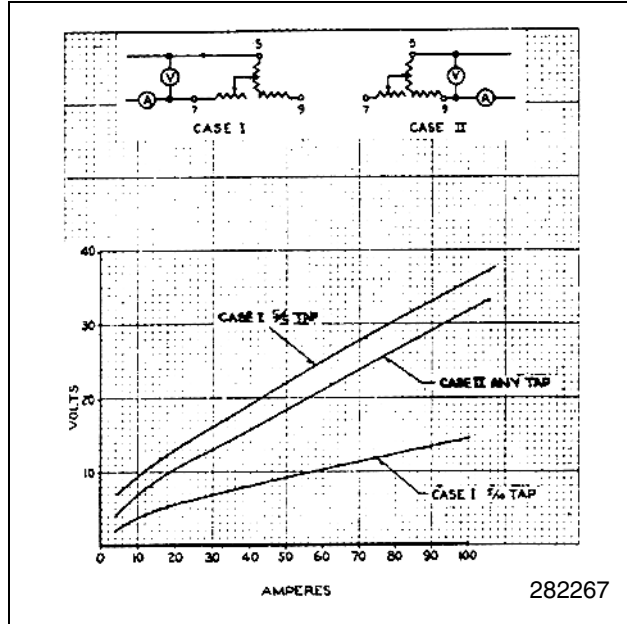
The above points should be taken with the relay cool. Care should be taken not to overheat the relay.

Reverse the connection to terminal 7 and 9 and apply 20 amperes to terminal 7. The relay should just operate when the current from terminal 9 is between the limits of 29 to 33 amperes.

7.1.4 Time Curve

With the time dial on the number 1 position, apply 20 amperes to terminals 5 and 9. The relay should operate between .080 and .10 seconds with a tap setting of 5-5.

7.1.5 Indicating Contactor Switch (ICS)

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

For proper contact adjustment, insert a .030" feeler gauge between the core pin and the armature. Hold the armature closed against the core pin and gauge and adjust the stationary contacts such that they just make with the moving contact. Both stationary contacts should make at approximately the same time. The contact follow will be approximately 1/64" to 3/64".
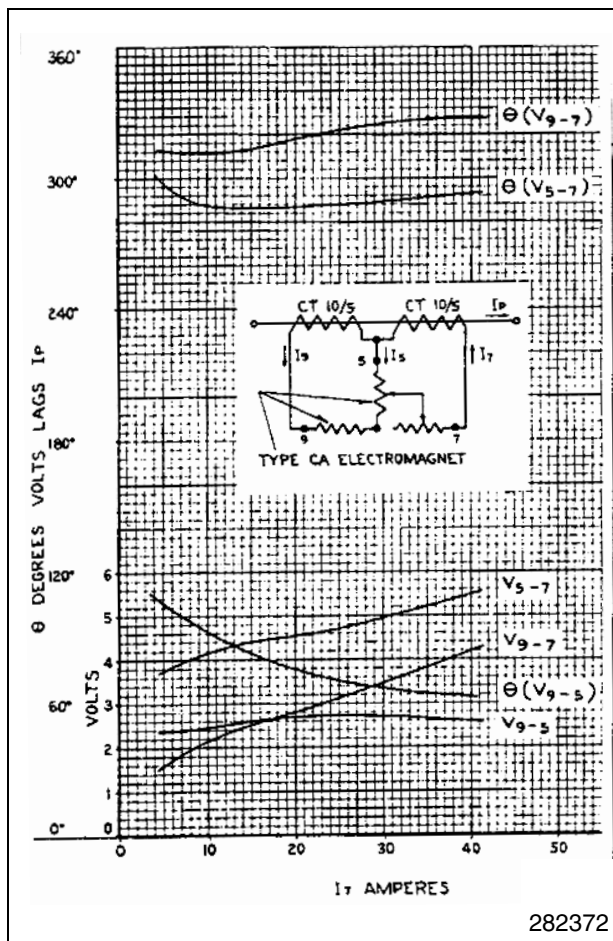
Figure 11. *Typical 60 Hertz Burden Curves for the Type CA Transformer Relay on the 5-5 Tap ($I_5 = 0$).*

Figure 12. *Typical 60 Hertz Burden Curves for the Type CA Transformer Relay on the 5-10 Tap ($I_5 = 0$).*

7.2 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 Section 7.1, Performance Test).

7.2.1 Contact

The index mark on the movement frame will coincide with the "O" mark on the time dial when the stationary contact has moved through approximately one-half of its normal deflection. Therefore, with the stationary contact resting against the backstop, the index mark is offset to the right of the "O" mark by approximately .020". The placement of the one time dial position in line with the index mark will give operating times as shown on the respective time-cur-
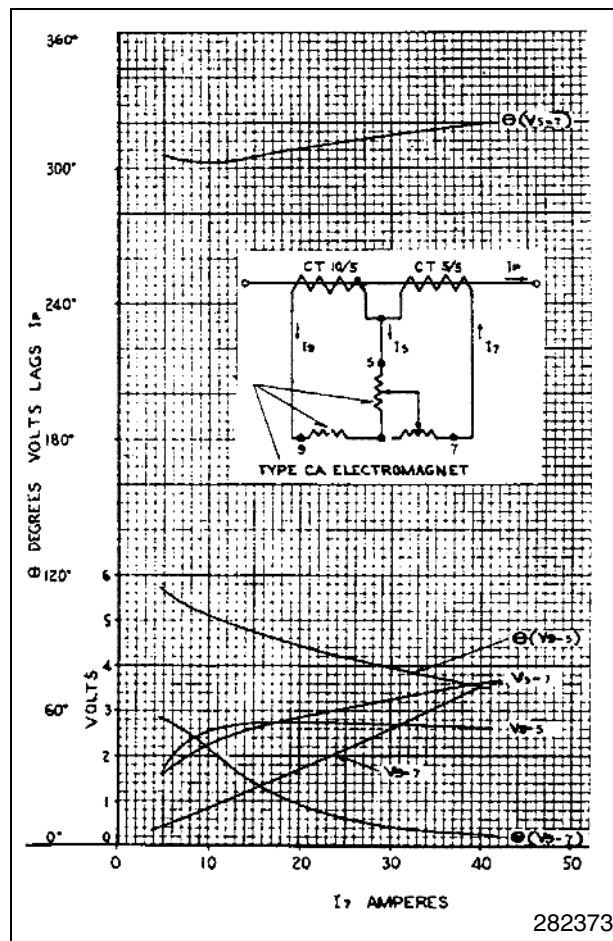
rent curves. For double trip relays, the follow on the stationary contacts should be approximately 1/32".

7.2.2 Minimum Trip Current

The adjustments of the spring tension in setting the minimum trip current value of the relay is most conveniently made with he damping magnet removed.

With a tap setting of 5-5, apply current to terminals 9 and 5 of the relay and adjust the control spring tension so that the moving contacts just closes between limits of 2.7 to 2.8 amperes. Apply current to terminals 7 and 5 of the relay. The contacts should just close between the limits of 2.9 to 3.1 Ampere.

7.2.3 Percentage Slope Characteristics

Points on the percentage slope curve can be checked by use of the test circuit of Figure 13. The operating current required to operate the relay
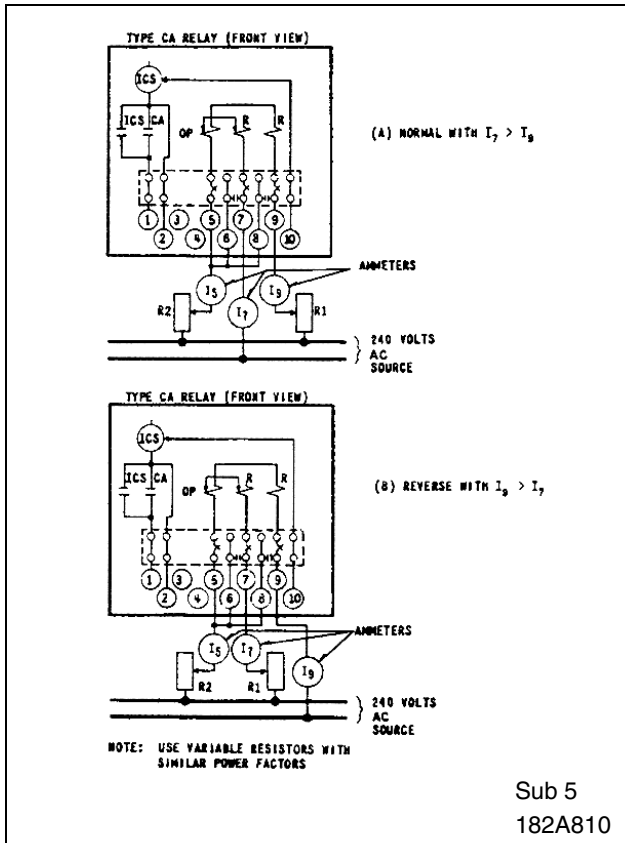
Figure 13. Diagram of Test Connections for the Type CA Transformer Relay in the Type FT-21 Case

Figure 14. External Schematic Diagram of the Type CA Transformer Relay in the Type FT-21 Case for Protection of a Wye-Delta. Transformer Bank

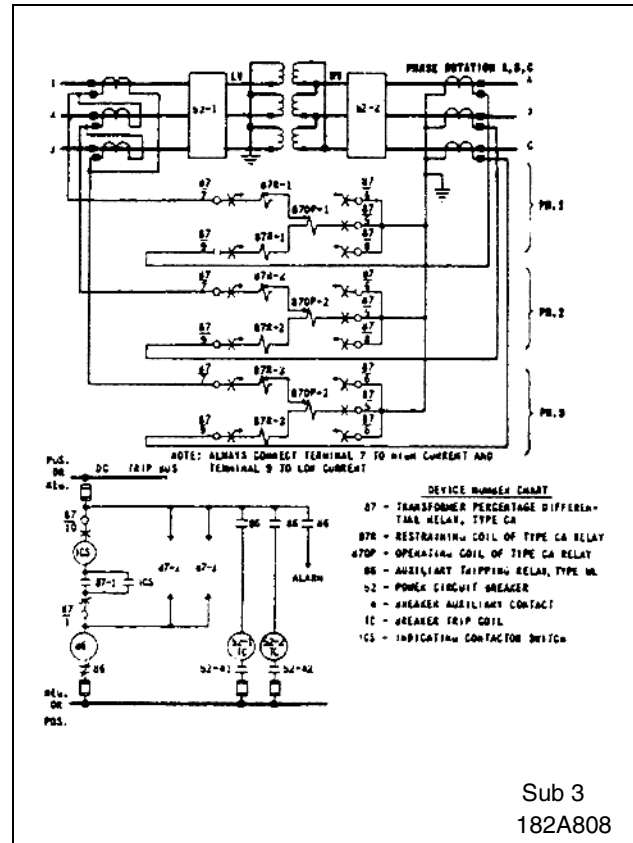should be within ±7% of the curve value. Care should be taken not to overheat the relay during these tests.

7.2.4 Time Curve

Place the permanent magnet of the relay and set the time dial at the number 1 position. Adjust the permanent magnet keeper until the contacts close between the limit of .085 to .095 seconds. With 20 amperes applied to terminals 5 and 9.

7.2.5 Indicating Contactor Switch (ICS)

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

For proper contact adjustment, insert a .030" feeler gauge between the core pin and the armature. Hold the armature closed against the core pin and gauge and adjust the stationary contacts such that they just make with the moving contact. Both stationary con-

tacts should make at approximately the same time. The contact follow will be approximately 1/64" to 3/64".

7.3 ROUTINE MAINTENANCE

All relays should be checked at such time intervals as may be dictated by experience to be suitable to the particular application.

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

8.0 RENEWAL PARTS

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

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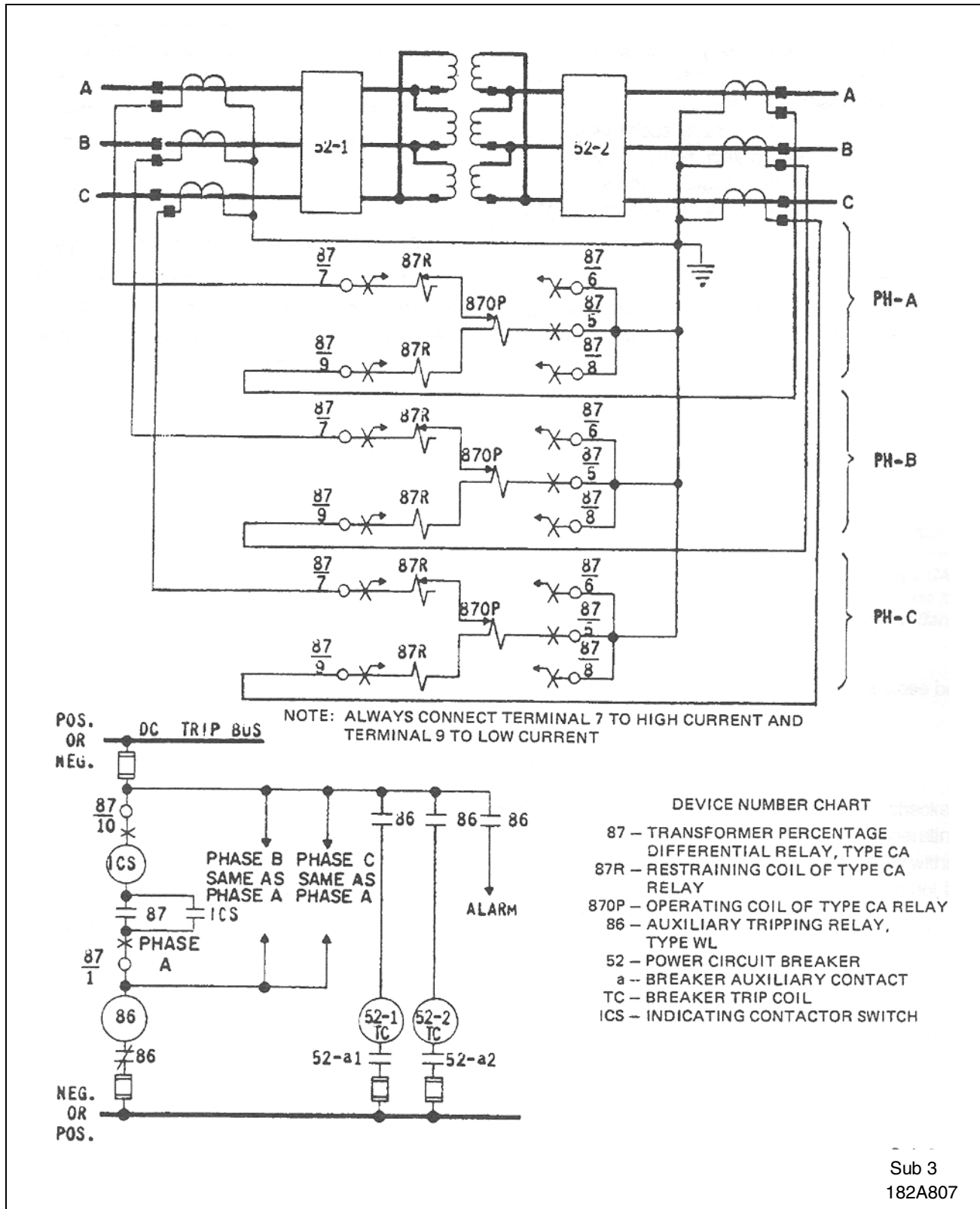
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Figure 15.   External Schematic Diagram of the Type CA Transformer Relay in the Type FT-21 Case for Protection of a Delta-Delta Transformer Bank.
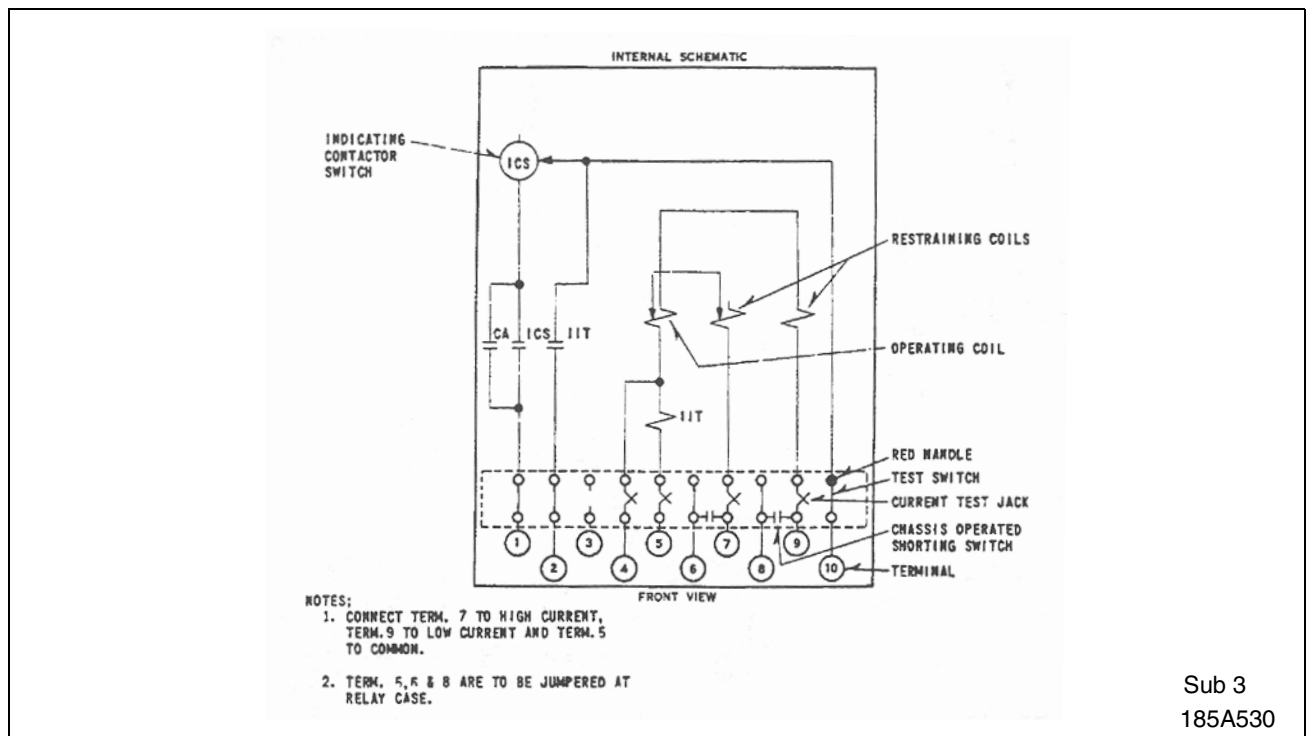
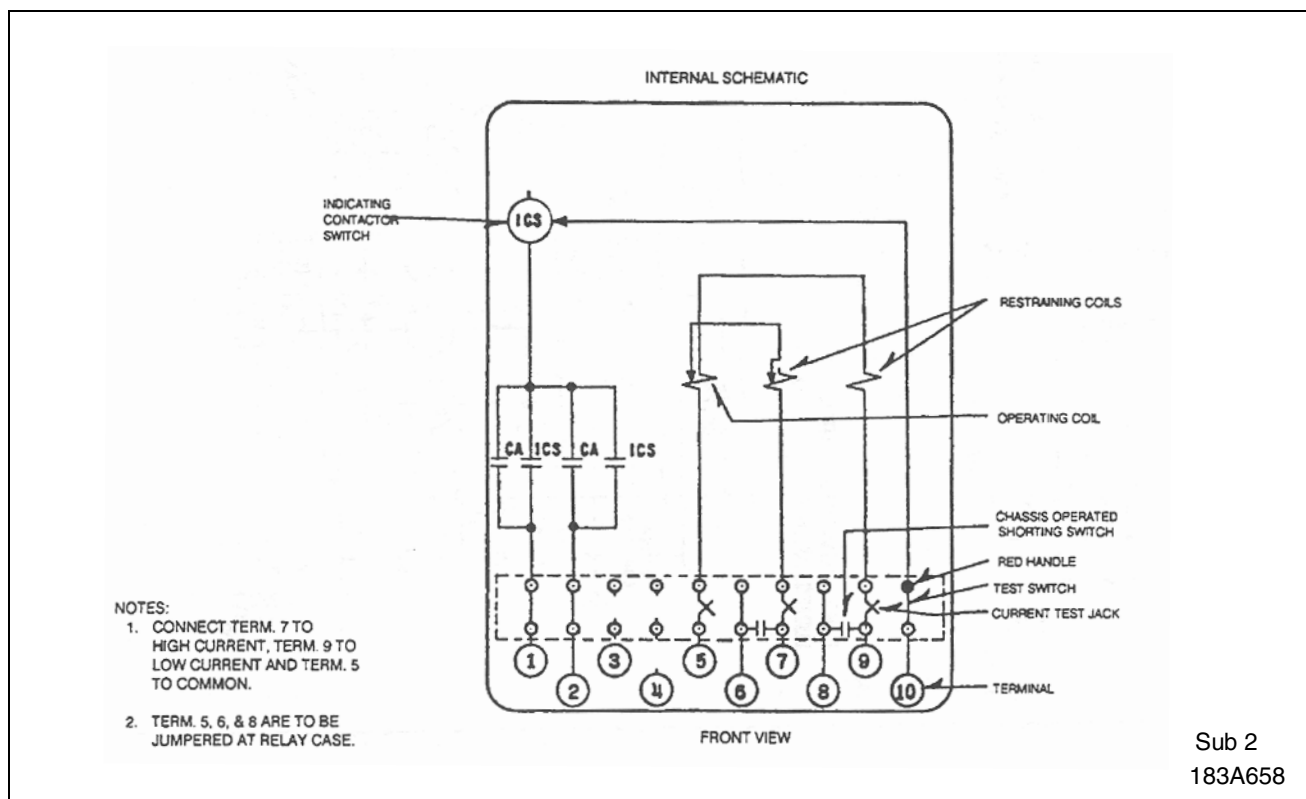Figure 16.   Relay Type CA Percentage with I.I.T. For Transformer Protection in Type FT-21 Case.

Figure 17. Relay Type CA Percentage Differential for Transformer Protection - Double Trip in Type FT-21 Case.
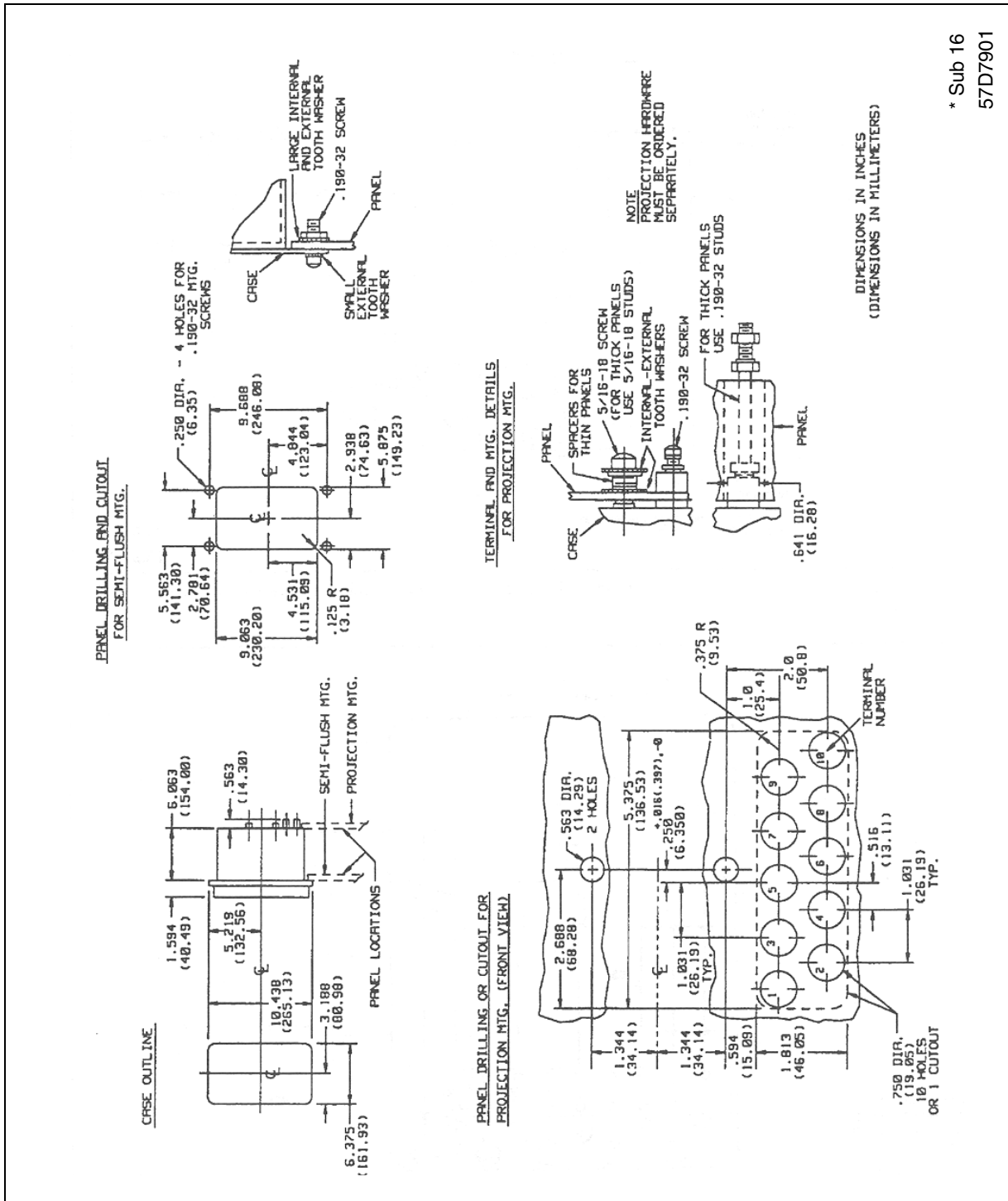
Figure 18. Outline and Drilling Plan for the Type CA Transformer Relay in Type FT-21 Case

* Denotes Change

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