RELAYING OF SYSTEMS WITH
NEUTRALS GROUNDED THROUGH A HIGH RESISTANCE

LUCAS H. PERRY
SENIOR RELAY ENGINEER
MINNESOTA POWER & LIGHT COMPANY

It has become increasingly common to ground power plant auxiliary systems, and other power distribution systems utilizing cables, through a high resistance. Such resistance is usually chosen to limit the ground fault current to a maximum of 5 or 10 amperes.

The primary advantage of this grounding scheme is that it greatly reduces or practically eliminates the hazard of cable fires - especially important when cables are laid in trays.

Another advantage is that all single line to ground faults, irrespective of location, will be about the same magnitude - nearly equal to the calculated maximum value. The variation in fault current, for various fault locations and fault contact resistance will be only on the order of 2 to 1, rather than the 100 to 1, or even 1000 to 1, as may occur with solidly grounded or low resistance grounded systems.

A third advantage is that high contact resistance ground faults can also be detected and cleared. For example, on a 480 volt system with a maximum SLG fault of 5 amperes and a 2.5 ampere primary relay pickup, a fault having up to 55 ohms contact resistance could be detected.

To relay such systems, a low ratio zero sequence, or torodial, current transformer is used for each circuit. All phase conductors of the circuit pass through the current transformer so its ouptut is a function of the zero sequence current only. Usually a low set instantaneous over-current relay is connected across the secondary terminals of the current transformer. The relay may trip the circuit, or alarm, or both.

Typically a 10/1 ratio current transformer will be used and the relay set for a secondary pickup of 0.25 amperes to 0.50 amperes.

Since this combination apparently offers a 2 to 1 ratio between fault current and relay pickup, some systems have been installed on the basis of such elementary analysis.

In practice, this combination of current transformer and relay offers all the protection as would exist if the relays and current transformers were left in the warehouse, or better still, never purchased.

In Table 1 are listed the impedance at minimum pickup of various electromagnetic instantaneous over-current relays which are or could be used for this application.

Figure 1 shows the secondary excitation curve, as supplied by the manufacturer, of one zero seqeunce current transformer. Figures 2 and 3 are secondary excitation curves of two other zero sequence current transformers drawn from test data.

Figure 4 is the simple circuit showing current flow at relay pickup assuming an ITH relay is used, set at 0.25 amperes, and the current transformer is that of Figure 1. No impedance is shown between the relay terminals and the current transformer terminals because usually such relays are mounted on the switchgear cabinets and the current transformer leads are only 10 feet to 15 feet long. Further, the resistance of the CT winding has also been neglected, since it is only 0.15 ohms.

The fault has been deliberately limited to 5.0 amperes. The calculated relay primary pickup is 4.8 amperes. This relaying is inadequate at best. (Since, by test, the actual relay primary pickup measures 5.0 amperes to 5.1 amperes, this relaying is, in reality, worthless.)

Test connections for a test of primary pickup of these relays is shown in Figure 5. Figures 6 and 7 show primary pickup as a function of relay setting for ITH and PJC relays connected to the current transformers of Figures 2 and 3. Data for these curves were obtained by test.

Some solutions to this problem are:

1. Use static over-current relays. An instantaneous over-current relay is available having a burden of less than one volt-ampere at 5 amperes and a range of 0.1 ampere to 1.0 ampere. A static time over-current relay is also available having a range of 0.1 amperes to 0.8 ampere and a maximum burden of 0.062 ohms. Either of these relays will provide an actual pickup of 110 percent to 120 percent of nominal pickup with CT's having secondary excitation curves as shown on Figures 1, 2 and 3.

2. Reconnect or change the resistor so the maximum fault is at least 200 percent of the actual relay primary pickup.

Concentric neutral single conductor cables may be used on these circuits. Where this is done, proper terminations of the concentric neutral conductors must be made at the source breaker if the zero sequence relays are to operate. Figures 8 and 9 show such proper connections. Figure 10 shows the connections which one can find.

Do not depend on drawings resulting in the proper connections. Make a visual inspection of every position after the cables have been installed and terminated. Even if this requires removing the back panels of the cabinets, make such inspections. I know of one power plant where, in spite of a drawing showing how the concentric neutrals should have been terminated and grounded, in about two-thirds of the circuits, the terminations actually made were those of Figure 10.

The special visual inspection of the cable terminations is even more important if the grounding resistor has only a short time rating. If the resistor opens because of a relaying failure, all the connected cables are exposed to the high voltages to ground which occur when a capacitance to ground is connected to an ungrounded system. (It appears obvious that a short time rated resistor must never be applied if the relaying is connected to alarm only, but this has been done, too.)

In this paper, I have referred to the manufacturer's specific equipment. In doing so, I am not finding fault with either the manufacturer or his equipment. There is nothing wrong with either the relays or the current transformers and proper relaying can be easily achieved so long as one does not attempt to exceed the limitations of either the current transformer or the relay. The respective manufacturers do publish burden data of their relays and current transformer secondary excitation curves. This problem exists because of the ignorance or indifference of the applications engineer.

TABLE 1

IMPEDANCE OF RELAY OPERATING COILS

RELAY TYPE	MINIMUM PICKUP	BURDEN	IMPEDANCE AT MIN. PICKUP
HFC	0.5 Amp		14.44 ohms
HNC	0.5 Amp		16.8 ohms
ITH	0.25 Amp	0.44 VA at 0.25 Amp	7.04 ohms
PJC	0.5 Amp	165 VA at 5 Amp	6.6 ohms
SC	0.5 Amp	225 VA at 5 Amp	9.0 ohms
SC-1	0.5 Amp	210 VA at 5 Amp	8.4 ohms

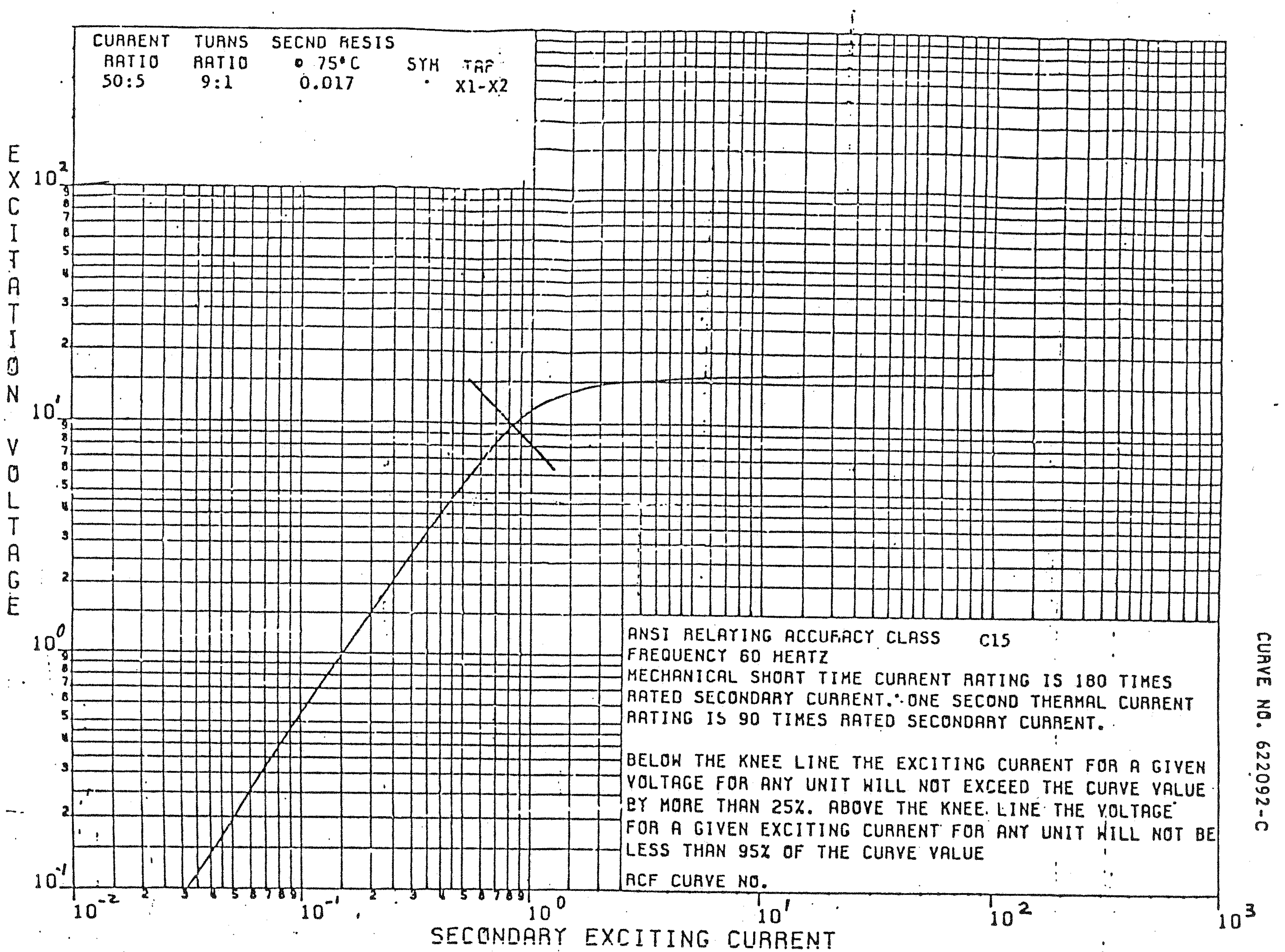

CURVE NO. 622092-C
CURRENT RATIO 50:5
TURNS RATIO 9:1
SECND RESIS @ 75°C 0.017
SYM ·
TAP X1-X2
EXCITATION VOLTAGE
SECONDARY EXCITING CURRENT
ANSI RELAYING ACCURACY CLASS C15
FREQUENCY 60 HERTZ
MECHANICAL SHORT TIME CURRENT RATING IS 180 TIMES RATED SECONDARY CURRENT. ONE SECOND THERMAL CURRENT RATING IS 90 TIMES RATED SECONDARY CURRENT.
BELOW THE KNEE LINE THE EXCITING CURRENT FOR A GIVEN VOLTAGE FOR ANY UNIT WILL NOT EXCEED THE CURVE VALUE BY MORE THAN 25%. ABOVE THE KNEE LINE THE VOLTAGE FOR A GIVEN EXCITING CURRENT FOR ANY UNIT WILL NOT BE LESS THAN 95% OF THE CURVE VALUE
RCF CURVE NO.

FIGURE 1

GES-32

For use with G-E Template NP-1093

GENERAL ELECTRIC

SECONDARY EXCITATION CHARACTERISTICS

ZERO SEQUENCE CT 480 V SWGR

Bushing Current Transformer, Type..................

For Power Circuit Breaker..................

Frequency 60 HZ Internal Resistance .... Secondary Turns 10

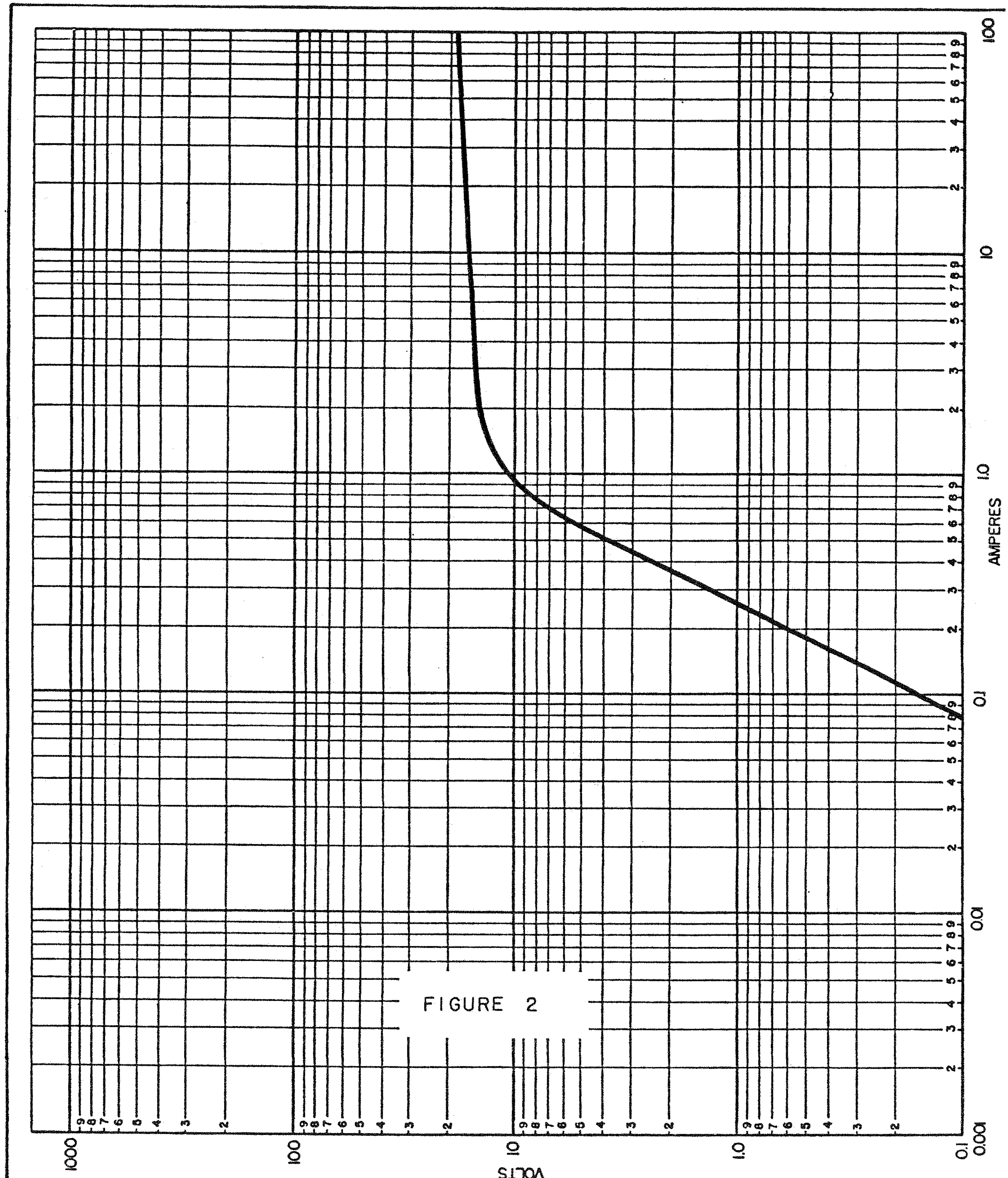


FIGURE 2

GENERAL ELECTRIC

SECONDARY EXCITATION CHARACTERISTICS

ZERO SEQUENC
CT
4160 V SWGR

Bushing Current Transformer, Type..................
For Power Circuit Breaker..................
Frequency 60 HZ Internal Resistance .... Secondary Turns 10

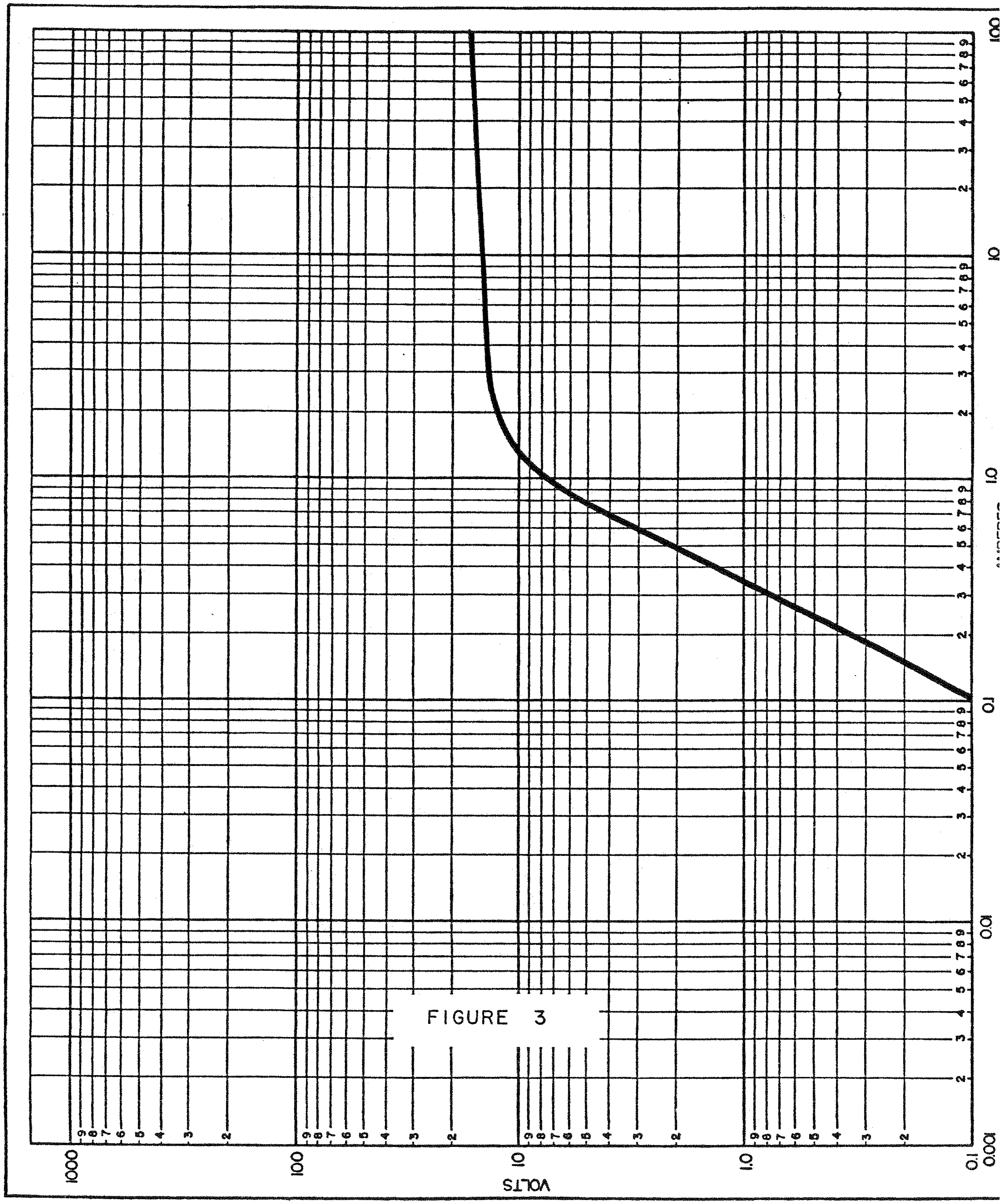


FIGURE 3

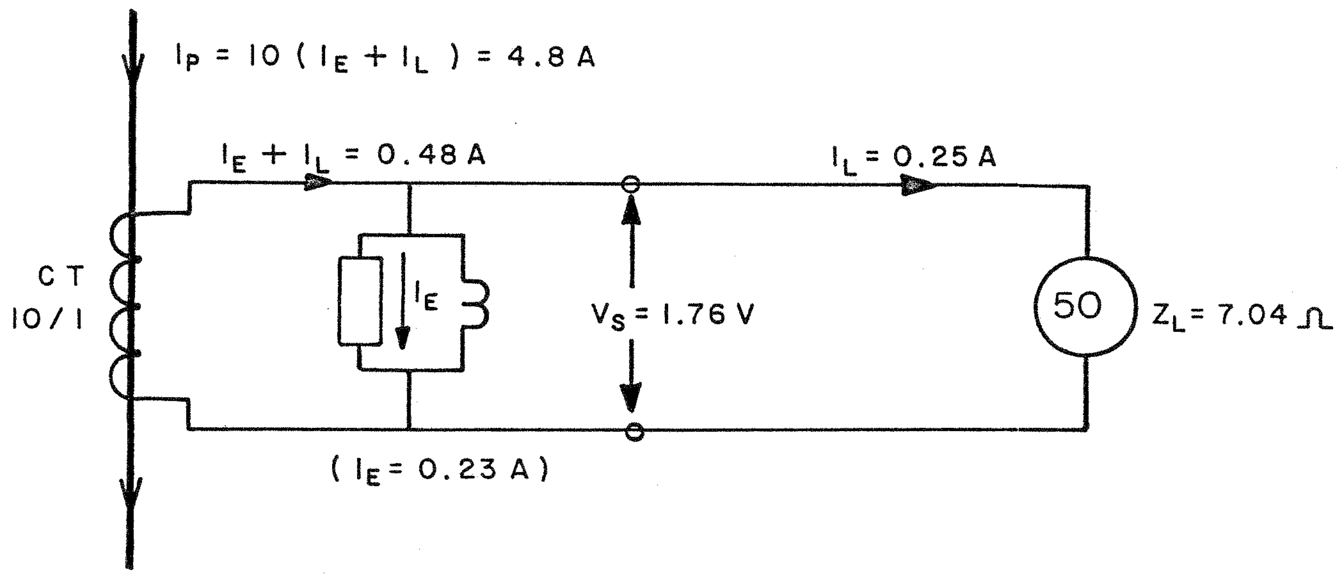

I_P = 10 (I_E + I_L) = 4.8 A
I_E + I_L = 0.48 A
I_L = 0.25 A
CT
10/1
I_E
V_S = 1.76 V
50
Z_L = 7.04 Ω
(I_E = 0.23 A)

FIGURE 4

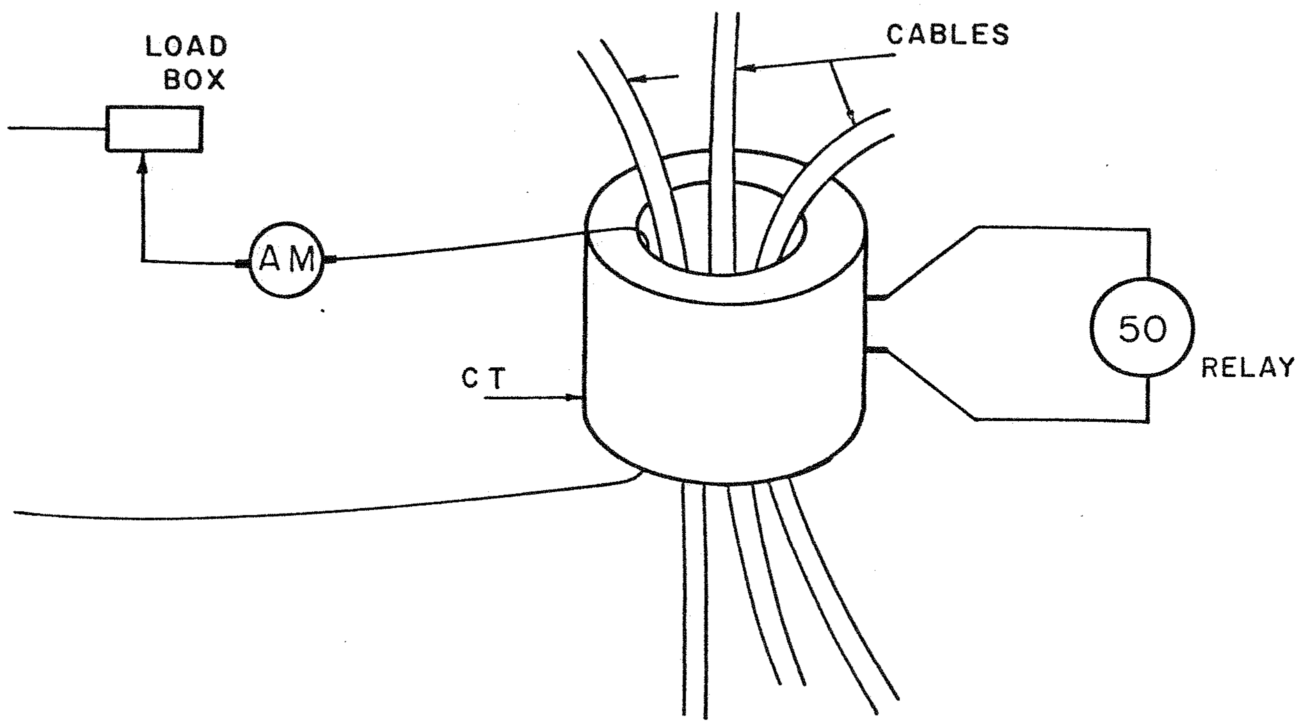
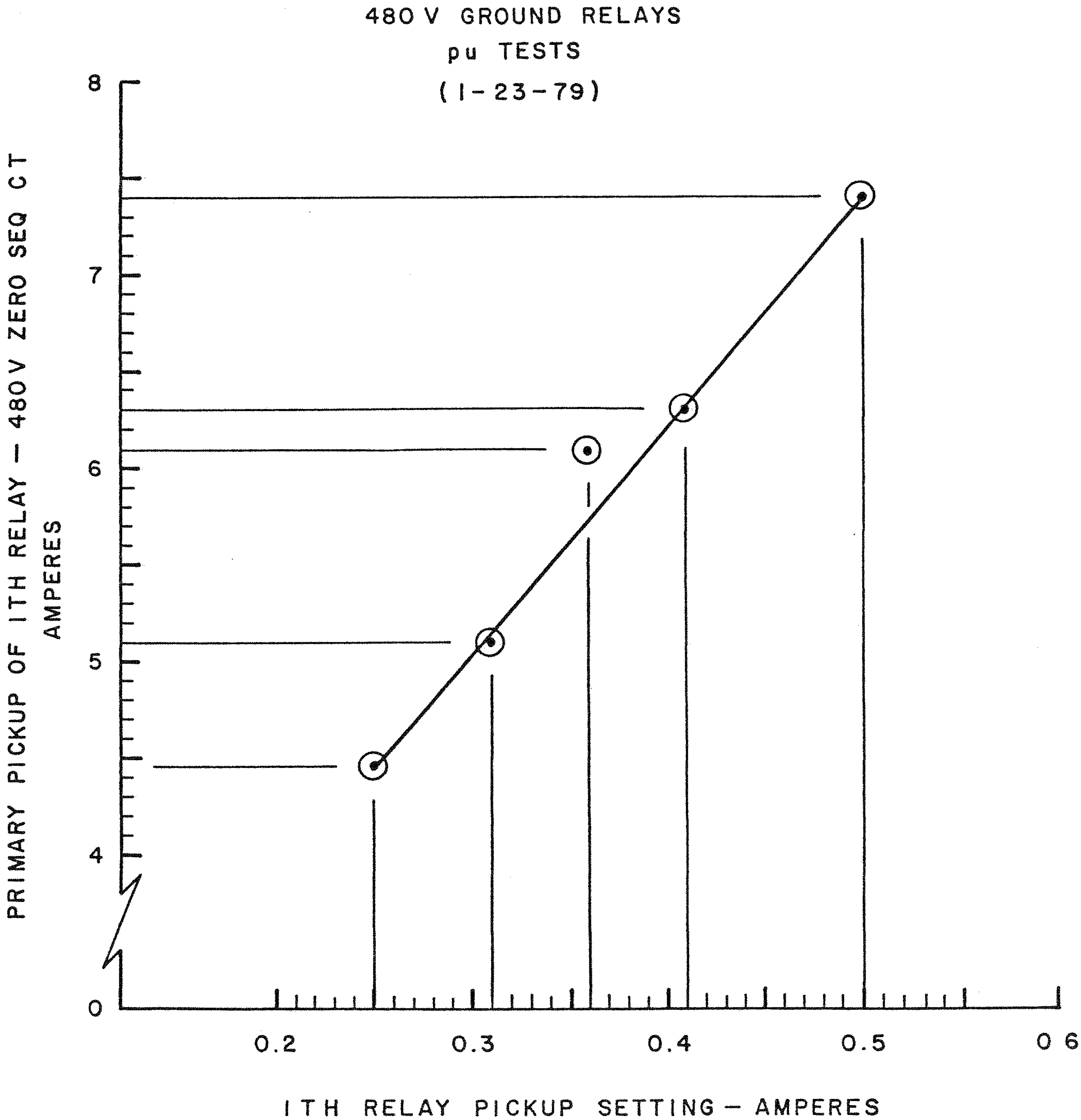
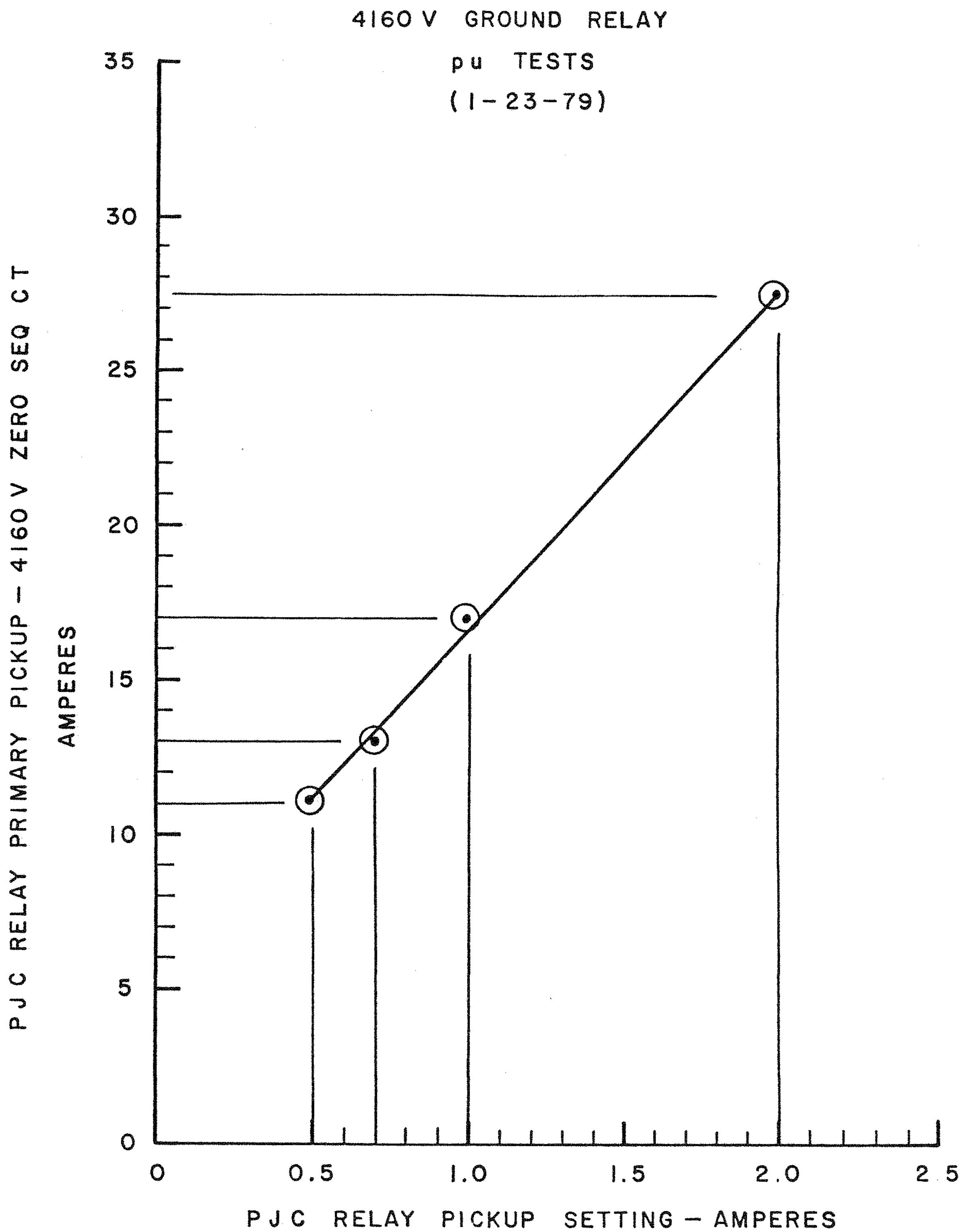


FIGURE 5



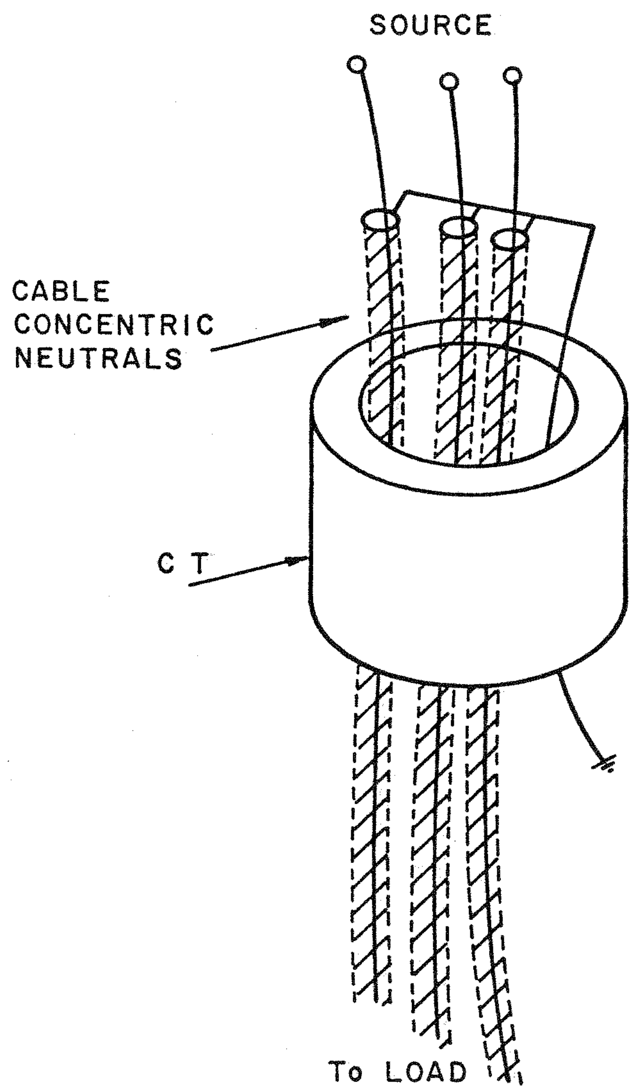
480 V GROUND RELAYS
pu TESTS
(1-23-79)
PRIMARY PICKUP OF ITH RELAY — 480 V ZERO SEQ CT
AMPERES
8
7
6
5
4
0
0.2
0.3
0.4
0.5
0 6
ITH RELAY PICKUP SETTING — AMPERES

FIGURE 6



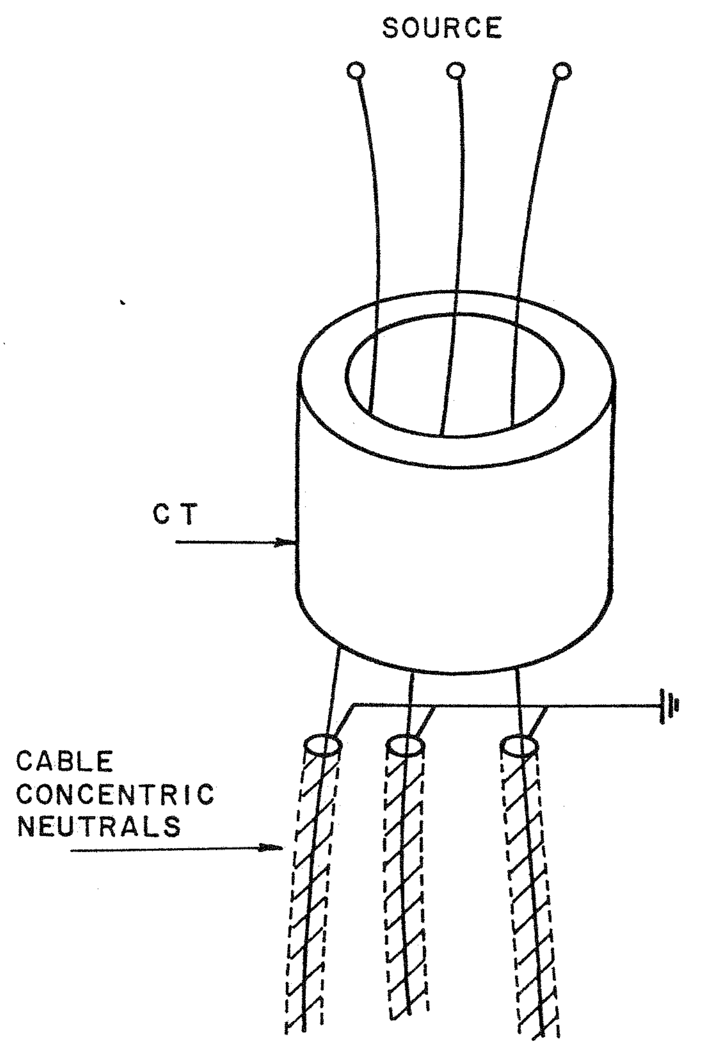
4160 V GROUND RELAY
pu TESTS
(1-23-79)
35
30
25
20
15
10
5
0
PJC RELAY PRIMARY PICKUP - 4160 V ZERO SEQ CT
AMPERES
0
0.5
1.0
1.5
2.0
2.5
PJC RELAY PICKUP SETTING - AMPERES

FIGURE 7



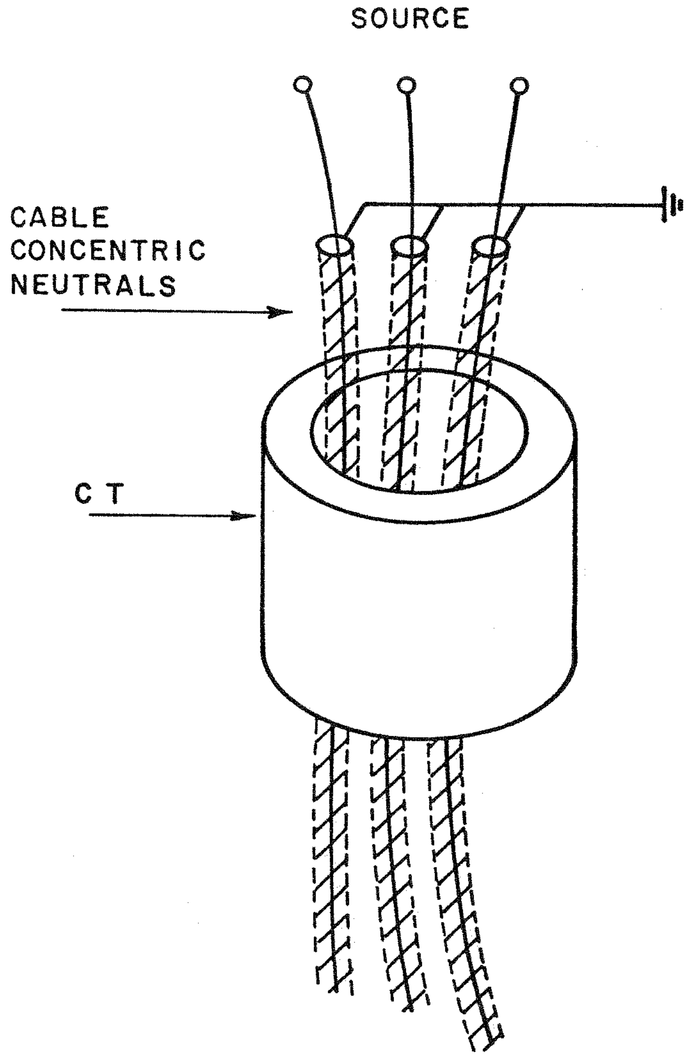
NEUTRAL GROUND WIRE MUST PASS BACK THROUGH CURRENT TRANSFORMER BEFORE BEING CONNECTED TO GROUND.

FIGURE 8



CONCENTRIC NEUTRALS CUT BACK TO LOAD SIDE OF CURRENT TRANSFORMER / AND GROUNDED.

FIGURE 9



WRONG WAY OF GROUNDING
CONCENTRIC NEUTRALS

FIGURE 10