INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

TYPE CA-6 PERCENTAGE DIFFERENTIAL RELAY

FOR BUS AND TRANSFORMER PROTECTION

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 type CA-6 percentage differential relay is usually applied for the differential protection of multi-circuit buses. The application of the CA-6 relays for bus differential protection may be divided into three categories. (In the following discussion an equivalent circuit is defined as a major source or a group of feeder circuits. The fault current contribution of all the paralleled feeders should not exceed 5% of the total phase or ground fault current, with normal bus connections.)

A) GENERATING STATION BUSES - FOUR EQUIVALENT CIRCUITS OR LESS - DC TIME CONSTANT OF 0.6 CYCLES (0.01 Sec.) OR MORE.

If the following requirements are met, the CA-6 may be satisfactorily applied:

1) The maximum external fault current through the bus should not exceed 100 symmetrical RMS secondary amperes.
2) The magnetizing current of the current transformers carrying a total external fault current of 100 symmetrical secondary amperes should not exceed one secondary ampere.

B) GENERATING STATION BUSES - MORE THAN FOUR EQUIVALENT CIRCUITS - DC TIME CONSTANT OF 0.6 CYCLES (0.01 Sec.) OR MORE.

The same requirements as in (A) apply. However, consideration must be given to the restraint coil connections.

Where more than 4 equivalent circuits are present, it is rarely necessary to provide two relays per phase. With little or no compromise in the protection scheme, one relay can handle at least 8 equivalent bus circuits. (See "Connections" for further discussion.)

C) SUBSTATION BUSES - DC TIME CONSTANT OF 0.6 CYCLES (0.01 Sec.) OR LESS.

If the following requirements are met, the CA-6 may be satisfactorily applied:

1) The maximum external fault current through the bus should not exceed 100 symmetrical RMS secondary amperes.
2) The magnetizing current of the current transformers carrying a total external fault current of 100 symmetrical secondary amperes should not exceed *ten secondary amperes.*

Where more than 4 equivalent circuits are present, it is rarely necessary to provide two relays per phase. With little or no compromise in the protection scheme, one relay can handle at least eight equivalent bus circuits. (See "Connections" for further discussion.)

A type CA-6 transformer relay is also available for 3 winding transformer protection. The standard bus relay should not be utilized for transformer differential applications.

CONSTRUCTION

The type CA-6 relay consists of three restraining elements (two restraining windings per element), one operating element, and an indicating contactor switch. The type CA-6 transformer relay also contains an indicating instantaneous trip unit.

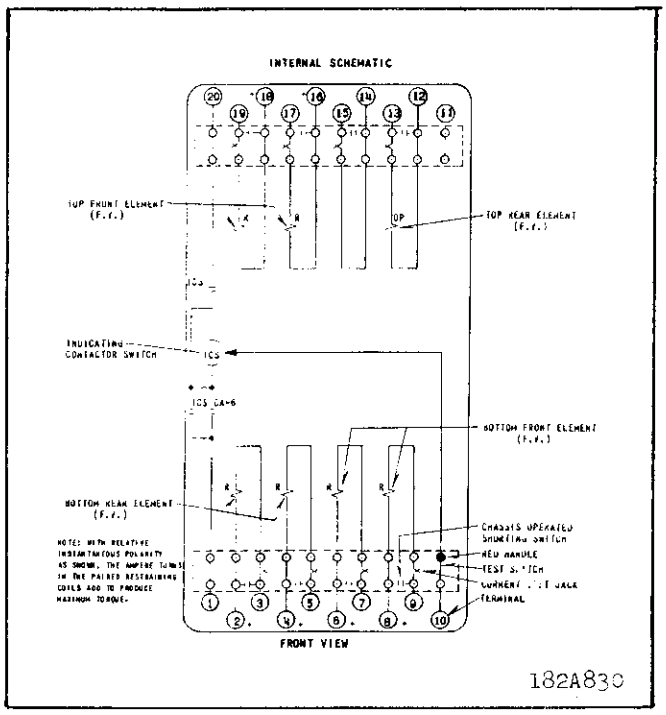

Fig. 1. Type CA-6 Relay for Bus Protection in Type FT-32 Case.

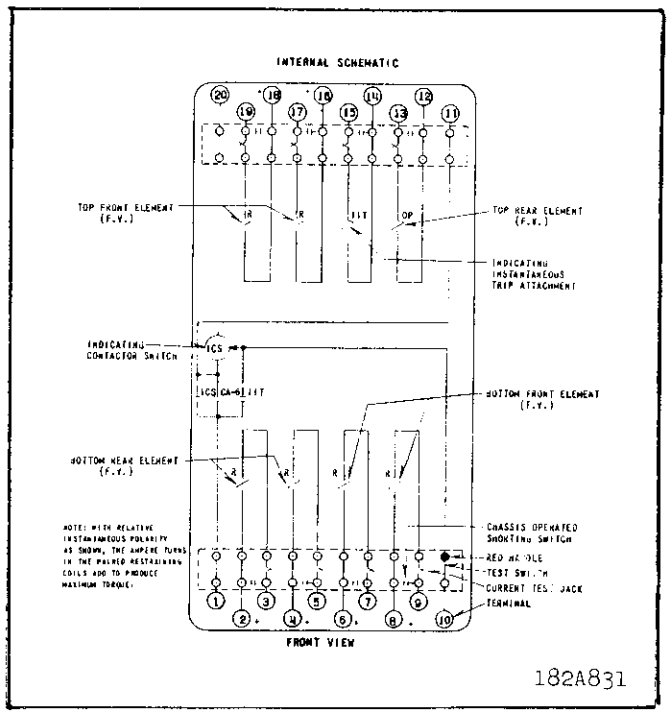

Fig. 2. Type CA-6 Relay for Transformer Protection, With Indicating Instantaneous Trip in FT-32 Case.

The relay operates on the induction-disc principle and consists of four electromagnets operating on two discs which are fastened to the same shaft. Three of the electromagnets are restraining elements with two separate restraining windings connected to receive the secondary currents from the various current transformers. The fourth electromagnet is the operating element with its winding connected to receive the differential or unbalance current thru an auxiliary current transformer. Taps are provided on this current transformer to control the sensitivity of the relay.

The two induction discs are mounted on a vertical shaft. The lower bearing for the shaft is a steel ball riding between concave sapphire jewel surfaces. A pin bearing is used on the upper end of the shaft.

The moving contact assembly is attached to a Micarta bushing on the disc shaft. When the moving contact strikes the stationary contact, the moving contact spring deflects to provide a wiping action. The electrical connection from the moving contact is made thru the spiral spring to the spring adjuster.

The stationary contact consists of a right angle bracket fastened to the element frame thru a Micarta insulating block. A contact screw projects thru the outer end of the bracket and provides adjustable contact separation.

The two lower electromagnets and the upper front electromagnet are restraining elements. The upper rear electromagnet is the operating element. Each restraining element has two windings brought out to separate terminals. (Fig. 1 and 2) The winding on the operating electromagnet is also brought out to a separate pair of terminals.

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 contact, completing the trip circuit. Also during this operation two fingers on the armature deflect a spring located on the front of the switch, which allows the operation indicator target to drop. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

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

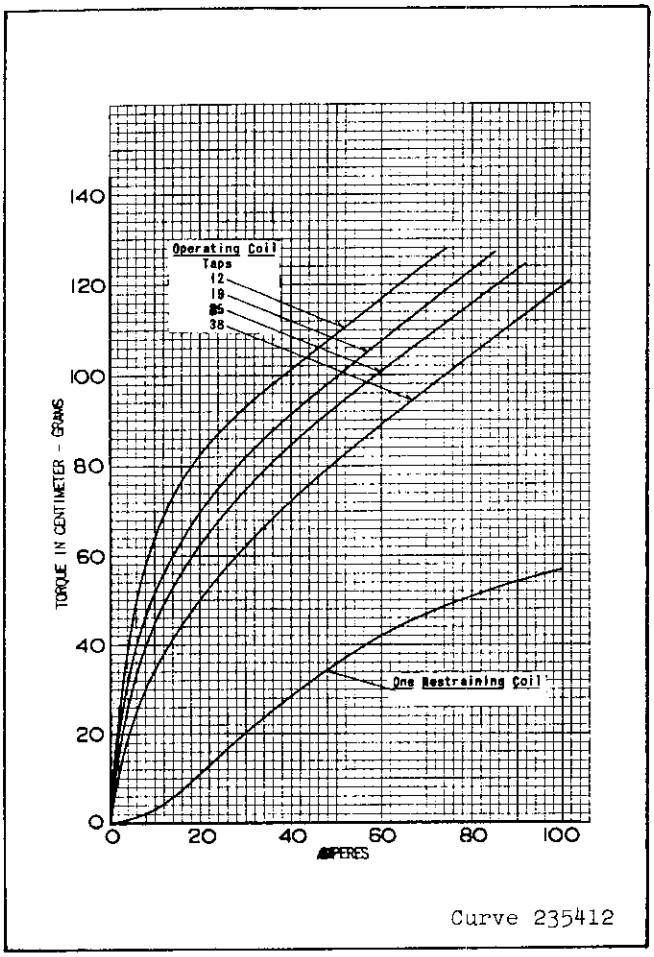

Fig. 3. Typical Torque Curves of the Operating & Restraint Coils.

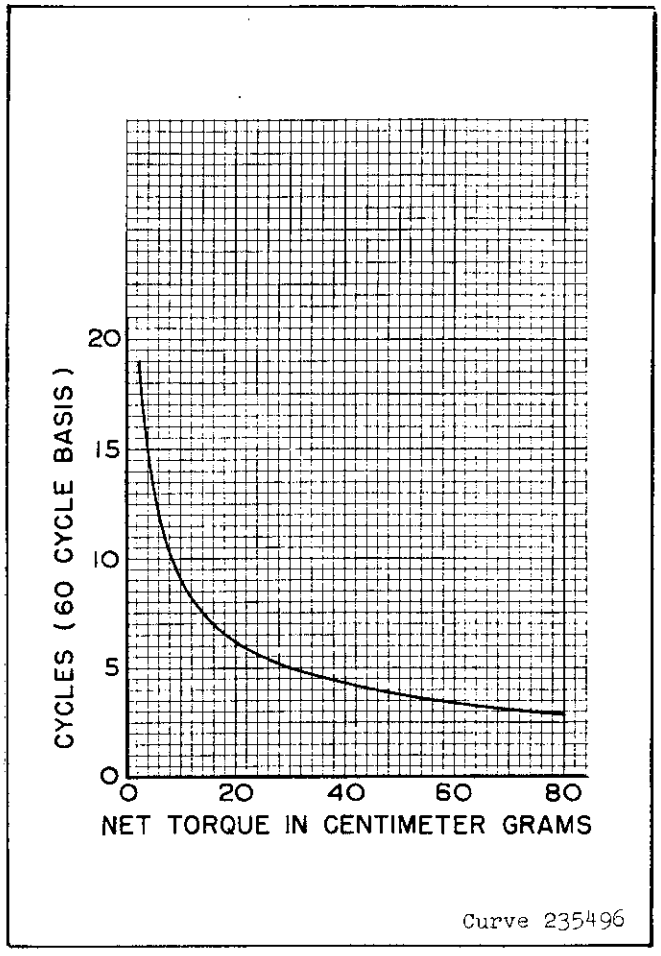

Fig. 4. Typical Differential Unit Time Curve.

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 contacts 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. The target is reset from the outside of the case by a push rod located at the bottom of the cover.

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.

OPERATION

The CA-6 relay has three restraining elements, each with two windings which are energized from the secondaries of current transformers connected to the bus. The relay has one operating electromagnet energized through an external auxiliary current transformers in accordance with the current flowing in the differential connection of the current transformers.

Refer to the internal schematic, Fig. 1. A current of 5 amperes in at terminal 18 and out of terminal 19 will produce a definite amount of restraining torque as indicated in Fig. 3. Similarly, a current of 5 amperes flowing in at terminal 16 and out of terminal 17 will produce an equal amount of torque. If both of these currents flow at the same time with the polarity as indicated above, their effect will be additive and they will produce the same torque as

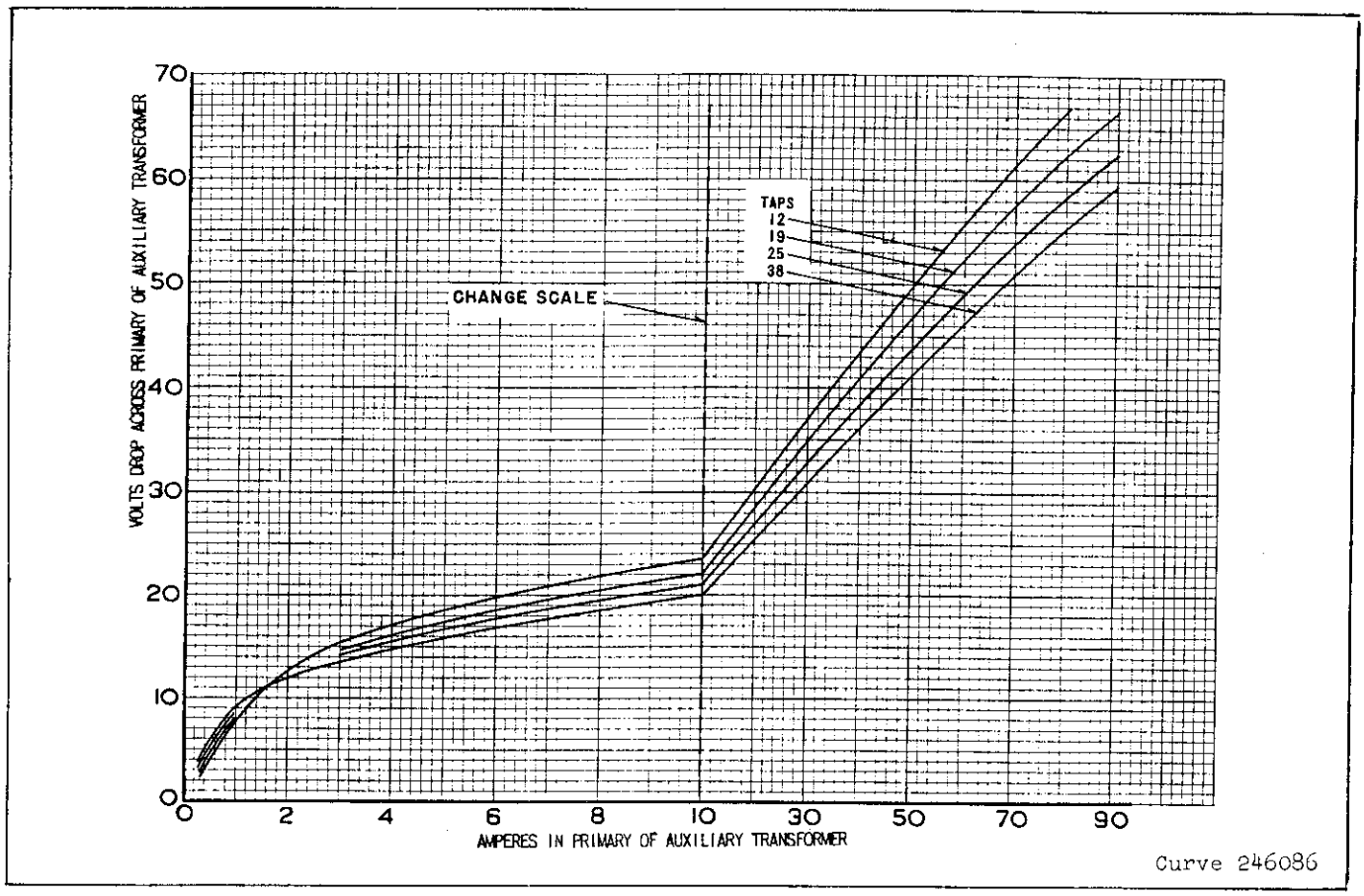

Fig. 5. Typical Burden Characteristics of The Operating Coil Circuit

though 10 amperes were flowing in one winding alone. Conversely, if equal currents flow in these two coils, but in opposite directions, their ampere turns will cancel and no torque will be produced. The same relationship applies for the other two restraining units of the relay.

This relay has variable percentage characteristics which means that the operating coil current required to close the relay contacts, expressed in percent of the total restraint current, varies with the magnitude of the restraint current. The relay sensitivity is high, corresponding to a low percentage ratio, at light currents, and its sensitivity is low, corresponding to high percentage unbalance, at high currents. The relay is made sensitive at low currents in order that it will detect light internal faults on the bus being protected. At the same time, however, its reduced sensitivity at the higher currents allows the various current transformers involved to depart from their true ratio to a large extent without causing false tripping of the relay for external faults.

The variable percentage characteristics are particularly advantageous when severe saturation of current transformers is caused by the d-c component of asymmetrical short circuits. In the case of buses located close to generating stations where the d-c component decays slowly, the breakdown in ratio of the current transformers will be much greater than would ever be expected from a consideration of the usual ratio curves of the current transformers involved.

CHARACTERISTICS

There are no taps inside the relay case. Taps controlling the sensitivity of the relay are incorporated in the external current transformer (see Fig. 11 for internal wiring.) The tap markings are: 12 - 19 - 25 - 38. These tap values, as indicated on the torque curves of Fig. 3, are the 60 cycle amperes required in the operating coil circuit to close the relay contacts against a 70 cmg. restraint torque.

Time of operation of the relay is shown in Fig. 4. To use this curve, determine the total restraining

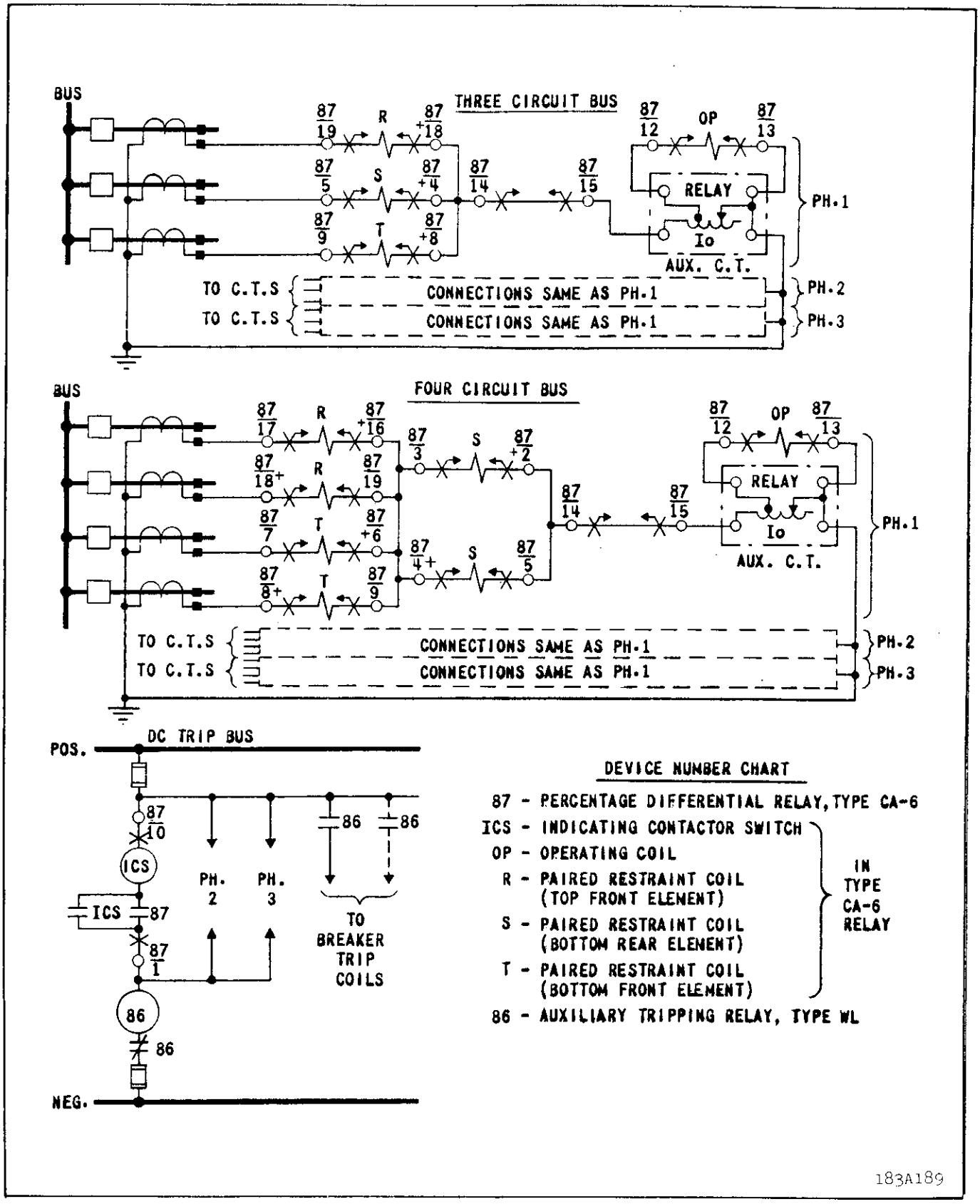

Fig. 6. External Schematic of One Set of Type CA-6 Relays for Three and Four Circuit Bus Protection.

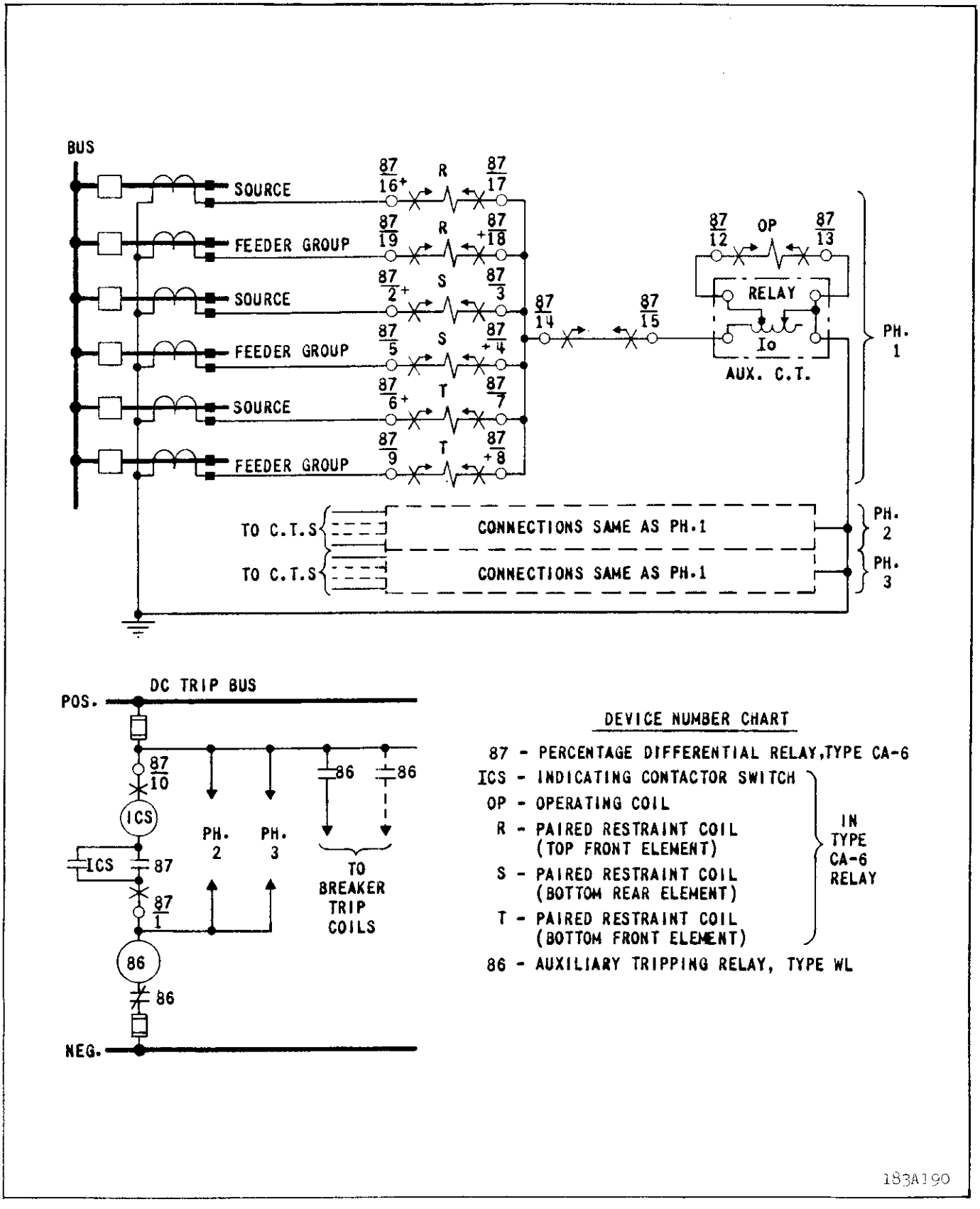

Fig. 7. External Schematic of One Set of Type CA-6 Relays for Protection of a Six Circuit Bus With Three Feeder Groups.

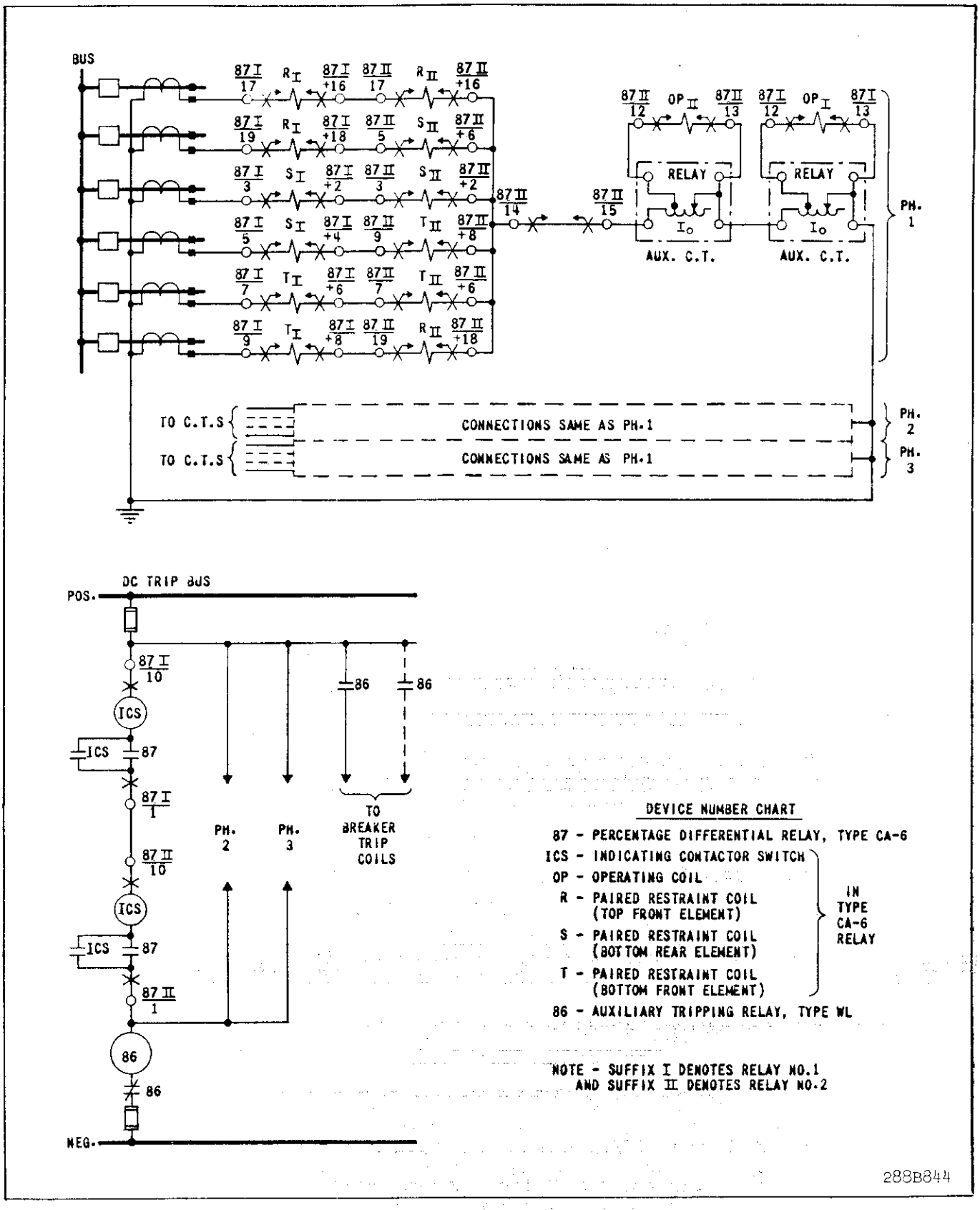

Fig. 8. External Schematic of Two Sets of Type CA-6 Relays for Six Circuit Bus Protection.

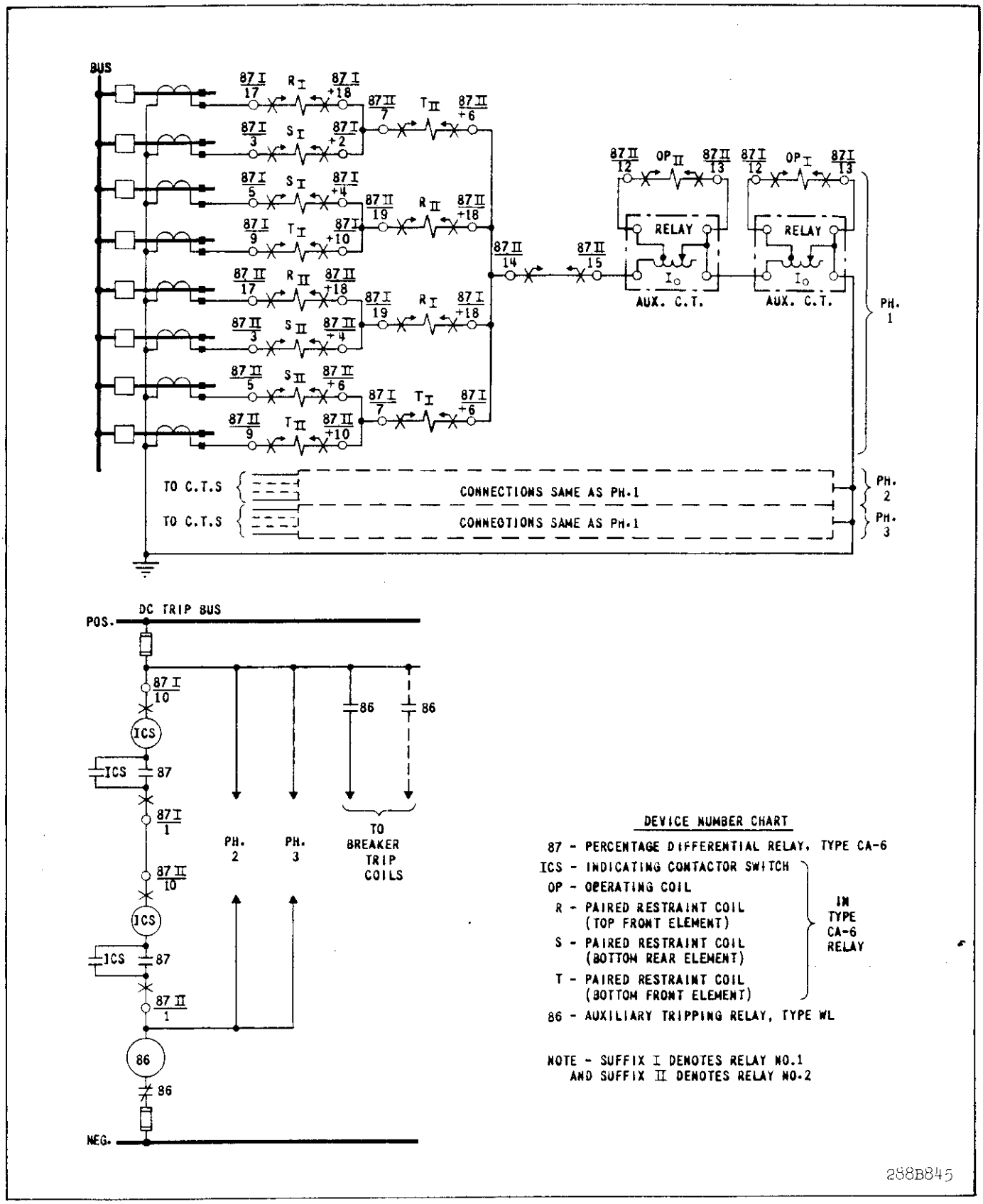

Fig. 9. External Schematic of Two Sets of Type CA-6 Relays for Eight Circuit Bus Protection.

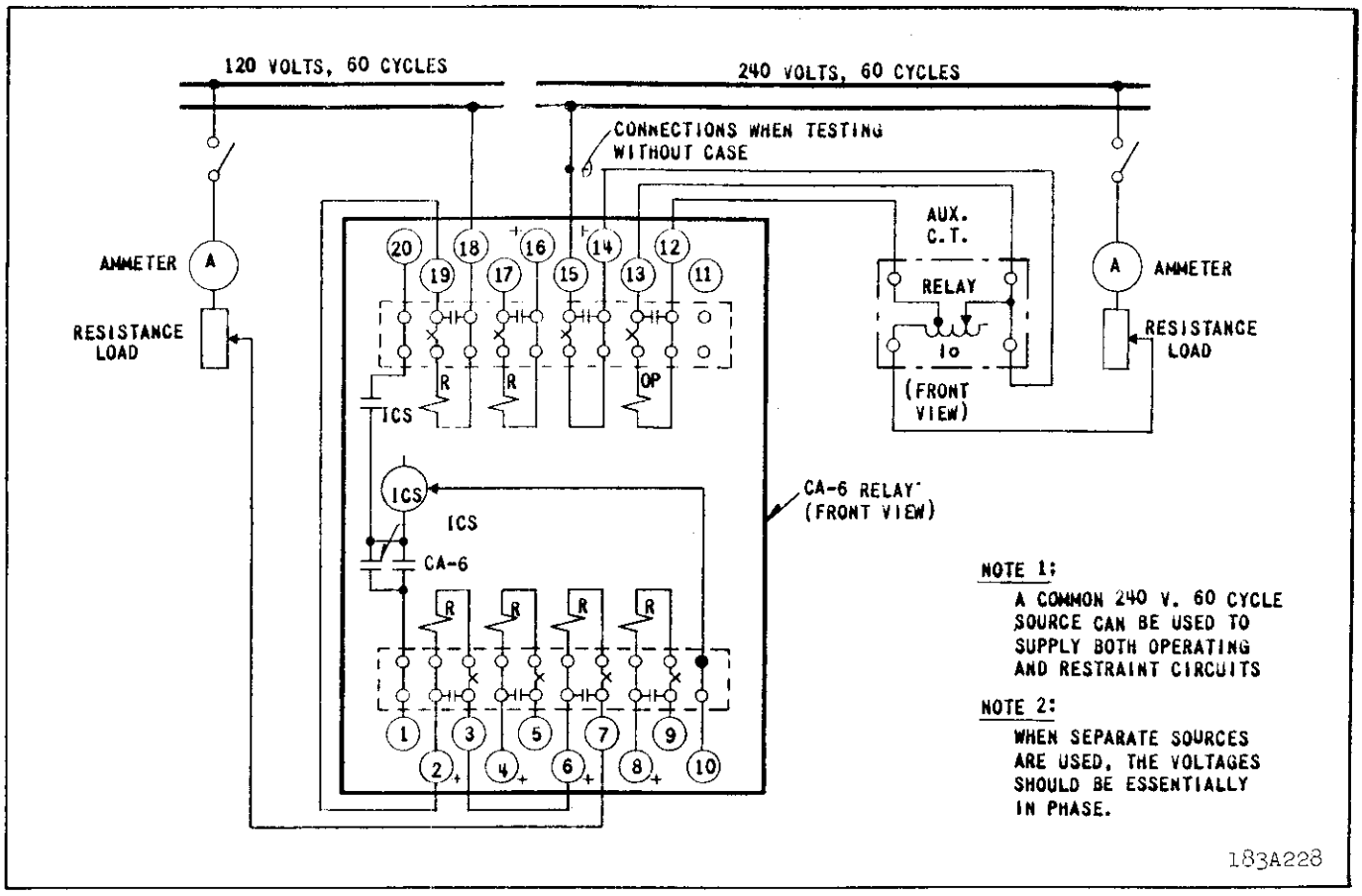

Fig. 10. Diagram of Test Connections for the type CA-6 Relay.

torque and substract this from the operating coil torque to determine the net torque in cmg. This curve applies only for a contact spacing of 1/4 inch.

The burden of each restraining coil is .75 volt-amperes, 70% power factor at 5 amperes, 60 cycles, with a continuous rating of 10 amperes. The burden of the operating coil circuit, including the external current transformer is variable, depending upon the current flowing thru it. (See Fig. 5) Under normal system operation it introduces no burden at all in the current transformer circuit because no current flows in the differential circuit. Under minimum tripping conditions, the burden of each operating coil circuit varies from 9 to 11 ohms at approximately 90° lag, depending upon the tap. Under maximum internal fault conditions when all of the current must flow thru the operating coils, the burden is reduced to approximately 1 ohm, because of saturation.

TRANSFORMER RELAY

The type CA-6 transformer differential relay includes an indicating instantaneous trip unit (See Fig. 2) and has a stronger spiral control spring than the bus differential relay. The instantaneous trip unit is intended to operate on internal faults on the order of 100 amps. (secondary) or higher because, when a transformer bank is connected to a high capacity bus, it is difficult to keep the maximum internal fault currents down to a 100 ampere value. Thus, the instantaneous unit assures prompt tripping at excessively high current values. At the same time, the instantaneous unit should not have a setting substantially lower than 100 amperes (secondary) in order to avoid a possible false operation for external faults. The stronger spiral control spring is provided in order that the relay maybe given a higher minimum trip setting, as noted under "Adjustments and Maintenance".

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

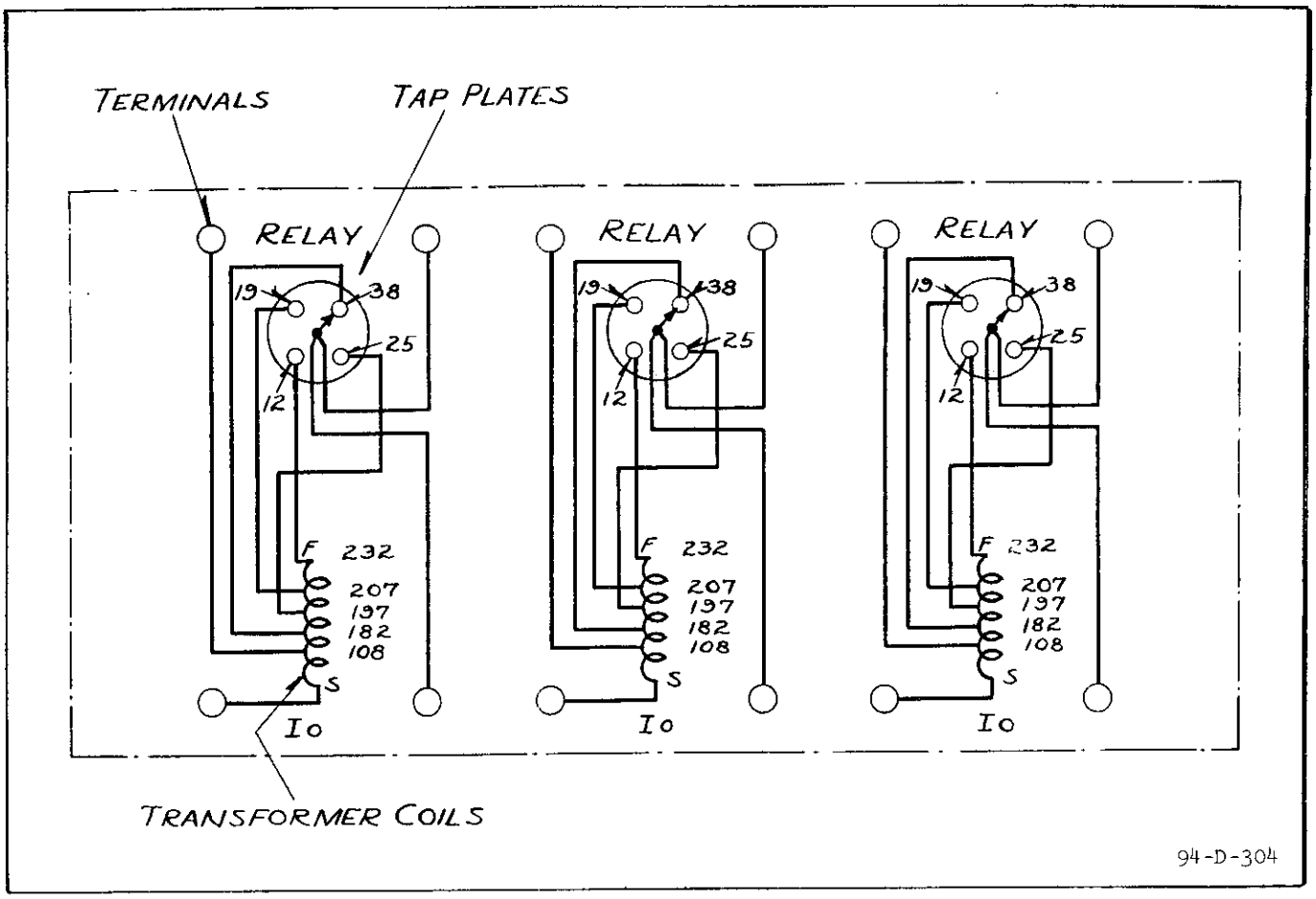

Fig. 11. Internal Wiring Diagram of the Auxiliary Current Transformer.

long enough to trip a circuit breaker.

The indicating instantaneous trip contacts will safely close 30 amperes at 250 volts d-c, and will carry this current long enough to trip a breaker.

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

TRIP CIRCUIT CONSTANT

Indicating Contactor Switch (ICS)

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

CONNECTIONS

One relay per phase is normally recommended for the protection of buses with up to 8" equivalent circuit" connections. An "equivalent circuit" is defined as major source or a group of feeder circuits. The grouped feeder circuits' fault contribution should not exceed 5% of the total phase or ground fault current, with normal bus connections. In paralleling current transformers for the feeder group or groups, the load current distribution should be examined to insure that the 10 ampere continuous rating of the relay restraint windings is not exceeded.

The recommended connections are outlined in Table I.

TABLE I

Case	Total No. of Eq. Ckts.	No. of Feeder Groups	Connections
I	3	0-2	Fig. 6
II	4	0-3	Fig. 6
III	5	0-1	Note 1
IV	5	2-4	Fig. 7
V	6	0-1	Note 1
VI	6	2-5	Fig. 7
VII	7	0-6	Note 1
VIII	8	0-7	Note 1

Note 1 -- Same as 4 circuit bus of Fig. 6 except parallel CT's in pairs. (1 set in parallel for 5 ckt. bus, 2 for 6 ckt. bus, etc.)

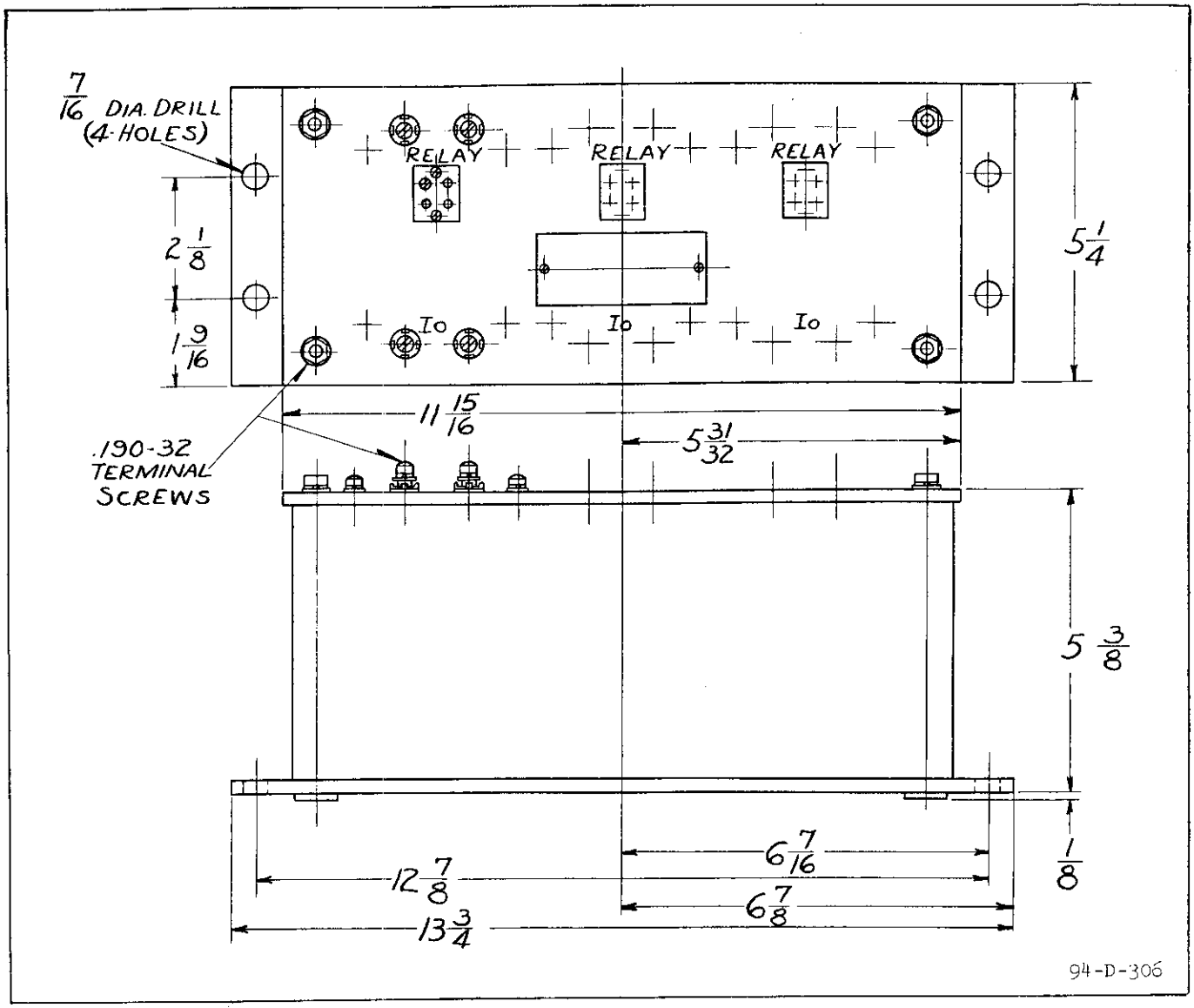

Fig. 12. Outline & Drilling Plan of the Auxiliary Current Transformer.

In cases III, V, VII, and VIII of Table I, at least one pair of current transformers is paralleled. Almost complete restraint cancellation will occur on an external fault, if all but two of the circuits are out of service and if the remaining circuits have their current transformers paralleled. In selecting the circuits to be paired, the following points should be observed:

1) Parallel circuits which are not likely to be left alone on the bus.
2) Where sources are to be paired, parallel the smaller sources, if there are less than 8 equivalent circuits.
3) Avoid pairing the two largest sources.
4) If feasible, parallel matched current transformers.

In case IV, with two feeder groups one of the restraint elements must be connected to 2 source circuits. These 2 source circuits should be selected so that they are the least likely to be left alone on the bus and are not the two largest sources.

Where the nature of the bus application is such that nearly complete restraint cancellation is very likely to occur for cases III, V, VII, and VIII of Table I, two relays per phase should be employed to insure restraint under all possible external fault conditions. Connections for 6 and 8 equivalent circuit buses, using 2 relays per phase, are shown in Figs. 8 and 9, respectively.

Where there are more than 8 equivalent circuits, the connections in Fig. 9 should be employed by

pairing current transformers in the same manner as outlined for single relay per phase applications.

SETTING CALCULATIONS

No calculations are required to set the CA-6 relay.

SETTING THE RELAY

BUS DIFFERENTIAL UNIT

The external current transformer taps are the only setting required. Where the d-c time constant is 0.6 cycles or less and where the current transformer ratio error as a result of a-c saturation exceeds 5%, it is recommended that the #38 tap be used. In all other cases, the #19 is recommended.

TRANSFORMER DIFFERENTIAL UNIT

Set the external current transformer tap. No other setting is required. It is recommended that the #19 tap be used.

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

Note: The CA-6 relay and external transformer are calibrated as a unit. Relays and transformers of matching serial numbers should be connected together.

The proper adjustments to insure correct operation of the relay have been made at the factory and should not be disturbed after receipt by the customer. However, if for any reason the adjustments have been changed or the relay taken apart for repair, the following instructions should be followed in reassembling and calibrating the relay.

All contacts should be cleaned periodically. 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.

DIFFERENTIAL UNIT

Adjust the top bearing screw to have approximately .002" clearance between it and the shaft. Adjust the stationary contact so that 1/4 inch contact separation is obtained when the moving contact is held in the maximum open position.

The tension of the spiral spring of bus differential relays should be adjusted so that the contacts just close when .14 ampere is flowing thru the #38 tap, or when .17 ampere is flowing thru the #12 tap. With the relay totally deenergized, the spring tension should reset the contacts to the full open position. The resetting time will be fairly slow because of the damping effect of the permanent magnets. If the contacts fail to reset with this spring tension adjustment, then the moving parts should be inspected for friction or interference.

The transformer differential relay is calibrated at the factory for a minimum pick up 1 ampere in the operating coil circuit when using the #19 taps. Adjust the spiral spring to obtain this calibration. The nominal pickup range, which can be obtained by spring adjustment, is 0.75 to 1.25 amperes.

The polarity of the restraining coils, as indicated on the wiring diagram, Fig. 1, should be checked if any rewiring has been done.

To check the calibration, pass 33 amperes through the three restraining elements in series using only one coil per element. See Fig. 10. Reference to Fig. 3 shows that this develops 23-1/2 cmg. per element or a total of 70 cmg. restraint. Pass current from a 220 volt a-c source through the primary of the auxiliary transformer. The current required on the various taps to just balance this restraint

torque (70 cmg.) should be as follows:

Tap	Amperes
38	36 to 44
25	24.5 to 30
19	18.5 to 24
12	11.5 to 15

The above values are obtained with the relay and transformer cold. Note that heating of the restraining circuits has very little effect when heated due to normal current flow. Since the operating circuit normally carries no current, it is important to prevent over-heating of the operating coil or auxiliary transformer during 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.

INDICATING INSTANTANEOUS TRIP (IIT)

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 IIT. The indicator target should drop freely.

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.

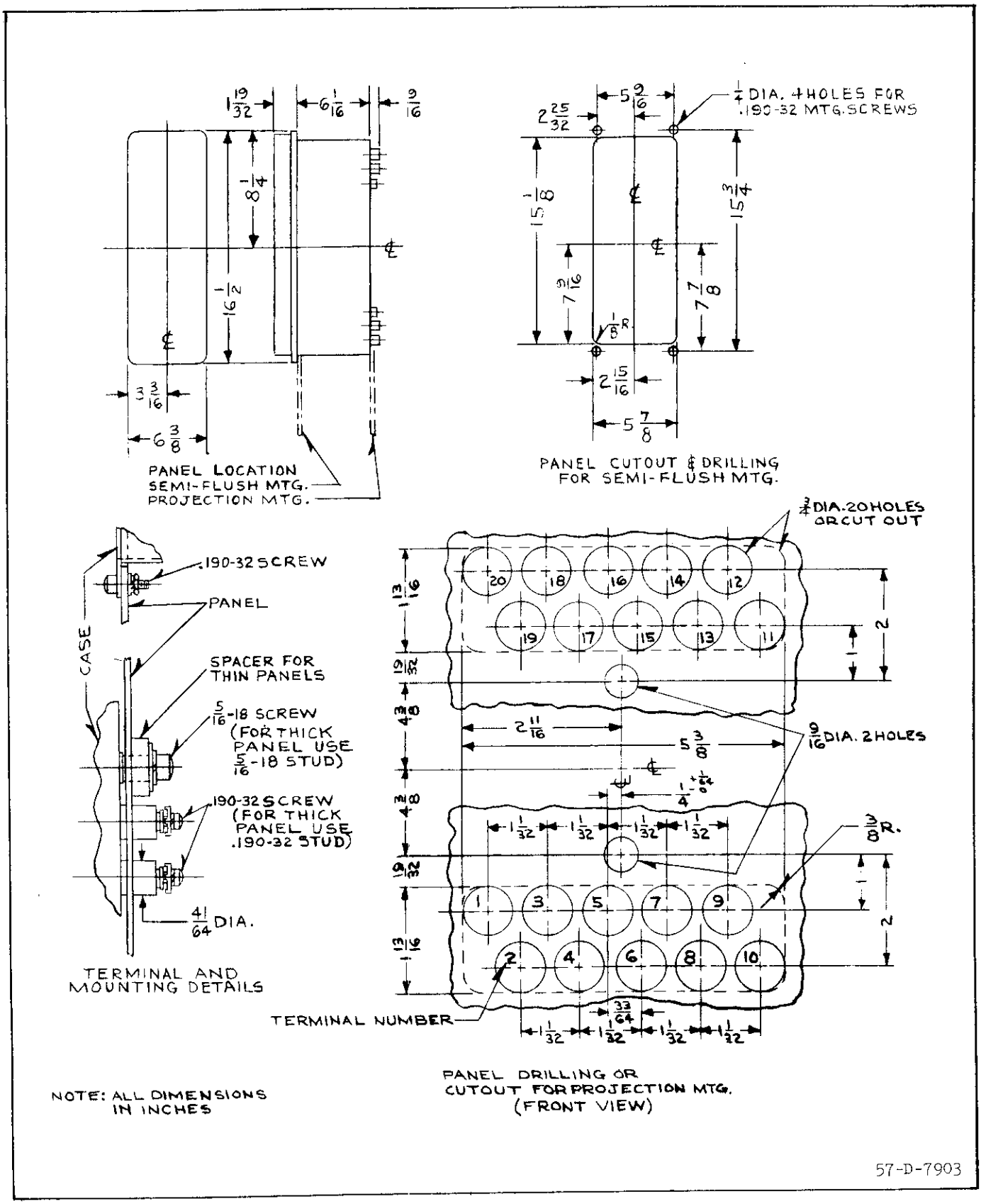

Fig. 13. Outline & Drilling Plan for the Type CA-6 Relay in the type FT-32 Case.