

# Instructions for Type GFR Ground Fault Protection Systems



I.L. 15321-B  
File 29-700

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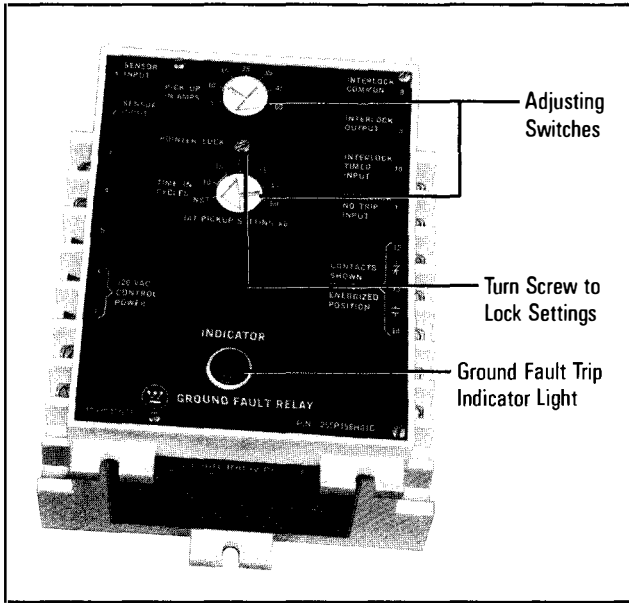


Fig. 1A Ground Fault Relay-Electrical Reset With Zone Interlocking (Cat. No. GFR60E1)

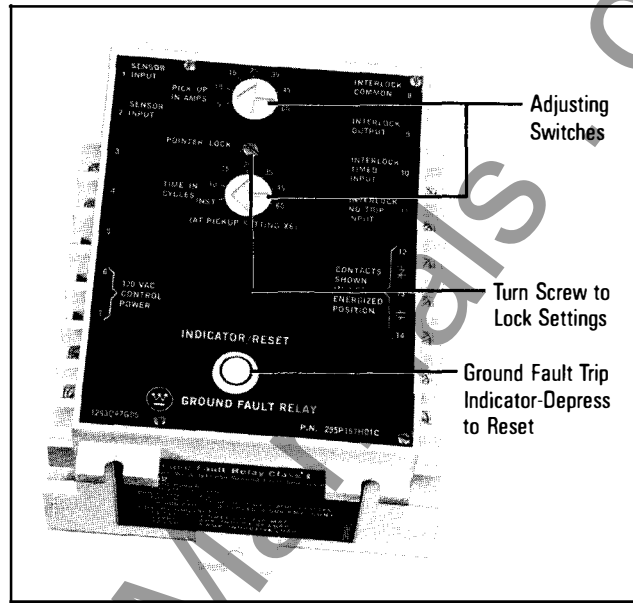


Fig. 1B Ground Fault Relay-Mechanical Reset With Zone Interlocking (Cat. No. GFR60M1)

**1.0 UL LISTED GROUND FAULT SENSING AND RELAYING EQUIPMENT**

Type GFR ground fault relays, current sensors, test panels and accessory devices are UL listed by Underwriters' Laboratories, Inc. in accordance with their standard for *Ground Fault Sensing and Relaying Equipment*, UL 1053, under File E48381.

**2.0 GENERAL PURPOSE**

A type GFR ground fault protection system, when properly installed on a grounded electrical system, will sense phase to ground fault currents. When the level of fault current is in excess of the pre-selected current pick-up and time delay settings, the GFR relay will initiate a trip action of a disconnect device, which will open the faulted circuit and clear the fault.

The GFR devices are UL Class I devices designed to protect electrical equipment against extensive damage from arcing ground faults.

**CAUTION: GROUND FAULT PROTECTION SYSTEMS DESIGNED TO PROTECT EQUIPMENT CANNOT SIMULTANEOUSLY PROVIDE PROTECTION FOR PERSONNEL AGAINST ELECTRIC SHOCK HAZARDS, SINCE THIS TYPE PROTECTION REQUIRES A SENSITIVITY IN THE LOW MILLI-AMPERE RANGE.**

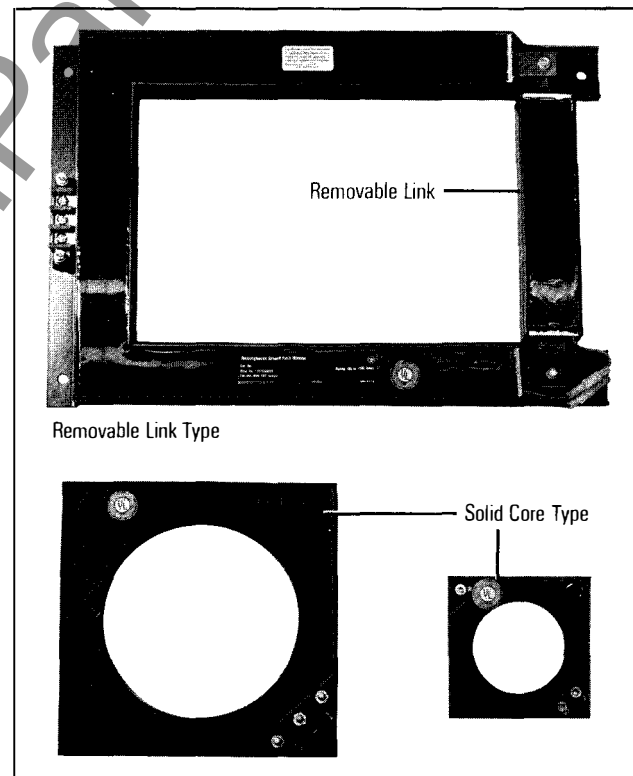


Fig. 2 Typical Ground Fault Sensors

### 3.0 DESCRIPTION

A basic type GFR ground fault protection system consists of a ground fault relay (GFR) as shown in Fig. 1, a ground fault current sensor (GFS) as illustrated in Fig. 2 and a disconnect device equipped with a shunt trip device. This disconnect device can be a molded case circuit breaker, a power circuit breaker, a bolted pressure switch or other fusible disconnect device, suitable for application with UL Class I Ground Fault Sensing and Relaying equipment. A typical molded case circuit breaker with a shunt trip device installed is illustrated in Fig. 3.

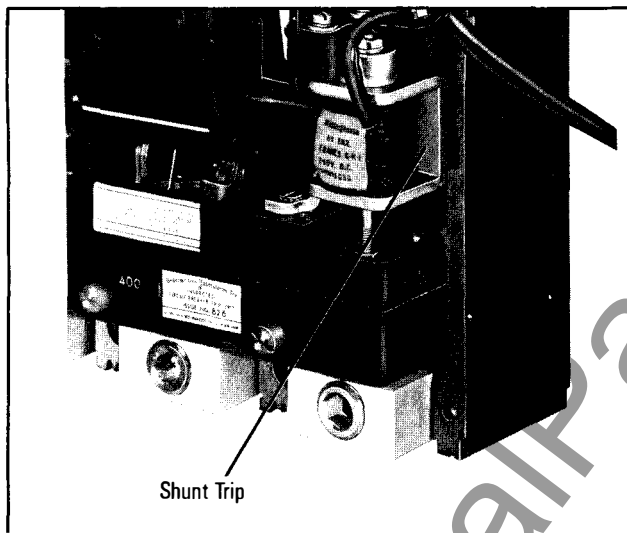


Fig. 3 Typical Shunt Trip Installation

Additional optional equipment can be added to the protection system to meet the requirements of the specifying engineer, including:

1. Ground Fault Test Panel – Fig. 4
2. Ground Fault Warning Indicator Relay – Fig. 5
3. Ground Fault Indicating Ammeter (1) – Fig. 6



Fig. 5 Ground Fault Warning Indicator Relay ①



Fig. 4 Ground Fault Test Panel ①

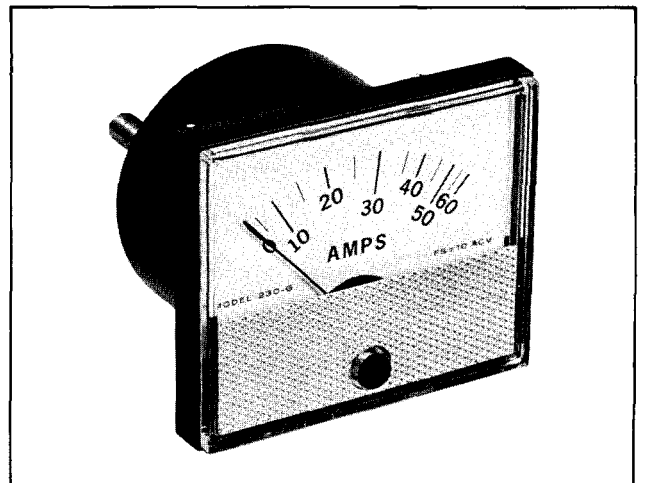


Fig. 6 Ground Fault Indicating Ammeter

① Recognized under the Component Program of Underwriters' Laboratories, Inc.

## 4.0 APPLICATION CONSIDERATIONS

### 4.1 General

Type GFR ground fault protective devices are designed to be used primarily on solidly grounded electrical distribution systems rated up to a maximum of 600 volts, 50/60 Hz, to provide for rapid clearing of arcing ground faults.

When properly applied, these devices will satisfy the requirements for ground fault protection of service entrance equipment as outlined in Sections 230-95 and 517-14 of the National Electrical code. When these devices are added to downstream feeder and branch circuits as well as the main service disconnecting devices as suggested in the fine print note of 230-95 and to the downstream feeders as required in 517-14, additional protection will be provided and selective coordination of tripping operations on arcing ground faults can be achieved.

With selectively coordinated ground fault protection equipment applied on main service disconnects and downstream devices, a greater degree of continuity of service is insured.

### 4.2 Methods of Achieving System Selectivity

There are two basic methods of achieving selective coordination between different levels of ground fault protective devices in a distribution system.

#### 4.2.1 TIME-CURRENT BAND SETTINGS

The first method employs adjustable time delay and current pick-up settings to achieve selectivity between upstream and downstream devices. When properly coordinated, downstream detection devices will use a time-current band setting that will initiate a downstream tripping operation and clear the faulted circuit before any upstream interrupting device tripping action can be initiated. This type of coordination necessarily requires the longest time delay settings to be placed on the upstream devices. This type of coordination is fine if the faults are always downstream.

#### 4.2.2 ZONE SELECTIVE INTERLOCKING

In a system employing zone selective interlocking type devices, selective coordination is still achieved for downstream faults by the use of time-current band settings. With appropriate settings, downstream interrupting devices will clear the faulted circuit before any upstream device can operate. However, with zone selective interlocking, additional intelligence is automatically pro-

grammed into the time-current coordination scheme to allow for variations in the pre-established tripping sequence to allow for alternate locations of the arcing ground fault. A zone selective interlock coordinated system provides for fast tripping of the nearest interrupting device upstream of the arcing ground fault regardless of the pre-set time delay settings. With this type of protection, the resulting systems damage level is the lowest possible because the interrupting devices are allowed to clear the fault as quickly as they can respond.

##### 4.2.2.1 Zone Selective Interlock Wiring

Zone interlock wiring is only applicable to type GFR relays equipped with zone selective interlocking as shown in Table 1. These relays are equipped with four additional terminals which have the following function:

- Terminal 8 – Common (Not used on 125V D-C GFR's)
- 9 – Output signal
- 10 – Input signal, time restraint
- 11 – Input signal, no trip

To make the relays function in a zone interlocking mode, all relays must be of the interlocking type and additional wiring connections are required. Typical connections for a main with multiple feeders and multiple branch circuits is illustrated in Fig. 7.

As shown by Note 1 in Fig. 7, twisted pair wiring must be used for interlock wiring to reduce the influence of stray magnetic fields in switchboards with high ampacity bus systems. Interlock wiring must be routed away from bus bars and separate from concentrated control wire groupings.

As shown by Note 3 in Fig. 7, any number – up to 50 – type GFR relays may be wired in parallel to transmit a single signal to upstream device. No supplementary relaying is required for this function.

##### 4.2.2.2 Zone Interlocking Operation Mode

Regardless of the time delay setting, any interlocking type GFR relay will respond near instantaneously unless a restraint signal – which is indicative of a ground fault further downstream in the next protective zone – acts to change the mode of operation to the pre-set time delay. On downstream circuits, it is frequently desired that a short time delay be observed before a tripping action is initiated. This can be accomplished by adding a jumper between terminals 9 and 10 on the downstream relay as indicated by Note 2 on Fig. 7. This jumper should not be used on any upstream relay as it will defeat the zone interlocking function.

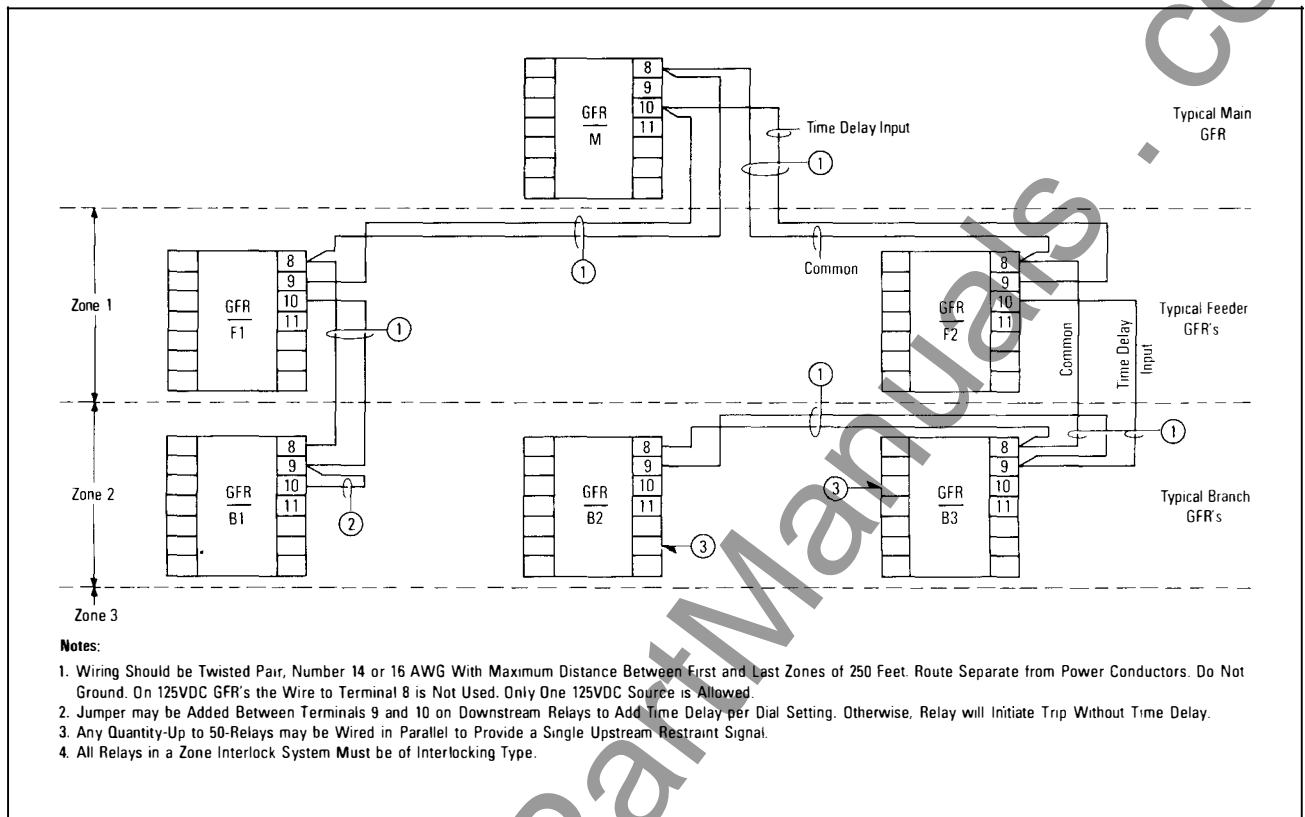


Fig. 7 Connection Diagram for Typical Zone Selective Interlocking System ©

## 4.3 Relay Settings

### 4.3.1 GENERAL

The exact individual relay time/current settings will vary between system installations depending upon the type of protection and level of selectivity desired. The Specifying Engineer can best make these decisions for any specific installation. For general applications, settings as described in the following conditions may be considered.

#### 4.3.1.1 Single Zone Level of Protection

**Minimum Pick-up** – 20% of disconnect rating. Increase to maximum pick-up setting (1200 Amp) where maximum service continuity is desired.

**Minimum Time Delay** – 10 cycles suggested. Any faster time will invite nuisance trips. Increase time when more than minimum damage level can be tolerated.

#### 4.3.1.2 Multiple Zones of Protection Without Zone Interlocking

**Minimum Pick-Up** – The pick-up setting of the downstream device should still be no less than 20% of the disconnect rating. Successive upstream settings should

be at least one step greater than the nearest downstream device pick-up setting.

**Minimum Time Delay** – The shortest time possible should be used on the branch circuit downstream. Increase the time delay on upstream devices in increments of one step or more for molded case breakers, and two steps or more for other slower operating type devices.

#### 4.3.1.3 Multiple Zones of Protection With Zone Selective Interlocking

Establish time/current coordination as in 4.3.1.2 for multiple zones without zone interlocking. This is done on the basis that most faults occur downstream and that the most downstream device should be set to clear the fault first leaving upstream devices for back-up fault protection.

Add zone interlocking to provide fast tripping of upstream devices regardless of pre-set time delay for faults in the upstream zones.

Where desired, nearly instantaneous operation of downstream devices can be defeated were time delayed operations are adequate. See 4.2.2.2.

Table 1

GFR Relay Types ③	120 Volt, 50/60 Hz Control			120 Volt Dc Control		
	Style 1293C47 ①			Style 1293C83 ①		
	Cat. No. GFR ② ④			Cat. No. GFR ② ④		
	Pick-up In Amperes			Pick-up In Amperes		
	1-12	5-60	100-1200	1-12	5-60	100-1200
Electrical Reset With Zone Interlocking	G11	G01	G03	G11	G01	G03
	12EI	60EI	1200EI	12EID	60EID	1200EID
Electrical Reset Without Zone Interlocking	G12	G02	G04	G12	G02	G04
	12E	60E	1200E	12ED	60ED	1200ED
Mechanical Reset With Zone Interlocking	G09	G05	G07	G09	G05	G07
	12MI	60MI	1200MI	12MID	60MID	1200MID
Mechanical Reset Without Zone Interlocking	G10	G06	G08	G10	G06	G08
	12M	60M	1200M	12MD	60MD	1200MD

① For complete style number, add group suffix from below, as G11, G01, G03.

② For complete catalog number, add suffix from below, as 12EI, 60EI, 1200EI.

③ All types require 120 volt, 50/60 Hz. control for test winding.

④ After March, 1983, an "A" suffix will be included after the GFR style number to signify that the GFR interlock is comparable with the SPB and Digitrip interlocks.

## 5.0 RELAY TYPE SELECTION (See Fig. 1)

### 5.1 Available Relay Types

The GFR ground fault relays are available in two basic types, ie, with and without zone selective interlocking. Each type relay must be reset following a trip operation. Each of the basic type relays is available with either an electrically held or mechanically latched output relay. The electrically held type must be electrically reset remotely – usually via a normally closed, momentary pushbutton in the control power circuit. In this type, a red lamp is provided for visual ground fault trip indication. The mechanically latched type must be manually reset by depressing the pushbutton on the face of the GFR relay. This manual reset bottom also serves as a mechanical pop-up trip indicator. A complete list of available styles is provided in Table 1.

### 5.2 Setting Adjustments

Each type relay is provided with two switches that are adjustable over the range selected. The top adjusting knob, as shown in Fig. 1, adjusts the pick-up level of the ground fault current. The bottom adjusting knob adjusts the time delay range. The calibration marks provided for both adjustments are shown in Table 2. After the desired values have been pre-set, the adjusting knobs can be locked in position by the pointer lock screw shown in Fig. 1.

### 5.3 Ground Fault Signal Memory

Arcing ground fault currents are, by definition, erratic in nature being caused by the intermittent striking and re-striking of an arcing ground fault. To avoid the instantaneous resetting of the solid state timing circuitry every time the fault current drops to zero, Type GFR ground fault relays are equipped with a memory response, which integrates these intermittent faults with time using a seven second time constant.

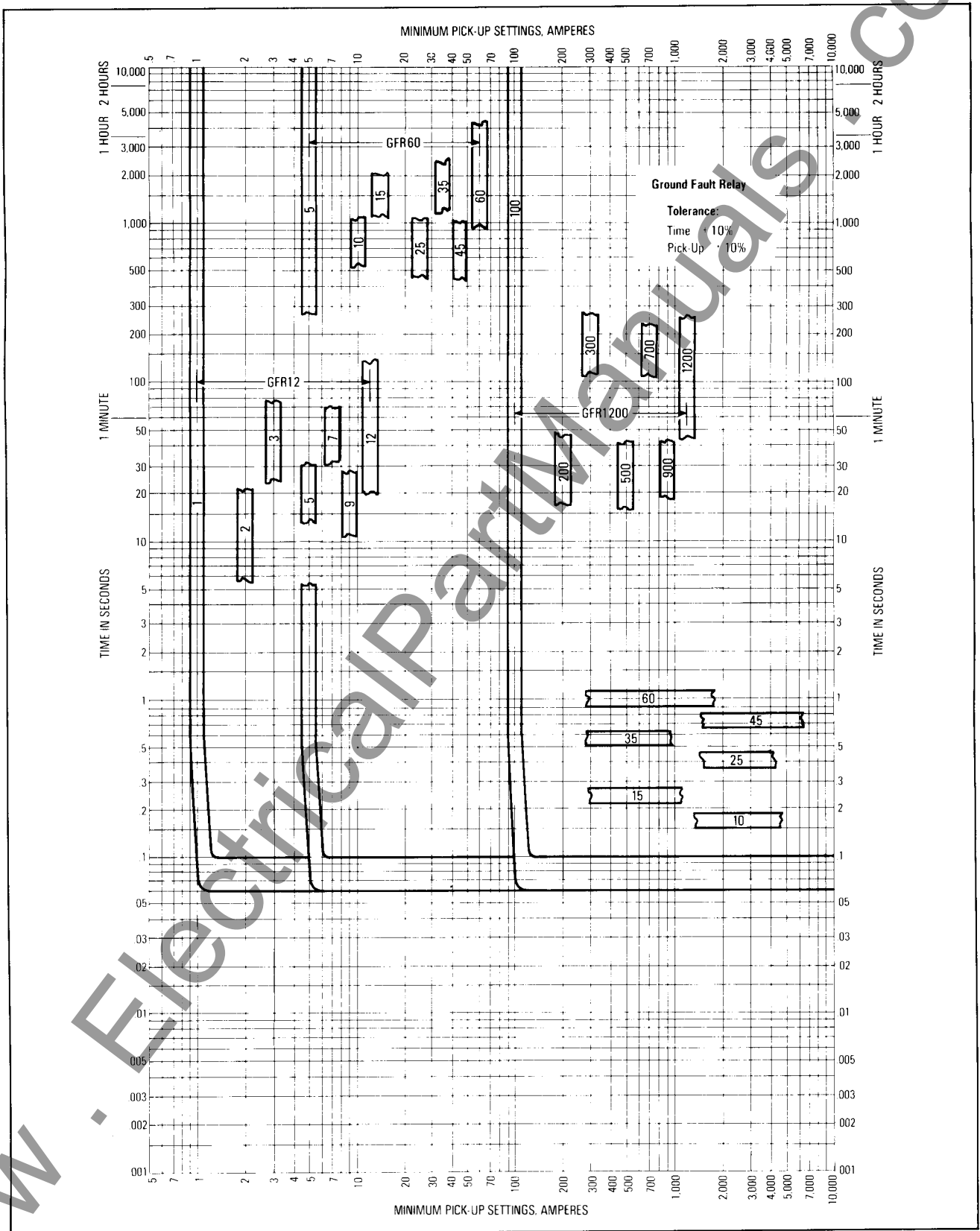


Fig. 8 GFR Relay Time-Current Curve ©

© Changed since previous issue.

Pick-up Amperes	Dial Marking*						
	1	2	3	5	7	9	12
1-12	1	2	3	5	7	9	12
5-60	5	10	15	25	35	45	60
100-1200	100	200	300	500	700	900	1200
Time Delay Cycles	I <sub>⊖</sub>	10	15	25	35	45	60

\*All Adjustments are in discrete steps.

#### 5.4 Time/Current Curves

The time/current performance curve of a Type GFR relay has a flat response, i.e., the operating time of any given fault current above its pick-up setting is essentially constant. There is some small variation in the lower ranges as indicated in Fig. 8, but very little. The pick-up and time delay tolerances, are  $\pm 10\%$ .

#### 5.5 Relay Selection, General

The specific type and pick-up range of relay selected is a factor of its intended application, which the specifying engineer can best determine. In general, the ratings may be selected on the following general basis:

##### 5.5.1 PICK-UP RANGE

1-12 Amp – Specific circuit application where low level sensitivity is required.

5-60 Amp – Individual branch and/or motor circuits where multi-level protection is provided.

100-1200 Amp – General purpose and service applications.

##### 5.5.2 TYPE OF SELECTIVITY

Relays without zone interlocking are best suited for single level applications where it is desired to only satisfy the minimum requirements of the National Electrical Code. Zone selective interlocking type relays should be selected for multi-level system applications where only the minimum amount of system damage can be tolerated following an arcing ground fault.

##### 5.5.3 TYPE OF OPERATION

Electrically held relays will satisfy most applications where reliable control power is available following a fault interruption. Where control power is derived from the load side of the disconnect device and a visual trip indication is desired, the mechanically held relay should be selected. Also, in applications where the control power is less than reliable and where an automatic reset could affect interlocking circuitry, the mechanically held relay should be selected.

#### 5.6 Relay Electrical Ratings

##### 5.6.1 CONTROL POWER REQUIRED

120 Volts, 50/60 Hz., 0.125 Amps, or  
125 Volts dc, 0.125 Amps

##### 5.6.2 TEST WINDING POWER REQUIRED<sup>Ⓢ</sup>

120 Volts, 50/60 Hz., 2.5 Amps

##### 5.6.3 OUTPUT CONTACTS

UL Heavy Duty Pilot Rating

240 Volts, 50/60 Hz., 3.0 Amps Continuous, 30 Amps Inrush

120 Volts, 50/60 Hz., 6.0 Amps Continuous, 60 Amps Inrush

28 Volts, dc, 3.0 Amps, Inductive Load

125 Volts, dc, 0.5 Amps, Inductive Load

##### 5.6.4 ZONE INTERLOCK – CONTACTS 8-9

Output Voltage, 6 Volts dc

Rated Amps, .01 Amps, dc

##### 5.6.5 MAXIMUM DIELECTRIC

Terminals to mounting screw 3000 Volts

#### 5.7 Mounting Arrangements<sup>Ⓢ</sup>

The type GFR Relay is supplied as standard in a surface and semi-flush mounted enclosure with outline dimensions as illustrated in Fig. 9. For installations requiring a semi-flush cover mounting, panel cutout and mounting dimensions are illustrated in Fig. 10.

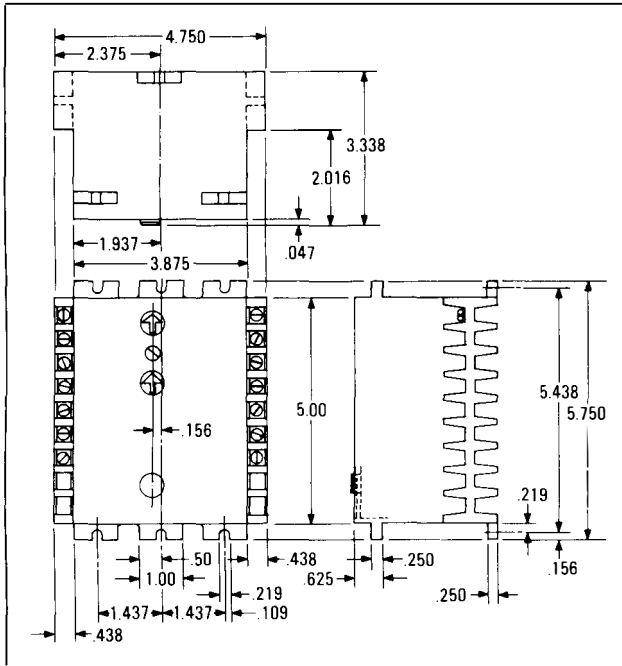


Fig. 9 Outline of Type GFR Ground Fault Relay ©

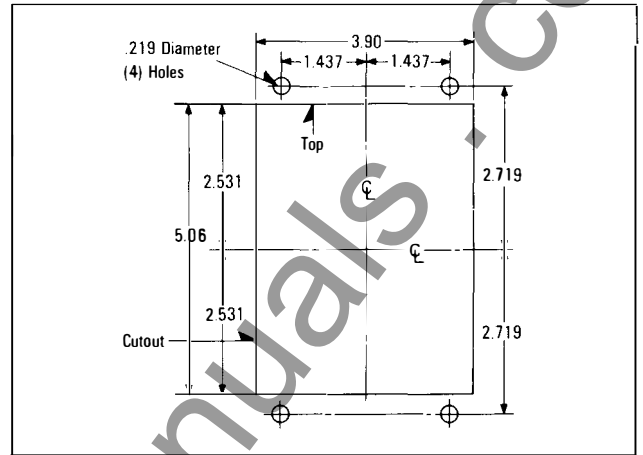


Fig. 10 Semi-Flush Cover Mounting Details for Type GFR Ground Fault Relay ©

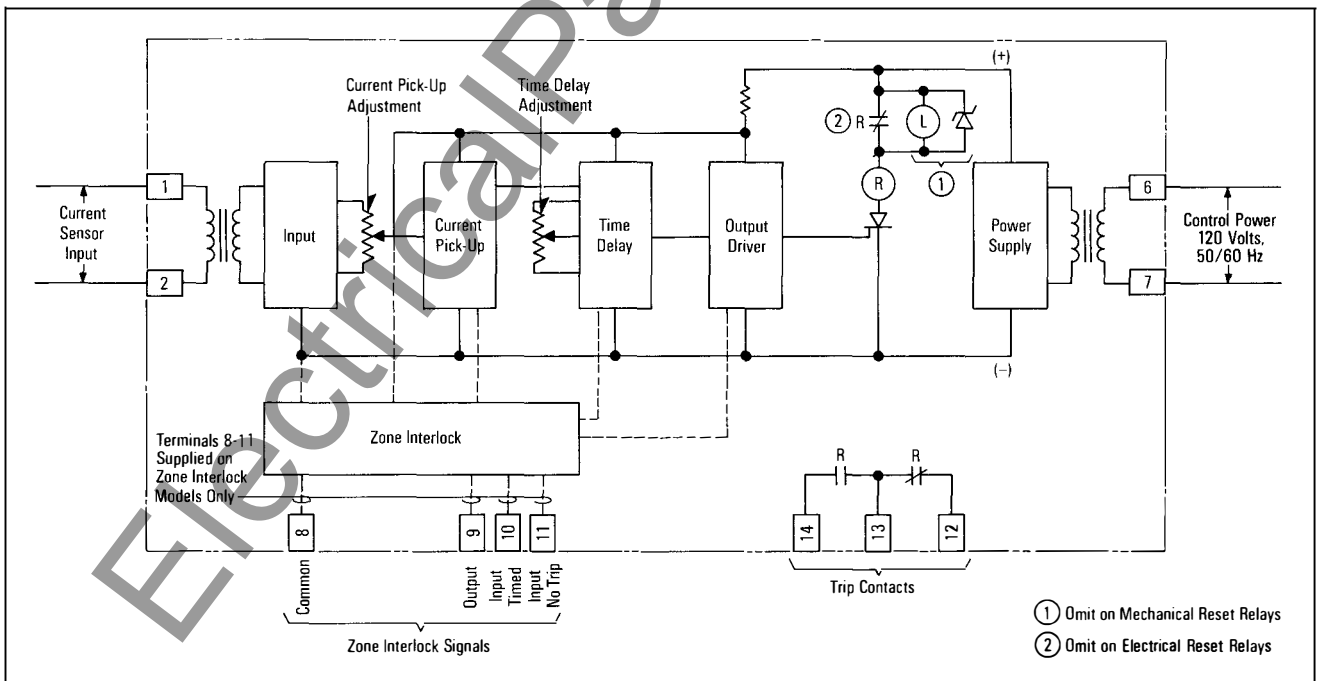


Fig. 11 Block Diagram for Typical GFR Ground Fault Relay ©

## 5.8 Connection Diagrams

### 5.8.1 RELAY CONNECTIONS

A simple block diagram is provided in Fig. 11 to illustrate the internal functional circuits of the type GFR Relay. Complete external connections are a function of the associated devices used with the relay along with the complexity of the system in which the components are applied. The terminals on the GFR relay are suitable for #16 through #14 AWG copper conductors. A maximum of two per terminal are permitted.

### 5.8.2 TYPICAL SYSTEM DIAGRAMS

Basic, typical radial distribution system diagrams are provided in this leaflet for guidance; refer to Figs. 11A, 11B, 11C, 11D and 11E.

Two multiple source distribution systems are illustrated in Figs. 11F and 11H. Fig. 11F illustrates a dual source distribution system with center point grounding as allowed in the National Electrical Code under Article 250-23a, Exception No. 4 Fig. 11H illustrates a multiple source, multiple ground distribution system with zone differential ground fault sensing methods employed.

### 5.8.3 ZONE DIFFERENTIAL GFR OPERATION PRINCIPLES – SEE FIG. 11H

5.8.3.1 In general,  $\frac{GFR}{M1}$  will operate only for ground faults within Zone 1 and  $\frac{GFR}{M2}$  for Zone 2. This includes ground faults for feeders located in these respective zones.

5.8.3.2 With “M1” and “T” closed and “M2” open and with a ground fault in Zone 2,  $\frac{GFR}{M1}$  will not operate to trip “M1” but,  $\frac{GFR}{M2}$  will to trip “T”.

5.8.3.3 Conversely, with “M2” and “T” closed and “M1” open and with a ground fault in Zone 1,  $\frac{GFR}{M1}$  will not operate to trip “M2” but  $\frac{GFR}{M2}$  will to trip “T”.

5.8.3.4 For properly co-ordinated main, tie and feeder interrupting devices, the feeder relays will always react to clear a downstream ground fault prior to operation of either the main or tie devices.

5.8.3.5 Zone interlock wiring between upstream and downstream devices can be included as shown. For this

scheme, no cross interlocking with “T” auxiliary contacts is required.

5.8.3.6 This scheme may be expanded to additional alternate sources as long as interrupting devices are available to isolate any potential ground fault on each side of the fault.

## 6.0 GROUND FAULT CURRENT SENSORS (See Table 5, Page 21)

### 6.1 General Description

As indicated in Table 5 (Page 21), Ground Fault Current Sensors (GFS) are available in a variety of physical sizes and current ratings to match the application requirements of the distribution system. Sensors should be selected to match the ampere rating of the specified GFR Relay. The physical size should be selected to properly encompass the required conductor configuration with space allowed for minimum clearances as shown in the applicable outline mounting figure. Outline references are given in Table 5.

Sensors are available with solid cores having round conductor openings and in split core designs with various size rectangular openings. On the split core designs, one core leg is removable to permit ease of installation around existing conductor assemblies.

Ground Fault Current Sensors are special rated current transformers and must be applied only with type GFR Relays shown in Table 1. *Sensors cannot be used with any other equipment.*

Sensors are insulated with cast epoxy and can be mounted directly to enclosure surfaces. Ideally, they should be installed so that all conductors passing through the sensor opening are physically centered in the window opening. Minimum clearances are specified in the applicable outline, but greater clearances will help reduce any possible error signals. Rectangular configurations are provided with compensating windings to reduce potential error signals.

All sensors are provided with integral test winding for use under simulated ground fault test conditions. With an input of 1.2 Amps into terminals 2-3, a rated output of 240·M.A. should be produced in terminals 1-3 with a tolerance of ±15%. For information purposes, the turns ratio and saturation levels of all sensors is provided in Table 5.

**6.2 Electrical Ratings**

**6.2.1 Maximum System Voltage**

600 V. @ 50/60 Hz.

**6.2.2 WITHSTAND**

Primary Amps	Time Seconds
200 KA	0.05
50 KA	0.3
⊕ 4 KA	Continuous

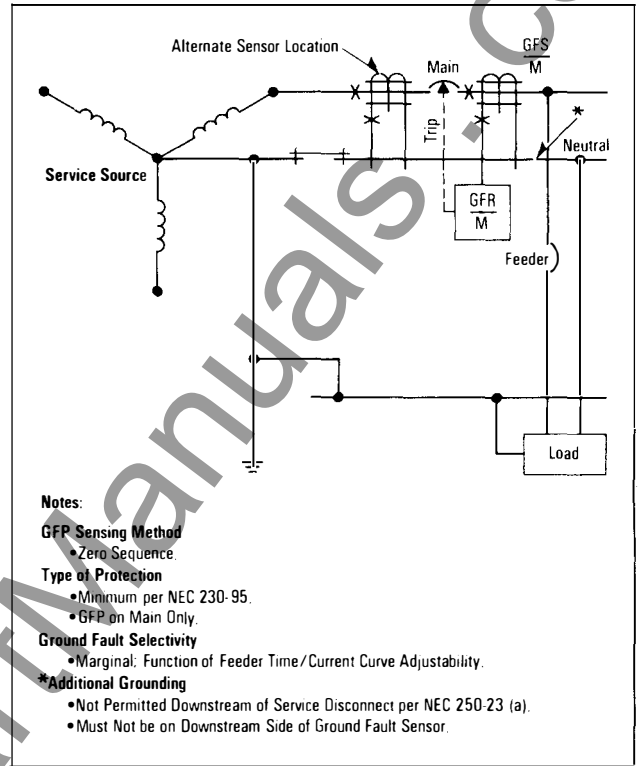
⊕ Except 1 KA on 12A. Solid

**6.2.3 DIELECTRIC WITHSTAND**

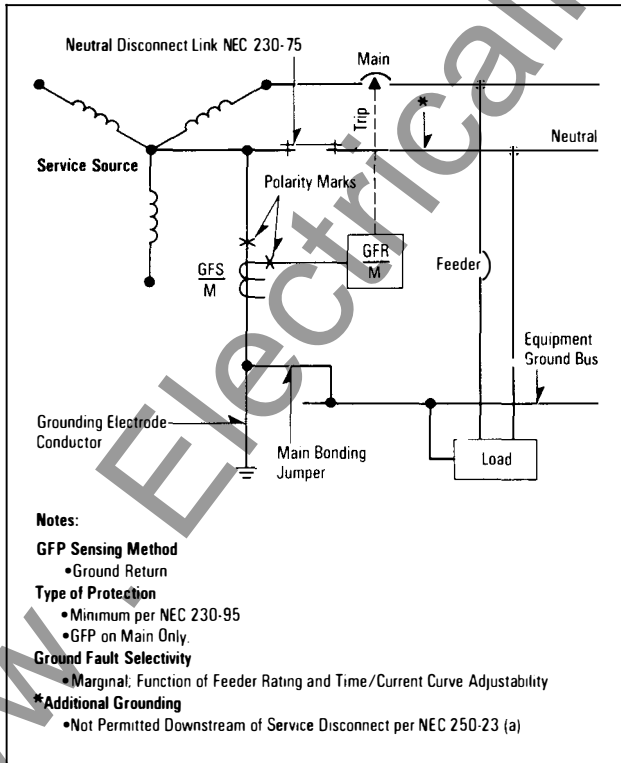
Windings to Mounting Holes – 3 KV  
 Windings to Inner Core Surface – 3KV  
 Mounting Surface to Inner Core Surface – 3KV

**6.2.4 MAXIMUM ERROR SIGNAL – WITH BOLTED PHASE THROUGH FAULT**

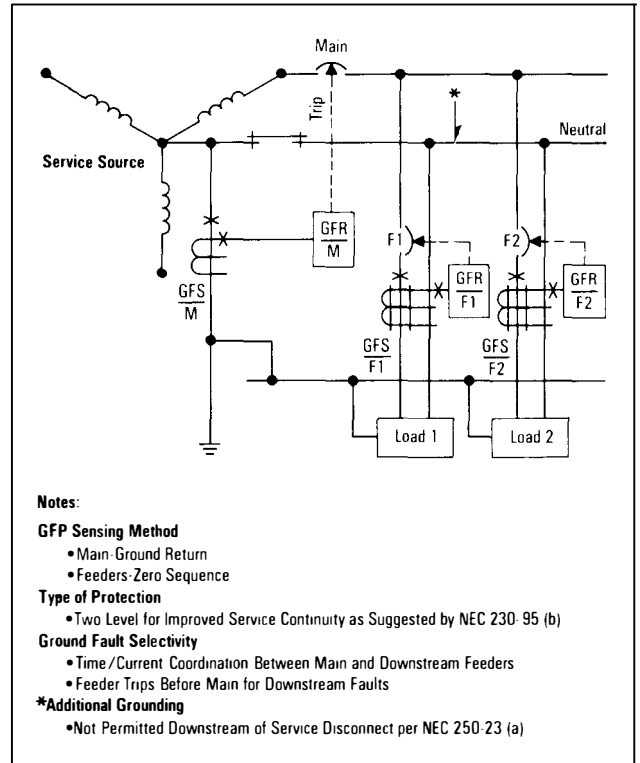
12 A Solid	1.0 A @ 144A
60A Solid	5.0 A @ 720A
1200A Solid	100 A @ 14.4 KA
60/1200 A R/L	100 A @ 15 KA



**Fig. 11B Simple Radial System With GFR on Main Only-Zero Sequence Sensing**



**Fig. 11A Simple Radial System With GFR on Main Only-Ground Return Sensing**



**Fig. 11C Simple Radial System With GFR on Main and Feeders-Ground Return Sensing on Main**

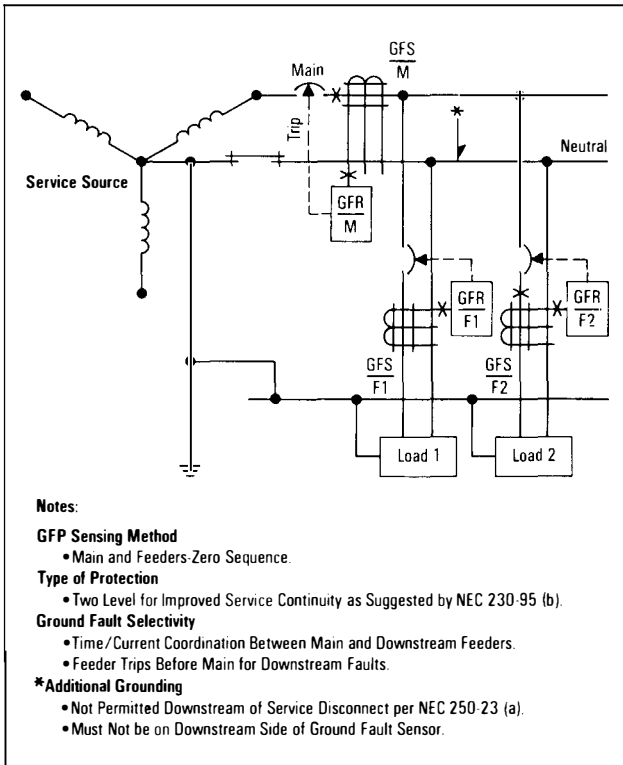


Fig. 11D Simple Radial System With GFR on Main and Feeders-Zero Sequence Sensing on Main

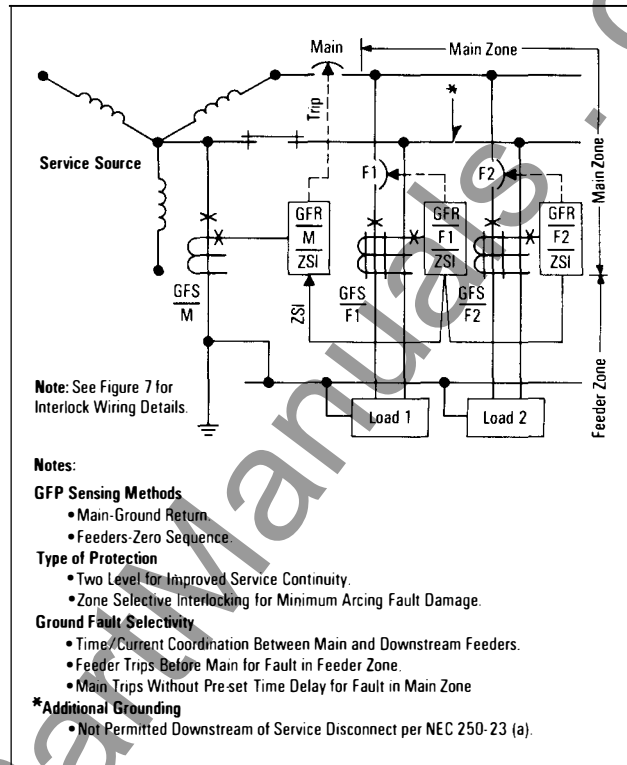


Fig. 11E Simple Radial System With GFR on Main and Feeders With Zone Selective Interlocking

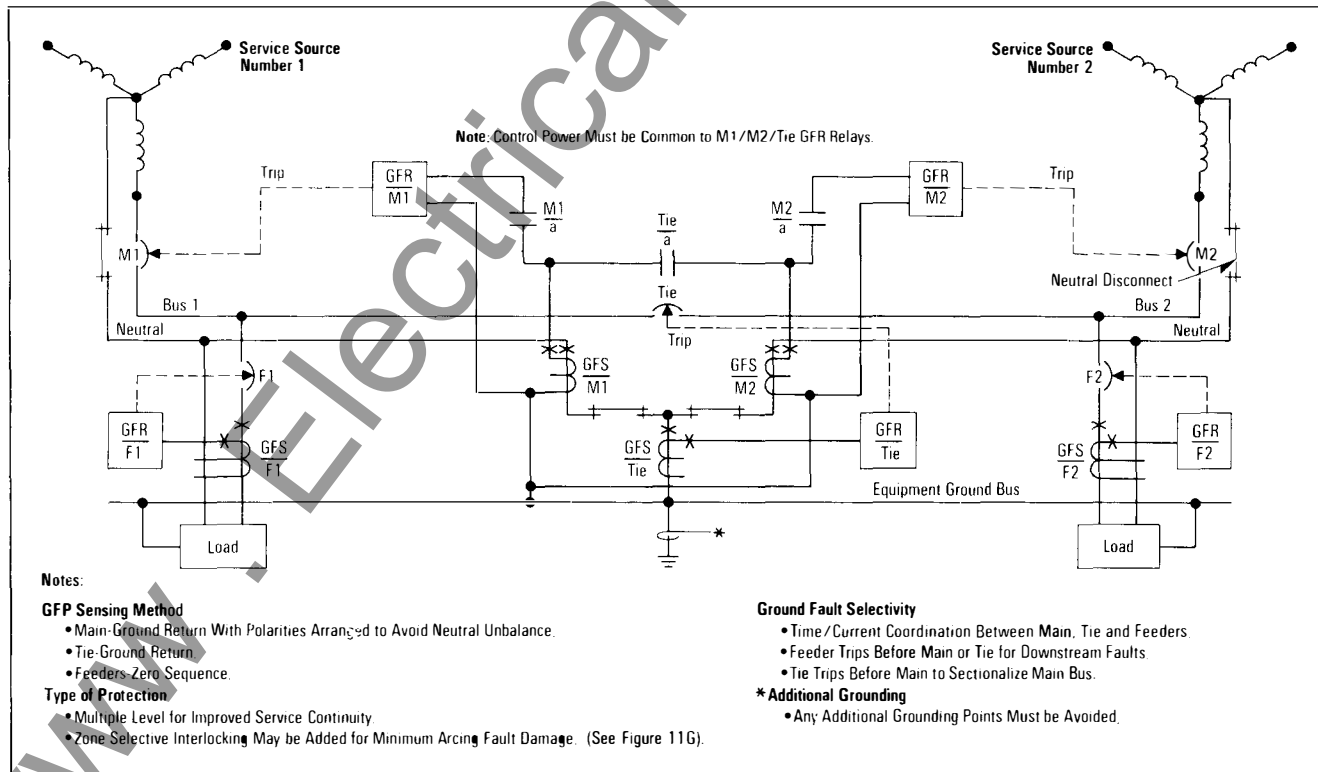


Fig. 11F Dual Source System Using Center Point Grounding (NEC 250-23a-Exception No. 4)

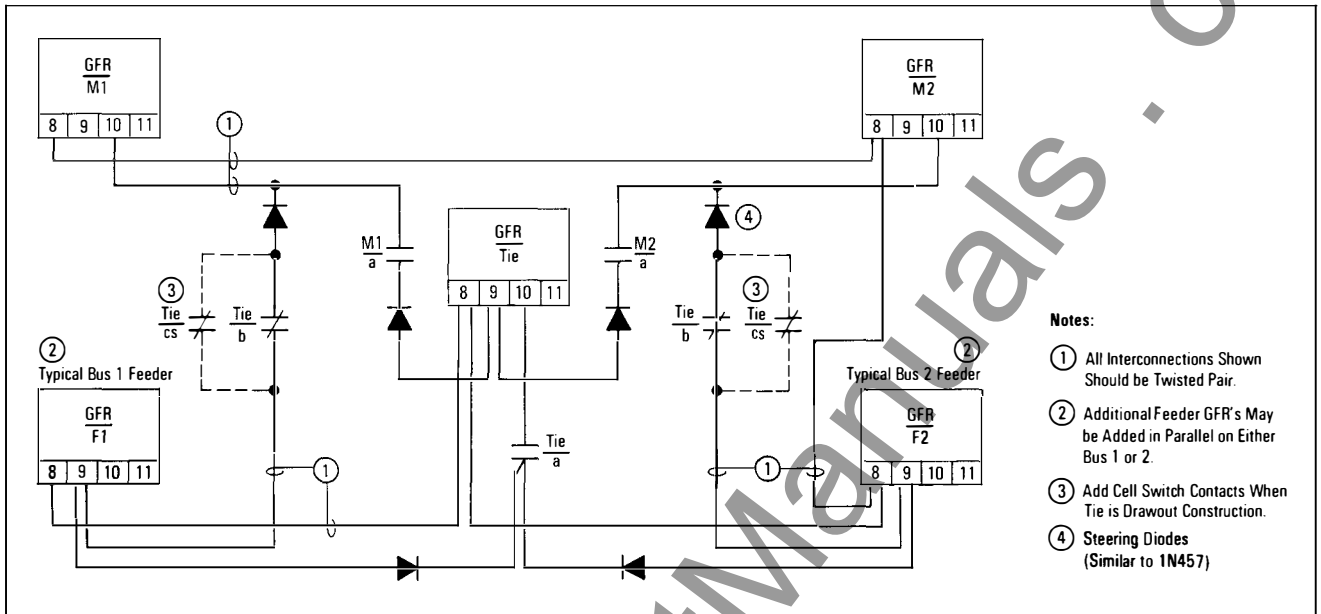


Fig. 11G Special Zone Interlocking Wiring that may be used with Dual Source System using Center Point Grounding (See Figure 11F)©

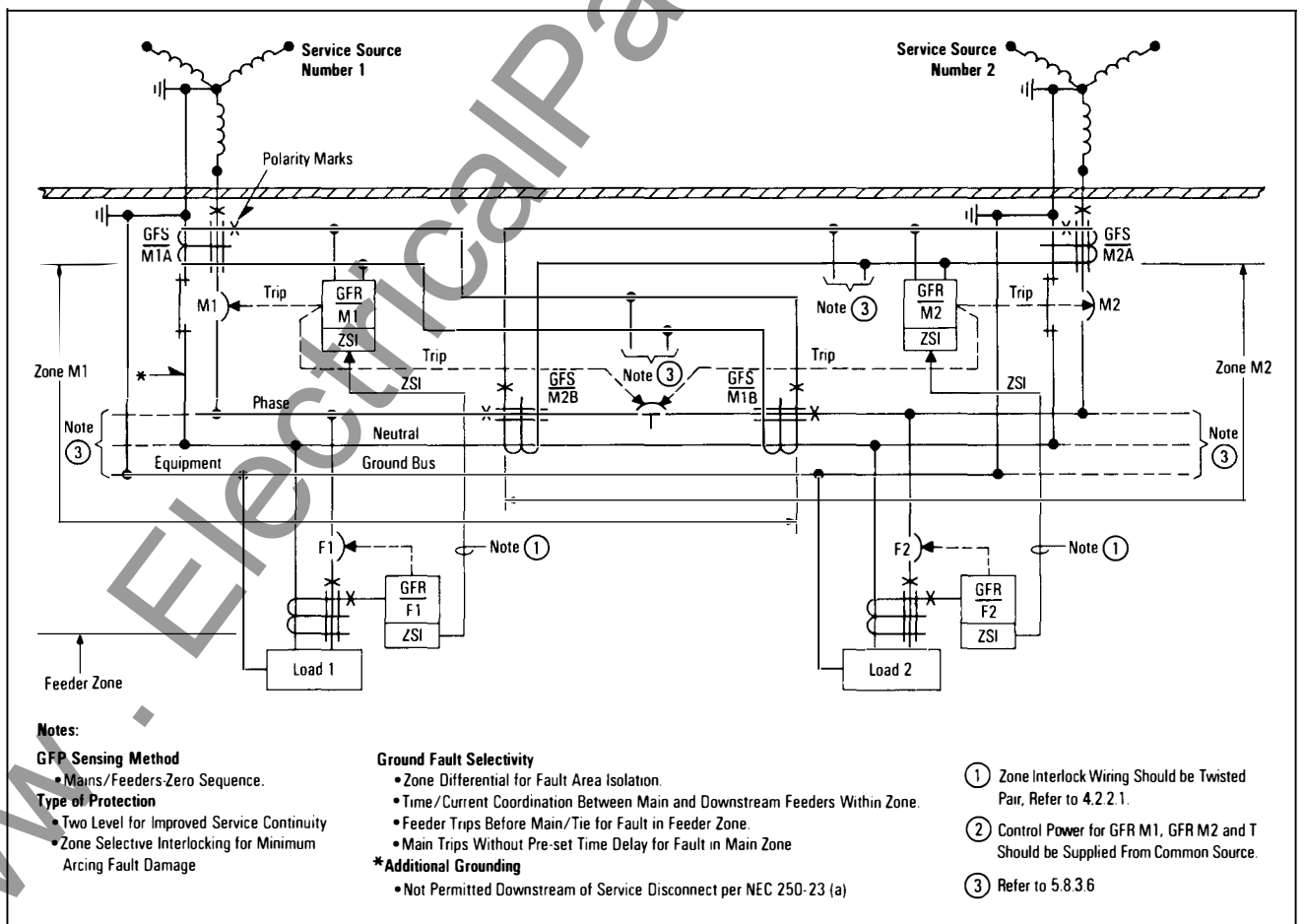


Fig. 11H Multiple Source, Multiple Grounded System Using Zone Differential Sensing

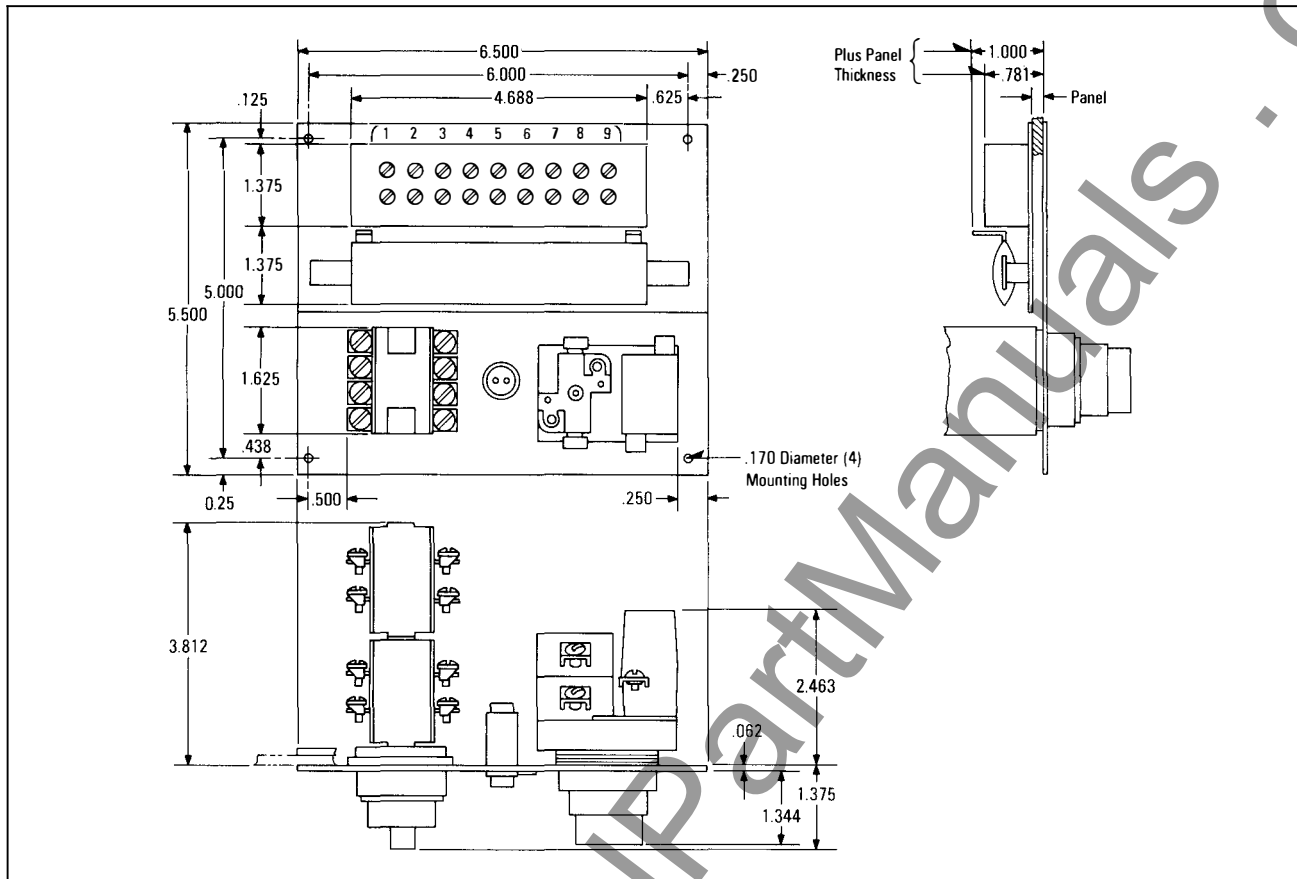


Fig. 12 Outline of Catalog No. GFRTPD and GFRTTP Ground Fault Test Panels ©

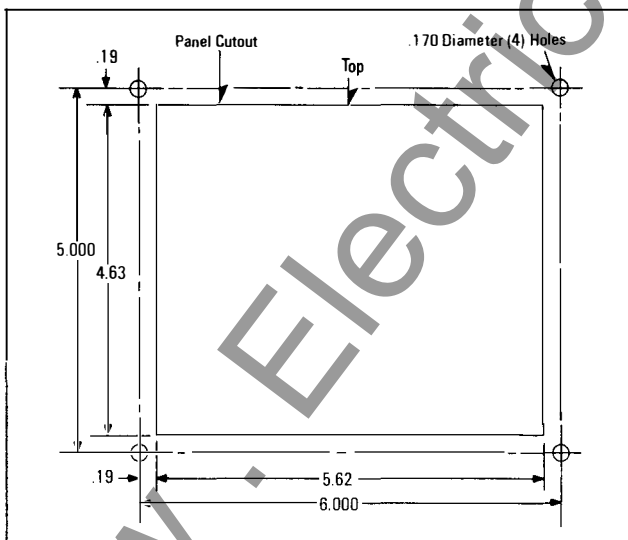


Fig. 13 Panel Cutout and Drilling Plan for Catalog No. GFRTPD and GFRTTP Ground Fault Test Panels ©

## 7.0 GROUND FAULT TEST PANEL (See Fig. 4)

### 7.1 General Description/Purpose

The test panel is designed to test the ground fault circuitry in the type GFR Ground Fault Relay along with its associated disconnect with a simulated, low-level test current from a location remote from the disconnect using a separate power source. Provisions are available to conduct a test in either of two operational modes: By opening the disconnect or by not opening the disconnect.

The test panel provides the easiest and most inexpensive method to conduct ground fault tests on a repeat basis. Tests can be conducted by qualified maintenance personnel during routine maintenance schedules.

**WARNING: THERE IS A HAZARD OF ELECTRICAL SHOCK OR BURN WHENEVER WORKING IN OR AROUND ELECTRICAL EQUIPMENT. ALWAYS TURN OFF POWER SUPPLYING THIS EQUIPMENT BEFORE WORKING INSIDE SWITCHBOARDS.**

## 7.2 Available Types

The test panel is available only as a semi-flush, cover mounted assembly under Cat. No. GFRTTP or GFRTPD (for dc control) as illustrated in Fig. 4. It is provided with a selector switch for initiating the desired test sequence, a red lamp to signify a ground fault trip operation, an amber light<sup>Ⓞ</sup> to indicate the availability of test power to the test panel, and an instruction nameplate. Outline dimensions are shown in Fig. 12 with panel cut-out and drilling plan details in Fig. 13.

## 7.3 Electrical Data<sup>Ⓞ</sup>

### Test Winding

Requires a 120 Volt, 50/60 Hz. control power source (300 VA) for operation.

### Ac Control Circuit

Requires a 120 Volt, 50/60 Hz., 0.125 Amp source; use same source as Test Winding, above.

### Dc Control Circuit

Requires a 125 Volt dc, 0.125 Amp source.

## 7.4 Operation Sequence

### 7.4.1 NORMAL OPERATING CONDITION<sup>Ⓞ</sup>

Test Power Lamp "OFF"

Ground Fault Lamp "OFF"

Selector Switch in "NORMAL" position

### 7.4.2 IF GROUND FAULT OCCURS<sup>Ⓞ</sup>

1. Breaker/Interrupter "OPENS"
2. Ground Fault lamp turns "ON"

### 7.4.3 ACTION REQUIRED

1. Locate and clear ground fault condition
2. Turn selector to "RESET" – hold six seconds
3. Release selector switch – spring return to "Normal"
4. Reset and close breaker/interrupter

### 7.4.4 TEST WITHOUT SERVICE INTERRUPTION<sup>Ⓞ</sup>

1. Turn selector switch to "TEST" – Hold one second  
Red and Amber lamps turn "ON"
2. Turn selector switch to "RESET" – Hold six seconds  
Red and Amber lamps turn "OFF"
3. Release selector switch – spring return to "Normal"

### 7.4.5 TEST WITH SERVICE INTERRUPTION<sup>Ⓞ</sup>

1. Depress and hold ground fault lamp
2. Turn selector switch to "TEST" – Hold one second  
Breaker/Interrupter "OPENS"  
Red and Amber lamps turn "ON"
3. Turn selector switch to "RESET" – Hold six seconds  
Red and Amber lamps turn "OFF"
4. Release selector switch – spring return to "Normal"
5. Release ground fault lamp
6. Reset and close breaker/interrupter

## 7.5 Connection Diagrams

Fig. 14A illustrates the external connections required for a complete GFP system using 120 volt a-c, 50/60 Hz. control power, including: Type GFR Relay, a ground fault sensor (GFS) and a test panel. A tabulation is also shown to illustrate the various contact positions of the selector switch and red lamp (switch). Fig. 14B illustrates the external connections required for 125 volt d-c control power.

Proper operation of the GFP system requires the use of twisted wire connections on certain terminations. Details are provided on the various connection diagrams including Fig. 7. Refer also to 4.2.2.1.

The terminals on the test panel are suitable for #18 through #14 AWG copper conductors. A maximum of two per terminal of the same size and type are permitted.

<sup>Ⓞ</sup> Note: The amber light turns "on" *only* during a test sequence.

darstellung Frank Schwaab

DB-50

m.o. D.O.

2+I

3 pos.

200 A.

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