

# AC Service Grounding Engineering Applications

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# 1 .General

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## 1.1

### **Purpose**

This practice:

- Describes alternating current (AC) power distribution ground systems required in buildings that house communication installations.
- Provides engineering requirements and general information pertaining to the design and installation of an effective and safe AC wiring and grounding system.

## 1.2

### **Filing**

### **Instructions**

### **and**

### **Supersedures**

Discard all previous issues and associated addenda of this practice and file this issue numerically in your GTE Telephone Operations practices set.

This practice supersedes and cancels:

- All policies, procedures, general instructions, letters, and memoranda which address this subject.
- Any document which provides information contrary to the information contained in this practice.
- 795-805-072MT, AC Service Grounding – Engineering Application.

## 1.3

### **Reason for Reissuing**

This practice has been reissued to incorporate multiple changes in the content. Read this entire practice to ensure your familiarity with the new information.

## 1.4

### **Responsibility**

This practice was published by the GTE Telephone Operations Administrative Services Department. For more information about this practice, contact the GTE Telephone Operations Headquarters Protection Engineering Support Department.

## 1.5

### **Disclaimer**

This practice was prepared solely for the use of GTE Telephone Operations. It must be used only by its employees, customers, and end users when installing, operating, maintaining, and repairing GTE Telephone Operations' equipment, facilities, and services. Any other use of this practice is forbidden. The information contained in this practice may not be applicable in all circumstances and is subject to change without notice. By using this practice the user agrees that GTE Telephone Operations will have no liability (to the extent permitted by applicable law) for any consequential, incidental, special, or punitive damages that may result.

## 2. Overview

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### 2.1 Introduction

This practice describes the design and application of AC wiring techniques that allow proper performance of electronic equipment (telecommunications) that is typically housed in a Central Office (CO) or a similar location.

Electronic equipment should perform satisfactorily without violating codes. Only listed material and/or equipment should be used and then only for the application for which they are listed.

The following chart shows that engineering applications in this document describe two separate AC grounding systems.

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System	Function
Service grounding	This function: <ul style="list-style-type: none"><li>• Supplies ground reference to the AC system.</li><li>• Consists of the Grounding Electrode Conductor (GEC) system,</li></ul>
AC equipment grounding	This function ensures that a ground path of dependable, low impedance exists throughout the AC power distribution system formed by: <ul style="list-style-type: none"><li>• Equipment Grounding Conductors (EGCs).</li><li>• Conduits.</li><li>• Raceways.</li><li>• Enclosures of AC-operated equipment.</li></ul>

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**NOTE:** Required specific grounding conductor leads and their gauges are listed in the GTE Telephone Operations Practice 795-805-071.

### 2.2 Scope

This practice applies to all:

- Electromechanical COs.
- Electronic COs.
- Digital COs (e.g., GTD-5, DCO, 5ESS, etc.).
- Remote ESA locations.
- Transmission sites.

### 2.3 Objective

The objective of this practice is to ensure that GTE Telephone Operations installations housing telecommunications equipment meet the requirements of the National Electrical Code (NEC) related to AC wiring.

The application of these techniques will ensure that all applicable code requirements, such as the NEC, are either met or exceeded.

Use the strictest set of requirements from among those of:

- Local codes.
- State codes.
- National codes.
- GTE Telephone Operations Practices.

## 2. Overview, continued

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### 2.4 Definitions

The following chart defines the acronyms and terms used in this practice.

Acronym or Term	Definition
AC	Alternating Current
AHJ	Authority Having Jurisdiction; the organization, office, or individual that is responsible for approving a piece of equipment, an installation, or a procedure such as: <ul style="list-style-type: none"><li>• A federal, state, regional, or local official.</li><li>• An OSHA, electrical, building, fire, labor, or health inspector with statutory jurisdiction.</li><li>• An insurance inspector.</li><li>• A building engineer or owner.</li><li>• A commanding officer.</li></ul>
Ampacity	The current (in amperes) that the conductor can continuously carry under the conditions of use without exceeding its temperature rating.
Approved	Acceptable to the Authority Having Jurisdiction.
AWG	American Wire Gauge
Bonding	the permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.
Bonding Jumper	A reliable conductor that ensures the required electrical conductivity between metal parts required to be electrically connected.
Branch Circuit	The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).
Building	A structure that stands alone or that is cut off from adjoining structures by fire walls with all openings in the walls protected by approved fire doors.

(continued)

## 2. Overview, continued

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### 2.4

#### Definitions

Acronym or Term	Definition
Cabinet	An enclosure that is: <ul style="list-style-type: none"><li>• Designed either for:<ul style="list-style-type: none"><li>- Surface mounting.</li></ul></li><li>OR</li><li>- Flush mounting.</li></ul> <ul style="list-style-type: none"><li>• Provided with a frame, mat, or trim in which a swinging door(s) is, or might be, hung.</li></ul>
CATV	Community Antenna Television
Circuit Breaker	A device designed to open: <ul style="list-style-type: none"><li>• And close a circuit manually.</li><li>• The circuit automatically on a predetermined overcurrent without damage to the circuit breaker when properly applied within the circuit breaker's rating.</li></ul>
CO	Central Office
Common Bonding	The interconnecting of separate ground electrodes necessary at locations where common grounding cannot or has not been used.
Common Grounding	The use of the same ground electrode by all services (e.g., telephone, power, CATV, etc.).
Conductor	A material usually in the form of wire, cable, or bar, suitable for carrying an electric current. The three types of conductors are: <ul style="list-style-type: none"><li>• Bare - Having no covering or electrical insulation.</li><li>• Covered - Encased within material of a composition or thickness that is not recognized by the NEC as electrical insulation.</li><li>• Insulated - Encased within material of a composition and thickness that is recognized by the NEC as electrical insulation.</li></ul>

(continued)

## 2. Overview, continued

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### 2.4 Definitions, continued

Acronym or Term	Definition
Connector, Pressure (Solderless)	A device that establishes a connection by mechanical force without using solder between either: <ul style="list-style-type: none"><li>• Two or more conductors.</li></ul> OR <ul style="list-style-type: none"><li>• One or more conductors and a terminal.</li></ul>
CRT	Cathode Ray Tube
Current Limiting Overcurrent Protective Device	A device that, when interrupting currents in its current limiting range, will reduce the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device was replaced with a solid conductor having comparable impedance.
DC	Direct Current
Delta System	A system or circuit without an intentional connection to ground, except through high impedance devices such as potential measuring devices or the service transformer.
Device	The unit of an electrical system that is intended to carry, but not use, electrical energy.
Discharge Current	The surge current that flows through the arrester after sparkover occurs.
Discharge Voltage	The voltage that appears across the terminals of an arrester during the passage of the discharge current.
Disconnecting Means	A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.
Effectively Grounded	Intentionally connected to earth through a ground connection or connections of sufficiently low impedance and having sufficient current carrying capacity to prevent hazardous voltages from building up.

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## 2. Overview, continued

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### 2.4

#### Definitions, continued

Acronym or Term	Definition
EGC	Equipment Grounding Conductor; the conductor used to connect the noncurrent-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor and/or GEC at either the: <ul style="list-style-type: none"><li>• Service equipment,</li></ul> OR <ul style="list-style-type: none"><li>• Source of a separately derived system.</li></ul> <p><b>NOTE: The Equipment Grounding Conductor is commonly called the green wire.</b></p> <p><b>The Equipment Grounding Conductor, under normal conditions, should not have current flowing.</b></p>
EMI	Electromagnetic Induction; the resultant electromotive force in a circuit or component caused by changes in the magnetic flux linking with that circuit or component.
EMT	Electrical Metallic Tubing
ENMT	Electrical Nonmetallic Tubing
Enclosure	A housing or cabinet for equipment or components.
Equipment	A general term for items used as part of, or in connection with, an electrical insulation, such as: <ul style="list-style-type: none"><li>• Apparatus.</li><li>• Appliances.</li><li>• Devices.</li><li>• Fittings.</li><li>• Fixtures.</li><li>• Material.</li></ul>
ESA	Electronic Serving Area
Feeder	All circuit conductors between service equipment and the final branch circuit overcurrent device.

(continued)

## 2. Overview, continued

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### 2.4 Definitions, continued

Acronym or Term	Definition
Fitting	An accessory (such as a locknut, bushing, or other part of a wiring system) that is intended primarily to perform a mechanical rather than an electrical function.
Follow (Power) Current	The current from the connected power source that flows through the surge arrester during and following the passage of the surge current.
GEC	Grounding Electrode Conductor; the conductor used to connect the grounding electrode to the equipment grounding conductor and/or the grounded conductor of a circuit at either the: <ul style="list-style-type: none"><li>• Service equipment.</li></ul> OR <ul style="list-style-type: none"><li>• Source of a separately derived system.</li></ul>
GFCI	Ground Fault Circuit Interrupter; the device that protects personnel by de-energizing a circuit within a set time when the current-to-ground exceeds a predetermined value that is less than that required to operate the overcurrent protective device.
GFP	Ground Fault Protector
Ground	A conducting connection whether intentional or accidental between any electrical circuit or equipment and the earth, or to some body that serves in place of the earth.
Grounded	Connected directly to earth or to some conducting body that serves in place of the earth.
Ground Electrode	One or more conductors in direct contact with the earth for the purpose of providing a connection with the earth.
Ground Fault Protection of Equipment	<p>A system intended to provide protection to equipment from damaging line-to-ground fault currents by disconnecting and opening all ungrounded conductors of the faulted circuit.</p> <p>This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device.</p>

(continued)

## 2. Overview, continued

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### 2.4

#### Definitions, continued

Acronym or Term	Definition
Ground Grid	A mesh of horizontal bare conductors and grounding electrodes that provides a common grounding system and voltage equalization for: <ul style="list-style-type: none"><li>• Electric devices.</li><li>• Metallic structures.</li></ul>
Ground Mat	A solid plate directly above the soil surface or a wire mesh below the surface, Used typically at power substations.
Ground Resistance	The ohmic resistance between the grounding electrode and a remote grounding electrode of zero resistance.
Grounded Conductor	An intentionally grounded system or circuit conductor.
Grounding Conductor	A conductor that is used to establish a ground and that connects a device, equipment, wiring system, or another conductor with the grounding electrode or electrodes.
Grounding System	The combination of conducting elements by which all equipment is connected to the earth.
IGZ	Isolated Ground Zone
Impulse Sparkover Voltage	The highest (peak) value of voltage reached by the impulse of a designated waveshape applied across the terminals of an arrester before the flow of the discharge current.
Incidental Ground	An unplanned or accidental connection to ground.
Integrated Zone	The area in a central office where all the equipment is intentionally or incidentally connected to ground through more than one point.
Isokeraunic Map	Shows the amount of lightning activity for an area indicating the average number of days per year on which thunder is heard.
Isolated Zone	The area in a central office where all the equipment is insulated from the building and is grounded by a single connection through the main ground busbar.

(continued)

## 2. Overview, continued

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### 2.4 Definitions, continued

Acronym or Term	Definition
kcmil	One thousand circular mils (replaces MCM)
kV	Kilovolt (one thousand volts)
Lead Numbers	The numbers assigned to grounding leads for identification purposes. Those referred to in this document are identified in GTE Telephone Operations Practice 795-805-071.
Listed	<p>A list of equipment or material, published by the authority having jurisdiction, which:</p> <ul style="list-style-type: none"><li>● Is acceptable to the authority having jurisdiction.</li><li>● Meets standards.</li><li>● Has been tested by an NRTL and is suitable for a specific purpose.</li></ul> <p><b>NOTE: The organization publishing the list:</b></p> <ul style="list-style-type: none"><li>● <b>Is concerned with the product evaluation.</b></li><li>● <b>Maintains periodic inspection of the production of listed equipment or materials.</b></li></ul>
LPG	Lightning Protection Ground
LPS	Lightning Protection System
Made Electrode	A ground electrode designed and installed for a specific site.
Main Bonding Jumper	The connection between the grounded circuit conductor (neutral) and the Equipment Grounding Conductor (EGC) at the main service panel. It can consist of a wire, busbar, or screw.
MC	Material Code or Item ID
Metallic Member	A noncommunications metallic cable component such as a shield or strength member.
MGB	Master Ground Bar
MGN	Multi-Grounded Neutral

(continued)

## 2. Overview, continued

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### 2.4 Definitions, continued

Acronym or Term	Definition
Multi-Grounded Neutral	<p>A neutral conductor of a wye-connected electric supply system that includes:</p> <ul style="list-style-type: none"><li>• At least four grounds per mile.</li><li>• Power ground connections at individual services.</li><li>• Solidly interconnected primary and secondary neutrals.</li></ul> <p><b>NOTE:</b> If it is not definitely known if the power system is of the MGN type, obtain the information from the power company.</p>
Mutual Resistance	The voltage change in one electrode produced by a unit of DC current in a second electrode.
NEC	National Electrical Code
NESC	National Electrical Safety Code
NRTL	Nationally Recognized Testing Laboratory
OSHA	Occupational Safety and Health Administration
OSP	Outside Plant
Outlet	The point on the wiring system at which current is accessed by equipment.
Overcurrent	<p>Any current in excess of the rated current of equipment or the ampacity of a conductor.</p> <p>It might result from:</p> <ul style="list-style-type: none"><li>• Overload.</li><li>• Short circuit.</li><li>• Ground fault.</li></ul>
Overvoltage	Abnormal voltage between two points of a system that is greater than the highest value appearing between the same two points under normal service conditions.
PDU	Power Distribution Unit
Power Frequency Sparkover Voltage	The root mean square (rms) value of the lowest power frequency sine wave voltage that causes sparkover when applied across an arrester's terminals.

(continued)

## 2. Overview, continued

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### 2.4 Definitions, continued

Acronym or Term	Definition
Protector	A device used on each circuit to limit voltage between telecommunication conductors and ground (earth). The protector must be electrically connected to a ground electrode to effectively operate and reduce the possibility of injury and damage to personal property.
PSB	Product Standardization Bulletin
PVC	Polyvinyl Chloride (nonmetallic)
Raceway	An enclosed channel that: <ul style="list-style-type: none"><li>• Holds wires, cables, or busbars.</li><li>• Functions in additional ways as allowed in the NEC.</li><li>• Is made of metal or insulating material.</li><li>• Can include:<ul style="list-style-type: none"><li>- Rigid metallic and nonmetallic conduits.</li><li>- Intermediate metallic conduit (thin wall).</li><li>- Liquid-tight flexible metal conduit.</li><li>- Flexible metal conduit and flexible metal tubing.</li><li>- Electrical metallic and nonmetallic tubing.</li><li>- Underfloor and surface locations.</li><li>- Cellular concrete and metal flooring.</li><li>- Wireways.</li><li>- Busways.</li></ul></li></ul>

(continued)

## 2. Overview, continued

### 2.4 Definitions, continued

Acronym or Term	Definition														
Receptacle	A contact device installed at the outlet for the connection of a single attachment plug.														
	<table border="1"> <thead> <tr> <th>Receptacle Type</th> <th>Definition</th> </tr> </thead> <tbody> <tr> <td>Single</td> <td>One contact device per yoke.</td> </tr> <tr> <td>Duplex or Multiple</td> <td>Single device containing two or more contacts on the same yoke.</td> </tr> <tr> <td>Nonisolated</td> <td>Single or double contact devices where the grounding conductor (green wire) terminal bonds to the yoke. These receptacles are frequently referred to as brown (see Exhibit 1).</td> </tr> <tr> <td colspan="2"><b>NOTE: The receptacles might be ivory, white, gray, or red but <u>not</u> orange.</b></td> </tr> <tr> <td>Isolated</td> <td>Single or double contact devices where the grounding conductor (green wire) terminal does not bond to the yoke. The receptacle has a distinctive orange color (see Exhibit 2).</td> </tr> <tr> <td colspan="2"><b>NOTE: Orange receptacles in COs are restricted to isolated equipment zone frames that serve only test equipment (not CRTs, printers, power supplies, modems, etc.)</b></td> </tr> </tbody> </table>	Receptacle Type	Definition	Single	One contact device per yoke.	Duplex or Multiple	Single device containing two or more contacts on the same yoke.	Nonisolated	Single or double contact devices where the grounding conductor (green wire) terminal bonds to the yoke. These receptacles are frequently referred to as brown (see Exhibit 1).	<b>NOTE: The receptacles might be ivory, white, gray, or red but <u>not</u> orange.</b>		Isolated	Single or double contact devices where the grounding conductor (green wire) terminal does not bond to the yoke. The receptacle has a distinctive orange color (see Exhibit 2).	<b>NOTE: Orange receptacles in COs are restricted to isolated equipment zone frames that serve only test equipment (not CRTs, printers, power supplies, modems, etc.)</b>	
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rms	root mean square														
Separately Derived System	A wiring system whose power is derived from generator, transformer, or converter windings and that has no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system.														

(continued)

## 2. Overview, continued

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### 2.4 Definitions, continued

Acronym or Term	Definition
Service	The conductors and equipment that deliver energy from the electrical supply system to the wiring system of the premises served.
Service Conductors	The supply conductors that extend from the street main or from transformers to the service equipment of the premises supplied.
Service Drop	The overhead conductors from the last pole or other aerial support, and including splices, if any, connecting to the service entrance conductors at buildings or other structures.
Service Entrance Conductors	<ul style="list-style-type: none"><li>• Overhead System - The service conductors that are:<ul style="list-style-type: none"><li>- Between the terminals of the service equipment and a point usually outside the building and clear of building walls.</li><li>- Joined to the service drop by tap or splice.</li></ul></li><li>• Underground System - The service conductors that are between the:<ul style="list-style-type: none"><li>- Terminals of the service equipment.</li><li>- Point of connection to the service lateral.</li></ul></li></ul> <p><b>NOTE: If the equipment is located outside the building walls, there might be no service entrance conductors, or they might be outside the building.</b></p>
Service Equipment	the necessary equipment, usually consisting of a circuit breaker or switch and fuses, and their accessories, which are: <ul style="list-style-type: none"><li>• Located near the point of entrance of supply conductors to a building or other structure (or an otherwise defined area).</li><li>• The main control and means of current cutoff.</li></ul>
Service Raceway	The raceway that encloses the service entrance conductors.
Sneak Current Protector	A protective device that is intended to limit currents that are too small to operate fuse links, stub cables, or the fuse of a fused primary protector.

(continued)

## 2. Overview, continued

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### 2.4

#### Definitions, continued

Acronym or Term	Definition
SPG	Single Point Ground; a single connection used to reference equipment to ground (earth).
Surge	A transient wave of current, potential, or power in the electrical circuit.
Surge Arrester	A protective device that: <ul style="list-style-type: none"><li>• Limits surge voltages on equipment by discharging or bypassing surge current.</li><li>• Prevents continued flow of follow current to ground.</li><li>• Can repeat its functions.</li></ul>
Surge Impedance	Impedance of a ground electrode at the frequency of the applied AC current.
UL	Underwriters Laboratories, Inc.
UPS	Uninterruptible Power Supply
Voltage (of a Circuit)	The greatest root mean square (effective) difference of potential between any two conductors of the circuit concerned. Some systems (e.g., three-phase, four-wire; single-phase, three-wire; and three-wire AC) might have various circuits of various voltages.
Waveshape Designations of a Surge	<p>A combination of two numbers that stands for the waveshape of a surge of current or voltage.</p> <p>The first number is an index of the wave front expressed in microseconds from zero to the peak of the wave.</p> <p>The second number is an index of the wavetail expressed in microseconds from zero to the instant that the wavetail reaches half of the crest or peak value.</p> <p>EXAMPLE: 10 x 20 microsecond wave.</p>
Weatherproof	Constructed or protected so that exposure to the weather will not interfere with its successful operation.

## 2. Overview, continued

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### 2.5 References

The following chart provides sources of supplementary information relating to this practice. The documents could be required for performing certain tasks.

See...	For Information About...
743-200-070	Emergency Generators Engineering Applications
795-805-071	Central Off ice Grounding Systems - Engineering Applications
795-805-073	Transmission Equipment - Central Off ice Grounding
795-805-074	Inspecting Central Office Grounding and Electrical Protection
795-805-075	Remote Electronic <b>Serving</b> Area Grounding Systems - Engineering Considerations
795-805-076	Northern Telecom DMS Switching Systems Grounding - Engineering Applications
795-805-077	Stromberg-Carlson DCO Switching Systems Grounding Engineering Applications
795-805-078	Engineering Guidelines for Grounding AT&T Switching Equipment in GTE Facilities
887-000-001	Requesting Deviations From Protection Practice Requirements
887-000-301	AC Power Line Suppressors - MZC Series, by MCG Electronics, Inc. - Description, Installation, and Maintenance
887-030-085	Engineering Considerations Radio Station Protection
887-030-087	Satellite Earth Station Protection Engineering Considerations
887-600-072	Engineering Methods for Measuring Electrode Ground Systems
887-795-070	Lightning Protection Systems - Risk Assessment Guidelines - Engineering Considerations

(continued)

## 2. Overview, continued

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### 2.5 References, continued

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**See the Following GTE PSBs... For Information About...**

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PSB 2725*	Surge Arresters (Joslyn)
PSB 2725.3*	Surge Arresters (MCG)
PSB 6141*	Clamp, Ground Connector

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\* Product Standardization Bulletins (PSBs) are published by the GTE Telephone Operations Standardization Management Department.

Additional information can be found in the:

- Current National Electrical Code (NEC), which is published by the National Fire Protection Association (NFPA).
- Local Electrical Code.
- Current Occupational Safety and Health Administration (OSHA) regulations.

### 2.6 Typical Voltages

Typical voltages found in COs are:

- 120 Vac.
- 208 Vac.
- 480 Vac.

Three-phase systems are preferred for large facilities because they can support larger loads with greater efficiency. Generally, GTE Telephone Operations standards are to provide single-phase service to remote (smaller) buildings.

A single-phase can be derived from three-phase systems. Three-phase systems should not be derived from a single-phase system.

Usually the higher voltages:

- Are less susceptible to on-premises disturbances.
- Are more stable.
- Have higher fault current capability.
- Have fewer losses.

### 2.7 Dedicated Circuits

The recommended wiring system dedicates electrical circuits to telecommunications equipment separately from those serving lighting, heating, ventilation, etc. to minimize interference.

### 2.8 Solidly Grounded Metallic Objects

All metallic objects in the building or site that enclose electrical conductors or that are likely to be energized by electrical currents must be effectively grounded for personal safety and to minimize fire hazards and equipment damages. The solid grounding of these conductors allows proper operation of overcurrent devices. The AC system supplying power to GTE Telephone Operations buildings must always be solidly grounded.

## 2. Overview, continued

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**2.9  
Leased  
Buildings** When communications systems are located in leased buildings and especially where the AC power entrance is shared with the building's other loads (e.g., industrial machines, welders, etc.), consider using an isolation transformer to minimize interference. Isolation transformers should be grounded properly.

**2.10  
Building the AC  
Distribution  
System** The AC service distribution system located in buildings that house telecommunications networks should be solidly grounded. A solidly grounded system has a low impedance bond in the AC secondary network extending from one or more of the AC service conductors directly to a ground electrode.

Bonding the AC service to the CO MGB by Lead 13 satisfies the NEC. GTE Telephone Operations also requires a separate grounding electrode (Lead 4). This is essential because of:

- CO ground system changes.
- Periodic testing.

**NOTE: Do not bond the AC service disconnect neutral by a direct path (other than Lead 13) to the CO ground field or system.**

me most common AC system:

- Uses a service transformer with a wye-connected secondary.
- Provides three-phase grounded AC service.

On new installations or upgrades where an AC service system transformer(s) uses a delta-connected secondary, establish a grounded conductor by grounding one phase of the transformer or the center tap of one phase, depending upon the secondary service voltage required.

**NOTE: In small installations, use a single-phase grounded system for the secondary system.**

**2.11  
GTE  
Responsibility** GTE Telephone Operations personnel must inspect and accept all AC electrical installations to ensure that the requirements of this practice are met.

GTE Telephone Operations is responsible for having a certified electrician install and connect all AC service distribution systems to comply with:

- The NEC.
- The local Electrical Code.
- This practice.

**2.12  
Safety Devices** To protect personnel and equipment (switching or transmission), provide additional safety devices such as:

- Power surge arresters (see Section 7).
- GFPs (see Section 8.1).
- GFCIs (see Section 8.2).

## 2. Overview, continued

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### 2.13 Requirements

All materials used for bonding, grounding, and AC power must be listed by a NRTL for the purpose, and installed as required by the NEC.

Only GTE Telephone Operations-approved materials should be used for powering, protection, and grounding of telephone switching systems.

GTE Telephone Operations requires that all conduit used in the isolated zone (IGZ) of a CO switchroom be of the rigid, nonmetallic type (PVC), which meets the requirements of NEC 347.

When local code or ordinance requires the use of metallic conduit, it should be used per NEC 346 and, in addition, the electrical continuity of metallic conduit must be interrupted before its entering the isolated area (IGZ) of the switchroom (see Section 5.6). Metallic conduit must also be bonded to grounding conductors when they are not run together with their phase conductor(s).

GTE Telephone Operations requires that all conductors used for AC wiring and for grounding be made of copper and not aluminum.

**NOTE: The use of material that is not GTE Telephone Operations standard must be approved via the deviation process (refer to GTE Telephone Operations Practice 887-000-001).**

### 2.14 AC Free Switch

Some switch manufacturers are migrating to a concept called “AC free switch.” AC free means that there is no commercial AC fed to the equipment (switching or transmission) area. Some equipment might use inverter (DC to AC) derived AC. Whenever a GTE Telephone Operations standard vendor has this type of switch, it should be given priority consideration.

## 3. Grounding Electrode System

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### 3.1 Requirements

The AC power service must be connected to a grounding electrode system according to requirements in NEC Article 250.

**NOTE: The application of the NEC requirements to a CO building is described in GTE Telephone Operations Practice 795-805-071.**

### 3.2 Required Bonding

A grounding electrode system requires bonding with any of the following when available (i.e., physically present):

- An AC main service power neutral.
- Any interior metal water pipe system that has at least 10 feet (3m) of contact with the earth.
- Any metal underground water pipe and/or water casing (10 feet [3m] minimum contact with earth) or where allowed by local authority. This might include a drilled well when required to meet earth resistance objectives in high-resistivity soil or rocky soils.
- A metal building frame including bonding of all building steel members.
- A ground field designed to meet the recommended minimum ground objectives (refer to GTE Telephone Operations Practices 795-805-071 and 795-805-075).

## 3. Grounding Electrode System, continued

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### 3.3

#### Lead Explanation

GTE Telephone Operations identifies all grounding leads by number. The master list is contained in GTE Telephone Operations Practice 795-805-071. The following chart describes the leads related to the AC power service grounding electrode system.

---

#### Lead No. Explanation

---

- |    |   |
|----|---|
| 4  | Provides the connection between the neutral busbar at the commercial AC service main disconnect switch to its grounding electrodes (see Exhibit 3). The gauge of this lead must be in accordance with GTE Telephone Operations Practice 795-805-071.  |
| 8  | Provides a bonding connection between the grounded neutral busbar at the commercial AC service main disconnect switch and the metallic water pipe (building side). The NEC restricts the point of connection to the first 5 feet (1.5m) of the interior side of the water pipe. The gauge of this lead should be in accordance with GE Telephone Operations Practice 795-805-071. See Exhibit 4 for a typical clamp for this application. |
| 13 | Provides a bond between the grounded neutral busbar at the commercial AC service main disconnect switch and the MGB. This lead allows the office to remain connected to ground whenever the Lead 5s are disconnected for testing purposes. Use GTE Telephone Operations Practice 795-805-071 to determine the proper conductor gauge.   |
- 

## 4. AC Service Ground

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### 4.1

#### Introduction

This section explains the:

- Grounded circuit conductor as the neutral conductor.
- Conductor connected to the ground electrode as the GEC.

### 4.2

#### Grounded AC System Voltage

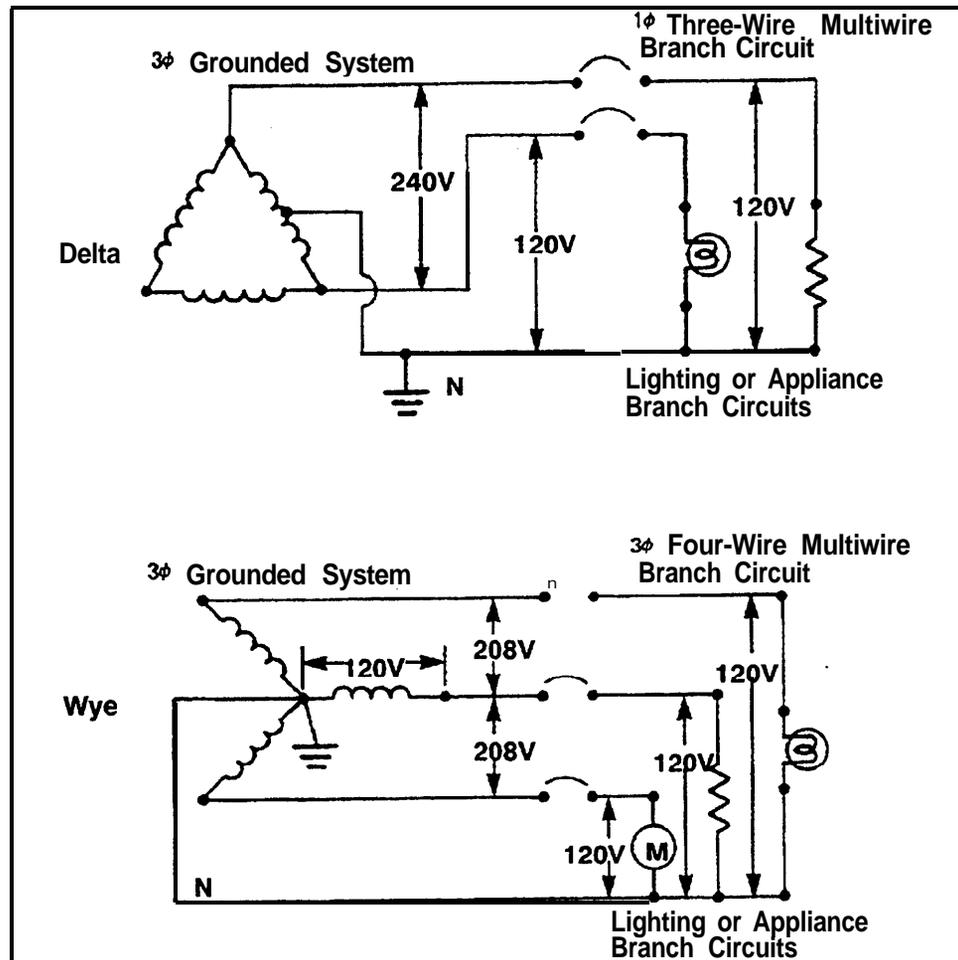
Grounded AC systems normally provide two or more voltages for telephone COs. In a typical three-phase, four-wire grounded system connected to a 120V/208V wye-wound transformer secondary winding, connecting loads:

- Across the phase legs (line-to-line) create the 208V potential.
- Between one phase leg and the neutral conductor (line-to-neutral) create the 120V potential.

## 4. AC Service Ground, continued

### 4.2 Grounded AC System Voltage, continued

The following illustration shows how the different voltages are obtained.



### 4.3 Three-Phase Grounded AC Systems

A three-phase grounded wye system uses four wires where:

- Three separate wires connect to each of the three-phase windings.
- One common wire connects to the opposite end of each phase winding of the wye secondary.

The grounded circuit conductor:

- Is called the neutral.
- Is bonded to an earth electrode with a GEC (Lead 4) at the:
  - Transformer (if outside the building).
  - Service main disconnect.
- Serves as a point of ground reference for AC voltages.
- Carries the current when an unbalanced load exists between phases.

## 4. AC Service Ground, continued

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### 4.3 Three-Phase Grounded AC Systems, continued

The grounded circuit conductor (neutral) must not connect to a grounded object between the main service disconnect and the load. Such a connection:

- Creates a permanent path in parallel with the neutral through the multiple ground connections.
- Violates the NEC.

**NOTE:** Isolate the neutral bus in all downstream branch circuit enclosures (see Section 4.7.2).

### 4.4 Single-Phase Grounded AC Systems

Single-phase grounded systems use a service transformer with a single secondary winding. Three conductors extend from the center and two ends of the secondary winding.

The center tap wire is bonded to earth and:

- Serves as the neutral.
- Serves as a point of ground reference for AC voltages.
- Carries the current when an unbalanced load exists between phases.

### 4.5 Neutral Conductor

The neutral conductor is:

- A grounded, current-carrying circuit conductor.
- Grounded only by terminations on the:
  - Supply transformer.
  - Busbars of the main branch service enclosure.

**NOTE:** The neutral conductor is not the EGC.

A neutral conductor is extended:

- With only those feeder or branch circuits that serve (or partially serve) equipment (telecommunications) designed to operate on lower voltages (e.g., 120V line-to-neutral).
- To the alternators of emergency engine sets in the CO.

**CAUTION:** Do not ground the neutral conductor to the framework of the alternators.

Size the neutral conductor the same as the phase conductors of a three-phase system to ensure that there is sufficient current-carrying capacity of:

- Residual currents.
- Fault currents.

## 4. AC Service Ground, continued

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### 4.5 Neutral Conductor, continued

The following chart describes the safety information.

Work With the...	Being Careful That...
Neutral Conductor	<p>The AC current is confined solely to the neutral conductor throughout the premises.</p> <p>When installing AC equipment, do not connect the neutral and the chassis, exposed metal, and metal frames at any point on the load side of the main and adjacent branch circuit enclosures.</p>
Neutral Busbar	<p>Branch circuit enclosures served by feeder circuits from the main service enclosure must have an insulated neutral busbar.</p> <p>Never use the branch circuit enclosure neutral busbar for terminating AC green wire grounding conductors.</p> <p><b>NOTE: An exception is that the neutral busbar can be used to terminate AC grounding conductors if a branch circuit panel enclosure serves as a main service disconnect panel.</b></p>

### 4.6 AC Service Grounding Electrode Conductor

The AC service GEC must connect the neutral of the AC service distribution system directly to an electrode system prescribed by the NEC. (See Section 3 and Exhibit 3.)

**NOTE: Although NEC rules are fulfilled if the AC service neutral is bonded to the CO grounding system, GTE Telephone Operations requires an electrode system that is not bonded directly to the CO ground field except through Lead 13.**

The AC service grounding electrode system is separate from the CO electrode ground field. This separation allows for periodic resistance measurements of the electrode ground field with no interruptions to the grounding electrode system.

The AC service neutral and ground electrode system provide a referenced ground for the AC system.

The specific requirements for electrodes and the grounding and bonding conductors are in:

- NEC Article 250.
- GTE Telephone Operations Practice 795-805-071.

## 4. AC Service Ground, continued

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### 4.6 AC Service Grounding Electrode Conductor, continued

The GEC (Lead 4):

- Is made of insulated copper (solid or stranded).
- Has wire sized according to NEC Article 250-94.
- is run with no sharp bends, and as few bends as possible.
- Is surface-supported and easy to see, which helps with inspection.
- Is continuous without reversible splices.

**NOTE: The NEC allows splices with either:**

- **Exothermic welding.**

**OR**

- **Listed irreversible compression type connectors.**

**The number of splices must be held to a minimum.**

The following chart describes the steps required when running a GEC.

---

Step	Running a GEC
1	Run the conductor through rigid nonmetallic conduit. <b>NOTE: Use nonmetallic sleeves when the conductor is run through walls or partitions.</b>
2	Mount the conduit using nonmetallic clamps.

---

Do not run the conductor through:

- Metallic conduit.
- Metal that forms a ring or circle around the grounding conductor.

If routing through metal is unavoidable, use conduit bonding-type locknuts (or a similar method) to solidly bond the conductor to:

- Any enclosing ring.
- Each end of the metallic conduit.

### 4.7 AC Service Ground System

Bond the GEC to the frame of the enclosure of the main service disconnect. Make this bond at the point of connection to the neutral (only in the main AC service panel).

In a typical installation, the main service disconnect panel:

- Mounts the service disconnecting switches or breakers (house service board).
- Has the ground bus mounted, bonded, or bolted in electrical contact with the enclosure metal.
- Terminates both the neutral (white) conductors and the AC equipment ground (green) conductors. These conductors run in distribution circuit conduit or raceways.

## 4. AC Service Ground, continued

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### 4.7 AC Service Ground System, continued

In the event of a line-to-line or line-to-neutral fault in a secondary service network, a low-impedance circuit:

- Exists through shorted AC service conductors.
- Ensures that there is quick clearing of the circuit.
- Allows a heavy current surge through the load circuit breakers.

A line-to-ground fault dumps current into the AC equipment ground system. The current does not follow a direct path back to the source without a direct bond between EGCs and the neutral.

The ground conductors carry the fault current directly to the neutral and then back to the load circuit breakers by transformer windings and phase leg conductors.

#### 4.7.1 Main Panel

The main service disconnect panel has a neutral busbar (N) that can be insulated from the enclosure. Most main panels also have a ground busbar (G) that is bonded or connected to the enclosure. The safety grounds or “green wire” grounds (EGC) terminate at the G busbar. The NEC requires that both busbars (N and G) be connected through the main bonding jumper. The NEC allows the use of a green screw in the N busbar to terminate the EGC. {See NEC Article 250-79}.

## 4. AC Service Ground, continued

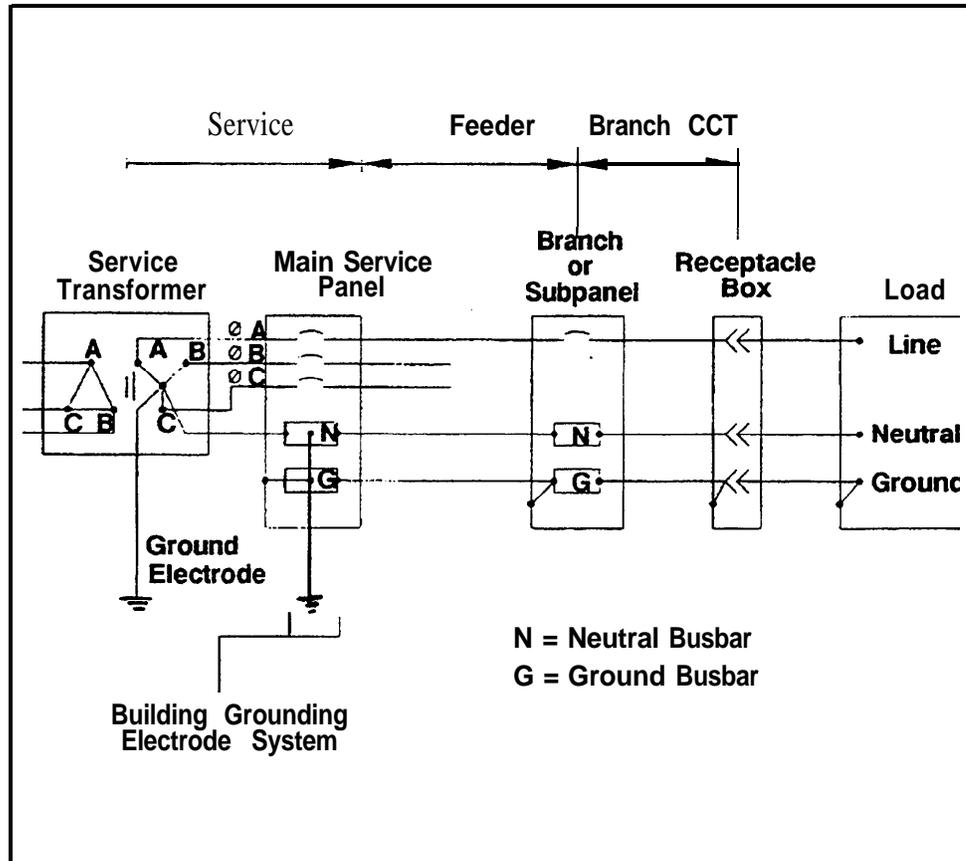
### 4.7

### AC Service Ground System, continued

#### 4.7.2 Branch Panels

Branch panels have a neutral busbar (N) that is isolated from the enclosure while the ground busbar (G) is bonded or connected to the enclosure. See the following illustration. Some branch panels might also have a dedicated, isolated ground busbar feeding the isolated (orange) outlets.

There must not be any connections between the different busbars in the branch panels.



## 4. AC Service Ground, continued

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### 4.8 AC Service

The following chart describes the AC service.

NEC Section	NEC Requirement	GTE Requirement
230-2	A single service must serve a CO, except for alternate routing.	Concurs with the NEC.
230-46	Service entrance conductors must not be spliced.	Concurs with the NEC.
230-71	Multiple service disconnect enclosures and single enclosures with six main disconnect switches are permitted.	Use a single enclosure containing six main disconnect switches. <b>NOTE: This provides a way to control surges and the AC grounding electrode system.</b>
230-91	<b>Use</b> service overcurrent protection at the nearest point of entry to the building in an accessible location.	Concurs with the NEC and further specifies to use an entrance on the floor level with the MGB. <b>NOTE: GTE Telephone Operations limits service conductors to no more than 20 feet (6m) from the ceiling, wall, or floor to service disconnect overcurrent protection after building entry.</b>
250-83 (c) and 250-84	A single $\frac{5}{8}$ inch (15.9 mm) x 8 foot (2.5m) rod when the test resistance is 25 ohms or less and requires 2 rods 6 feet (1.8m) or more apart for higher test resistance.	Concurs with the NEC. Refer to Exhibit 3.

### 4.9 Transformers

Transformers, which are electrical devices consisting of coupled windings, with or without magnetic cores, are used to transfer power by electromagnetic induction between circuits at the same frequency but change values of voltage and current. Transformers installed in buildings can perform a variety of functions such as:

- Convert from wye-to-delta connections on three-phase power systems.
- Reduce starting currents and voltages on motors.
- a Reduce common mode (longitudinal) noise.
- Provides isolation.
- Step the voltage either up or down.
- Establish a separately derived system.

## 4. AC Service Ground, continued

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### 4.10 Transformer Grounding

The secondary coils of a transformer must be grounded at the transformer as required by NEC Article 250-5.

#### 4.10.1 Step-Down Transformers

Step-down transformers are introduced into the distribution circuit when voltage (other than that supplied by the service transformer) is required to power loads.

The distribution circuit powered by the step-down transformer secondary winding must have a grounded (neutral) conductor. (This is described in NEC Article 200-2.)

**Using** a separate conductor, extend the neutral from the supply source to the secondary neutrals. This neutral conductor should be run with the phase conductors. The EGC(s) should ground the transformer enclosure and other exposed metal (see Exhibits 5 and 6).

If a neutral is extended to the primary of the transformer as was done with a grounded wye system, bond the primary and secondary neutrals instead of extending a separate neutral from the transformer supply to the secondary (see Exhibit 5).

**NOTE: Step-down or isolation transformers not associated with a separately derived system might be provided on different floor levels.**

#### 4.10.2 Separately Derived Systems

Separately derived systems are not recommended in COs. The only exceptions are:

- Existing sites with such a system.
- COs in leased space of a very large multifloor building.
- COs within a very large multistory company-owned building.

If a separately derived system **is** used:

- Do not bond the neutral of the transformer secondary directly to the primary or supply source neutral.
- Ground me secondary neutral with a GEC (Lead 20A) extended to the nearest FGB/MGB as required by NEC 250-26.
- Treat the transformer secondary neutral as a main service disconnect neutral where the equipment grounding green wire conductor and the neutral are bonded together.

Separately derived systems are described in NEC Article 250-5(d). The grounding is described in NEC Article 250-26.

## 4. AC Service Ground, continued

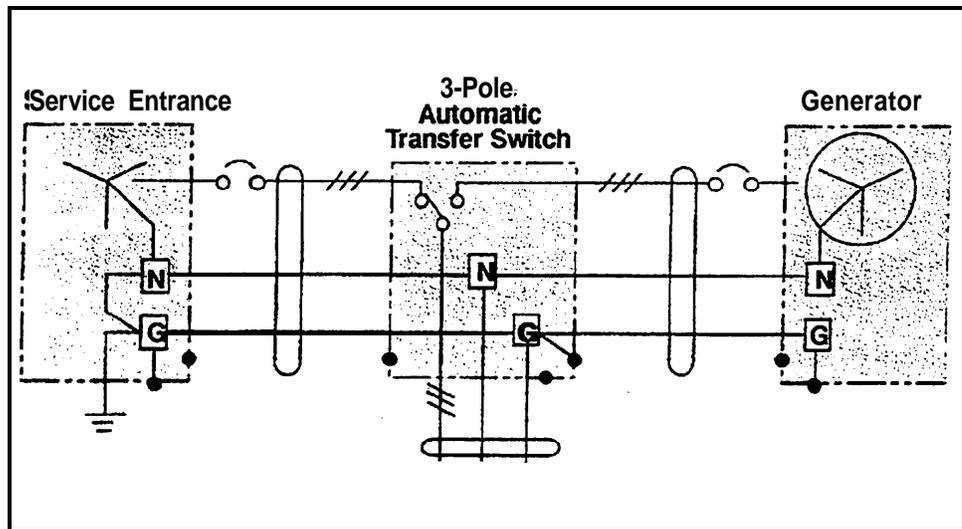
### 4.11 Emergency Generators

Auxiliary power sources supply on-site generated power to selected loads either manually or automatically.

Permanent (on-site) emergency generators are devices used as auxiliary sources of electric power to provide electricity during cases of commercial AC power failure.

GTE Telephone Operations considers emergency generators to be non-separately derived sources because the neutral is continuous and solidly interconnected to the power service neutral. This is accomplished by using three-pole transfer switches. See the following illustration. See Exhibit 7 for a typical wiring block diagram.

**NOTE:** Do not connect the emergency generator's neutral to the generator's frame (chassis).



Follow these precautions when working with a generator:

- Never connect the generator's supply directly to the commercial supply. Connections must be made through a three-pole transfer switch (see Section 4.12).
- Ensure that the EGC (green wire) extends from the frame of the generator to the transfer switch panel where it bonds to the tub.
- Ensure that the generator located in a separate building has its own ground electrode (either a ground rod or a connection to the CO ground ring - Lead 1).

**NOTE:** NEC Article 702-8 has requirements for grounding the neutral in these cases and for identification signs.

## 4. AC service Ground, continued

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4.12

### Generator Automatic Transfer Switch

Equip the automatic transfer switch with automatic controls that provide:

- A time delay after a commercial power failure. This delay ensures that:
  - There is automatic startup to the proper frequency and voltage.
  - The voltage on load conductors (particularly inductive motor loads) has decayed to nearly zero.
- Automatic synchronization of frequency, phase, and voltage for:
  - Manual transfer at zero crossing for routine operation.
  - Both manual and automatic retransfer at zero crossing to commercial power service.

The AC transfer panel can be located with the main disconnect combined as a transfer/main disconnect. NEC 702 allows supplementary overcurrent protection when the transfer switch is on the load side of the main disconnect.

Refer to GTE Telephone Operations Practice 743-200-070 for additional information on emergency generators and transfer switches.

If a transfer/main disconnect panel is used, ensure that the equipment (switching or transmission) grounding AC EGC (green wire) conductors originate at the service disconnect neutral and extend to any subsequent panels.

**This extension to subsequent panels exceeds  
NEC Article 250-92 (c) (1) and ensures continuity without using  
metal raceways and conduits.**

4.13

### Portable AC Generator Connectors

When the cord connecting a portable generator to the receptacle plug does not have an EGC:

- Run EGC green wire from the frame of the portable AC generator and connect it to the sleeve of the plug.
- Run an EGC from the connecting plug sleeve and connect it to the tub of the transfer switch.

4.14

### Overcurrent Protection of Generators

NEC Article 240-21 requires providing overcurrent protection for the rated capacity on stationary and portable generators. This protects conductors from the generator to the transfer panel and the next downstream panel.

Do not substitute overcurrent protection of generator field windings for output protection.

4.15

### UPS Systems

A UPS is also an auxiliary power source. A UPS system differs from a generator system in that the UPS also provides a means of regulating the voltage, conditioning the power, or improving the quality of the power.

A UPS system (see Exhibit 8) consists typically of:

- Batteries.
- Generators.
- Power conditioners.
- Inverters.
- Transfer switches.

## 4. AC Service Ground, continued

### 4.15

#### UPS Systems, continued

UPS systems are not needed for most CO installations, but might be required for:

- Computer installations.
- Data processing (or other sensitive electronic equipment installations).

In general terms all the requirements of this practice are applicable to UPS systems. UPS systems supplying 400 Hz power require the use of metallic non-ferrous conduit (aluminum).

The individual components of the UPS system must be installed and grounded in accordance with the manufacturer's specifications and NEC requirements.

### 4.16

#### AC Generating Devices

The standby supply provides neutral and green wire grounding conductors where inverters are used (see Exhibit 9).

Inverters are devices that change DC to AC. Some inverters have both AC and DC on the input side with one set as the primary source and the other as a backup. AC free switches do not use an AC input when the inverter is in the IGZ area.

All inverters located within the IGZ must be isolated from the frame (relay rack).

**Do not feed isolated and nonisolated loads from the same inverter.**

The following chart provides information about wiring inverters.

If the Inverter...	Then the...
Has an internal AC commercial transfer switch	The inverter neutral is permanently connected to the nonisolated commercial supply panel (nonseparately derived). The green wire is: <ul style="list-style-type: none"><li>• A wire to the load.</li><li>• Permanently bonded to a green wire furnished from the commercial supply panel.</li></ul>
Does not use commercial AC power and an associated transfer switch (separately derived source)	<ul style="list-style-type: none"><li>• Inverter neutral must extend to the FGB/MGB (Lead 20A).</li><li>• One Lead 20A per inverter.</li><li>• Neutral must bond to the frame of the inverter.</li><li>• Neutral busbar must be grounded to the cabinet enclosure of the first protective current-interrupting panel (within the inverter or externally).</li><li>• AC green wire is derived from the common neutral of enclosure bonding in the first panel (the same as for the main AC service panel).</li></ul>

**NOTE: GTE Telephone Operations does not recommend using inverters having internal transfer switches that transfer the neutral.**

## 4. AC Service Ground, continued

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4.17

The following chart identifies conductors.

### Conductor Identification

Conductor Type	Identifying Marks						
Neutral	White or neutral gray covering as required in NEC Article 220-6.						
AC equipment (switching or transmission) and convenience outlet grounding	Green covering as required in NEC Article 210-5(b).						
Equipment Grounding	<table border="1"><thead><tr><th>For...</th><th>Use...</th></tr></thead><tbody><tr><td>#6 AWG or smaller</td><td>Green insulation.</td></tr><tr><td>Larger than #6 AWG</td><td>Green tagging or tape at:<ul style="list-style-type: none"><li>• Junction boxes.</li><li>• Each main, intermediate, and branch enclosure.</li></ul></td></tr></tbody></table>	For...	Use...	#6 AWG or smaller	Green insulation.	Larger than #6 AWG	Green tagging or tape at: <ul style="list-style-type: none"><li>• Junction boxes.</li><li>• Each main, intermediate, and branch enclosure.</li></ul>
	For...	Use...					
#6 AWG or smaller	Green insulation.						
Larger than #6 AWG	Green tagging or tape at: <ul style="list-style-type: none"><li>• Junction boxes.</li><li>• Each main, intermediate, and branch enclosure.</li></ul>						
<b>NOTE: Remember that:</b> <ul style="list-style-type: none"><li>• GTE Telephone Operations requires color identification of equipment grounding.</li><li>• The conductor must be insulated copper wire (solid or stranded). See NEC Article 250-95 for size specifications.</li></ul>							

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**NOTE:** Lead 45 and Lead 46 for orange receptacles should be green with yellow stripes at each:

- Main enclosure.
- Intermediate enclosure.
- Branch enclosure.

## 4. AC Service Ground, continued

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### 4.18 NEC Requirements

White previous sections summarized the basic NEC requirements for grounding neutral conductors for services of 600V or less, individual installations must conform to all NEC requirements for the specific service provided.

Use the following chart to locate NEC information about grounding neutral conductors.

---

See...	For Information About...
NEC Article 200	Grounded (neutral) conductors.
NEC Article 250	Service grounding.

---

If local codes differ from the NEC, installations must conform to:

- The local code requirements.
- All provisions of the NEC.
- The GTE Telephone Operations Practices 795-805 subdivision that does not conflict with the local code.

### 4.19 Lead Requirements

GTE Telephone Operations identifies all grounding leads by number. The master list is in GTE Telephone Operations Practice 795-805-071. The following chart is an easy reference that shows leads related to AC service grounding.

---

Lead No.	Explanation
20A	<ul style="list-style-type: none"><li>• Connects the secondary of a separately derived source (transformer neutral) to the nearest ground bar (MGB/FGB).</li><li>• Is used on separately derived systems such as step-down transformers.</li><li>• Is required by NEC 250-26 and sized per NEC Table 250-94 (but not smaller than #6 AWG).</li></ul>
45	<ul style="list-style-type: none"><li>• Connects the AC power neutral bus in the main disconnect switch, via intermediate panels, to the isolated ground bus (not neutral or ground) of an AC branch circuit enclosure serving the isolated ground (orange) outlets.</li><li>• Is sized per NEC Table 250-95 (but not smaller than #6 AWG).</li><li>• Is a green wire with a yellow tracer or marked the lead with yellow tape or tag at each AC enclosure.</li></ul> <p><b>NOTE:</b> Lead 45 is isolated in all intermediate panels and in the final enclosure.</p>

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(continued)

## 4. AC Service Ground, continued

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### 4.19

#### Lead

#### Requirements, continued

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Lead No.	Explanation
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- |    |  |
|----|--|
| 46 | <ul style="list-style-type: none"><li>• Connects to Lead 45 at the isolated bus in a branch panel.</li><li>• Feeds the dedicated (orange) AC outlets green wire ground.</li><li>• Is a green insulated conductor with a yellow tracer or marked the lead with yellow tape.</li><li>• Is the green wire ground of a given 120 Vac circuit, originating at a branch panel isolated (orange) ground bus serving the isolated grounded outlets (orange in color).</li><li>• Is sized per NEC Table 250-95. Refer to GTE Telephone Operations Practice 795-805-071.</li></ul> |
|----|--|
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## 5. AC Equipment Grounding

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### 5.1

#### Introduction

AC equipment (switching or transmission) grounding consists of:

- A network of insulated, green wire conductors.
- Raceways or conduits.

To ensure an adequate ground fault return path:

- Provide the required EGC (green wire).
- Enclose the EGC in the conduit (even if it is metallic) with the phase conductors for all branch circuits serving telephone equipment areas and DC power plants.

### 5.2

#### Green Wire Conductors (EGCs)

The insulated, green wire conductors:

- Extend through the conduit or raceways that carry associated AC phase conductors.
- Connect to the noncurrent-carrying framework of the AC system apparatus..
- Provide a low impedance path for fault current from a point of fault to overcurrent protection devices.

**NOTE: This path ensures fast operation in spite of unintended gaps in the raceways.**

### 5.3

#### Using the Green Wire Conductors

Run the #6 AWG wire (Lead 20) from the green wire bus inside each enclosure with the downstream load circuit breakers to the closest MGB/FGB on the same floor

lead 20 is not required for the main service disconnect panel (see Exhibit 10).

## 5. AC Equipment Grounding, continued

---

### 5.4 IGZ Area – Lighting

Branch circuits and conduits that serve all light fixtures in each isolated equipment (switching or transmission) zone must not:

- Extend outside the perimeter of the equipment's IGZ.
- Serve receptacles.

This separation:

- Reduces influence from outside the specific switch.
- Allows identification of circuits and conduits.

Bond AC green wire (Lead 30) at each light fixture. The individual bonds minimize RFI caused by fluorescent ballasts.

The new type of light fixtures need only one Lead 30 per fixture-bank as long as the sides of the fixtures are not painted and there is deliberate electrical continuity from section to section.

**CAUTION: Fixtures must not contact switching frames.**

### 5.5 Non-IGZ Area – Lighting

AC light fixtures for the miscellaneous equipment area that is outside the IGZ area must comply with basic NEC requirements.

GTE Telephone Operations requires an AC green wire (Lead 30) to minimize RFI caused by fluorescent ballasts.

### 5.6 IGZ Area – Nonisolated Receptacles

Branch circuits and conduits that serve nonisolated (brown) receptacles (15 or 20 amp) inside the IGZ must:

- Not extend outside the perimeter of the IGZ.
- Remain separated from lighting and isolated receptacles to:
  - Reduce influences from outside the specific switch.
  - Allow identification of circuits and conduits.
- Be in nonmetallic conduit before contact with the isolated equipment zone.

**NOTE: ENMT conduit is required within switching frames (see Section 2.13).**

Mount nonisolated (brown) receptacles above kickplates in nonmetallic boxes with nonmetallic covers using in equipment frames located inside the IGZ (see Exhibits 1 and 11).

If nonmetallic conduit is used, nonmetallic components are required to:

- Comply with the NEC.
- Maintain the GTE Telephone Operations' isolated equipment zone single point ground concept.

Nonisolated AC receptacles (brown) inside the IGZ are limited to equipment other than test equipment, such as:

- Modems.
- Printers.
- Power supplies.
- Recorders.

## 5. AC Equipment Grounding, continued

---

### 5.7 Non-IGZ Area - Nonisolated Receptacles

On other equipment (switching or transmission) frames, walls, columns, etc. outside the IGZ use:

- Nonisolated AC receptacles (brown).
- Metallic conduit.

Use insulated AC green wire grounding conductors (Lead 30) for receptacles in:

- Miscellaneous equipment areas (non IGZ).
- DC power equipment areas.

### 5.8 IGZ Area – Isolated Receptacles

Restrict the use of isolated (orange) receptacles to within isolated equipment zones.

isolated (orange) receptacles must be powered from commercial AC (see Exhibit 2).

**NOTE: Because AC provided by an inverter provides the required isolation, a brown outlet should be used.**

Branch circuits and conduits that serve isolated (orange) receptacles in isolated equipment zones must:

- Not extend outside the IGZ area.
- Remain separated from lighting and brown receptacles to:
  - Reduce influences from outside the specific switch.
  - Allow identification of circuits and conduits.
- Be in nonmetallic conduit before contact with the isolated equipment zone.

**NOTE: Type ENMT is required within switching frames.**

Mount isolated (orange) receptacles in kickplates in nonmetallic boxes with nonmetallic covers using any digital or isolated equipment zone (see Exhibit 10).

**NOTE: The isolated (orange) receptacles must only serve permanently mounted test equipment if the receptacles are mounted above the kickplate.**

Isolated (orange) receptacles provide:

- A low-noise green wire reference for sensitive test equipment used in isolated equipment zones.
- A method to avoid defeating electronic switching frame isolation. The yoke of the orange receptacle is deliberately separated from the green wire terminal.

Brown receptacles derived from inverters that are intended to be used for test gear should be marked using tape or other similar means (see Section 2.4).

## 5. AC Equipment Grounding, continued

---

### 5.9 Using Isolated Receptacles

Use isolated (orange) receptacles only in isolated electronic or digital frames for portable and rack-mounted equipment (switching or transmission).

Do not use isolated (orange) receptacles for:

- Drills.
- Floor buffers.
- Vacuum cleaners.
- Hand tools.
- Wire wrap tools.
- CRTs.
- Modems.
- Printers.
- Power supplies.
- Other similar equipment.

**NOTE: Improper usage causes operational problems with switching systems.**

### 5.10 Installing Isolated Receptacles

Use the following chart to install the isolated (orange) receptacles allowed in NEC Article 250-74, Exception 4, and NEC Article 384-20, Exception 1.

---

Step	Installing Isolated Receptacles
1	Bond the insulated, AC green wire grounding conductor (Lead 45) that serves the isolated (orange) receptacle to the neutral in the service entrance main disconnect panel.  <b>NOTE: Use insulated #6 AWG green wire conductor with yellow stripes.</b>
2	Insulate Lead 45 from conduits and intermediate panels.
3	Terminate Lead 45 in the branch AC enclosure serving isolated (orange) receptacles by: A. Separately isolating the terminal strip. B. Insulating the split bolt connector. <b>CAUTION: Do not terminate any AC green wire on the branch panel neutral unless this panel is also the main service disconnect.</b> C. Identifying the exterior panel with a 2 inch (50 mm) square of yellow paint or tape.  <b>NOTE: An isolated busbar is not required if the branch circuit panel acts as the main service disconnect.</b>

---

(continued)

## 5. AC Equipment Grounding, continued

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### 5.10

#### Installing Isolated Receptacles, continued

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#### Step Installing isolated Receptacles

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- 4 Perform the following steps:
- A. Bond the green wire grounding conductors (Lead 46) serving isolated (orange) receptacles to the dedicated grounding conductor (green marked with yellow stripes).
  - B. Run dedicated circuit conductors and conduits for multiples to orange receptacles.
- CAUTION: Do not terminate any other AC green wires (fixture, nonisolated) on the separate branch panel isolated strip or split bolt.**
- 

**NOTE: Use nonmetallic conduits, nonmetallic boxes, and nonmetallic covers within electronic switching frames to comply with the NEC and GTE Telephone Operations' single point ground concept.**

**The NEC requires bonding isolated metal boxes with a nonisolated green wire grounding conductor. Using metal boxes violates GTE Telephone Operations' single point ground concept.**

### 5.11

#### Lead Explanation

**GTE Telephone Operations** identifies all grounding leads by number. The master list is in the GTE Telephone Operations Practice 795-805-071. The following chart shows how the leads are related to AC equipment grounding.

---

#### Lead No. Explanation

---

- |       |   |
|-------|---|
| 20    | <ul style="list-style-type: none"><li>• Connects the ground bus (not the neutral bus) in each AC branch panel enclosure serving battery chargers, lighting, and receptacles in telephone equipment areas to the FGB/MGB located on the same floor as the branch panel.</li><li>• Is a #6 AWG insulated copper conductor.</li></ul>  |
| <hr/> |   |
| 29    | <ul style="list-style-type: none"><li>• Connects the ground bus (not the neutral bus) in an AC branch panel enclosure to the frame of the battery charger/rectifier.</li><li>• Is sized per NEC Table 250-95 and terminated at the appropriate ground terminal/lug inside the charger or rectifier.</li><li>• Is the EGC (green wire) for the AC circuit(s) that feed the charger(s) or rectifier(s).</li></ul> |

**NOTE: See Section 6 for specific information.**

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- |    |   |
|----|---|
| 30 | <ul style="list-style-type: none"><li>• Connects the ground bus (not the neutral bus) in an AC branch panel enclosure to the nonisolated (brown) AC outlets.</li><li>• Is sized per NEC 250-95.</li></ul> |
|----|---|

**NOTE: See Section 5.6 for applications of brown outlets in cos.**

---

# 6. Battery Charger Ground

## 6.1 Introduction

The CO battery charger frame must be grounded with an insulated green wire. (See Section 5.11 and Exhibit 12.) The green wire is secured to the:

- Service enclosure grounding bus at the source of AC power (not the neutral).
- Charger frame grounding clamp inside the charger enclosure.

At battery chargers, do not connect the DC positive conductor to the charger enclosure or frame. AC grounding conductors must be:

- Insulated.
- Large enough to safely carry the ground fault current.

Each rectifier installed in the power plant is arranged to operate from an individual feeder and with an individual overcurrent protection device.

AC power and grounding conductors must be at least as large as those required by the local building code and the NEC.

## 6.2 Charger Grounding

The following chart shows how the leads are bonded together for nonmodular chargers.

Step	Bonding the Leads
1	Bond Lead 29 (the insulated green wire) and Lead 32 within the same clamp.
2	Bond Lead 32 to Lead 31.
3	Extend Lead 31 to the MGB or FGB. (Refer to GTE Telephone Operations Practice 795-805-071.)

The AC power wiring conduit or raceway is attached to the service enclosure by using NRTL listed fittings. This grounds the raceway to the building power service ground.

## 6.3 Modular Chargers

In modular power boards, the chargers are mounted on the same rack as the PCU/PDU and sometimes the batteries.

In newer modular power board designs, many of the rectifier frames and shelves, frame ironwork, EGC post, and rectifier chassis are all tied together via deliberate ground connections. In these cases:

- Tie Lead 29 to the AC ground position on the charger shelves.
- Ensure deliberate ground connections between:
  - Lead 29 AC ground positions and the chassis of the rectifier shelf.
  - Chassis of the rectifier shelf and the frame ironwork.

**NOTE: The deliberate ground connection can be via a ground strap or through the use of approved external tooth star-type and flat-type washers.**

- Tie Lead 31 (from the MGB) to the ironwork of the modular power board frame supporting the rectifier shelves. The connection must be to a nonpainted surface utilizing compression lugs and approved joint compound. Lead sizes will be a minimum of a #6 stranded conductor.

All ground connections must be deliberate. When the requirements of this section cannot be met, Lead 32 must be added to terminate on the same point (electrically) as Lead 29 on a one per charger shelf basis (see Exhibit 12).

# 7. Power Surge Arresters

---

## 7.1 Introduction

Surge arresters are overvoltage protective devices that:

- Limit surge voltages on equipment by discharging surge currents to earth.
- Limit the magnitude of overvoltages.
- Prevent the continued flow of follow current to ground.
- Are capable of repeating these functions.

Overvoltage protective devices are typically called:

- Arresters when used in AC power circuits.
- Protectors when used in telecommunications pairs.

## 7.2 Key to the Exhibits

Exhibits in this practice that deal with arresters that apply to COs are:

- Exhibit 5.
- Exhibit 6.
- Exhibits 13 through 18.

## 7.3 Surge Arrester Location

Protection is provided as GTE Telephone Operations standard procedure:

- On the load side of the commercial AC power service main disconnect panel.
- On branch circuits to tower warning lights.

**NOTE: Special connections are required to discharge faults to the tower structure (see Section 7.13).**

- On circuits leaving the building (see Exhibit 5).

As an option on the load side of the emergency generator transfer switch for generator-produced surges.

The arresters on the:

- Secondary side of the distribution center are located next to the:
  - AC main service disconnect cabinet:
  - Emergency generator transfer switch cabinet.
  - Junction box on the tower leg where the conduit makes its transition into the building.
  - Junction box of branch circuits leaving the building.
- Primary side of the transformer (and on isolation gaps, when required) are provided by the power company.

## 7.4 Other Transformers

In large load centers, GTE Telephone Operations might own and provide transformers that:

- Convert the incoming service to the needed load voltages.
- Are usually located between the commercial/standby transfer switch and the power service cabinet.
- Might have the appropriate arresters connected across their primary side.

## 7. Power Surge Arresters, continued

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### 7.5 Primary Arresters

The power company provides primary arresters to protect its distribution transformers against lightning surges. These arresters do not provide all the protection needed for:

- Building wiring.
- Load equipment.

Surges from lightning, line faults, or switching operations can still damage the telecommunications equipment over the power service entrance conductors.

Switching loads within an installation produce transients that can reproduce throughout the entire secondary wiring system. Surge potentials greater than 5 kV have been measured on residential and industrial power circuits.

### 7.6 Secondary Arresters

Obtain a high degree of protection for powered telecommunications equipment by adding arresters to the secondary power circuits

Some power companies operate their distribution systems with separate grounds for the:

- Primary lightning arresters.
- Secondary neutral.

If the grounds are separate, discuss making an interconnection between them with the power company.

When primary and secondary neutrals are not continuous (interconnected), the arrester on the primary side of the distribution transformer is usually grounded with a single rod. This rod provides only minimal grounding.

### 7.7 Interconnections

Secondary service grounds offer superior grounding where they use:

- Extensive metallic piping systems.
- A made electrode ground field.
- Metallic well casings.

When a secondary neutral is solidly grounded, the transformer might be better protected by the interconnection of the primary and secondary neutrals either:

- Directly.  
OR
- Through an isolation gap (if required by the power company).

Interconnection reduces the dielectric stress between the primary and secondary windings of the distribution transformer. This improves the prospects of power service continuity.

## 7. Power Surge Arresters, continued

---

### 7.7 Interconnections, continued

If the power company operating procedures or local electrical codes do not permit a solid interconnection, then:

- A suitable isolation gap must be:
  - Provided by the power company.
  - Included in the interconnection to isolate the grounds (except for lightning currents).
- The GTE Telephone Operations Project Engineer or GTE Telephone Operations' Consulting Engineer must:
  - Verify that primary arresters, primary-secondary neutral interconnections, and grounds are provided.
  - Request the power company make any needed improvements or corrections.

The secondary arresters are available in ratings which:

- Vary from 120 to 480 Vrms.
- Refer to the nominal rms voltage on which they are used (Le., the voltage which the arrester can satisfactorily extinguish).
- Do not refer to the surge sparkover or operating potential.

When the secondary arrester has the AC green wire terminal in the arrester enclosure, run the green wire with the other associated arrester conductors to the respective main service disconnect panel or generator transfer panel.

**NOTE: Use conduit (nonmetallic is preferred) that is as short as possible and does not exceed 4 feet (1.2m).**

The protection arrangements discussed in this document supersede all previous ones requiring:

- Arresters at two locations.
- Intervening wiring in steel conduit.

Using arresters that are heavy-duty devices and have lower sparkover voltages:

- Improves protection.
- Avoids the inconvenience of:
  - Having critical lengths of wiring in steel conduit.
  - Placing an arrester and supplemental capacitors at the weatherhead.

To ensure that there is direct low-resistance, low-impedance paths to ground for surge currents, bond together and ground all:

- Conduit.
- Raceways.
- Switch boxes.
- Metal equipment (switching or transmission) cabinets containing power wires.

Use NRTL listed connectors and other electrical hardware to provide interconnections.

## 7. Power Surge Arresters, continued

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### 7.8 Standard Surge Arresters

The current GTE Telephone Operations standard surge arresters come in their own service enclosures ready to install. Each unit has:

- Replaceable alarm relays.
- Alarm lamps.
- Cartridge fuses.
- Gas tube/silicon carbide disc or metal oxide arrester units.

**NOTE: Even though some arresters have internal fuse wires designed to fail as arrester elements fail short, provide GTE Telephone Operations standard cartridge fuses to protect the arrester as a whole.**

Metal sleeves shipped in the fuse holders by the manufacturer must be replaced with GTE Telephone Operations standard fuses when the holders will accommodate the standard fuses.

When the arrester fuse holders are too small for the GTE Telephone Operations standard fuses:

- Retain the metal sleeves in the arrester holders.
- Provide external fuse holders with standard fuses.

GTE Telephone Operations standard fuses are:

- FRM and FRN up to 250V.
- FRS between 250V-600V in 30- and 40- amp.

### 7.9 Inductance

Inductance is chiefly a function of length. The inductance of arrester leads can detract from arrester effectiveness. Short connections are essential to achieve maximum protection. Lead length must never exceed 4 feet (1.2m).

Plan the physical arrangement of the installation to minimize all surge arrester lead lengths including the ground or neutral lead.

**NOTE: NEC Article 280 requires that the surge arrester leads:**

- **Be no longer than necessary.**
- **Avoid unnecessary bends.**
- **Be no smaller than #14 AWG.**

### 7.10 Engineering Applications Aids

Aids are available for the building project engineer and contractor, such as:

- Enlarged prints of schematic wiring diagrams.
- Bulletins on specific arresters.
- Further application assistance.

Obtain aids from the manufacturer. GTE Telephone Operations standard vendors are:

- Joslyn (PSB 2725).
- MCG (PSB 2725.3).

Refer to GTE Telephone Operations Practice 887-000-301 for additional information on the MCG arresters.

# 7. Power Surge Arresters, continued

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## 7.11 Selecting a Surge Arrester

The following chart shows how to select the correct arrester for a particular application by considering seven major characteristics.

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No.	Characteristic
1	Transients withstand voltages of the insulation and equipment components to be protected.
2	Speed of operation. At transients close to normal operating voltage waveforms, greater protection is available by using solid-state elements. These operate several times faster than gas tube elements. This greater protection is needed when the problem source is near or within the CO (e.g., emergency generator transfer to or from the load).
3	Normal steady-state voltage of the circuit (hot wire to ground) to be protected.
4	Maximum AC voltage interrupting the rating of the arrester (i.e., the maximum steady-state voltage at which the arrester will clear power follow current).
5	Severity of the anticipated transients (peak current) the arrester must handle.
6	Reliability (service life) required of the arrester according to the size and importance of the protected facility.
7	Cost of the arrester, associated material, and installation, in relation to replacement cost of the protected equipment and its required service life.

---

**NOTE:** Select a surge arrester model that will allow connecting an individual arrester module between each of the phases and ground and between neutral and ground.

## 7.12 Fuses

In all cases, fuses are provided in series with arrester leads. If an arrester accidentally becomes permanently grounded, fusing an arrester as shown in the exhibits in this document eliminates the possibility of either:

- Blowing a main fuse.
- OR
- Causing supply conductor damage.

The operating efficiency of the arrester is not impaired by installing fuses, because the neutral ground terminal is internally connected to the cabinet.

**CAUTION:** Install only recommended fuses.

## 7. Power Surge Arresters, continued

### 7.13 Aircraft Warning Lights

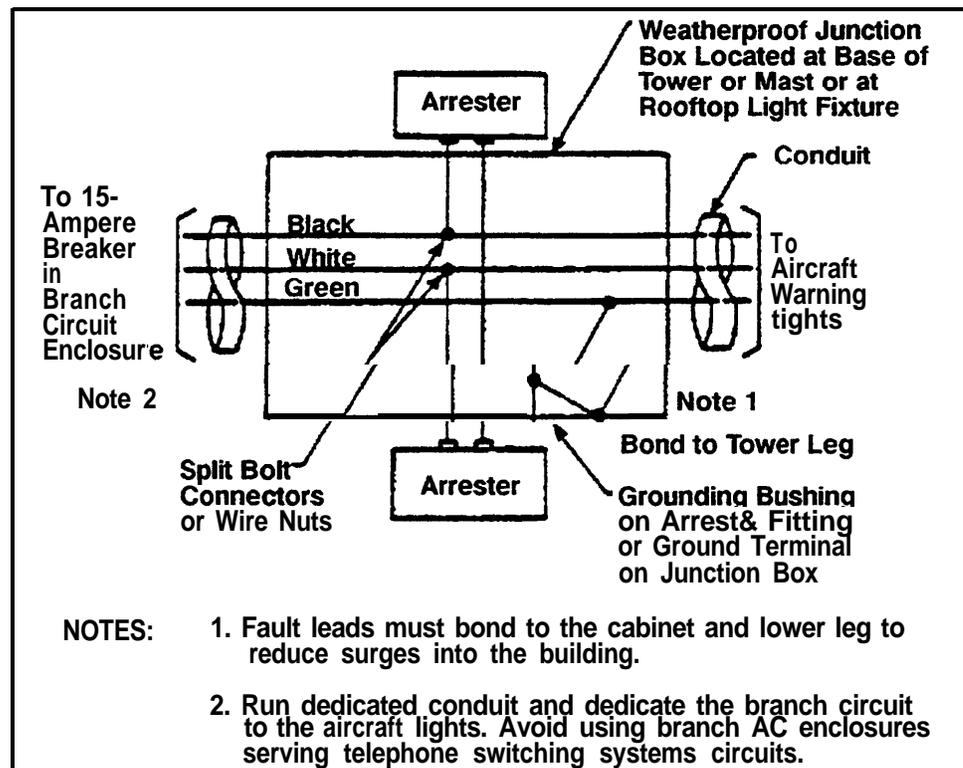
Protect branch circuits for aircraft warning lights by adding arresters at the:

- Warning light fixtures on rooftops.
- Base of antenna masts or towers equipped with warning lights.

Bond the arrester lead (or the terminal normally bonded to the AC neutral) to the tower leg. This reduces the fault currents that reenter the building.

**NOTE:** Mount the arrester on the tower leg where the conduit makes a transition to enter the building.

For each 120V, 15-amp branch circuit, use two arresters as shown in the following illustration. Normally, at least two branch circuits are required for diversity.



### 7.14 Branch Circuit Leaving Building

Protect branch circuits that leave the building, such as:

- Parking light standards or poles.
- Lighted signs (not conforming to building exterior profile).
- Receptacle exterior (rather than on outside) of the building.
- Remotely located mechanical equipment.

Bond GTE Telephone Operations standard arresters to each phase and neutral conductor of the branch circuit with the arrester discharge bonded in multiple with the:

- Junction enclosure.
- AC equipment grounding green wire conductor.
- No. 2 gauge PVC insulated conductor to a separate earth ground.

Refer to Exhibit 19 for wiring details and required earth ground.

## 7. Power Surge Arresters, continued

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### 7.15 Protecting Emergency Generators

Protect emergency generator output with GTE Telephone Operations standard service arresters when the generator is outside the building, such as:

- On the building's roof.
- In a separate structure.
- In a weatherproof housing.

The arrester is a requirement for these situations.

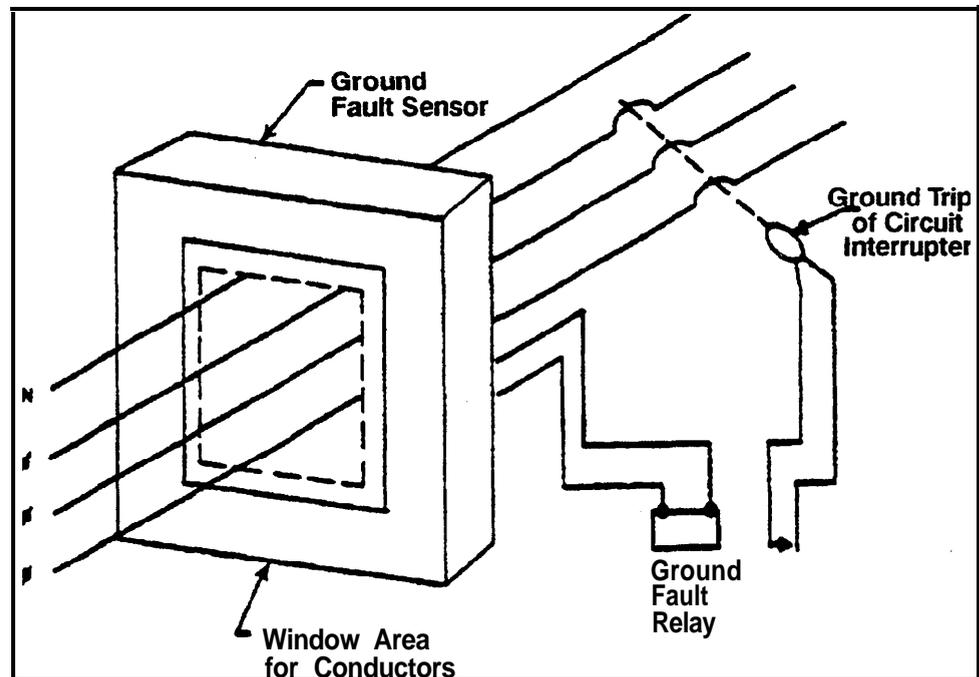
Provide the arrester and install as shown in Exhibit 4.

## 8. Ground-Fault Protection

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### 8.1 Ground-Fault Protection of Equipment

The following illustration and Exhibit 5 illustrate the sensor with its ground-fault relay. Two GFPs might be required. (See the chart that follows the illustration.)



## 8. Ground-Fault Protection, continued

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### 8.1 Ground-Fault Protection of Equipment, continued

The following chart shows the effect that a ground fault has on go and return currents and the sensor's output versus the effect of normal circuit conditions.

If...	The Go and Return Currents...	The Sensor...
Circuit conditions are normal	From all phase conductors and neutral (if used) add up to zero	Produces no output signal.
A ground fault occurs	Do not add up, their difference is equal to the current of the ground fault	Provides an output: <ul style="list-style-type: none"><li>• Proportional to the current of the ground fault.</li><li>• Measured by the ground-fault relay, which activates the ground-fault shunt trip mechanism of the circuit interrupting device, which opens the circuit breakers for the phase conductors.</li></ul>

**NOTE:** The system does not depend on any particular fault-current ground return path. It can flow in all or any of them (the green wire, conduit, superstructure, reinforced concrete, etc.). The green wire does not pass through the device's sensor window.

One type of ground-fault protection system is the Type GP GROUND-CENSOR™? The imbalance of go and return current in the normal load conductors (phase and neutral wires) powers it.

In COs the GFP is required for arcing fault protection against fire and equipment damage and not for personnel protection.

The trip mechanism is adjustable to trip on fault currents from 200- to 1200-amp. NEC Article 230-95 requires:

- This device for grounded wye-power service entrances of over 150V phase to ground, but not exceeding 600V nominal phase to phase for any service-disconnecting means rated 1000 amp or more. Additional ground fault protection can also be used on smaller services or downstream on critical loads.
- The time delay to trip at a maximum of one second for 300 amp or greater ground-fault currents.
- The GFP system must be tested when installed and a written record kept for the NEC's enforcing authority.

Fire pump motors do not require a GFP.

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GP GROUND-CENSOR is a trademark of the Square D Company.

## 8. Ground-Fault Protection, continued

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### 8.2 Ground-Fault Protection of Personnel

GFI's might be provided by one of the following when required for the protection of personnel:

- A 5 mA ground-fault interrupter mounted in AC branch circuit enclosures in COs in place of the standard breaker.
- OR
- A duplex receptacle in place of standard duplex convenience outlets in telephone COs.
  - The GFCIs have the following characteristics:
    - Voltage of 120Vac.
    - Frequency of 60 Hz.
    - Rated current of 15 amp (rated for use on 15 and 20-amp branch circuits.
    - Maximum current of 20 amp.
    - Current sensitivity of 6 mA.
    - Trip time is  $T = (20/I) 1.43$  where T = seconds and I = mA.
    - Brown color.

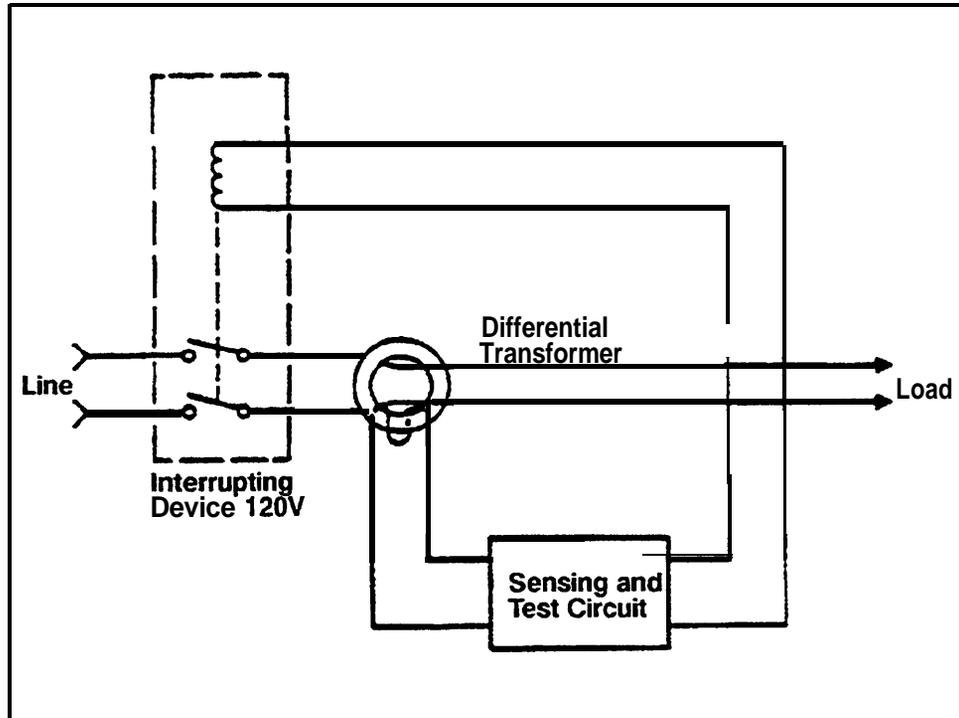
**NOTE: Do not use the GFCI receptacles where orange receptacles are required because isolation integrity must be maintained. Use ground fault circuit breakers on circuits with orange receptacles.**

## 8. Ground-Fault Protection, continued

### 8.2 Ground-Fault Protection of Personnel, continued

Installing either of these devices provides protection against low-level ground faults. If faulty equipment is touched, the current leaks through the person to the ground on the load side of the protected circuit:

- Causing an imbalance that produces a flux in the magnetic core or the differential current transformer as shown in the following illustration:



- Inducing voltage into the transformer's secondary winding, activating the solid-state circuitry in the sensing unit.
- Completing a circuit to the interrupter operate coil, opening the line.

**NOTE:** Periodically check the built-in test circuit that is included.

The NEC Article 210-8 requires GFI at the following locations:

- Bathrooms.
- Rooftops.
- Outdoors when placed at less than 6.5 feet (1.95m) above ground level.
- Unfinished basements (concrete floor).

**NOTE:** When AC receptacles/outlets are provided in cable vaults (or manholes that serve a similar purpose) that have constant, or periodic, accumulations of water, the receptacles should be equipped with GFI protection. There is not need to retrofit existing locations unless problems are encountered.

## 8. Ground-Fault Protection, continued

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### 8.2 Ground-Fault Protection of Personnel, continued

Article 305-6 also requires GFI at sites where temporary power is being provided for:

- Construction.
- Remodeling.
- Maintenance.
- Repair.

Temporary power is defined as 125V, single phase circuits not derived from the structure's permanent wiring.

# Exhibits

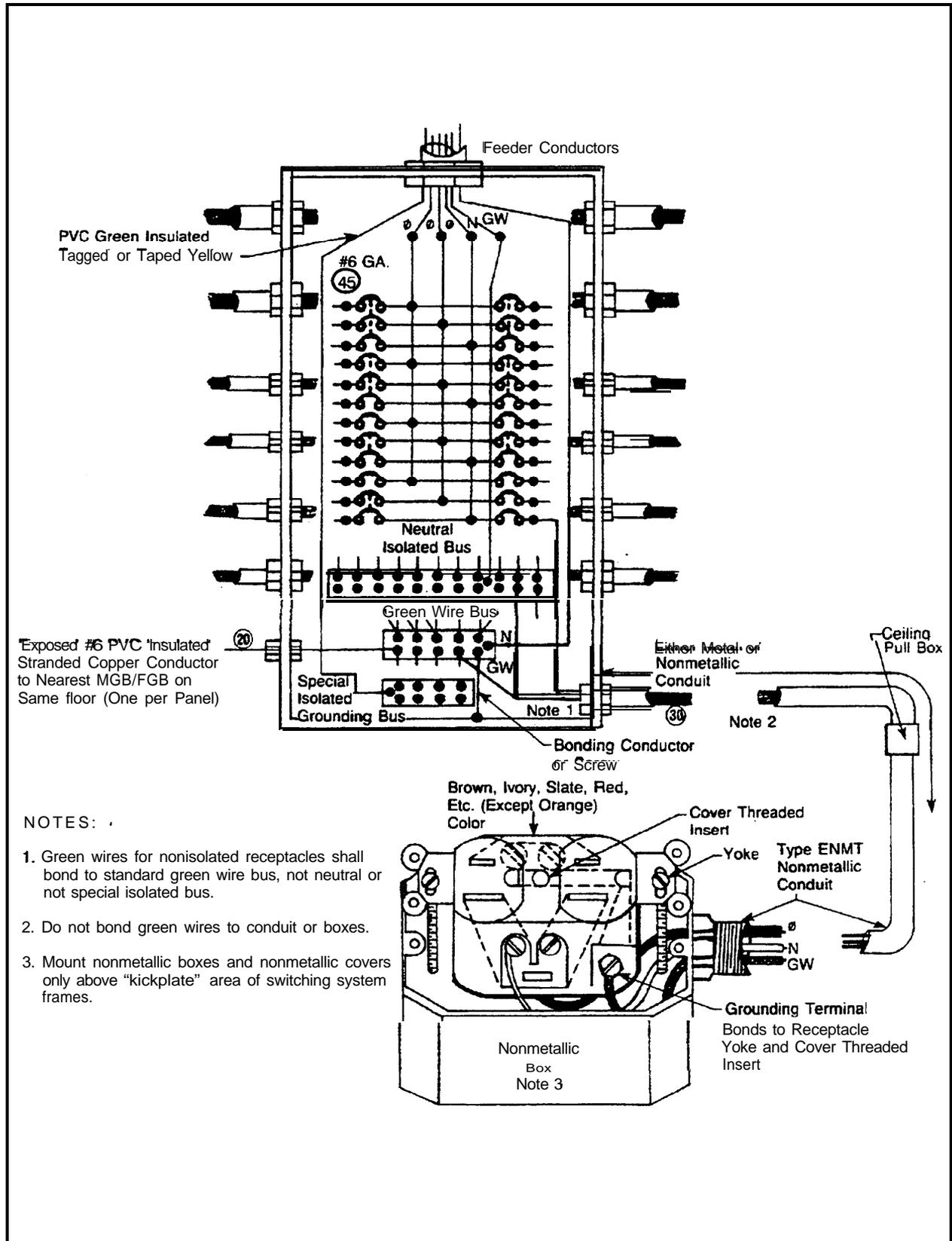


Exhibit 1 - Branch Panel with Nonisolated Receptacle

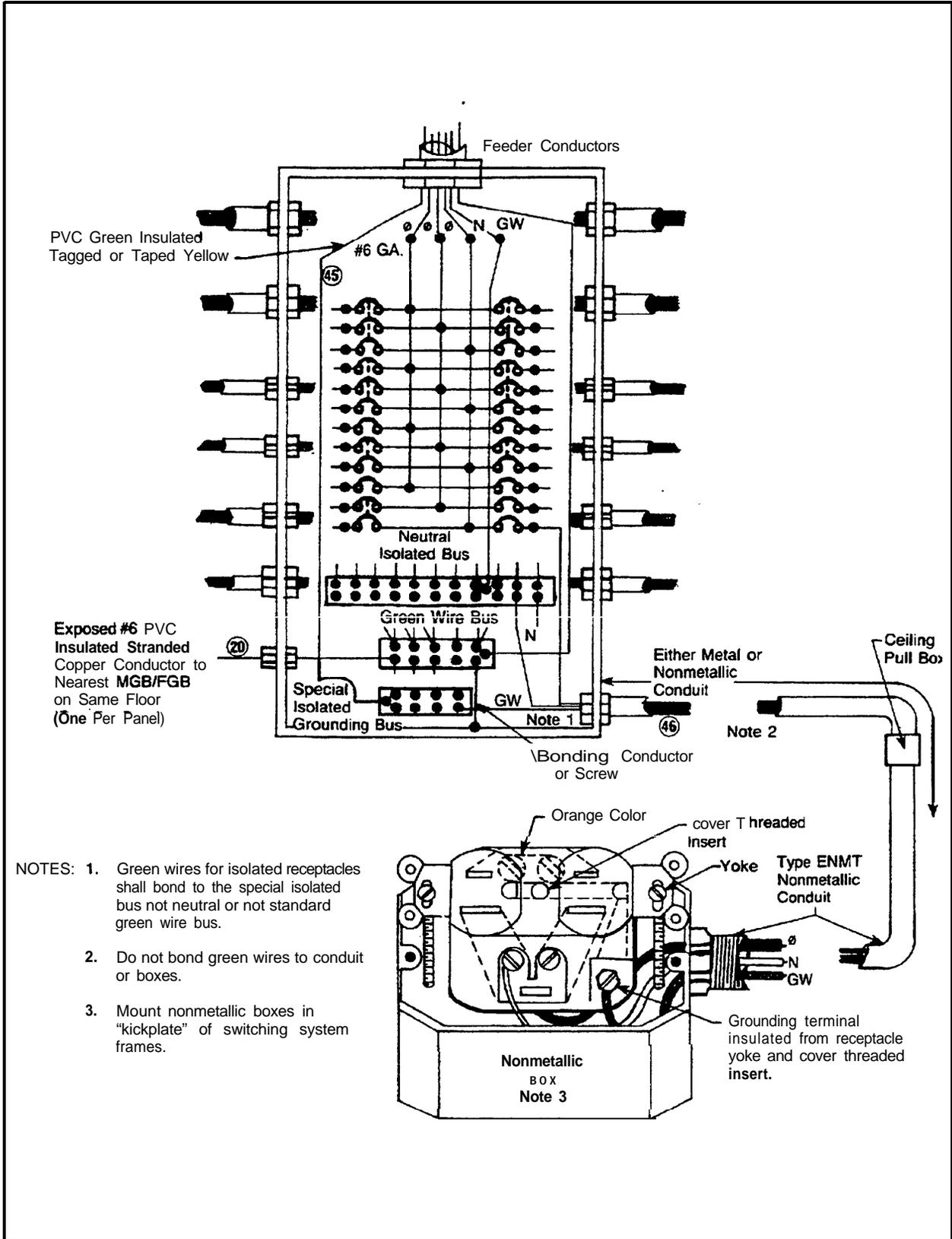


Exhibit 2 - Branch Panel with Isolated Receptacle

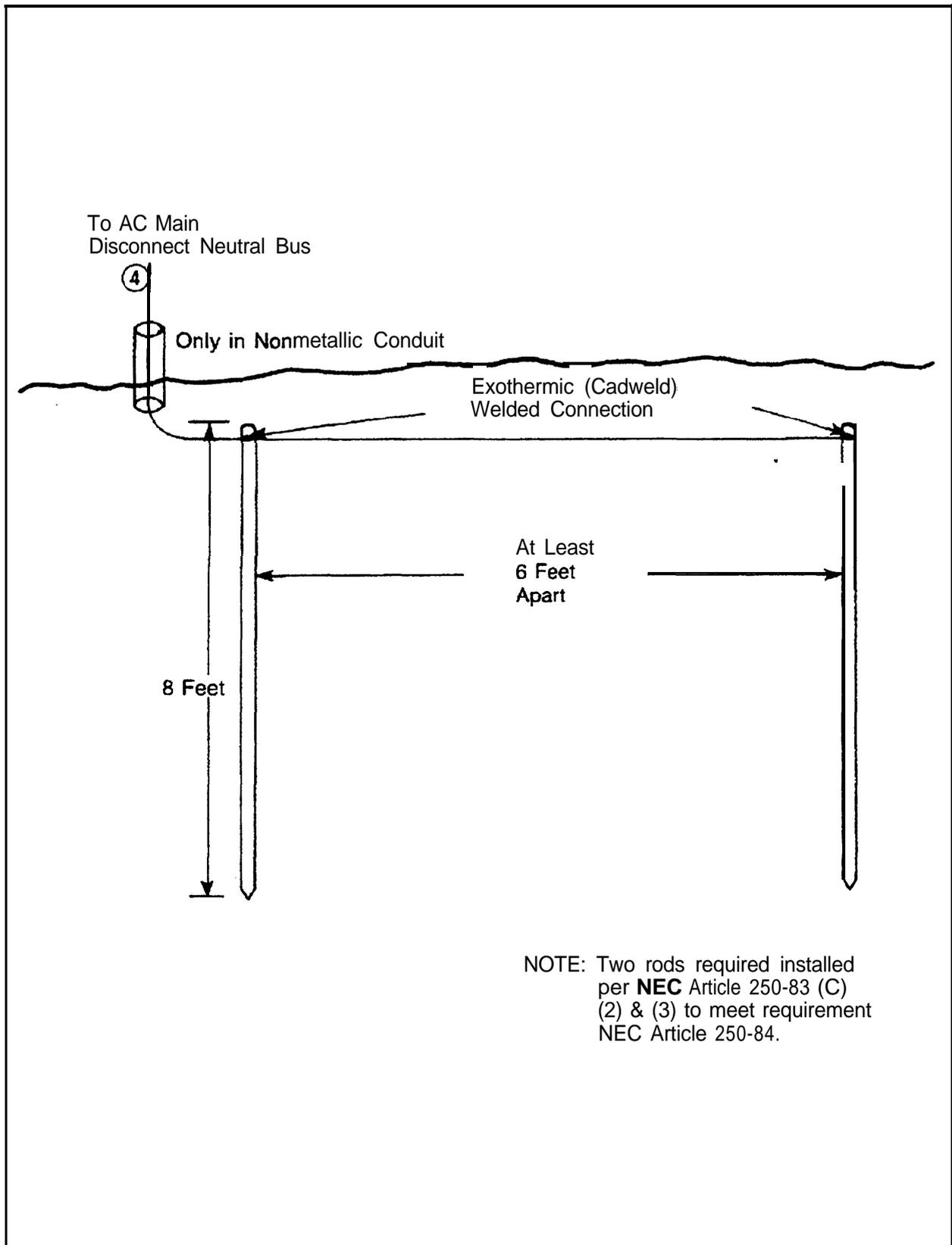


Exhibit 3 - Required Driven Electrode Grounding of AC Service

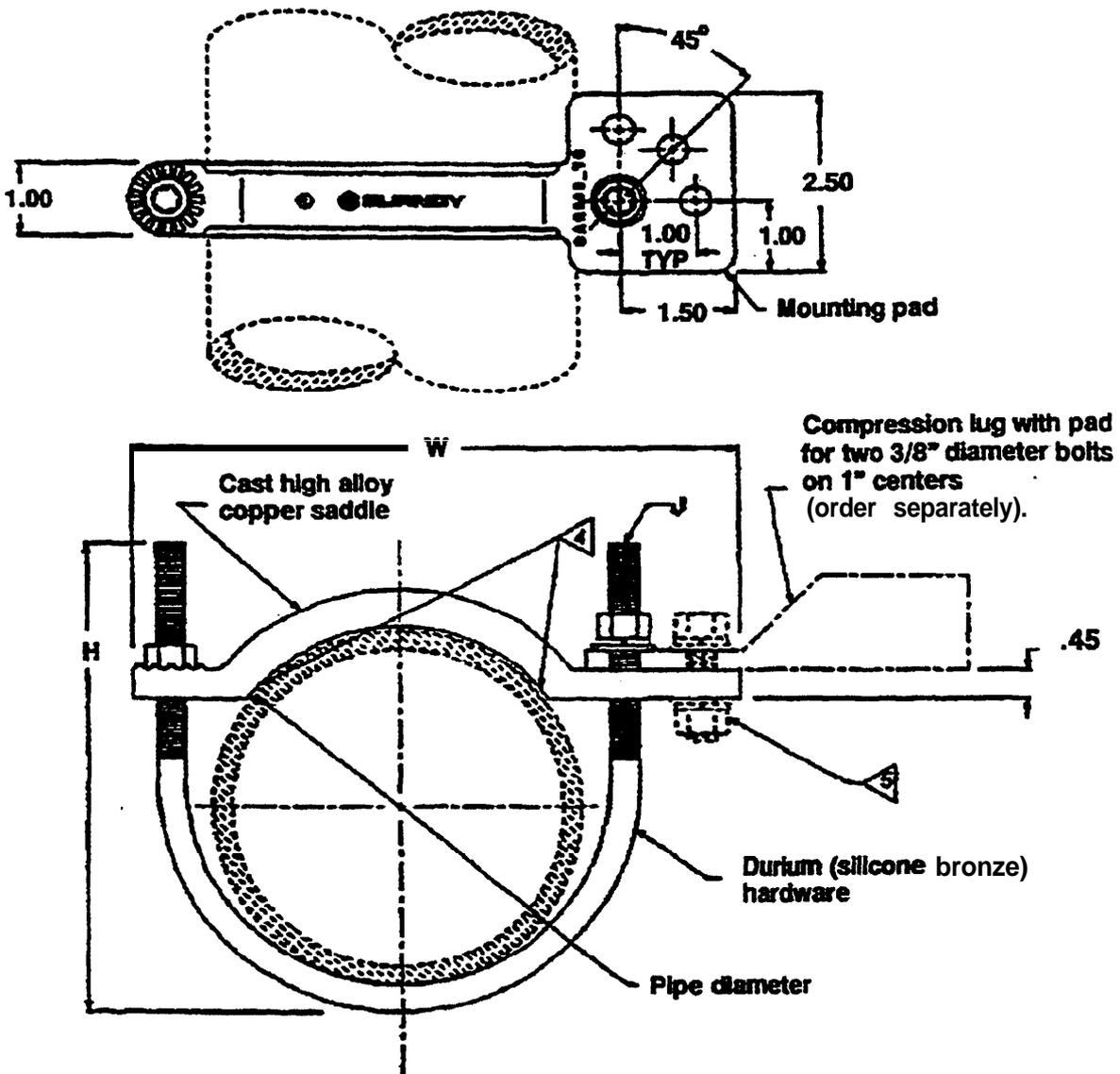


Exhibit 4 - Ground Clamp Detail

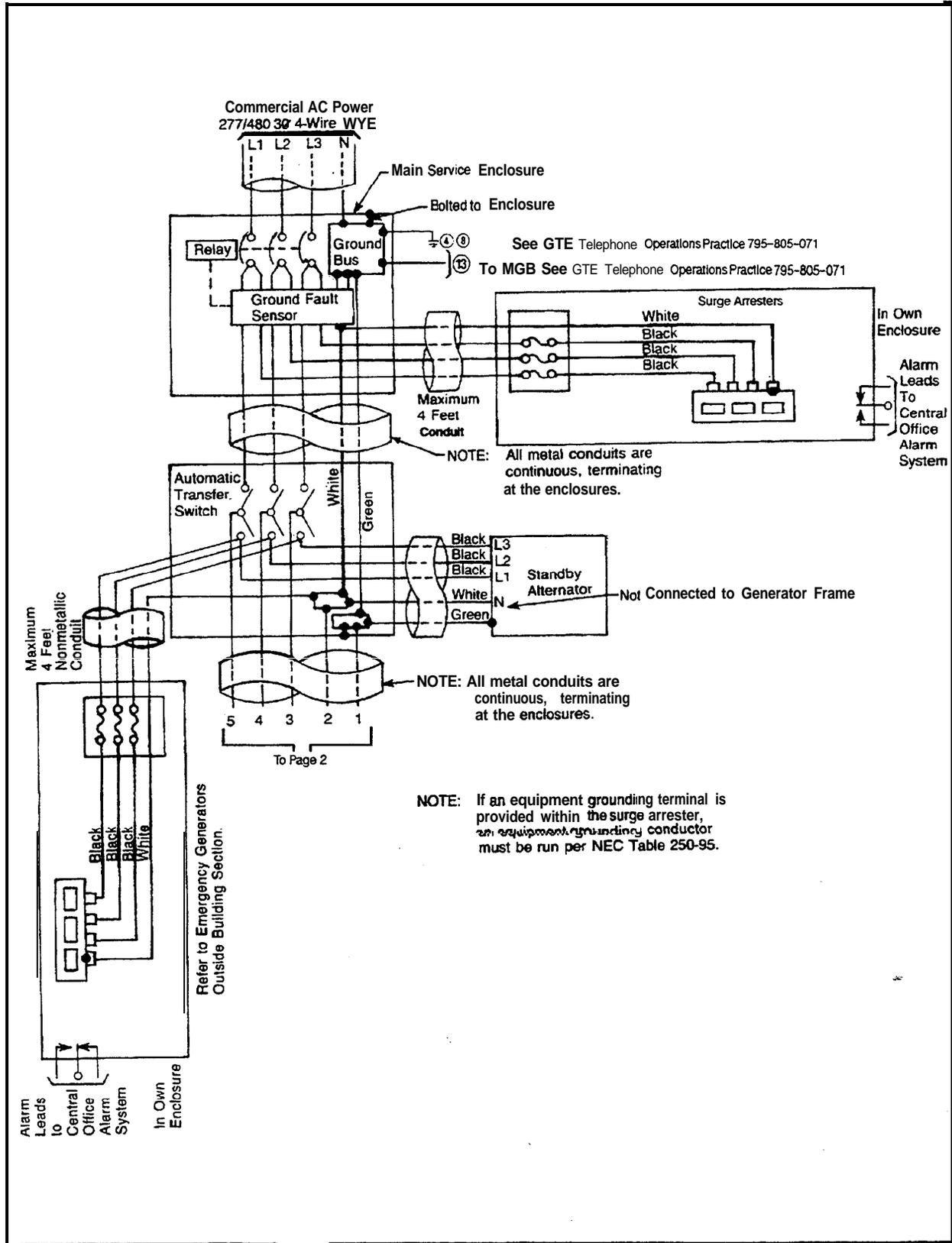
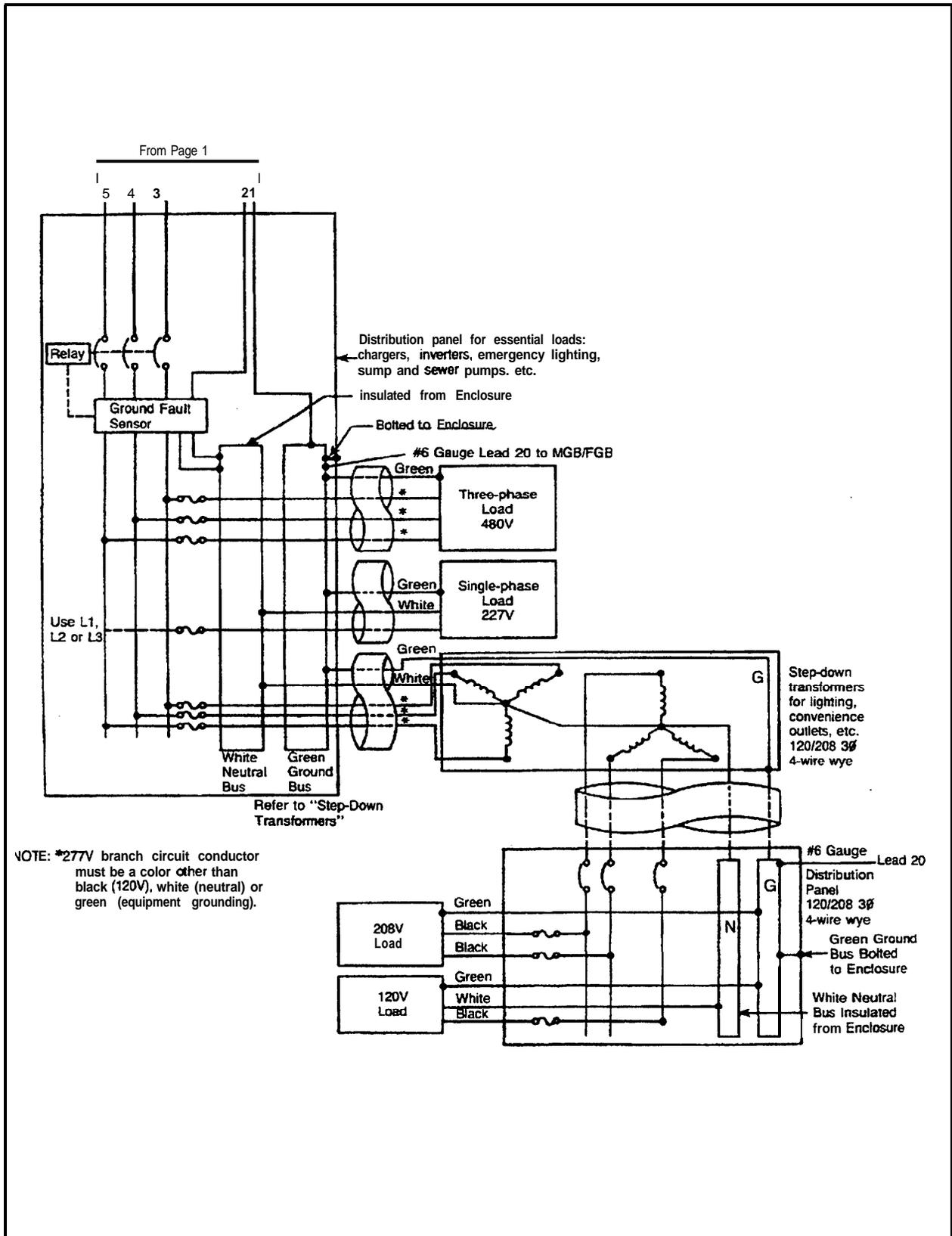
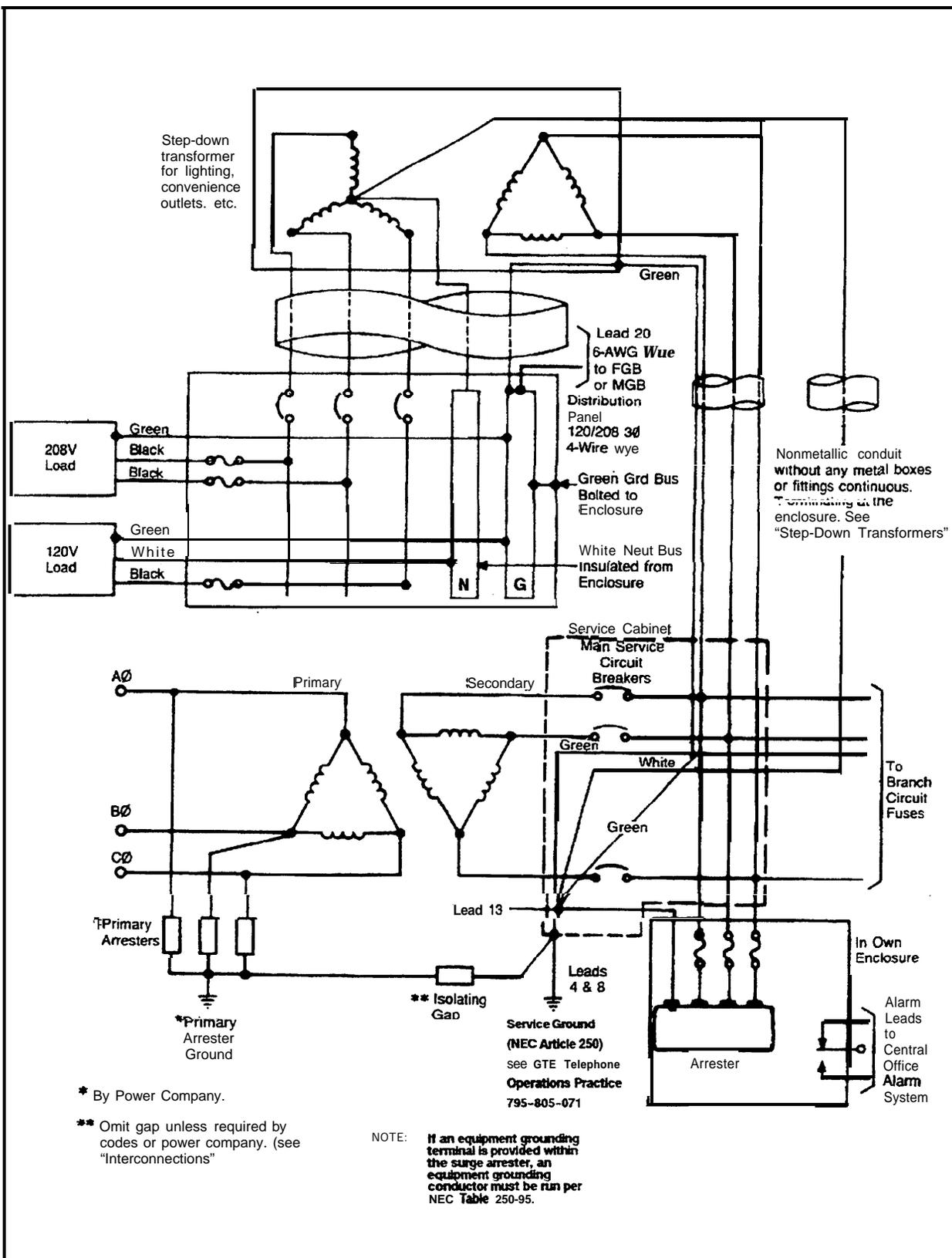


Exhibit 5 - Power Arrangement for a Large Equipment Center 227V/480 Vac, Three-Phase, Four-Wire, Wye-Grounded Neutral Service with a Standby Power Unit (Page 1 of 2)



**Exhibit 5 - Power Arrangement for a Large Equipment Center 227V/480 Vac, Three-Phase, Four-Wire, Wye-Grounded Neutral Service with a Standby Power Unit (Page 2 of 2)**



**Exhibit 6 - Connection Diagram for 240V or 480 VAC, Three-Phase, Three-Wire, Ungrounded Delta Service from a Three-Phase, Three-Wire, Ungrounded Delta Primary**

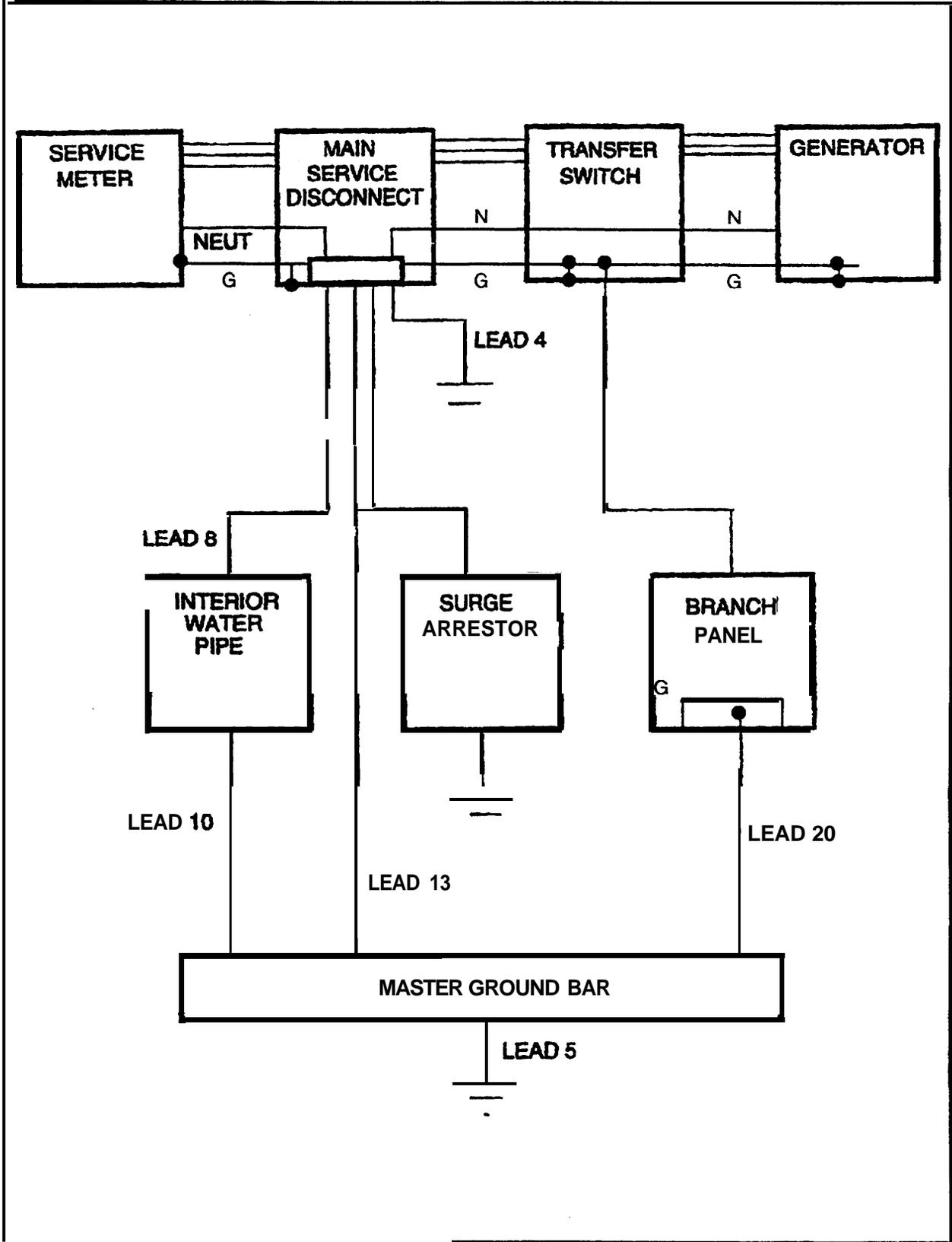
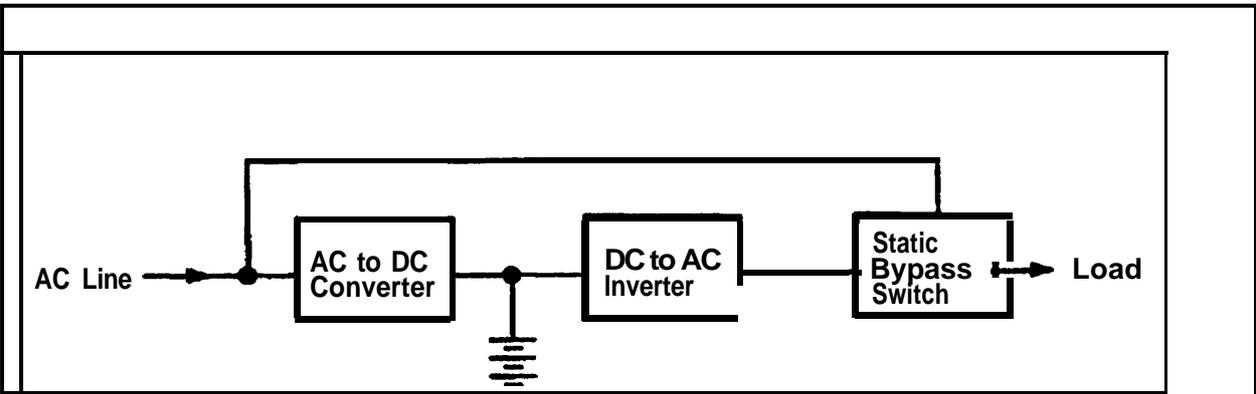
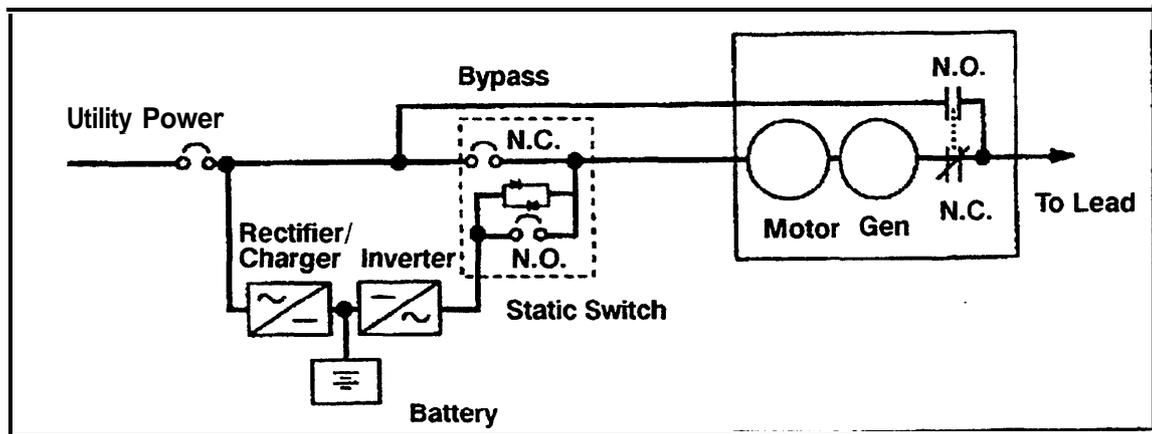


Exhibit 7 - Typical Wiring for CO Generators



A. Block Diagram of a Typical Static UPS System



B. Block Diagram of a Typical Rotary UPS System

Exhibit 8 - Typical UPS Systems

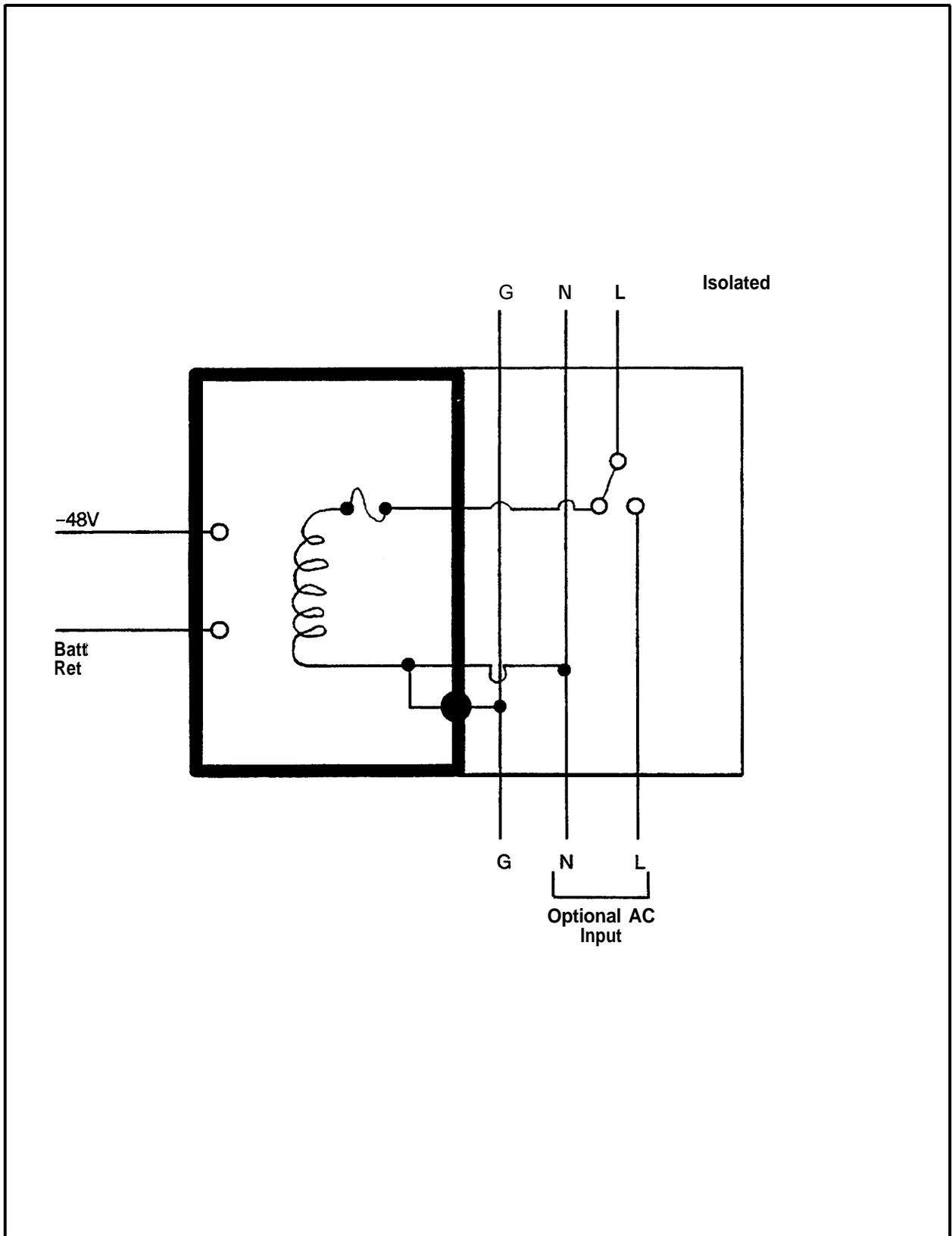
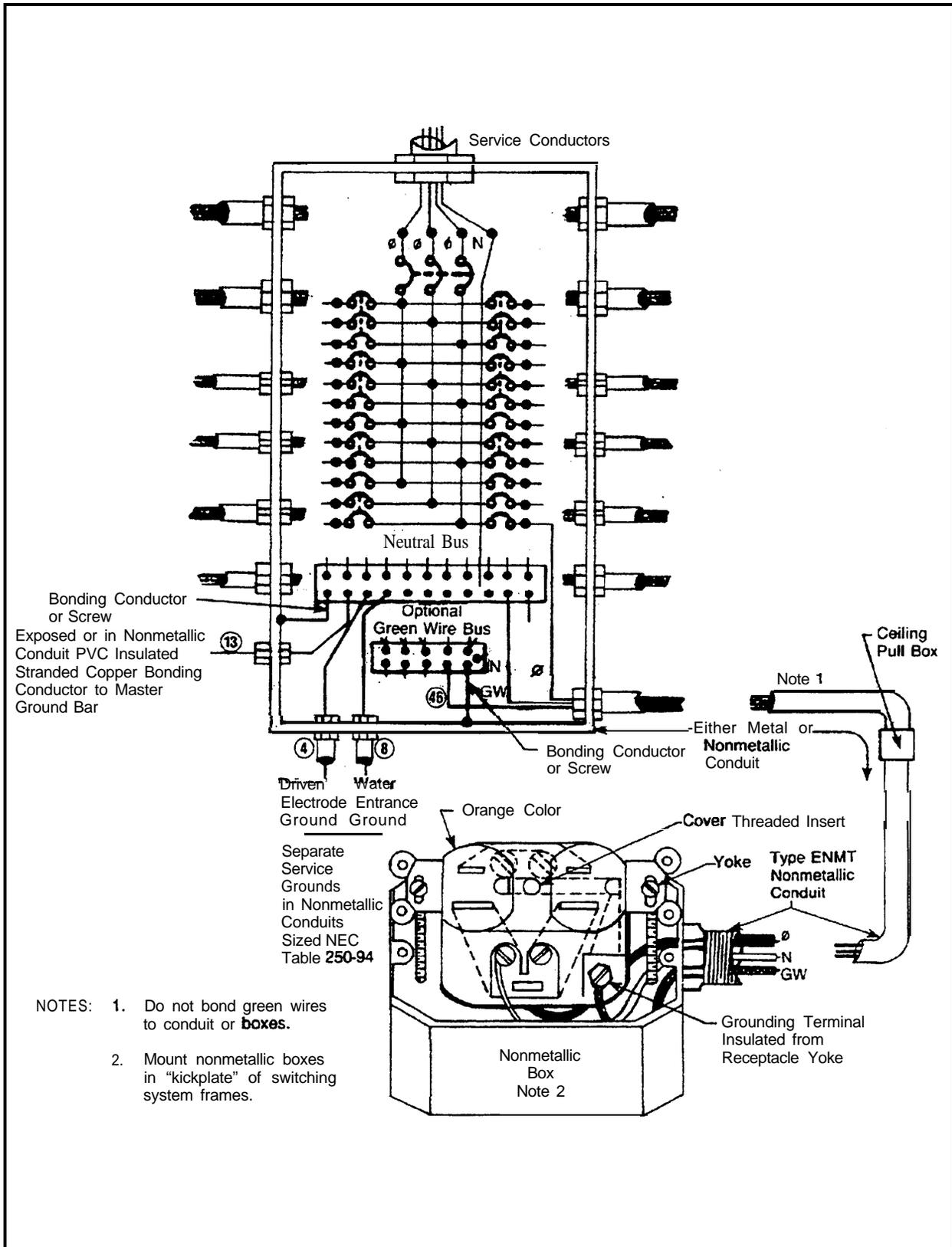


Exhibit 9 - Typical Inverter Wiring and Grounding

# Exhibits, continued



**Exhibit 10 - Combined Main Service Disconnect and Branch Panel with Isolated Receptacle**

# Exhibits, continued

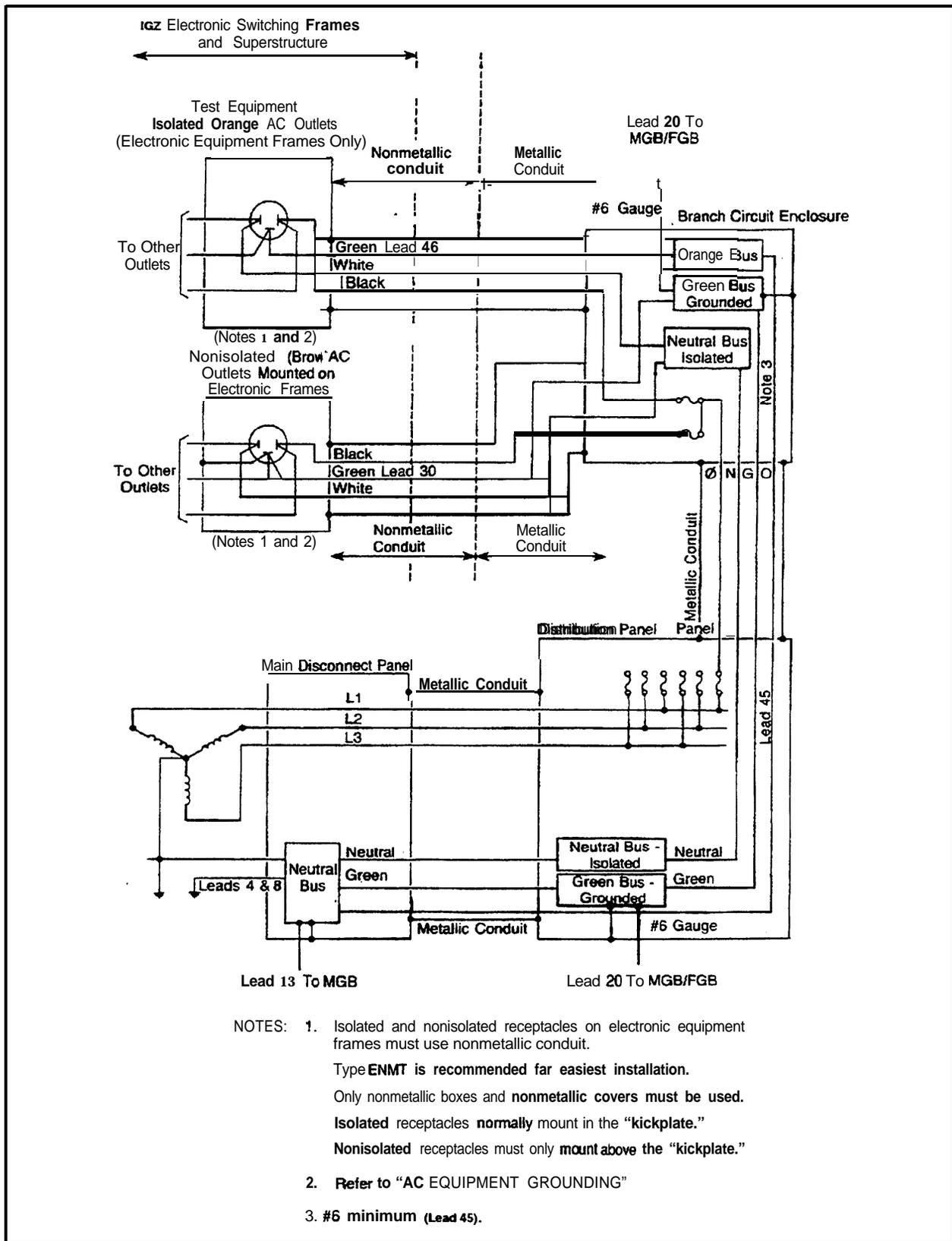


Exhibit 11 - AC Wiring Standard (Brown) and Isolate Ground (Orange) Receptacles

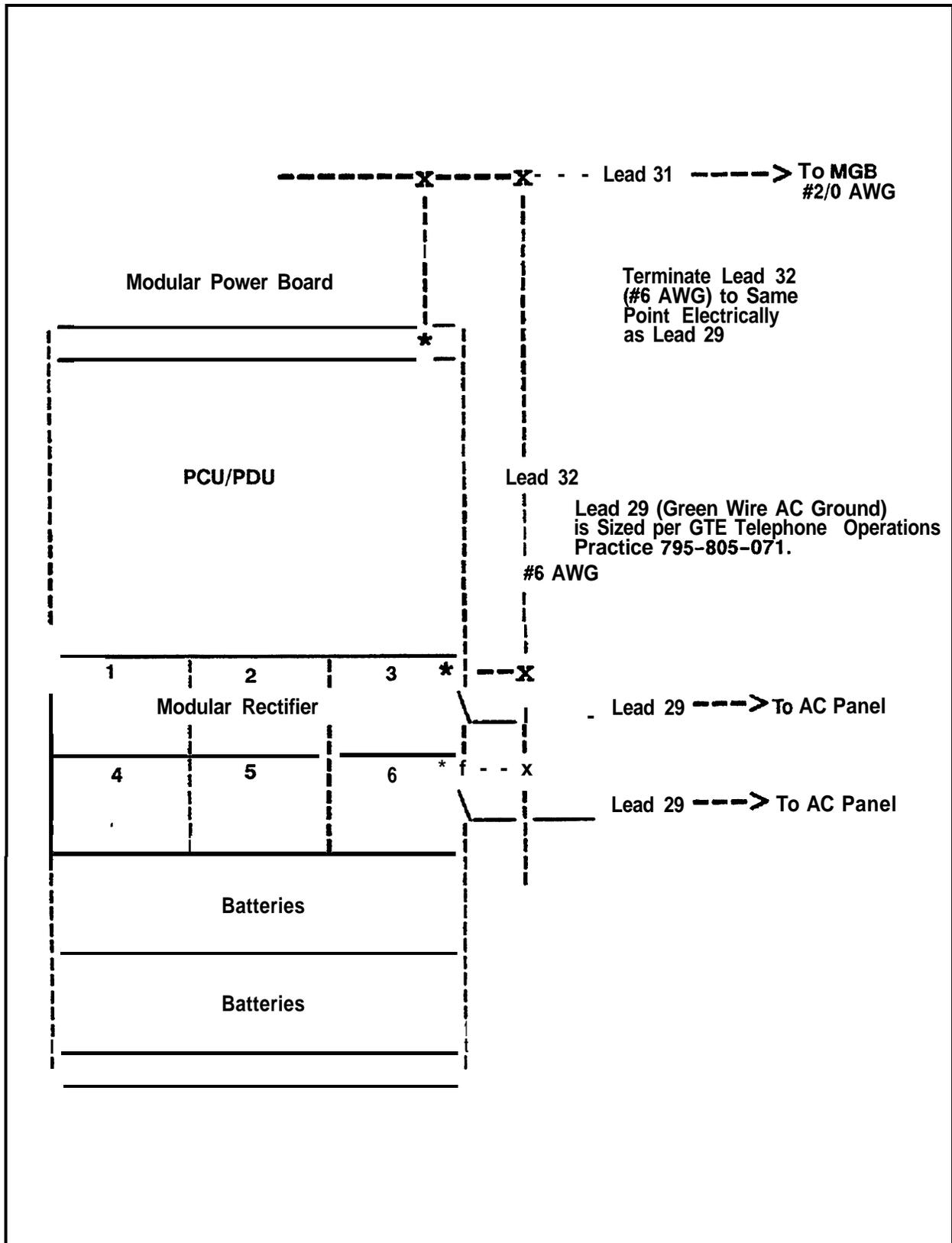


Exhibit 12 - Typical Grounding for Modular Rectifiers

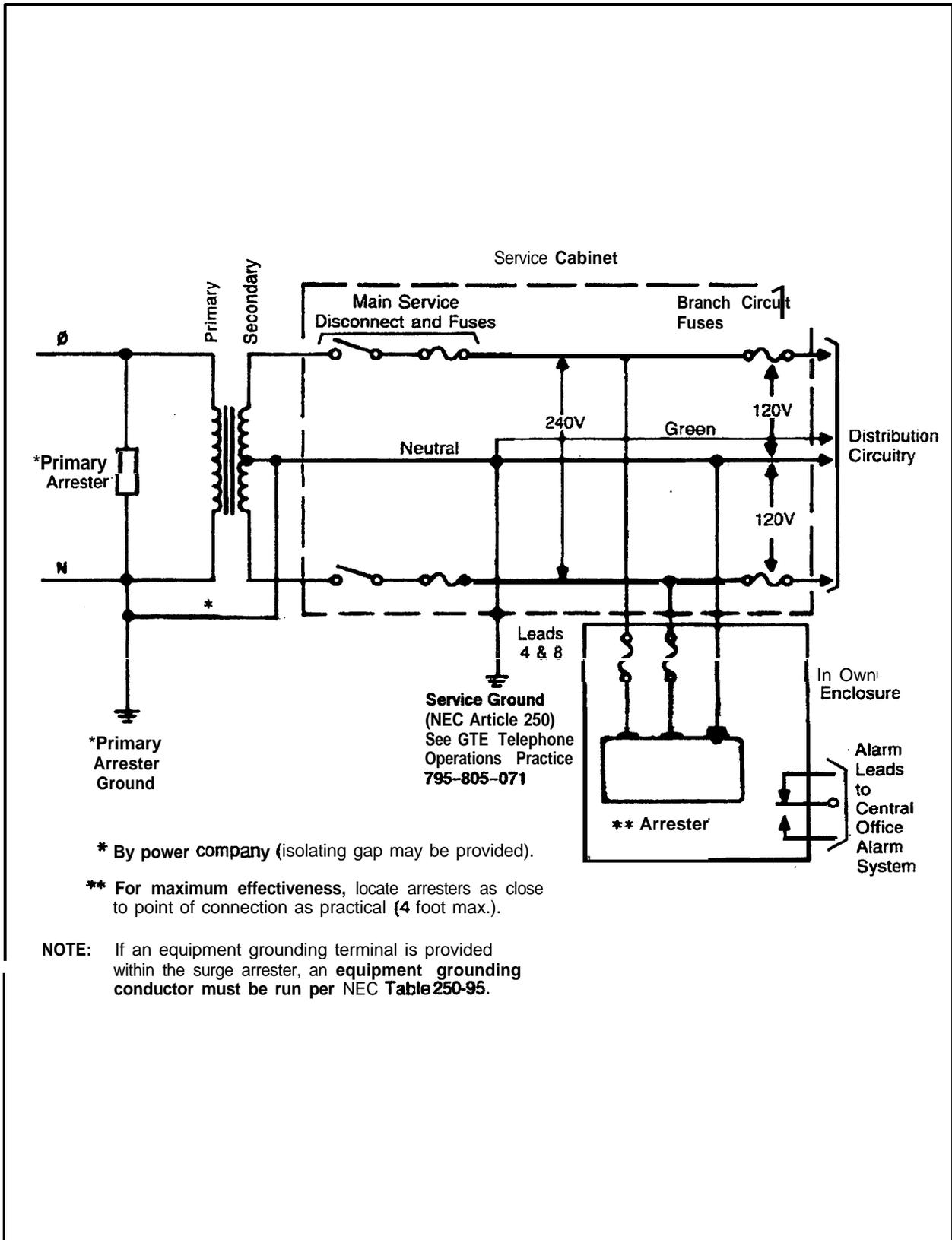


Exhibit 13 - Connection Diagram for 120V/240 Vac, One-Phase, Three-Wire, Grounded Neutral Service from a Single Phase

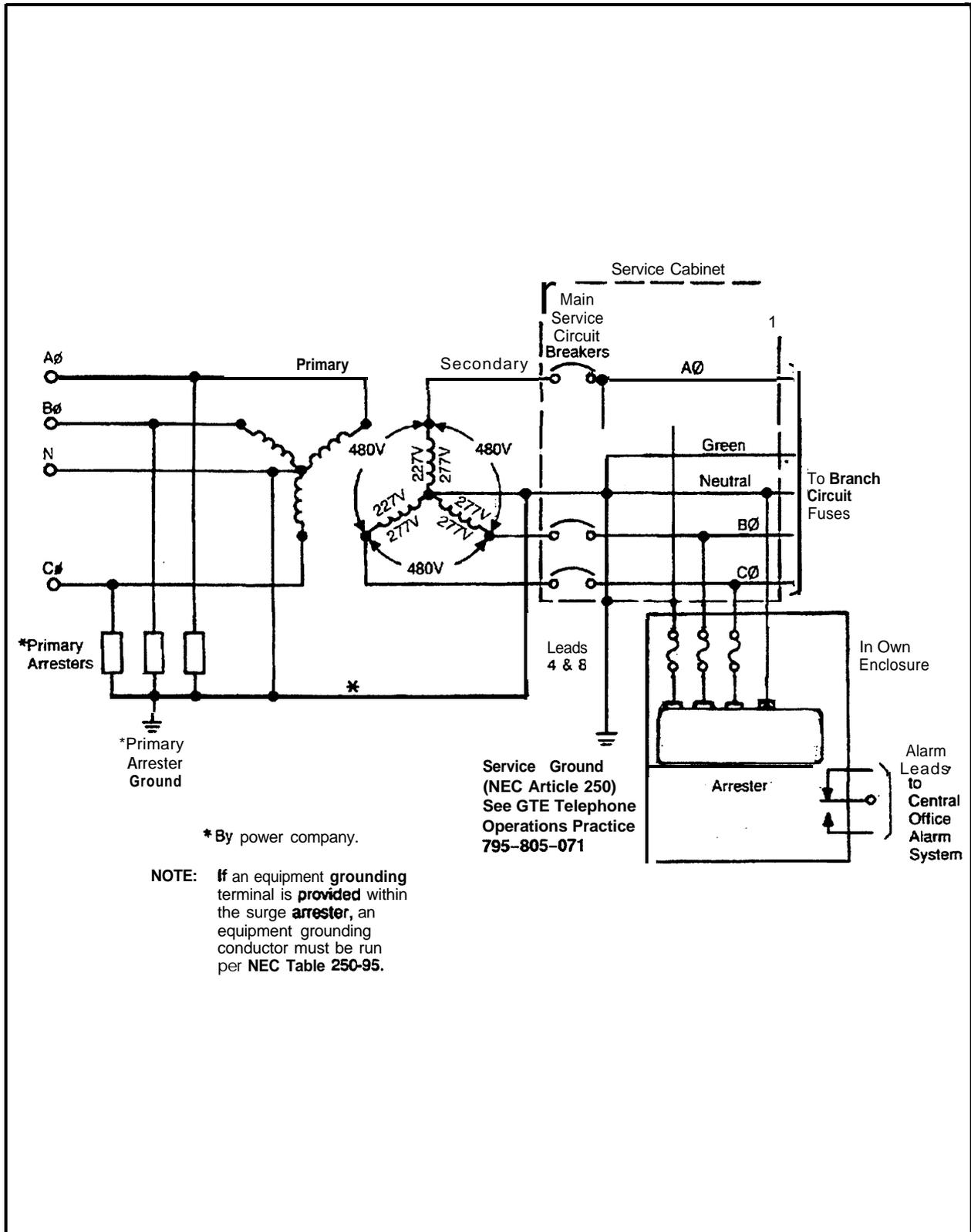


Exhibit 14 - Connection Diagram for 277V/480 Vac, 120V/208 Vac, or 347V/600 Vac, Three-Phase, Four Wire, Wye-Grounded Neutral Service from a Three-Phase, Four-Wire, Wye-Multigrounded Neutral Primary

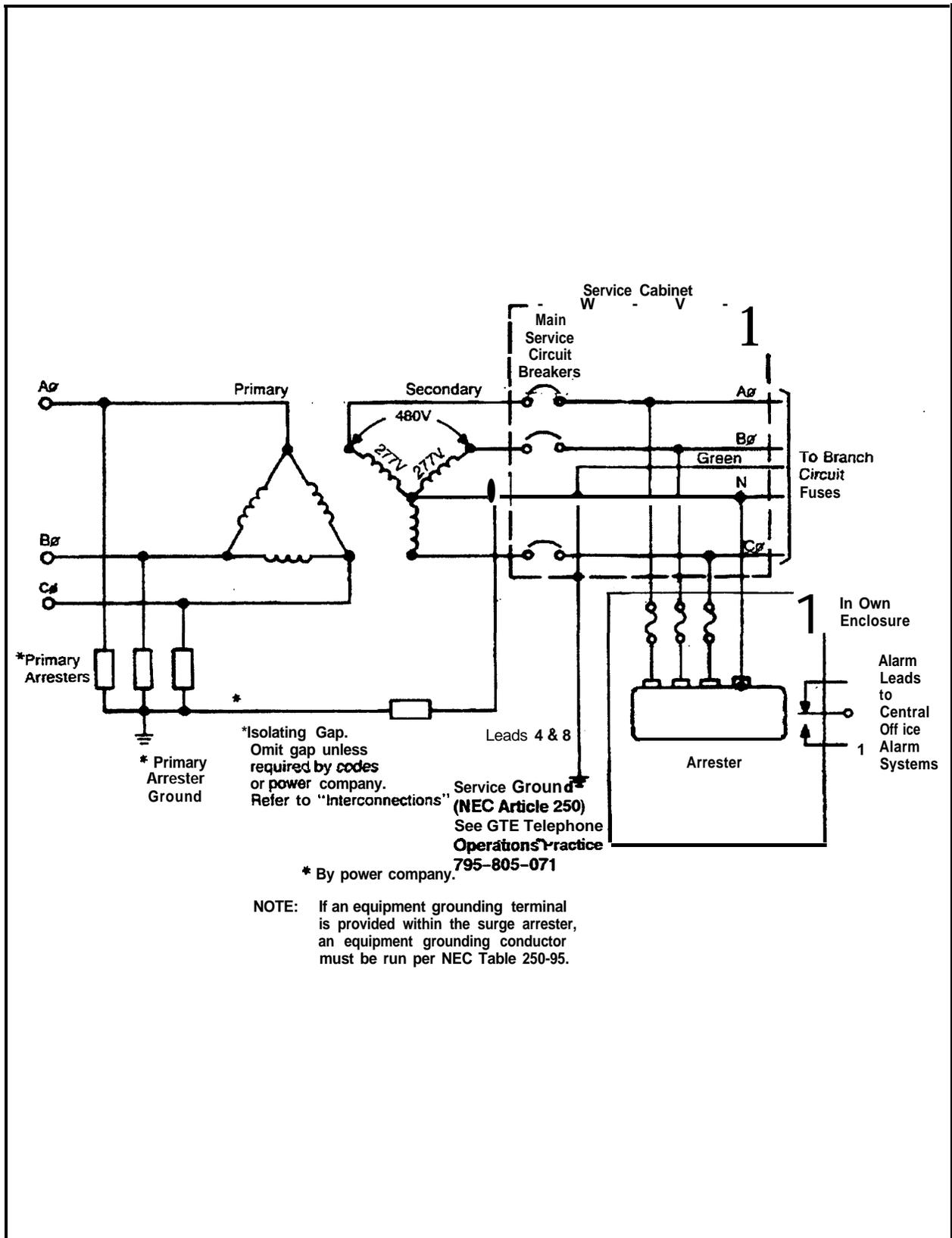


Exhibit 15 - Connection Diagram for a 277V/480 Vac, 120V/208 Vac, or 347V/600 Vac Three-Phase, Four-Wire, Wye-Grounded Neutral Service from a Three-Phase, Three-Wire Delta Primary

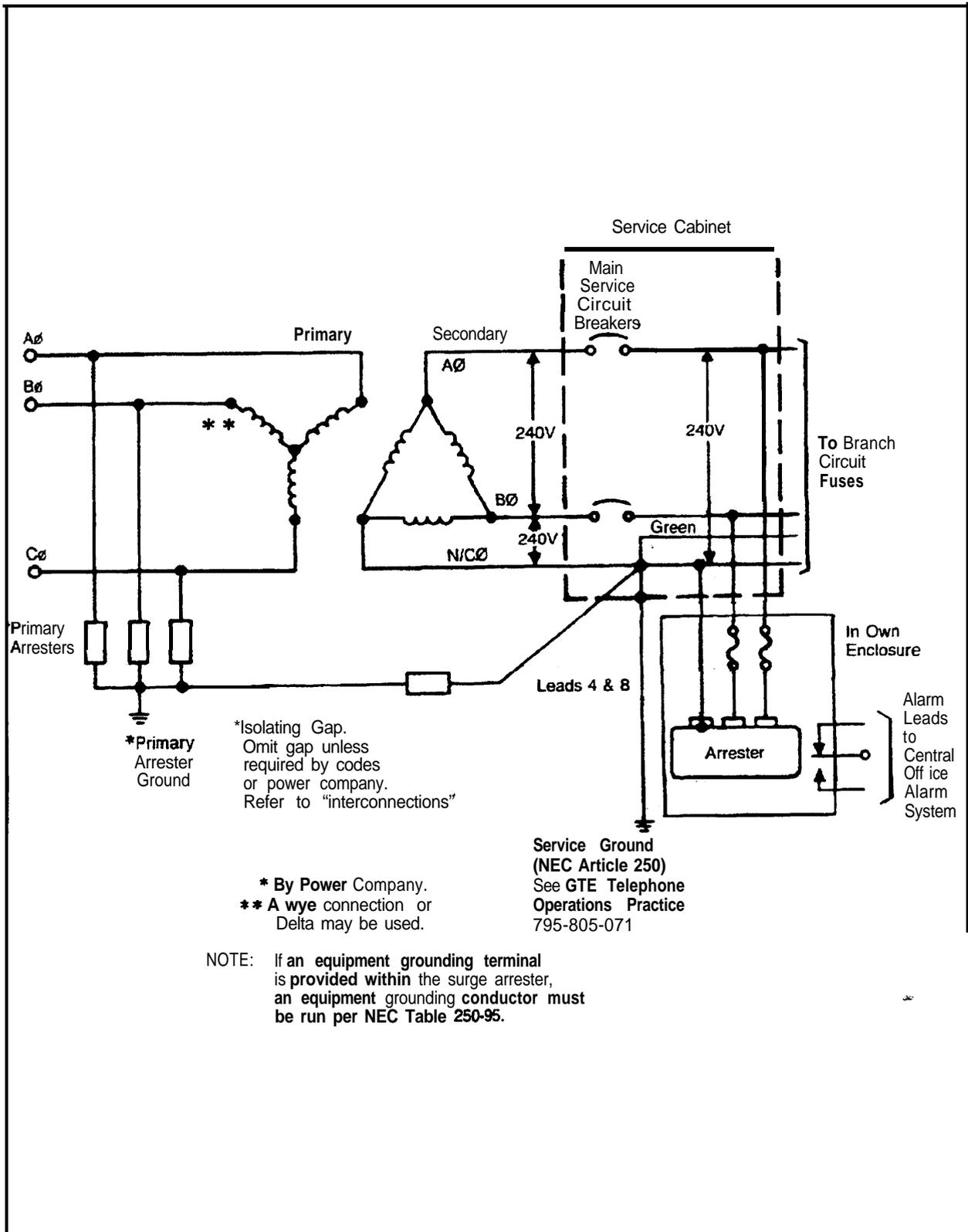


Exhibit 16 - Connection Diagram for a 240 Vac, Three-Phase, Three-Wire, Corner Grounded Delta Service from a Three-Phase, Three-Wire, Wye-Remote or Ungrounded System or from a Three-Phase, Three-Wire Delta Primary

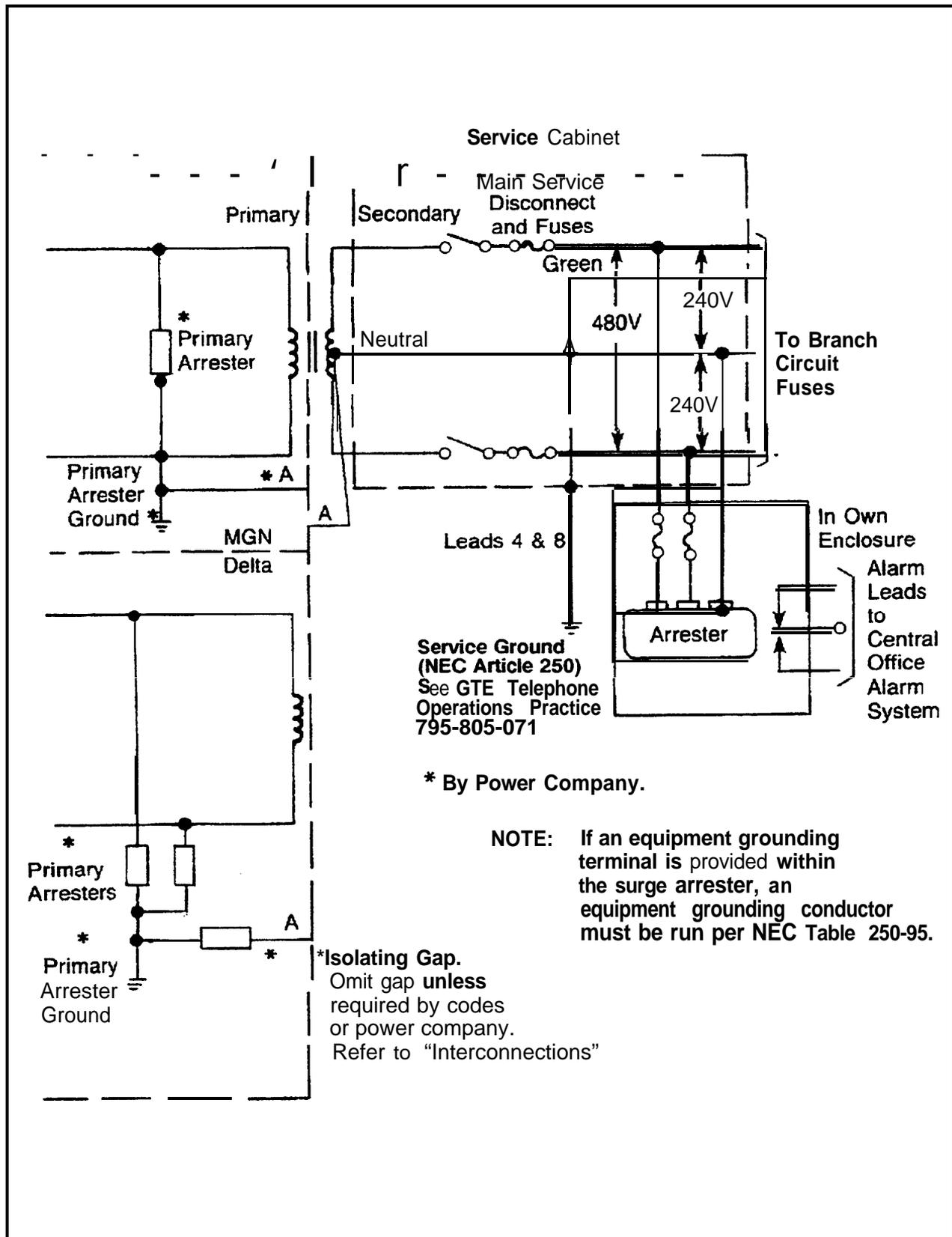
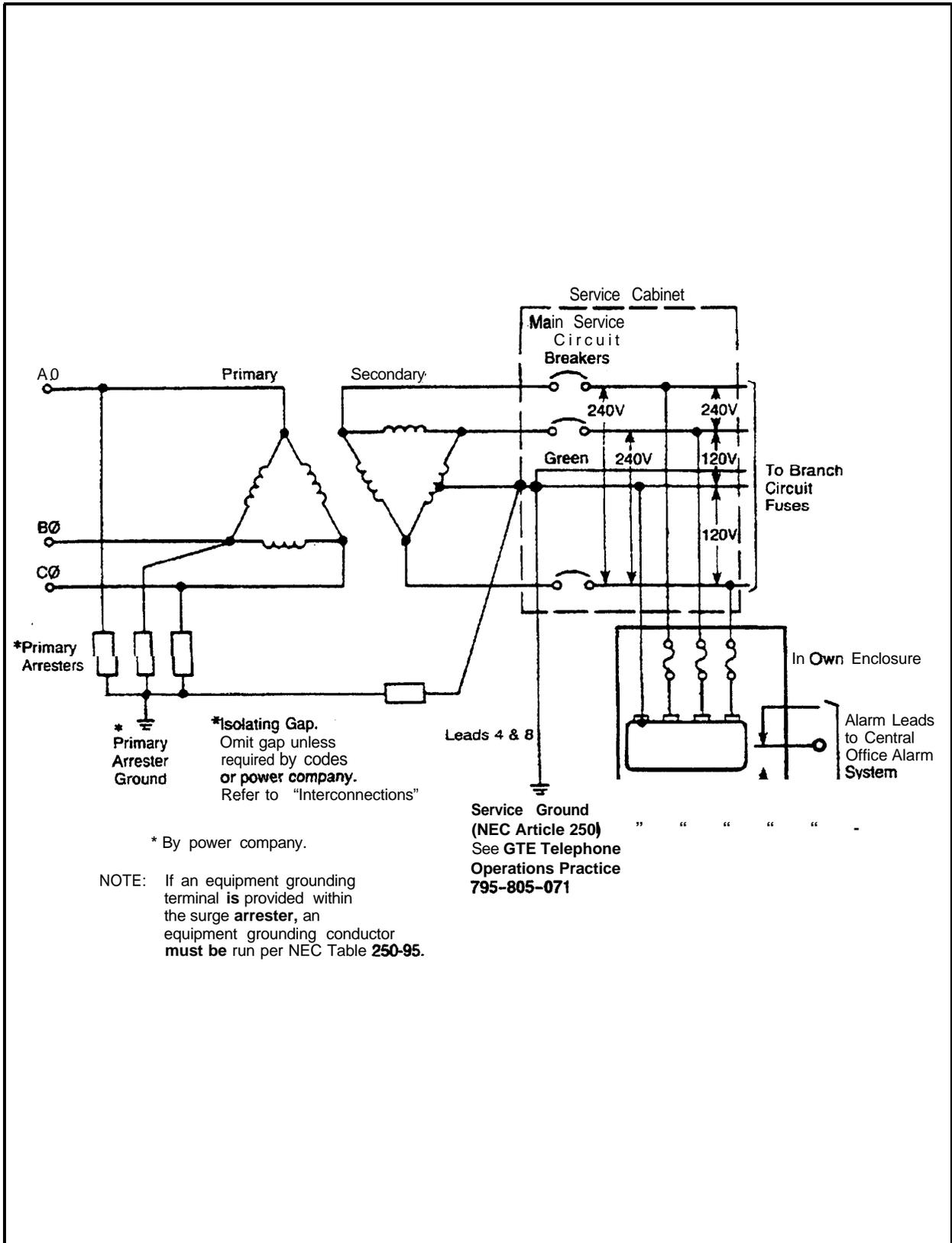


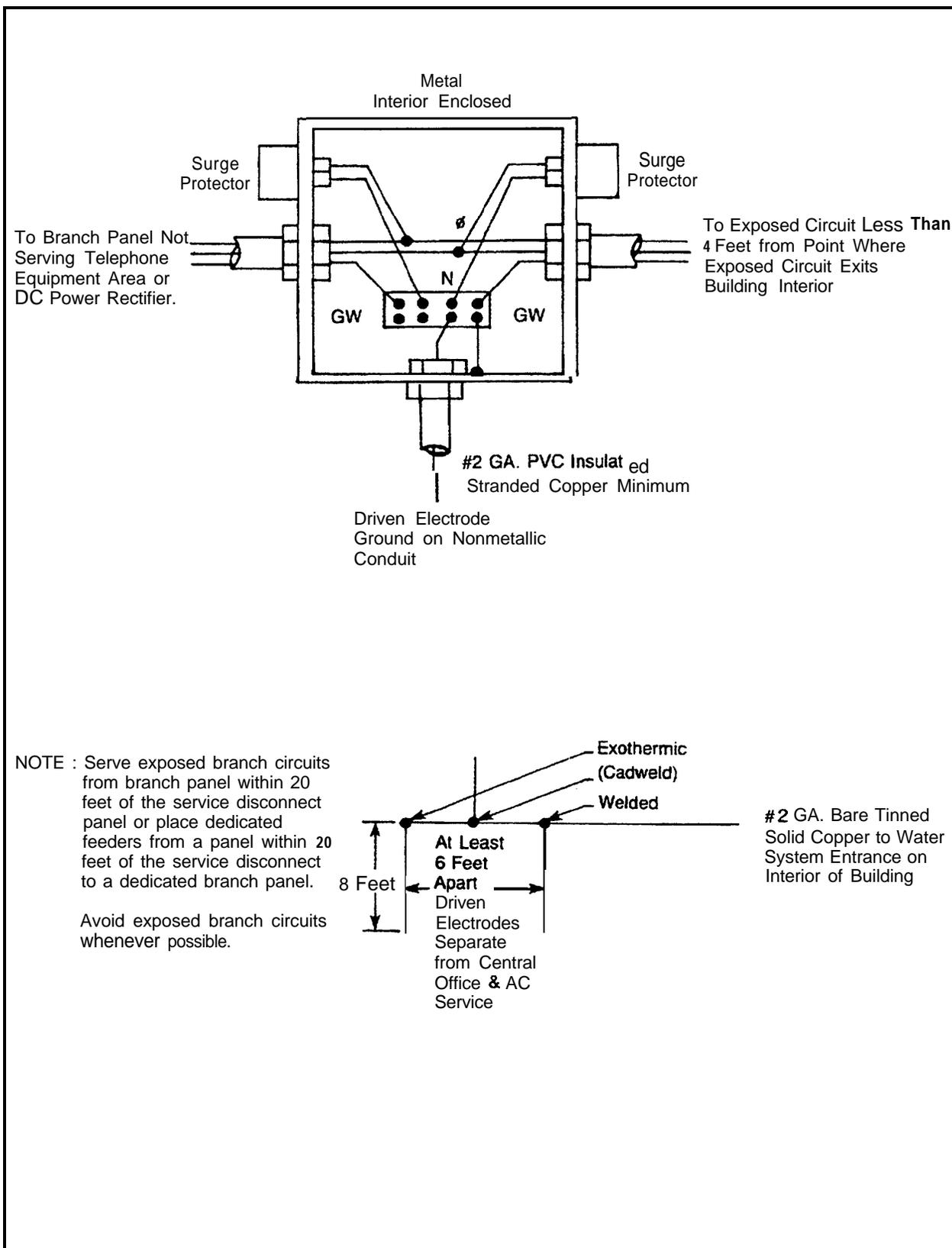
Exhibit 17 - Connection Diagram for 240V/480 Vac, One-Phase, Three-Wire Grounded Neutral from a One-Phase, Ungrounded Delta or Multigrounded Neutral Primary

# Exhibits, continued



**Exhibit 18 - Connection Diagram for 240 Vac, Three-Phase, Four-Wire, Center-Tap Grounded Delta Service from a Three-Phase, Three-Wire, Ungrounded Delta Primary**

# Exhibits, continued



**Exhibit 19 - Exposed Branch Circuit Protection (Other than Tower tights)**