CHAPTER

2

GROUNDING AND BONDING

After reading this chapter and completing the exercises, you will be able to:

- Discuss how grounding and bonding work
- Differentiate between "grounding and bonding systems" and "grounding and bonding equipment"
- Understand cable protection and equipment-grounding practices
- Identify the three types of telecommunications circuit protectors
- Understand how documentation helps you and your network

The grounding and bonding of telecommunications cable and equipment are essential to any installation. This chapter provides basic information and application instructions for all the key aspects of grounding and bonding. The standards and practices used in this chapter are in accordance with the relevant standards organizations.

Every effort has been made to ensure that the recommendations in this chapter are technically accurate and provide necessary site, equipment, environmental, and safety requirements. However, local or regional conditions may require additional investigations or safeguards. You should always consult the applicable international, federal, state, and local requirements.

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A Closer Look at Grounding and Bonding

When studying grounding and bonding, you must understand the applicable codes and standards, their origins, and the basic terms used throughout the specifications. Many of the terms are specific to the practices of grounding and bonding.

Codes, Standards, and Organizations

The organizations responsible for the following standards are the four main sources for information about grounding and bonding codes and practices.

- **National Electrical Code (NEC)** — As stated in Article 90-1 of the NEC, the code's purpose is the practical safeguarding of people and property from electrical hazards. Compliance with the NEC and proper maintenance will result in a hazard-free installation. This safety code is written and administered by the **National Fire Protection Association® (NFPA)**.
- **ANSI/EIA/TIA-607: Commercial Building Grounding and Bonding Requirements for Telecommunications** — This standard specifies a uniform infrastructure for telecommunications grounding and bonding within commercial buildings. It also provides specific guidelines for designing the grounding and bonding system.
- **Underwriters Laboratories UL-497: Protectors for Paired Conductor Communication Circuits** — Underwriters Laboratories Inc. is an independent testing lab that defines safety standards for electrical equipment. UL-497 applies to telecommunications.
- **IEEE Standard 142-1991: Grounding of Industrial and Commercial Power Systems** — This international standard, which is very similar to ANSI/EIA/TIA-607, specifies a uniform grounding system for industrial and commercial power systems within commercial buildings.

Grounding, Bonding, and Effective Ground

Grounding and bonding are actually two separate concepts. One way of distinguishing the two is to consider one as the physical medium and the other as the method for creating that medium. A **ground**, the physical medium, is a conducting connection between an electrical circuit or equipment and the earth, or to some other conducting body that serves in place of the earth. Grounding is the backbone of effective protection for all telecommunications systems.

Bonding, the method, is the permanent joining of metallic parts to form a conductive path that ensures electrical continuity and safely conducts current. An **effective ground** is an intentional connection to a low-resistance earth ground that permits current to discharge into the earth without buildup of hazardous voltages on the **cable**, equipment, or people.

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Grounding and Bonding Components

The telecommunications grounding system is made up of several components. When designed and installed following the appropriate codes, specifications, and safety practices, these components create a system that effectively safeguards personnel, property, and equipment. Figure 2-1 illustrates a typical grounding and bonding network.

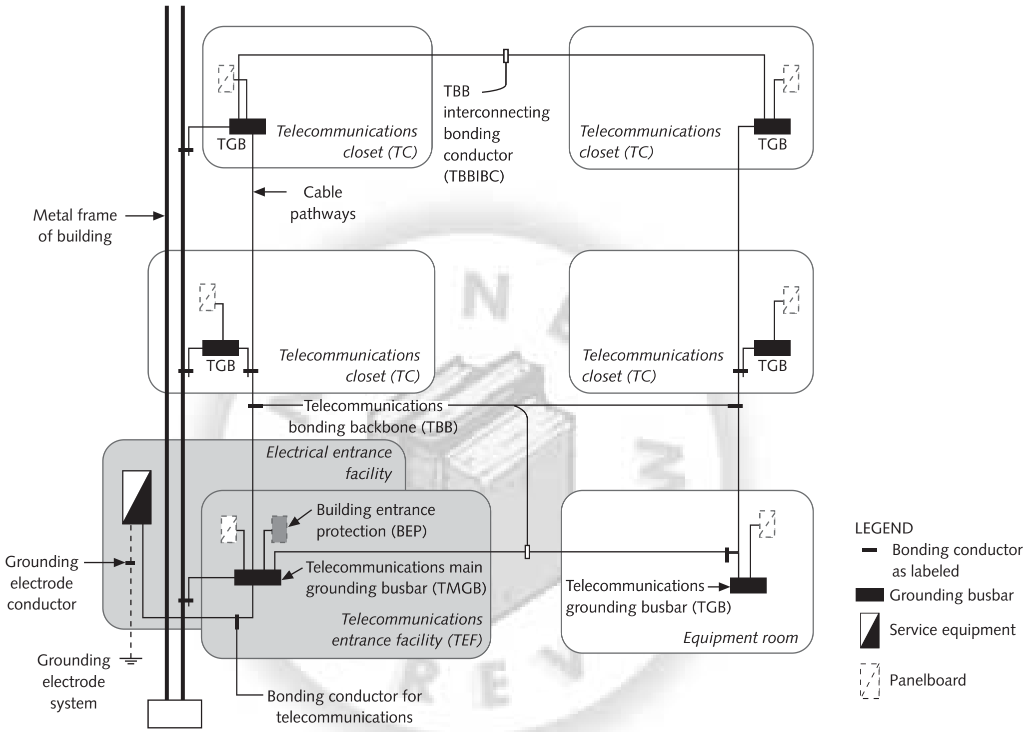

Figure 2-1 Grounding and bonding network

The most common hazard in these networks is electric shock, which occurs from accidental contact with energized devices or circuits. Shock hazards include touching a faulty or improperly grounded electrical component, standing on a damp floor while working on or near electrical equipment, and using or being near conducting material during a lightning storm.

The effects of electrical current on the human body are primarily determined by the magnitude of the current and the duration of the shock. If a person makes contact between an object that has voltage and another object that is grounded, the current will flow through those contact points. The amount of current that can be forced through a body is usually determined by the electrical voltage on the energized circuit. Currents as low as 20 **mA** (20 **milliampere**, or 20/1000 **ampere**) for a fraction of a second are enough to kill a person. Although strong electric shock can kill by damaging vital organs, lower currents can also cause injuries and death from involuntary muscle reflex reactions.

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Next you will learn the individual components of a grounding and bonding network. To begin, every building has a **grounding electrode**, a conductor or group of conductors that provides a direct, low-resistance connection to the earth. A **grounding conductor** connects the electrical equipment to the grounding electrode and the building's main grounding **busbar**, a conductor that serves as a common connection point for two or more circuits.

Bonding Conductor for Telecommunications

Any conductor used specifically for bonding is called a **bonding conductor**. For example, the conductor that connects the building's service (power) equipment ground to the telecommunications grounding system is called the **bonding conductor for telecommunications (BCT)**. The BCT is a No. 6 **AWG (American Wire Gauge)** or larger insulated copper conductor that connects the equipment ground to the telecommunications main grounding busbar.

Telecommunications Main Grounding Busbar

The telecommunications main grounding busbar (TMGB) is the foundation of the telecommunications grounding system (Figure 2-2). The TMGB is a solid copper busbar with insulated standoffs. It is ¼" thick, 4" high, has a variable length, and is drilled with rows of holes according to the **National Electrical Manufacturers Association (NEMA)** standards for the attachment of bolted compression fittings.

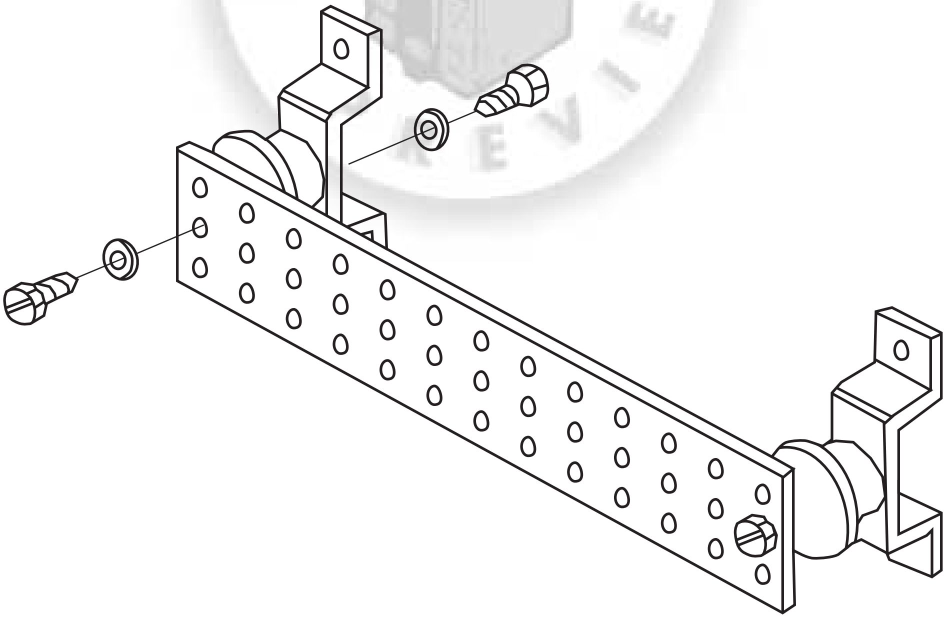

Figure 2-2 Typical telecommunications main grounding busbar

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The TMGB serves as an interface between the building's service equipment (power) ground and the telecommunications infrastructure. The TMGB also serves as a central connection point for the telecommunications bonding backbone (TBB) and equipment.

There is usually only one TMGB per building. It is typically located in the **entrance room (facility)**, the entrance to a building for both public and private network service cables, or the **main telecommunications room**. This room is the main equipment room or main cross-connect for the interconnection of entrance cables, first-level backbone cables, and equipment cables. The TMGB should minimize the length of the BCT and TBB.

Telecommunications Grounding Busbar

In each telecommunications room the telecommunications grounding busbar (TGB) provides a common point of connection for systems and equipment bonding to ground (Figure 2-3). The TGB is a solid copper busbar with insulated standoffs and the same dimensions and drill holes as TMGBs. The TGB should be installed as close as possible to the panelboard in the telecommunications room.

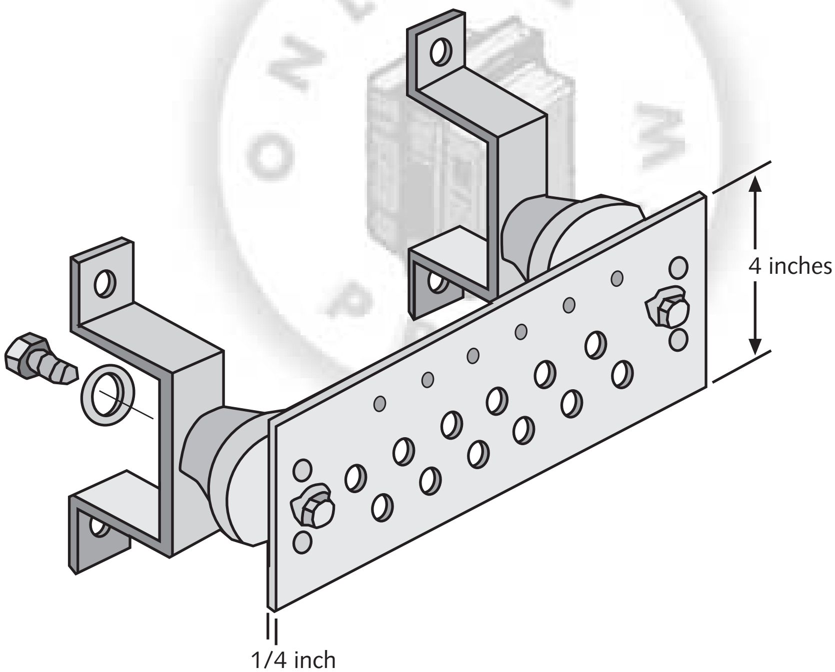

Figure 2-3 Telecommunications grounding busbar

If a **backboard** (a panel for mounting system hardware and equipment) is located in the same room as a TGB, it should be bonded to the TGB.

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Telecommunications Bonding Backbone

The TMGB and all TGBs are interconnected by a No. 6 AWG or larger insulated conductor called the telecommunications bonding backbone (TBB). Its primary function is to reduce or equalize differences in the telecommunications systems bonded to it. The TBB is considered a part of the grounding and bonding infrastructure (the telecommunications pathways and spaces in the building structure), but it is independent of all equipment and cable.

The TBB begins at the TMGB and extends throughout the building, using the telecommunications backbone pathways. The TBB is connected to the TGBs in all of the telecommunications rooms. When TBBs and other TGBs are located in the same space, they all must be bonded to one TGB.

When planning the TBB installation, the following design considerations are important:

- Be consistent with the design of the telecommunications backbone cabling system.
- You can use multiple TBBs if the size of the building permits it.
- The bonding conductors used between a TBB and TGB must be continuous and routed in the shortest, most direct path as possible. Plan the route to minimize the length of the TBB.
- Do not use interior water pipe systems of the building as a TBB.
- Do not use metallic cable shields as a TBB in new installations.
- When there are multiple vertical TBBs, they must be bonded together at the top floor, and at a minimum of every third floor in between, using a telecommunications bonding backbone interconnecting bonding conductor.
- Install TBBs without the use of splices.

All of the foregoing items—the grounding electrode, grounding conductor, BCT, TMGB, TGB, and TBB—together form the **ground system**. This system of hardware and wiring provides electrical paths from the telecommunications cabling and equipment to the earth-ground point. The primary responsibility of this system is the safeguarding of personnel, property, and equipment from **foreign electrical voltages** and currents. Foreign voltage is any voltage imposed on a system that is not supplied from the central office, telephone equipment, or the system itself.

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GROUNDING AND BONDING—SYSTEM VS. EQUIPMENT

A building has six types of grounding and bonding systems, and each performs a unique function. The combination of the following systems provides the overall protection for the building and its occupants, so their design and installation must be coordinated.

- Lightning protection system
- Grounding electrode system
- Electrical bonding and grounding system
- Electrical power protection system
- Telecommunications bonding and grounding system
- Telecommunications circuit protector system

This chapter focuses on telecommunications bonding and grounding and the telecommunications circuit protector. It is important, however, to understand the purpose of each grounding system.

Each type of telecommunications equipment has its own grounding and bonding specifications. These specifications are separate from grounding systems, and are in addition to the general rules specified in NEC Article 250.

Grounding Systems

The following sections explain each grounding system. These systems are separate from the grounding of equipment, which is described in a later section.

Lightning Protection System

A lightning protection system provides a designated path for lightning current to travel. Lightning protection systems neither attract nor repel lightning strikes; they simply intercept and guide the current to ground, preventing harm to the building and any occupants.

Lightning protection systems are made up of several components, as shown in Figure 2-4. **Air terminals (lightning rods)** are slender rods that are usually installed on a roof at intervals defined by industry standards (not exceeding 20 feet). The **conductors** are copper or aluminum cables that interconnect the air terminals and the other system components. **Ground terminations (ground rods)** are metal rods that are driven at least 10 feet into the earth to guide lightning current harmlessly to ground. To protect computers and other office equipment from rapid rises in current or voltage, called **surges** or **transients**, you should install **surge arresters** at the main electrical panel and **surge suppressors** in each outlet.

The telecommunications ground must be bonded to the lightning protection system within 3.7 meters (12 feet) of the base of the building, and may need additional bonding depending on the spacing, building dimensions, and construction.

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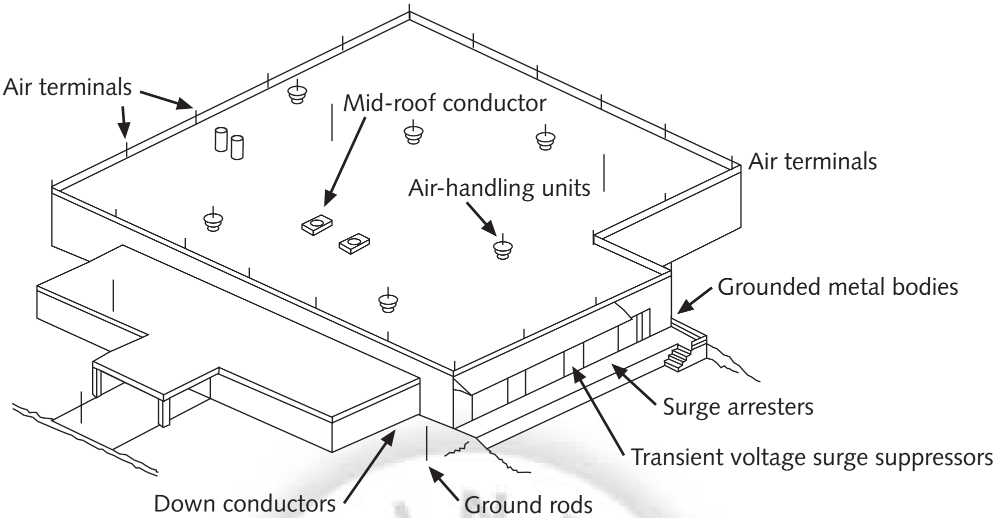

Figure 2-4 Lightning protection system

Grounding Electrode System

The **grounding electrode system** is the end product of bonding together all metal underground water pipes, the metal frame of the building, any electrode that is encased in concrete, any ground ring, and any **made and other electrodes**. These electrodes are not specified in NEC Article 250H, but defined instead in NEC Article 250, section 83, subsections b–d. They include rod and pipe electrodes, plate electrodes, and metal underground systems such as piping systems. The grounding electrode system forms a single, reliable ground for a building. NEC Article 250H, sections 81–86, defines the specifications for this system.

Electrical Bonding and Grounding System and Electrical Power Protection System

Both the electrical bonding and grounding system and the electrical power protection system refer to the general requirements for all electrical installations. They include specific requirements for grounding systems, circuits, and equipment; the circuit conductor ground; the location of grounding connections; the types and sizes of grounding and bonding conductors and electrodes; the methods of grounding and bonding; and conditions in which a substitution for grounding is permitted. All of the specifications are covered in depth in NEC Articles 250A and 250B.

Three scientific principles guide telecommunications bonding conductors:

- **Equalization — Potentials**, the measured voltages between different ground points, are very dependent on the **impedance**, the total opposition to the flow of electrical current between these points. Ground equalization is improved because the additional bonding lowers the impedance between different ground

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points. Bonding conductors should be routed with minimum bends or changes in direction, with bonding connections made directly to the points being bonded, and without unnecessary connections or splices in the bonding conductors. The shortest, most direct path and the use of large conductors provide for low impedance. Multiple conductors or wide strips provide even lower impedance.

NOTE: When splices are unavoidable, always use approved connectors and make the splice accessible.

- **Diversion** — Because the bonding conductor follows the telecommunications cable and is directly connected to system grounds at each end, electrical transients that are forced down the cable path are diverted by the bonding conductor and are less likely to influence the telecommunications conductors.
- **Coupling** — The closer the bonding conductor is to the telecommunications cable, the greater the mutual electromagnetic coupling. Coupling tends to partially cancel electrical transients when they reach the telecommunications equipment. A tightly coupled bonding conductor or a backbone cable shield is often called a coupled bonding.

The effect of each principle varies from building to building, and depends on a range of factors. It is often difficult to predict or measure specific results, but using any combination or all three principles is usually beneficial to the telecommunications equipment.

The type of bonding conductor (Figure 2-5) used in most commercial buildings depends on the application and the fault-current-carrying capacity needed. Bonding conductors should be copper, must be insulated, and must be at least No. 6 AWG. (The ANSI/EIA/TIA-607 specification also suggests consideration of No. 3/0 AWG copper conductors.) In addition, bonding conductors should not be placed in metal conduits, cable trays, or **raceways**, and must be marked appropriately, using a green label. (A raceway is any enclosed channel designed for holding wires, cables, or busbars.)

NOTE: If you must use metal conduits, cable trays, or raceways, you must bond both of their ends to bonding conductors.

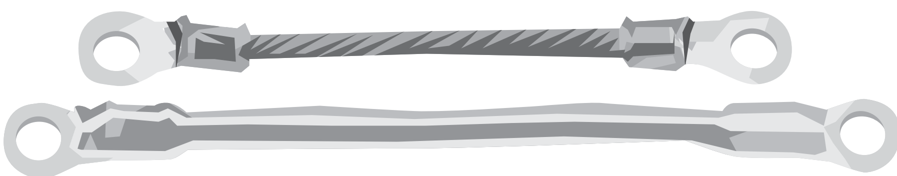

Figure 2-5 Typical grounding and bonding conductors

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Equipment Grounding

Each type of grounding equipment has its own set of grounding and bonding specifications, in addition to the general rules specified in NEC Article 250.

Two different methods are used for grounding, and each serves a different purpose. These methods, equipment grounding and earth grounding, must be kept separate except for a connection to prevent differences in potential from a possible flashover during a lightning strike.

The primary purpose of **equipment grounding** (safety grounding) is to remove potentially dangerous voltage from the equipment. It also protects against electrical shock and prevents heat buildup in the equipment due to a **ground fault**, current misdirected from the hot (or neutral) lead to a ground wire, box, or conductor.

Earth grounding is an intentional connection from a circuit conductor, usually the neutral, to a ground electrode placed in the earth. Besides protecting people and equipment, an earth ground provides a safe path for the dissipation of **fault currents**, lightning strikes, static discharges, EMI and RFI signals, and interference.

Earth Grounding and Bonding Specifications

The NEC requires earth grounding and bonding of telecommunications equipment, antennas and lead-in cables, and network-powered broadband communications systems. These specifications and requirements are published in NEC Article 800D-40.

The communications system grounding conductor should be bonded at the nearest accessible location to any of the following earth-ground locations:

- The building or structure grounding electrode system
- The grounded, metallic water-piping system within the building
- Any power service that is external to enclosures, such as exposed metallic service raceways, exposed grounding electrode conductors, or any other approved means for the external connection of a corrosion-resistant conductor to the service raceway or equipment
- The metallic power service raceway
- The service equipment enclosure
- The grounding electrode conductor or the grounding electrode metal enclosure
- The grounding conductor or grounding electrode of a separate building that is grounded to another electrode in a junction box, panelboard, or similar enclosure immediately inside or outside the building

The bonding jumper must be no smaller than AWG 6 copper or equivalent; you must connect it between the communications system grounding electrode and the building's power grounding electrode system.

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Termination is the connection of a cable or wire to connecting hardware. You must terminate the earth ground to the grounding electrode using one of the following methods:

- **Exothermic welding** — A method of permanently bonding two metals together with a controlled heat reaction that results in a molecular bond. See Figure 2-6 for an example.
- **Listed lugs or listed clamps** — Two types of connectors used for connecting the earth ground to the grounding electrode. These connectors must always be made of the same material as the conductors.
- **Listed pressure connector** — A device that establishes a connection between two or more conductors or between one or more conductors and a terminal. This device uses mechanical pressure to make connections, not soldering.

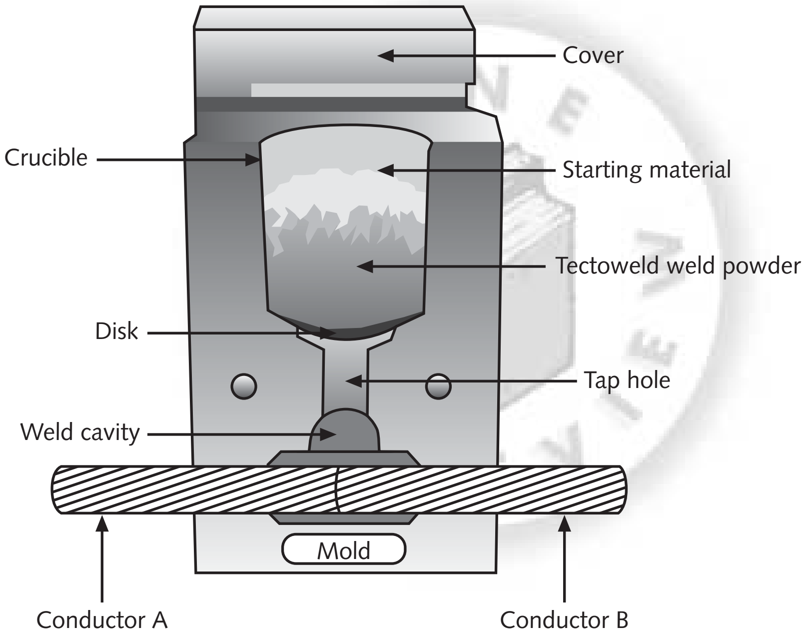

Figure 2-6 Typical exothermic weld

When the earth-ground termination is to a pipe or rod, or is buried, it must be listed for direct burial and clearly labeled.

If you run the earth-ground conductor in a metal raceway, then you must bond both ends of the metal raceway to the earth grounding conductor.

Water Pipes

Underground water pipes historically have been the first choice for a grounding electrode. With the increased use of nonmetallic pipes, however, electrical systems can no longer rely on plumbing systems. Water pipes must be bonded to another electrode type.

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Exercise caution when using a water pipe as an intersystem bonding conductor; in such cases, the bonding conductor must be at least AWG No. 6 copper.

Intrinsically Safe Systems

An intrinsically safe system operates by preventing ignition of a flammable or combustible material under normal or abnormal conditions. You can use these systems in **hazardous (classified) locations**, which NEC Article 500 defines as places where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers.

A primary advantage of intrinsically safe systems is that NEC Article 504-20 allows the use of ordinary wiring. However, the system still must conform to Article 504, which may impose additional requirements that are specific to the hazardous location. Some of these additional requirements are included in Chapters 7 and 8.

Intrinsically safe systems are composed of safe interconnecting cables, cable shields, enclosures, cable trays, and raceways. All of these items must be grounded with an equipment grounding electrode, and bonded using bonding jumpers, bonding fittings, or other approved methods.

Earth Grounding of Communications Systems

The communications systems listed in this section must be earth grounded. When grounding several communications systems, you should bond them all to a common point at the building grounding electrode system. Specifications for each earth-grounded system are summarized in the following list.

- **Low-voltage circuits of less than 50 volts** — Grounding is not required for these systems; however, you must ground them when the primary power supply system exceeds 150 volts to ground, the primary power supply system is ungrounded, or the secondary conductors are installed as overhead conductors outside.
- **Telephone systems** — The protective metallic **sheath** of communications cables and primary protectors must be grounded to the earth grounding electrode as close as possible to the **point of entrance** of the phone cable to the building. Bond the telephone system's ground to an acceptable earth ground, using an AWG No. 14 or larger **insulated** copper conductor. The insulation separates wires and prevents conduction between them. Run the conductor in as straight a line as possible and guard it from any physical damage. If you run the conductor in a metal raceway, bond both ends to the conductor or to the same terminal or electrode to which the grounding conductor is connected.
- **Antennas, satellites, lead-in conductors, and other receiving systems** — You must ground this equipment to the earth grounding electrode. The grounding of the antenna mast and lead-in conductors helps protect the receiving equipment from voltage surges, as well as voltage transients that result from

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lightning. (A mast is the metal structure that supports receiving antennas; the **lead-in** is the part of the antenna cable that enters the building and continues inside to the final connection.) Each conductor of a lead-in from an outdoor antenna must be connected to a listed **antenna discharge unit**, which can be outside or inside the building as close as possible to the entrance of the conductors to the building. You must ground antenna masts and discharge units to an acceptable earth ground with an AWG No. 10 bare or insulated copper conductor. Run this conductor in as straight a line as possible.

- **CATV systems** — Earth-ground the shield of the coaxial cable as close as possible to the point of entrance to the building. Use an AWG No. 14 or larger insulated conductor that is listed as suitable, has a current-carrying capacity approximately equal to that of the coaxial cable's outer conductor, and is run in as straight a line as possible from the CATV ground to an acceptable earth ground.
- **CCTV and MATV systems** — Closed-circuit television (CCTV) and master antenna television (MATV) circuits within a building do not need to be earth grounded, unless they are connected to coaxial cable that may extend beyond the building structure and be exposed to lightning. The sheath of the coaxial cables that enter the building must be earth grounded as close as possible to the point of entrance to the building. Bond an AWG No. 14 or larger insulated copper conductor from the CCTV or MATV ground to an acceptable earth ground. Run this conductor in as straight a line as possible.
- **Sound (audio) systems** — For metal raceways and enclosures with sound circuits that operate at less than 50 volts, earth grounding is not required unless the cables are exposed to lightning. If the sound circuits operate at 60 volts to ground or more, you must ground their metal enclosures and raceways and provide an equipment grounding conductor.
- **Network-powered broadband communications systems (NPBCS)** — The sheath of an NPBCS cable that enters a building must be grounded to an acceptable earth ground as close as possible to the point of entrance to the building. Use a conductor within the range of AWG No. 14 copper to AWG No. 6 copper for the bonding, depending on the current-carrying capacity of the cable. Run this conductor in as straight a line as possible. If you use metal raceways for the network-powered broadband entrance cable, you must bond them to an acceptable earth ground. Again, the conductor you use should be within the range of AWG No. 14 to AWG No. 6 copper.

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Cable Protection and Equipment-Grounding Practices

The communications cables, wire, and equipment inside a building are generally considered to be nonexposed. Inside cable and wire is defined by NEC Article 800-52 as any communications cables and wires that run from the equipment to the **protector**, a device used to protect facilities and equipment from abnormally high voltages or currents. These cables and wires have their own special requirements for proper installation, in addition to those for grounding and bonding telecommunications systems in commercial buildings.

All types of communications cables and wires must be rated for resistance to the spread of fire, be suitable for the installation site, and have a voltage rating of at least 300 volts. The conductors in these cables, other than fiber-optic cable, must be copper. For a complete list of cable types, including fire resistance ratings and suitable installation locations, consult NEC Article 800-51.

Specific installation requirements for communications cables and wires include:

- The separation of communications cables and electrical power cabling
- Using approved firestopping methods around the penetrations through firewalls, partitions, floors, or ceilings when cables are installed in hollow spaces, vertical shafts, and ventilation or air-handling ducts. Chapter 7 discusses firestopping in detail.
- The use of a conduit when the installation is in a space used for environmental air
- Using the exterior of any conduit or raceway as a means of support

These specifications are further defined in NEC Article 800-52.

Unshielded Backbone Cable

When you use an unshielded backbone cable, you should use a telecommunications backbone bonding (TBB) conductor with it. The TBB should be a No. 6 AWG insulated copper conductor that is routed along the backbone cable route, with minimal separation between the TBB and the cable along the entire distance. You must bond the TBB to the approved ground using a grounding busbar that is closest to the termination point of the cable.

Shielded Cable

Some indoor cables, such as coaxial, twinaxial, and shielded twisted-pair, rely on their interior shielding as a major factor in their transmission performance. These shields are usually grounded at each end to a connector panel, which you must bond to the closest approved ground with a grounding conductor of the shortest possible length.

Equipment Grounding

All manufacturers, service providers, and customers have their own requirements for grounding telecommunications equipment. The following practices most commonly apply to commercial buildings.

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In smaller equipment rooms and entrance facilities, the grounding connections on the installed equipment (e.g., protector panels and PBX cabinets for voice switching) are usually connected directly to the closest approved ground. An electrical contractor generally provides this ground. Usually a coupled bonding conductor is installed directly between the protector's ground terminal and the PBX ground terminal.

In larger buildings that have multiple equipment rooms or separate entrance facilities, multiple TGBs are necessary. Each TGB should be bonded with a minimum No. 6 AWG insulated copper conductor, directly to the nearest approved building ground. This direct bonding results in a connected set of telecommunications grounds that are distributed throughout the building.

When positioning busbars, it helps to place them where the bonding conductors can easily follow the telecommunications cabling, and where the busbars are near their associated equipment. In addition, the TMGB must provide sufficient protection to safely carry lightning and power-fault currents. Typical grounding bars and accessories are shown in Figure 2-7.

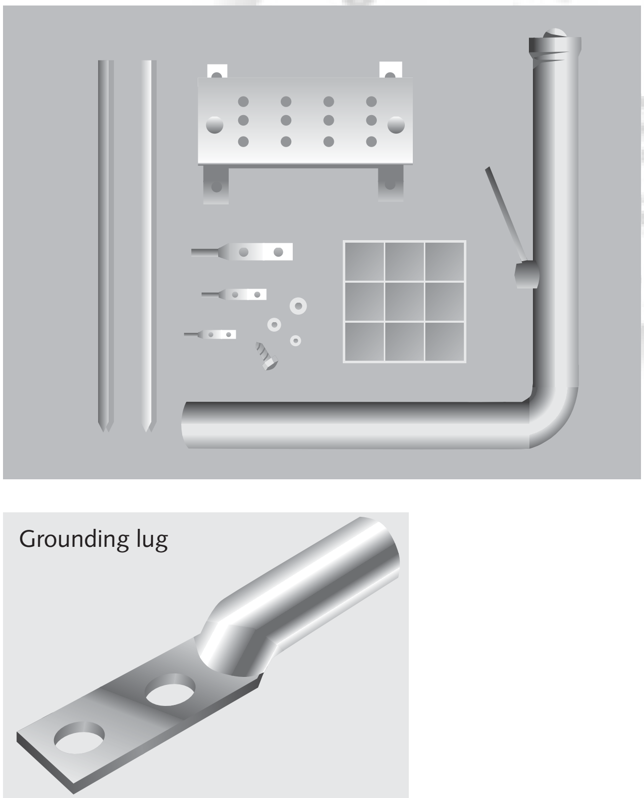

Figure 2-7 Typical grounding bars and accessories

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Telecommunications Circuit Protectors

A telecommunications circuit protector is a device that protects telecommunications facilities and equipment from abnormally high voltages and currents. High voltage and currents are usually caused by exposure to lightning, accidental contact with electrical light, or power conductors operating at over 300 volts to ground.

Based on Underwriters Laboratories (UL) standards, there are three types of telecommunications circuit protectors:

- **Primary protectors** — Primary protectors are intended for use on exposed circuits, to minimize damage to equipment due to electrical disturbances from lightning, power crosses, power faults, induction, and electrostatic discharge. These protectors must be installed as close as possible to the point where the exposed conductors enter the building. Locating the primary protector so that the grounding conductor is as short as possible will help limit potential differences between communications circuits and other metallic systems (Figure 2-8).

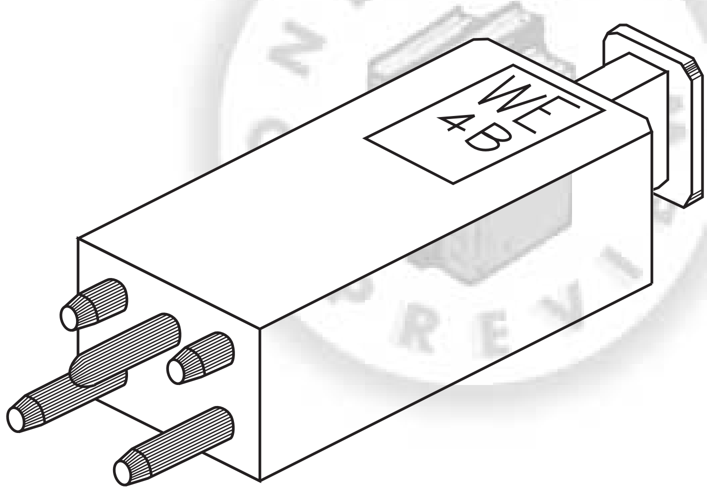

Figure 2-8 Typical primary protector module

- **Secondary protectors** — Although secondary protectors are mentioned by the NEC, they are not required. They are typically used for additional protection behind primary protectors. Besides providing voltage protection, they also protect against **sneak current**, which flows through terminal wiring or equipment at a voltage too low to make the primary protector operate. Secondary protectors can be installed anywhere, including directly behind primary protectors or at telephone set and communications terminal equipment.

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- **Data and fire alarm protectors** — These protectors are not required by the NEC, but they must provide primary protection against transients from lightning. They do not protect against power faults and should only be used according to the manufacturer's guidelines.

Because there is some functionality overlap in the available products, always consult the manufacturer concerning specific applications. However, you should always comply with the following general rules for protectors:

- A primary protector is required whenever a circuit may be exposed to electrical power faults and lightning.
- When the circuit may be exposed to lightning surges only, a primary protector or a data and fire alarm protector is required.
- When a circuit may be exposed to sneak currents, a secondary protector or a primary protector with secondary protection is required.

Some manufacturers include secondary and other forms of protection in their primary protectors. These additional functions are known as enhanced protection, and are usually provided for a specific application.

Primary Protectors

Although manufacturers use many types of materials for protection, the following materials are the most typical primary protectors:

- **Carbon blocks** — These are the original protection devices. An air gap between carbon elements is set to arc at about 300 to 1000 volts and conduct surge current to a grounding conductor. When the surge current drops low enough, the arc stops and the protector resumes its normal isolation of the ground. When a surge or fault current overheats the carbon blocks, they short permanently to ground. Carbon blocks are usually installed in pairs and are the least expensive option among primary protectors. However, they tend to wear out quickly under extreme conditions, and can cause leakage and noise on voice circuits.
- **Gas tubes** — These protection devices are an improvement over carbon blocks, although they operate in the same way—by providing an arc over a gap to a grounding conductor. Because they use a special gas, the tubes are set to a higher arc than carbon blocks; as a result, they have a higher rate of reliability. In addition, they have a tighter tolerance on arc breakdown voltage and are usually set to arc at a lower voltage than carbon blocks.
- **Solid state** — This newest type of protection device relies on high-power semiconductor technology. Although it is more expensive than carbon blocks and gas tubes, the cost of solid-state can be recovered over its extended life expectancy. Solid-state protectors are fast acting and well balanced, and do not deteriorate with age below a maximum surge current.

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Primary Protector Installation

Before selecting and installing any form of protection, the telecommunications designer should be aware of all customer and manufacturer requirements, as well as the specifications for protectors. In addition, the designer is responsible for ensuring that there are no obstructions around protectors, that protector locations will not be used for storage, and that additional space is allocated in the building entrance facility and the equipment room(s) to accommodate additional protection, even if it is not needed for the existing equipment.

When the protectors are ready to be installed, you should observe the following installation practices:

- Ensure that primary protectors are installed immediately adjacent to the exposed cable's point of entrance, and that the associated grounding conductor is routed as directly as possible to the closest approved ground.
- For long-term reliability, ensure that the installation is in a noncorrosive atmosphere.
- For personnel safety at protector locations, adequate lighting is very important.
- When a protector is installed in a metal box, bond the box with an approved grounding conductor directly to the protector's ground.
- When a new cable and protector are installed in a building beside an existing protector, bond the new protector directly to the old one, and add a separate grounding conductor for the new protector.
- When a protector must be installed outside a building, use cabinets, boxes, and mounting hardware that is listed for that purpose to avoid environmental degradation.
- Never locate primary protectors or their associated grounding near any hazardous or easily ignitable material.

Secondary Protectors

Secondary protectors must coordinate with the lightning transient and power-fault requirements of primary protectors. For this reason, secondary protectors often include one of the previously described protection device materials, and secondary protection is usually available as an option on primary protectors. When secondary protection is provided as an option, the protection device is qualified to both the UL-497 and UL-497A standards.

Because secondary protectors must handle sneak current, they are constructed differently than primary protectors. The materials used to handle sneak current are:

- **Heat coil** — This device has coils that are designed to detect low-level current by heat. The heat melts a spring-loaded shorting contact that permanently shorts the line to ground. If shorted, the heat coil requires manual inspection and replacement.

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- **Sneak-current fuse** — This fuse opens the station circuit wiring under a sustained low-level current. When opened, the fuse requires manual inspection and replacement. The fuse is placed on the station side of the protection device.
- **PTC resistors** — Positive Temperature Coefficient (PTC) resistors are used in place of sneak-current fuses. They are designed to limit sustained current as they heat. The advantage of PTC resistors is that they do not need to be replaced after the sneak-current fault is cleared.

HOW DOCUMENTATION HELPS YOU AND YOUR NETWORK

You know from Chapter 1 that documentation is important and can save you time, but you still don't have a clear picture of why it helps you and your network. The following list summarizes the advantages of keeping accurate documentation:

- It provides a comprehensive reference to help you determine hardware and software requirements for additions to the network.
- It can make additions, moves, and changes to equipment and workstations easier.
- It can be a valuable source of troubleshooting information.
- It can provide the necessary justification for adding staff or equipment.
- It helps determine compliance with standards.
- It provides proof that your installations meet a manufacturer's hardware or software requirements.
- It can help reduce training requirements, which saves time.
- It makes security management more effective.
- It helps you comply with software licensing agreements.

Keeping your documentation current and accurate helps you perform network tasks more quickly and with less chances for error. For example, just moving a workstation from one end of the office to the other can prove difficult and time-consuming unless your network configuration is properly documented. By the same token, proper documentation of the move will make future tasks easier, at least on this area of the network.

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Chapter Summary

- All telecommunications systems require grounding and bonding systems. Several associations provide codes, standards, and minimum requirements for installing these systems. ANSI/EIA/TIA-607, "Commercial Building Grounding and Bonding Requirements for Telecommunications," is the primary source of installation information. The second most important source is the NEC.
- A grounding and bonding network is made up of insulated copper conductors. These conductors are run in parallel with the telecommunications cables, and link rooms containing telecommunications equipment to a common ground. The recommended size for these conductors ranges from No. 6 to No. 3/0 AWG insulated copper.
- These conductors are bonded to solid copper grounding busbars, which are installed in the entrance facility, the main telecommunications room, and all other telecommunications rooms. In addition to the conductors that run throughout the building, telecommunications equipment, frames, cabinets, raceways, and protectors are grounded to the busbars.
- The busbars throughout the building are bonded together with a backbone cable of at least No. 6 AWG insulated copper. This backbone cable is also connected to the main grounding busbar, which is bonded to the electrical service (power) ground and an earth ground.
- Telecommunications circuit protectors are used to protect telecommunications facilities and equipment from abnormally high voltages and currents. This protection is in addition to the requirements and recommendations for grounding and bonding telecommunications systems.
- Documentation makes your job easier and helps you and your networks work more efficiently.

Key Terms

air terminals (lightning rods) — Slender rods installed on a roof at regular intervals to ground lightning current.

American Wire Gauge (AWG) — The system used to specify wire size. The greater the wire diameter, the smaller the value is.

ampere — The basic unit for measuring electrical current.

ANSI/EIA/TIA — The three associations involved in developing telecommunications industry standards. Their full names are the American National Standards Institute, Electronic Industries Alliance, and Telecommunications Industry Association, respectively.

antenna discharge unit — The bonding location for the antenna lead-in cable.

backboard — A panel used for mounting connecting hardware and equipment.

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bonding — The permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity, the capacity to safely conduct current, and the ability to limit differences in potentials between the joined parts.

bonding conductor — A conductor used specifically for bonding.

bonding conductor for telecommunications (BCT) — The conductor that interconnects the building's service equipment (power) ground to the telecommunications grounding system.

busbar — A conductor that serves as a common connection point for two or more circuits.

cable — An assembly of one or more insulated conductors within a sheath, constructed to permit use of the conductors singly or in a group.

conductors — Copper or aluminum cables that interconnect various system components. Wires through which a current of electricity flows.

earth grounding — An electrical connection to the earth obtained by a grounding electrode system.

effective ground — An electrical connection to a low-resistance ground that permits current to discharge without the buildup of hazardous voltages on the telecommunications cabling.

entrance room (facility) — An entrance to a building for both public and private network service cables.

equipment grounding — An electrical connection of the non-current-carrying metal parts of equipment raceways and other enclosures to the grounding electrode system.

fault current — *See* foreign electrical voltage.

foreign electrical voltage — Any voltage (current) imposed on a system that is not supplied from the central office, telephone equipment, or the system itself. This unwanted voltage is also known as fault current.

ground — A conducting connection, whether accidental or intentional, between an electrical circuit or equipment and the earth, or to some other conducting body that serves in place of the earth. Grounding is the backbone of effective protection for all telecommunications systems.

ground fault — Current misdirected from the hot (or neutral) lead to a ground wire, box, or conductor.

ground system — A system of hardware and wiring that provides an electrical path from a specified location to an earth-ground point.

ground terminations (ground rods) — Metal rods driven into the earth to guide lightning current harmlessly to ground.

grounding conductor — A conductor used to connect electrical equipment to the grounding electrode and a building's main grounding busbar.

grounding electrode — A conductor that provides a low-resistance, direct connection to the earth.

grounding electrode system — One or more grounding electrodes bonded to form a single, reliable ground for a building, tower, or similar structure.

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hazardous (classified) locations — A location where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers.

impedance — Total opposition to the flow of electrical current.

insulated — Coated with dielectric material that physically separates wires and prevents conduction between them.

lead-in — The part of the antenna cable that enters a building and continues inside to the final connection.

lightning rods — Slender rods installed on a roof at regular intervals to ground lightning current.

mA (milliampere) — A measure of a unit of electrical current, equal to 1/1000 of an ampere.

made and other electrodes — Any electrode not specified in NEC Article 250H, but defined in NEC Article 250, section 83, subsections b-d. These electrodes include rod and pipe electrodes, plate electrodes, and metal underground systems such as piping systems.

main telecommunications room — The main equipment room or main cross-connect for the interconnection of entrance cables, first-level backbone cables, and equipment cables.

National Electrical Code (NEC) — An electrical safety code written and administered by the NFPA.

National Electrical Manufacturers Association (NEMA) — A standards association that focuses on electrical power and grounding.

National Fire Protection Association (NFPA) — The association that writes and administers the NEC.

point of entrance — The point at which cabling emerges through an exterior wall, through a floor, or from a conduit. It can also be the point where the local service provider's cabling ends and the customer's cabling begins.

potentials — Measured voltages.

protector — A device used to protect facilities and equipment from abnormally high voltages or currents.

raceway — Any enclosed channel designed for holding wires, cables, or busbars.

sheath — A protective covering over a conductor assembly that may include one or more metallic members, strength members, or jackets.

sneak current — A foreign voltage that is too low to make an overvoltage protector operate.

surge — A rapid rise in current or voltage, usually followed by a fall back to a normal level. Also referred to as a transient.

surge arresters (suppressors) — Devices that are installed in conjunction with a lightning protection system to protect electrical wiring and electronic systems.

termination — The act of connecting a cable or wire to connecting hardware.

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transient — A rapid rise in current or voltage, usually followed by a fall back to a normal level. Also referred to as a surge.

Underwriters Laboratories — A U.S.-based independent testing laboratory that creates safety tests and standards for electrical equipment.

REVIEW QUESTIONS

1. Which organization produces codes and standards for the grounding and bonding of telecommunications systems in commercial buildings?
   a. IEEE
   b. NEC
   c. ANSI/EIA/TIA
   d. all of the above
2. The most common electric shock occurs from inadvertent contact with energized devices or circuits. Name another common shock hazard to avoid.
   a. touching a faulty or improperly grounded electrical component
   b. standing on a damp floor while working on or near electrical equipment
   c. using or being near conducting material during a lightning storm
   d. all of the above
3. The effects of an electric current on the body are primarily determined by the magnitude of currents and duration of shock. People can die when exposed to currents as low as 20 mA (20/1000 ampere) for a fraction of a second. True or False?
4. Which organization and standard specifies a uniform infrastructure for telecommunications grounding and bonding?
   a. NEC Article 250
   b. ANSI/NFPA 780, Lightning Protection Code
   c. UL-497, Protectors for Paired Conductor Communication Circuits
   d. ANSI/EIA/TIA-607, Commercial Building Grounding and Bonding Requirements for Telecommunications
5. Where must a telecommunications ground be bonded to the lightning protection system ground?
   a. anywhere there is a ground
   b. within 12 meters of the base of the building
   c. within 3.7 meters (12 feet) of the base of the building
   d. within 1 meter of the building

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6. At what voltage is safety grounding not required for the metal parts of equipment and electrical raceways of low-voltage systems?
   a. 60 volts or less
   b. less than 50 volts
   c. Safety grounds are not required for low-voltage systems.
   d. less than 100 volts
7. Metal raceways for low-voltage and limited-energy circuits that become energized by higher-voltage systems must be bonded in accordance with which standard?
   a. ANSI/NEMA
   b. IEEE 142-1991
   c. NEC Article 250-92(b)
   d. ANSI/EIA/TIA-607
8. Electrical current can create a fire from excessive heat buildup. What can cause this heat buildup?
   a. If a grounding path has a high resistance, the ground-fault current might not be significant enough to open the circuit protection device to clear the fault. This will result in dangerous voltage in all metal parts, and the buildup of ground-fault current could cause a fire.
   b. a surge of dangerous voltage
   c. an isolated grounding connector that is too long
   d. an overcurrent protection device that has a lower rating than the impedance of the grounding path
9. The NEC requires earth grounding of telecommunications equipment, antennas and lead-in cables, and network-powered broadband communications systems. True or False?
10. To which of the following earth-ground locations must the communications systems be bonded?
    a. building and structure grounding electrode
    b. metal service raceway
    c. building or structure grounding electrode conductor
    d. all of the above
11. Historically, the first choice for a grounding electrode was an underground water pipe connected to a utility distribution system. This is still the best practice today. True or False?

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12. What are the three scientific principles behind telecommunications bonding conductors?
    a. grounding, diverting, and bonding
    b. equalization, diversion, and coupling
    c. equality, impedance, and resistance
    d. resistance, equalization, and coupling
13. The telecommunications bonding backbone (TBB) is used to interconnect all telecommunications grounding busbars with the telecommunications main grounding busbar (TMGB), and is generally considered part of a grounding and bonding infrastructure, but is independent of equipment or cable. True or False?
14. What is the primary function of the TBB?
    a. to join all of the telecommunications systems
    b. to provide a common ground for all the telecommunications systems bonded to it
    c. to reduce or equalize differences between telecommunications systems bonded to it
    d. to shield the other telecommunications systems that are bonded to it
15. The TMGB serves as ________________.
    a. a central point for all the TBBs and equipment to connect
    b. the grounding electrode for the TBBs and equipment
    c. the protection for the telecommunications systems
    d. a dedicated extension of the building grounding electrode system for the telecommunications infrastructure, and as the central connection point for the TBBs and equipment
16. What is the basic function of telecommunications circuit protectors? (Choose all that apply.)
    a. to carry lightning and power-fault currents
    b. to protect against sneak current
    c. to arrest surges or overvoltages that come from exposed circuit pairs
    d. to protect against sustained hazardous currents
17. A busbar where grounding and bonding conductors can be connected is commonly referred to as a ________________.
    a. terminal ground
    b. grounding terminal
    c. grounding bus
    d. bus strip

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18. Inside cable and wiring is defined by NEC Article 800-52 as any communications cable and wire that runs from ________________.
    a. the work area to the TMGB
    b. the telecommunications room to the equipment
    c. the equipment to the protector
    d. the protector to the telecommunications room
19. Why are some indoor cables shielded?
    a. to protect the wires inside the cable
    b. to ensure transmission performance
    c. to prevent EMI
    d. to prevent electric shock
20. What is an overcurrent protective device with a circuit-opening element that is severed (opened) when heated by the passage of an overcurrent?
    a. fuse
    b. coil
    c. bond
    d. ground
21. Which device grounds a conductor when its current time limits are exceeded, and is suitable for sneak current protection?
    a. resistor
    b. circuit
    c. conductor
    d. heat coil
22. What is the total opposition that a circuit offers to the flow of current at a particular frequency?
    a. impedance
    b. resistance
    c. current
    d. inductance
23. What is the name for a network of grounded building components that includes metal underground water piping, a metal building frame, a concrete-encased electrode, a ground ring and rod, and pipe electrodes?
    a. primary protectors
    b. telecommunications grounding busbar
    c. building grounding electrode system
    d. telecommunications bonding backbone

ONLINE PREVIEW

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24. The property of a conductor that determines the current produced by a given potential difference, impedes the flow of current, and results in the dissipation of power and heat is called ______________.
    a. impedance
    b. resistance
    c. inductance
    d. current

Hands-on Projects

Project 2-1

Each of the following six systems—lightning protection, grounding electrode, electrical bonding and grounding, electrical power protection, telecommunications bonding and grounding, and telecommunications circuit protectors—is recognized as performing a unique function within a building and providing overall protection for the building and its occupants. Proper design and coordination of these systems are important.

1. Using your text, define each system and explain the purpose and importance of each.
2. Visit the following Web sites and read the articles related to the six systems. Summarize any additional or new information you acquire. If you know of any other appropriate Web sites, use them as well.
   - *www.elec-toolbox.com/usefulinfo/lightprot.htm*
   - *www.lightning.org/protect.htm*
   - *www.faqs.org/faqs/electrical-wiring/part1/section-29.html*
   - *www.epanorama.net/documents/groundloop*
   - *www.psihq.com.* Click **Informational Readings** on the home page. Select the articles you want to read from the list.
   - *www.mikeholt.com*

Project 2-2

Three equipment design methods are commonly used to protect large telecommunications equipment from residual circuit surges. List and define each of the design methods, and explain their advantages and disadvantages.

Project 2-3

Article 250 of the NEC covers general rules for telecommunications grounding and bonding. The NEC also covers some specific requirements. What are they, and why are they important?

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Project 2-4

Define earth grounding. List and explain the types of protection it provides. Some useful Web sites for this project are *www.sgscorp.com/system.htm* and *www.mikeholt.com*.

Project 2-5

Explain the importance of bonding conductors, then identify and explain the importance of their three design considerations. A useful Web site for this project is *www.uic.edu/depts/accc/telecom/art8.html*.

Project 2-6

1. Define safety grounding and earth grounding, identifying differences between the two.
2. Identify the eight communications systems that must be earth-grounded, and briefly discuss each one.

CASE PROJECTS

Case Project 1

Answer the following questions about the many guidelines for cabling inside a building.

1. Describe what might happen if the electrical power cabling were routed directly next to the communications cable.
2. Explain why the communications cable should be routed as close to the middle of the building as possible.
3. Your company is in an area that is not generally affected by weather. As the communications specialist, however, you have been asked to research lightning protection systems and write a report identifying the pros and cons of installing a system now or later.
4. Explain why it is important to ground or protect the cables leading into the building, and identify possible problems if they are not protected.

Case Project 2

Three types of telecommunications circuit protectors are defined by UL standards. List each type, explain when each one is used, and describe the composition of each type. For more information on UL-497, UL-497A, and UL-497B, go to *http://ulstandardsinfonet.ul.com*. Click **Catalog of Standards**, click **UL Standards & Outlines**, and then scroll to the appropriate standard numbers.

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Case Project 3

Discuss the installation practices for choosing a form of primary protection. In your discussion, include actions that the designer should always perform before making the choice. For assistance, go to *www.ch.cutler-hammer.com*. You then have two choices for finding relevant articles: click the **Quick Links** list box and then click **Surge Suppression**, or type **Surge Protection Devices** in the For Documents text box.

Case Project 4

Explain "sneak current" and the components used to handle it. Use the following Web sites for assistance:

- *www.its.bldrdoc.gov/fs-1037*. Search the glossary.
- *www.itwlinx.com*. Click **Articles** in the Browse box and read any articles you want.
- *www.bourns.com/pdf/2400revB1.pdf*

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