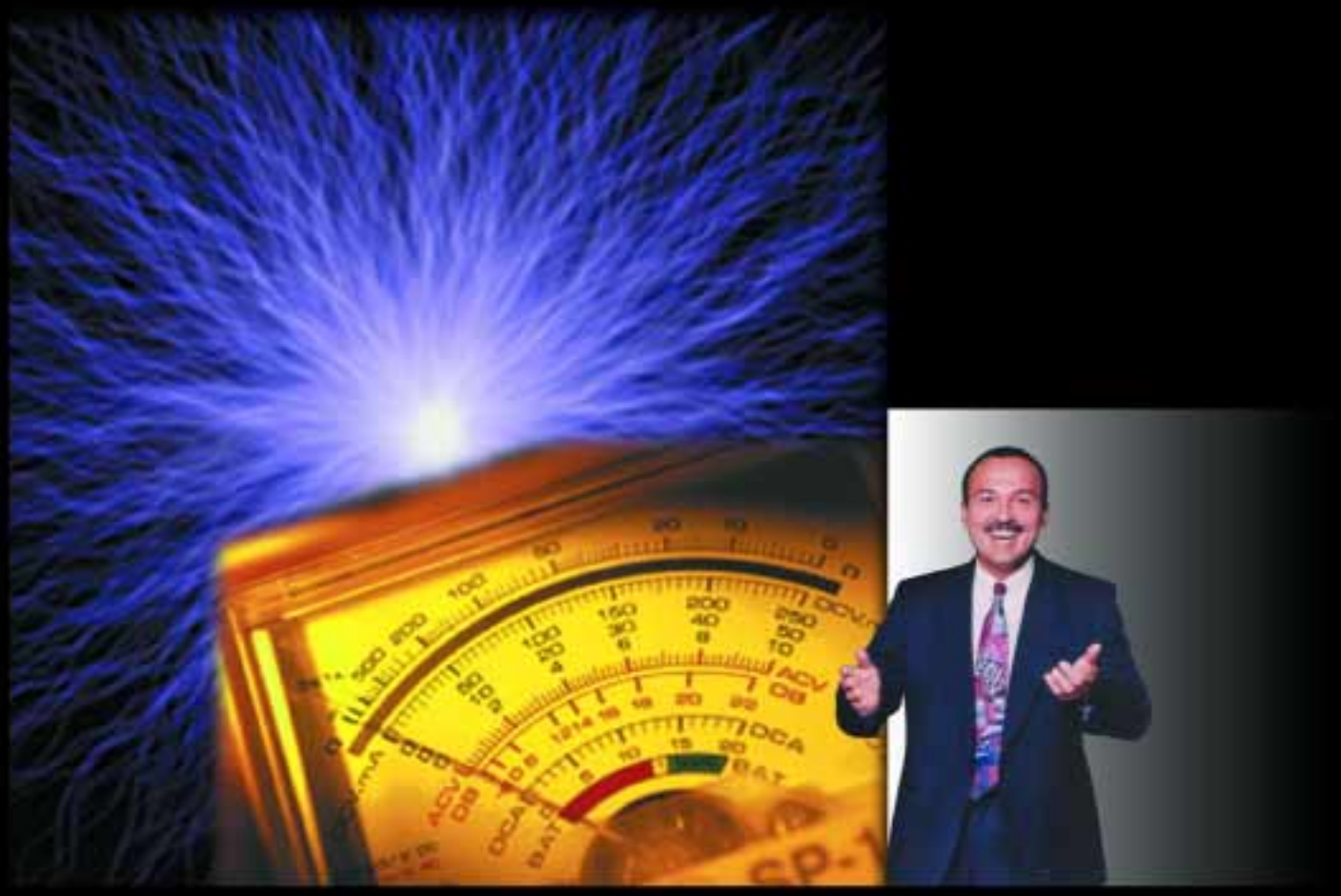
Mike Holt's Illustrated Guide

Low Voltage and Limited Energy



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Foreword

The *National Electrical Code*® (NFPA standard 70-1999) contains installation rules for all kinds of electrical products and systems. It is adopted into law by more than 42,000 states, counties, cities, and smaller jurisdictions.

Many electrical professionals, including electricians, contractors, and even inspectors, think of the *Code* primarily as a "power wiring" book. And so it is. But not just power wiring. The *National Electrical Code* also provides detailed requirements for the installation of many types of low-voltage wiring systems.

New businesses, home offices, and many homes today are having low-voltage wiring installed to meet the need for state-of-the-art technologies for audio, video, telecorurnunications, and high speed data transfer. But many electrical professionals are not familiar with the important *NEC*® safety requirements for the installation of non-power installations. Too often, low-voltage systems aren't installed properly or inspected for *Code* compliance and user safety.

Some jurisdictions don't even require electrical permits for the installation of telephone, cable TV, access control, nurse call, fiberoptic, and other low-voltage control and communications circuits-even though these systems are covered by the *National Electrical Code*.

THE NEED TO INSPECT LOW-VOLTAGE SYSTEMS

There are important safety reasons to inspect low-voltage installations for *Code* compliance. Here are just a few of them:

• Audio - Audio voltages can be as high as 70 volts AC.

• Telephone - Telephone ringing voltages can be as high as 90 volts AC.

• Shock hazard - Incorrectly instalied low-voltage wiring may accidentally become energized at line voltages, thus endangering both installers and users.

• Grounding - Proper grounding of communication circuits, CATV cables, TV and satellite masts, etc. are essential to prevent fires and electric shock from dangerous potential differences between the electrical systems.

• Working space - In general, low-voltage distribution equipment must meet the same working clearances as all other equipment rated under 600 volts [Section 110-16].

• Broadband - A new Article 830 on "Network-Powered Broadband Communications Systems" was added to the 1999 *Code*, covering futuristic Information Superhighway wiring systems for interactive multimedia services.

• Lifeline - Many jurisdictions now require that free or low-cost "lifeline" telephone service be made available to all citizens, recognizing that telephone corurnunication is not an option but a necessity in today's world. With new types of Internet and interactive services beginning to take over the function of traditional telephones, it is even more important that these alternative low-voltage systems be installed safely and reliably- in accordance with the *National Electrical Code*.

About the Author

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Unit 1. Introduction

"Low-voltage and Limited-energy" are terms not defined by the National Electrical Code. And strictly speaking optical fiber cable systems, which transmit information using high-speed bursts of light generated by tiny lasers, are "no-energy and no-voltage." In developing this book we considered various alternative terms for describing all the different technologies. But in the end, we decided to stick with "low-voltage and limited-energy" to describe these diverse systems because they are familiar terms widely understood in the electrical industry.

Articles covering Low-voltage and limited-energy devices, wiring, and systems are generally contained in Chapter 7 and 8 of the National Electrical Code. Even the Code itself seems m consider them to be an after-thought, since it groups most of them in the back of the NEC. In addition to the requirements of Chapter 7 and 8, we must be aware of the rules that apply to low-voltage lighting (Article 411), Intrinsically Safe Systems (Article 504), and Sound (Audio) Systems (Article 640). The following is a brief description of each system and its required wiring method.

NEC CHAPTER 4- EQUIPMENT FOR GENERAL USE

Article 411 - Low-Voltage Lighting

Article 411 covers listed low-voltage lighting systems consisting of an isolating power supply. Low-voltage show window and landscape lighting are examples of lighting systems required to comply with Article 411. At the time of publication, there was no listed low-voltage lighting system that complies with Article 411, but Underwriters Laboratories Inc. (UL) is currently developing a standard (UL 2108) for these systems, **Fig. 1-1.**

Power - Listed low-voltage lighting systems must operate at no more than 30 volts on the secondary, with each circuit limited to 25 amperes [411-2].

Wiring Method - Low-voltage lighting must be installed in accordance with the listed system instructions [110-3(b)] using listed systems power supply, fixtures, and cables [411-2].

NEC CHAPTER S - SPECIAL OCCUPANCIES

Article 504 - Intrinsically Safe Systems

Article 504 covers the installation of listed intrinsically safe systems, apparatus, and wiring in Class I, TI, and III hazardous (classified) locations. Intrinsically safe systems and devices such as switches, thermocouples, light-emitting diodes, connectors, and resistance temperature devices limit spark or thermal temperatures to a level that prevents ignition of flammable or combustible material.

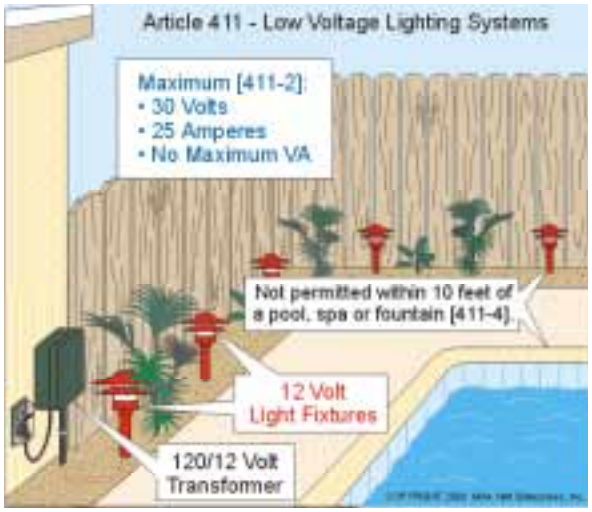


FIGURE 1-1

Wiring Method – Intrinsically safe apparatus and wiring can be installed exposed using any of the wiring methods suitable for unclassified locations, including Chapter 7 and Chapter 8 cables such as CL2 (Class 2), CL3 (Class 3), MP (multi-purpose coaxial), or PLTC (power-limited tray cable) [725-611.

NEC CHAPTER 6- SPECIAL EQUIPMENT

Article 640 - Sound Systems

Article 640 covers equipment and wiring for audio signal generation, recording, processing, amplification and reproduction; distribution of sound, public address and speech-input systems; temporary audio system installations; and electronic organs or other electronic musical instruments.

Examples of permanently-installed distributed audio system locations include but are not limited to restaurants, hotels, business offices, commercial and retail sales environments, churches and schools. Both portable and permanently installed equipment locations include but are not limited to residences, auditoriums, theaters, stadiums, movie and television studios. Temporary installations include auditoriums, theaters, stadiums, and outdoor events such as fairs, festivals, circuses, public events and concerts, **Fig. 1-2.**

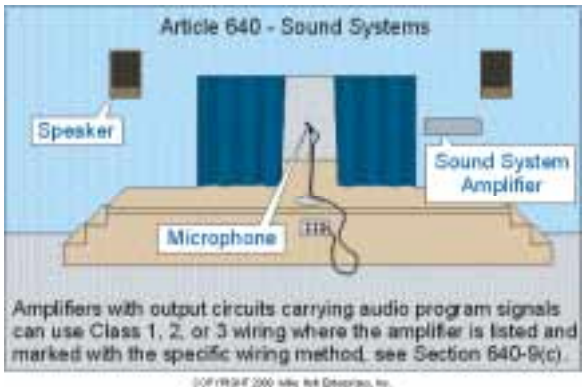


FIGURE 1-2

Note: Fire and burglary alarm signaling devices are not covered by Article 640.

Power – Limited by the listing of the product.

Wiring Method – The wiring method for sound systems are dependent on the voltage and power output limitation of the sound system equipment. It can be Class 1, Class 2 or Class 3 wiring according to the amplifier listing and marking, but generally the following applies [640-

- ***Class 2 Wiring Methods*** - Sound systems of 25 volts and not over 100 watts (typically residential systems) must be wired with Class 2 wiring methods.
- ***Class 3 Wiring Methods*** - Sound systems of 70.7 volts, and not over 100 watts (typically commercial systems) must be wired with Class 3 wiring methods.
- ***Class 1 Wiring Methods*** - All other sound systems.

NEC CHAPTER 7-SPECIAL CONDITIONS

Article 720 - Circuits Operating At Less than 50 Volts

Article 720 was originally developed for low-voltage installations known as “farm lighting plants” which operate at about 32 volts (six 6-volt batteries connected in series, allowing for voltage drop), **Fig. 1-3.** Those in rural areas who didn’t have access to electric utility power installed this low-voltage system. Today, this article applies to any low-voltage systems wiring that is not covered by Articles 411-Low-voltage Lighting, or 725-Control, Signaling and Power Limited Circuits.

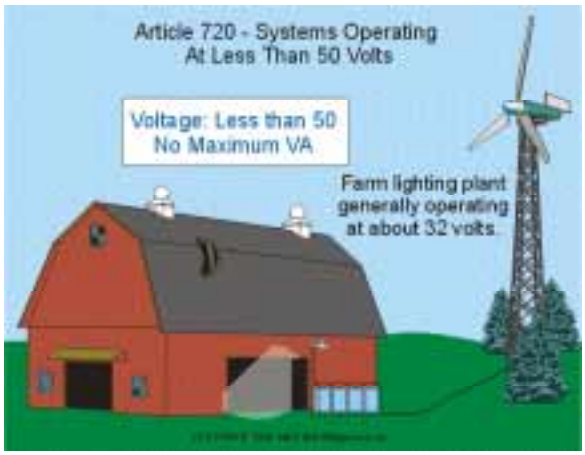


FIGURE 1-3

Power – Wiring complying with Article 720 cannot operate at more than 50 volts, but there is no power or current limitation for these systems.

Wiring Method – Section 90-3 specifies that all wiring must be installed in accordance with the general requirements of Chapters 1 through 4 unless modified by Chapters 5 through 7. Article 720 does not modify the general requirements of Chapter 1 through 4, therefore all wiring for Article 720 installations must be in accordance with Chapters 1 through 4, except that the minimum conductor size is No.12 [720-4]. This means that 600 volt insulated conductors (minimum No.12) must be installed in a Chapter 3 wiring method, splices must be in outlet boxes [300-15], and overcurrent protection must be as specified in Section 240-3.

Article 725- Remote-Control, Signaling, And Power-Limited Circuits

Article 725 contains requirements for remote-control, signaling, and power-limited circuits that are not an integral part of a device or appliance. A remote-control circuit controls other circuits through a relay or solid state device. A signaling circuit supplies energy to an appliance or device that gives a visual and/or audible signal. A power-limited circuit is used for functions other than signaling or remote-control. Article 725 classifies these types of circuits into Class 1, 2, and 3 wiring systems.

Class 7 Remote-Control and Signaling Circuit [Article 725 - Part B]

A Class 1 remote-control and signaling circuit is that portion of the wiring system between the load side of the circuit overcurrent device and the connected equipment. Class 1 circuits can operate at up to 600 volts with no ampere limitation [725-21(b)]. A motor control circuit with individual overcurrent protection is considered a Class 1 remote-control circuit and it must be installed in accordance with Article 725, Part B, **Fig. 1-4.**

Author's Comment: Motor control circuit conductors tapped to the motor branch circuit supply conductors are not Class 1 conductors, but rather motor control conductors as defined in Section 430-71. Overcurrent for these conductors must be in accordance with the values listed in Table 430-72(b), **Fig. 1-5.**

Power – Class 1 remote-control and signaling cannot operate at more than 600 volts, and there is no power or current limitation for these systems.

Wiring Method – All wiring for Class 1 remote-control and signaling circuits must be in accordance with Chapters 1 through 4. This means that 600 volt insulated conductors [725-27] must be installed in a Chapter 3 wiring method [725-25], splices must be in outlet boxes [725-25], and overcurrent protection must be as specified in Section 240-3 [725-24].

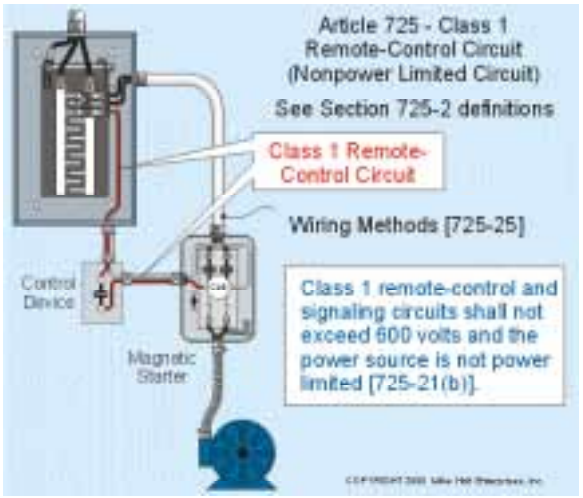


FIGURE 1-4

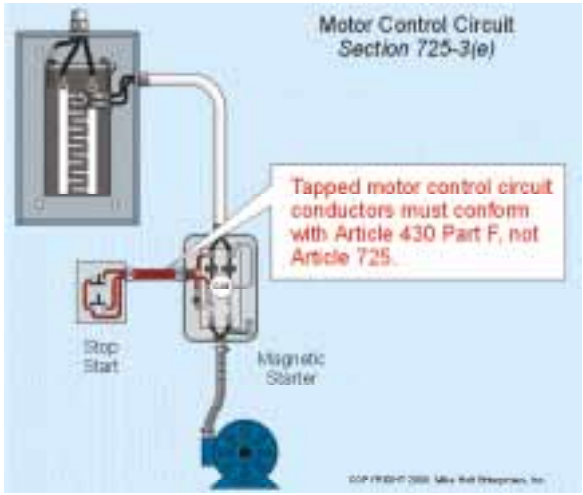


FIGURE 1-5

Author's Comment: Motor control circuit conductors tapped from the load side of a motor's short-circuit and ground-fault protective device are not considered a Class 1 remote-control circuit [725-3(e)]. The motor control tap conductors must be installed in accordance with the requirements contained in Article 725 - Class 1 Power-Limited Circuit Article 430, Part F, and not the requirements in Article 725.

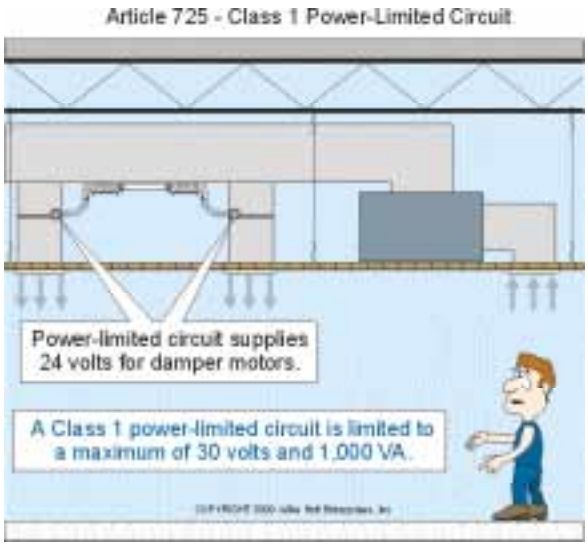


FIGURE 1-6

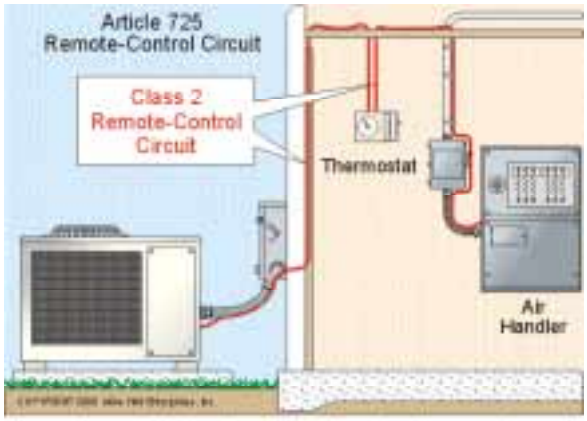


FIGURE 1-7 A remote-control circuit controls other circuits or equipment.

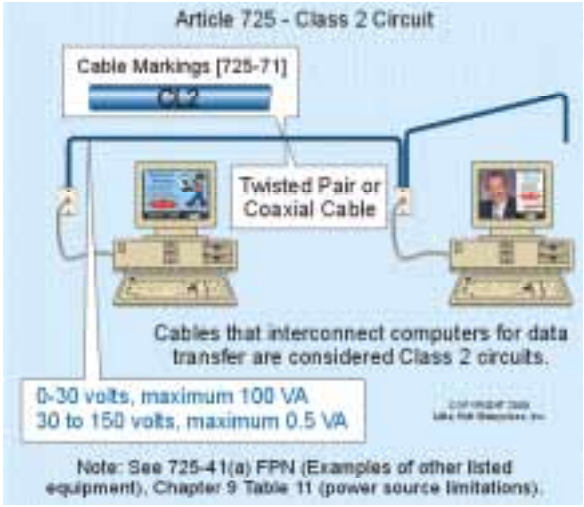


FIGURE 1-8

Power-Limited Class 1 Circuit [Article 725 Part B]

A power-limited Class 1 circuit is defined as that portion of the wiring system between the load side of the power-limited supply and the connected equipment. Power-limited Class I circuits are not as common as nonpower-limited Class 1 circuits. An example of their use would be to operate low-voltage damper motors to control environmental airflow, **Fig. 1-6.**

Power (1,000 VA) – Power-limited Class 1 circuits can be either ac or dc and must be supplied from a power source that limits the output to 30 volts and 1,000 VA [725-21(a)]. Power-limited Class 1 circuits are necessary when the energy demands of the system exceed the energy limitations of Class 2 or Class 3 circuits (100 VA) [Chapter 9 Table 11(a)].

Wiring Method – All wiring for power-limited Class 1 circuits must be installed in accordance with Chapters 1 through 4. This means that 600 volt conductors [725-271 must be installed in a Chapter 3 wiring method [725-251, splices must be in outlet boxes in accordance with Section 300-15 [725-25], and overcurrent protection must be as specified in Article 240 *[725-24]*.

Class 2 Circuit [Article 725 - Part C]

A Class 2 circuit is that portion of the wiring system between the load side of a Class 2 power source and the connected equipment. Class 2 circuits consider safety from a fire initiation standpoint and provide protection from electric shock by limiting the current [Chapter 9 Table 11(a)].

Class 2 circuits (not over 30 volts at 100 VA) include wiring for thermostats, programmable controllers, burglar and security systems, as well as limited-energy voice, intercom, background music, sound systems, and public address systems. In addition, cables (twisted-pair or coaxial) that interconnect computers for Local Area Networks (LAN) are considered a Class 2 circuit, see Section 725-41(a)(4), **Fig. 1-7** and **Fig. 1-8.**

Note: A cable that connects the modem of a computer to the telecommunications system (telephone line) is considered a telecommunications circuit and it must be installed in accordance with the requirements of Article 800.

Power - Class 2 ac power sources must be durably marked where plainly visible to indicate the class of supply and electrical rating. A Class 2 power source not suitable for wet location use shall be so marked.

Voltage Range	**Power Ampere**
O to 2O Volts	100VA 5 ampere
2l to 3OVolts	100VA 3.3 ampere
31 to 150 Volts	0.5 VA (5 milliamperes)

Wiring Method - Class 2 systems must be wired with CL2, CM, or PLTC cables [725-61] and a Chapter 3 wiring methods cannot be used [725-52].

Class 3 Circuit [Article 725 - Part C]

A Class 3 circuit is that portion of the wiring system between the load side of a Class 3 power source and the connected equipment. Class 3 circuits consider safety from a fire initiation standpoint. Because these circuits permit dangerous voltages (up to 100 volts for inherently limited power source) and power levels (100 VA) [Chapter 9 Table 11(a)], the Code contains additional requirements to safeguard against electric shock.

Class 3 circuits (over 30 volts not over 100 VA) are used for circuits operating at over 30 volts when the energy demands exceed 5 milliamperes. Examples of Class 3 circuits would include signaling circuits such as some burglar and security systems; voice, intercom, background music, sound and public address systems; as well as nurse call systems [640-2(b)].

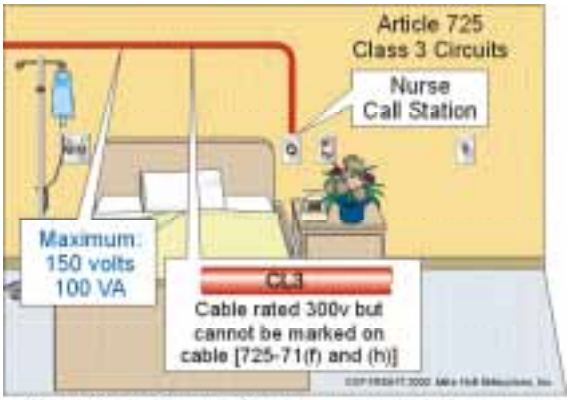
Power - Class 3 ac power sources must be durably marked where plainly visible to indicate the class of supply and electrical rating. Inherently-limited Class 3 ac power sources power shall not exceed 100 VA when the voltage is between 31 to 100 volts and not inherently-limited Class 3 ac power sources must not exceed 100 VA when the voltage is between 31 to 150 volts, Fig. 1-9.

Wiring Methods - Class 3 circuit conductors must be installed using either of the following methods:

• Class 3 cable such as CL3, CM, or PLTC listed for the application [725-61 and 725-71]. If the cables are installed in a raceway, the raceway must be mechanically installed in accordance with its normal rules. However, the raceway is not required to be grounded, see Unit 5 of this booklet.

• Single conductors not smaller than No. 18 (listed Type CL3) can be used and do not have to be installed in a Chapter 3 wiring method. These conductors can be installed as open single conductors because they have passed the vertical flame test and all the testing and listing requirements of a CL3 cable.

Note: According to Section 725-71(g) in the 1999 NEC, single conductor fixture wire installed in a raceway or cable for Class 3 circuits must be marked CL3. Some believe this was not the intent of the Code panel.



Class 3 circuits over 30 volts can have higher power capacity (100 VA) than Class 2 circuits (0.5 VA).

FIGURE 1-9

CAUTION: Class 2 and Class 3 remote-control circuits for safety-control equipment shall be classified as Class 1 if the failure of the equipment introduces a direct fire or life hazard [725-8(a)]. An example would be a boiler explosion caused by the failure of the low-water cutoff control circuit.

Article 727- Instrumentation Tray Cable

Instrumentation tray cable (ITC) is used in industrial establishments where the conditions of maintenance and supervision assure that only qualified persons will service the installation.

ITC cable is a factory assembly of two or more insulated conductors, with or without grounding conductor(s), and enclosed in a non-metallic sheath or armor. This system was added to the 1996 National Electrical Code to make legal a wiring method that had been used on off-shore oil rigs for years.

Power (750 VA) - Type TTC cable cannot be installed on any circuit that operates at more than 150 volts or more than 5 amperes [727-1].

Wiring Method - Exposed TTC cable must be listed and have a voltage rating of not less than 300 volts [727-6]. In addition, because of the dangers associated with Type ITC cables, splices must be contained in outlet boxes or conduit bodies in accordance with Section 300-15 [727-3], and overcurrent protection must be as specified in Section 727-9.

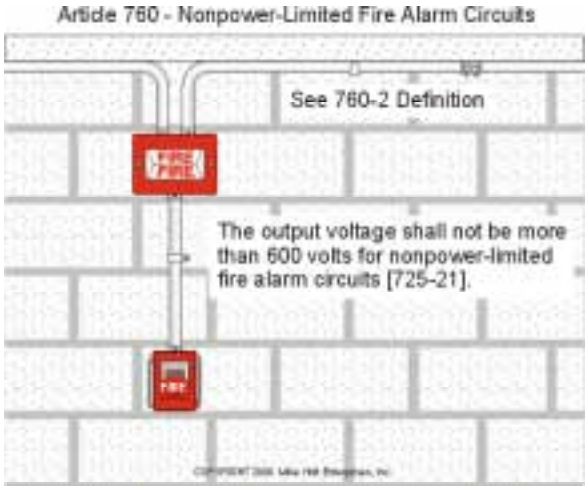


FIGURE 1-10

Article 760 - Fire Alarm Signaling Systems

Article 760 covers the installation of wiring and equipment for fire alarm systems, including all circuits controlled and powered by the fire alarm system. Fire alarm systems include fire detection and alarm notification, voice communications, guard's tour, sprinkler waterflow, and sprinkler supervisory systems. Circuits controlled and powered by the fire alarm system include elevator capture, elevator shutdown, door release, smoke doors and damper control, fire doors and damper control, and fan shutdown, but only where these circuits are powered by and controlled by the fire alarm system [760-1]. There are two types of fire alarm systems, nonpower-limited and power-limited.

Nonpower-Limited Fire Alarm (NPLFA) Circuits [Article 760 - Part B]

A nonpower-limited fire alarm circuit is that portion of the wiring system between the load side of the overcurrent protection device and the connected equipment of all circuits powered and controlled by the fire alarm system.

Power - Nonpower-limited fire alarm circuits cannot operate at more than 600 volts, and there is no power or current limitation for these systems, **Fig. 1-10**.

Wiring Methods - Nonpower-limited fire alarm circuits (not exceeding 150 volts) conductors must be installed using either of the following methods:

- An acceptable wiring method described in Chapter 3. Splices must be in outlet boxes in accordance with Section 300-15 [760-25], and overcurrent protection must be as specified in Article 240 [760-23].
- Exposed listed nonpower-limited fire alarm cable marked Type NPLFA (nonpower-limited fire alarm) cable can be used where not subject to physical damage [760-30].

Power-Limited Fire Alarm (PLFA) Circuits [Article 760- Part C]

A power-limited fire alarm circuit is that portion of the wiring system between the load side of a power-limited fire alarm transformer, Class 3 transformer or fire alarm control panel [760-

41] and the connected equipment of all circuits powered and controlled by the fire alarm system, **Fig. 1-11**.

Power-Limited Fire Alarm Circuit Power (Inherently-Limited) (ac)

Voltage	Power
Ampere	
O to 20 Volts	100VA
5 ampere	
2O to 3O Volts	100VA
3.33 ampere	
3O to 100 Volts	100 VA
1 ampere	

Wiring Methods - Power-limited fire alarm circuit conductors must be installed using either of the following methods:
• An acceptable wiring method described in Chapter 3, splices must be in outlet boxes in accordance with Section 300-15 [760-52(a)],
• Exposed Power-Limited Fire Alarm (FPL) cables, communications wires and cables (CM), and multipurpose coaxial cables (MP) [Figure 760-61] can be used where not subject to physical damage [760-52(b) and 760-61]. But all splices and devices must be installed within an outlet box in accordance with Section 300-15 [760-52(b)].

Article 770- Optical Fiber Cables and Raceways

Article 770 covers optical fiber cables used to transmit light for control, signaling, and communications. This article also contains the requirements for composite cables (often called "hybrid" in the field) that combine optical fibers with current-carrying metallic conductors.

Wiring Method - Optical fiber cable does not carry power or voltage, therefore the cable can be installed with power conductors, or with other low-voltage or limited-energy circuits [770-52], **Fig. 1-12**. Optical fiber cables must be marked "OFC." Optical fiber cables are not required to be installed within a raceway, but if installed in a raceway, it must be a listed optic-fiber raceway or of a type described in Chapter 3 of the Code [770-6].

Article 780- Closed-Loop Power Distribution

Article 780 covers the "Smart House" wiring system, which uses a special flat cable combining No.12 power conductors with Class 2 and 3 twisted-pair and coaxial conductors.

Author's Comment: Effective August 1997, Smart House, L.P declared bankruptcy. Type NMS cable described in Article 780 is no longer manufactured but is still available.

NEC CHAPTER 8- COMMUNICATIONS SYSTEMS

Chapter 8 of the National Electrical Code covers the wiring requirements for communications systems such as wiring for telephones, radio and TV antennas, satellite dishes, CCTV and CATV

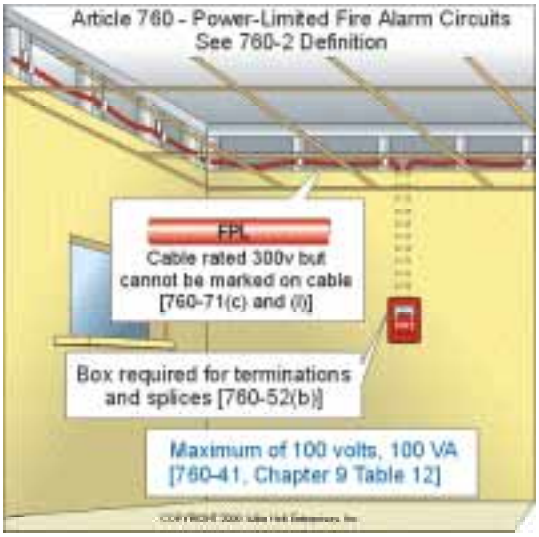


FIGURE 1-11

FIGURE 1-12

systems. The installation requirements for communications Systems contained in Chapter 8 are independent of the Code requirements for Chapters 1 through 7, except where they are specifically referenced [90-3].

Article 800 - Telecommunications (Telephone) Circuits

Article 800 covers the installation requirements for telephones and wiring for other related telecommunications purposes such as computer local area networks (LAN) and fire and burglar alarm systems connected to central stations, **Fig. 1-13**.

> **Wiring Methods** - The NEC requires telecommunications cables to have a voltage rating of not less than 300 volts [800-50 and 800-511. Cables that meet this requirement are marked CM (Communications) or MP (Multipurpose). Optical fiber cables used for telecommunications circuits must be installed in compliance with the requirements of Article 770 [800-52(a)(1)].
>
> **Author's Comment:** Cables used for computers for the purpose of exchanging data must be installed in compliance with Article 725, Class 2 signaling circuits, not Article 800 [725-41(a)(4)].

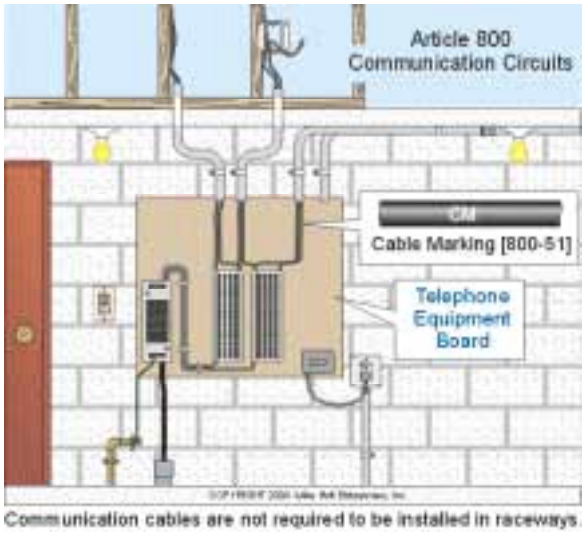


FIGURE 1-13 Communication cables are not required to be installed in raceways.

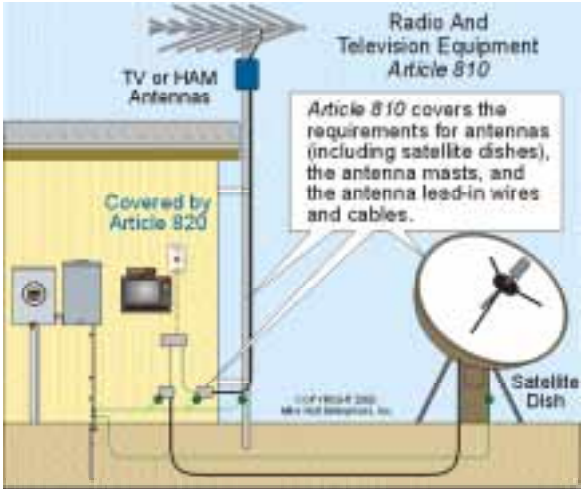


FIGURE 1-14

Article 810 - Radio and Television Equipment

Article 810 covers antenna systems for radio and television receiving equipment, amateur radio transmitting and receiving equipment, and certain features of transmitter safety. This Article covers antennas such as multi-element, vertical rod, dish, as well as wiring and cabling that connects them to the receiving equipment, Fig. 1-14.

> **Wiring Methods** - Exposed cables wiring for connecting antennas to equipment must be Type CATV or CM [Figure 820-531 installed in accordance with Article 820 [810-2] or Type OF optical fiber cable installed in accordance with Article 770 [8l0-2]. Wiring for sound systems such as "surround sound" must be installed in accordance with Article 640 - Sound (Audio) Systems.
>
> **IMPORTANT NOTE:** Neither Article 810 nor any other Article deals with power-line carrier (PLC) automation control systems, such as X-10 or CEBus. These systems transmit an electrical signal over the existing building power conductors to control receiving devices for home automation, security, and factory automation processes. Section 810-1 of the National Electrical Code specifies that equipment and antennas used for coupling carrier current to power line conductors are not within the scope of Article 810.

Article 820- Community Antenna Television Systems

Article 820 covers the installation of coaxial cables for the distribution of limited-energy high frequency signals for television, cable TV, and closed circuit television (CCTV) often used for security purposes [810-2], **Fig. 1-15.**

> **Wiring Methods** – Exposed coaxial cables must be Type CATV or CM installed in accordance with Article 820 [820-53].
>
> **Author's Comment:** Coaxial cable used to interconnect computers for the purpose of exchanging data for Local area networks (LAN) or corporate office intranets must be installed in accordance with Article 725, Class 2 or 3 circuits [725-41(a)(4)].

Article 830- Network-Powered Broadband Communications Systems

This new Article is intended to provide the necessary requirements for network-powered broadband communications systems that provide voice, audio, video, data and interactive services through a network interface unit (NIU).

An example of a network-powered broadband communications system would be hybrid fiber-coaxial (HFC) cable used for video/audio conferencing or interactive multimedia entertainment systems, **Fig. 1-16.**

Two classifications of network-powered broadband communications system circuits have been accepted for the 1999 Code and both types involve some risk of electric shock. The intent of Article 830 is that the classification limits, together with wiring methods and mechanical protection, should result in an installation equivalent in safety to those now permitted in the NEC.

Low-Power Circuits

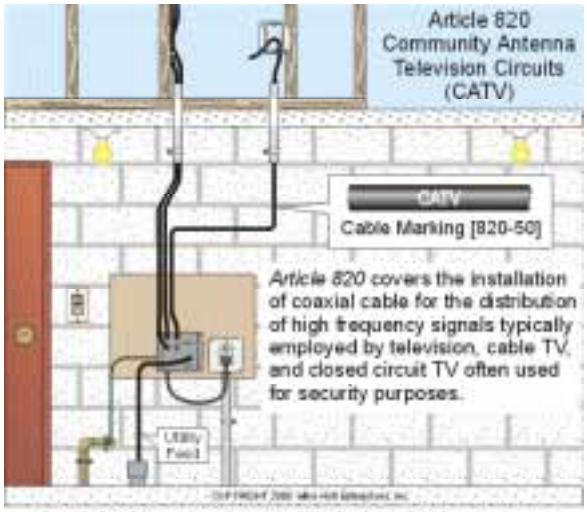
Low-power circuits are essentially the same as "Not Inherently Limited Class 3 circuits up to 100 volts and 100 VA." These circuits are intended to power one network interface unit (NIU) installed in a single family residence.

> **Wiring Methods** – Prior to January 1, 2000, existing coaxial cable types can be used for low-power broadband systems. After that date only listed Type BL (Broadband Low-power), BM (Broadband Medium-power), CM, or MP coaxial cables can be used.

Medium-Power Circuits

Medium-power circuits are similar to "Class 3 circuits up to 150 Volts and 100 VA." These circuits are intended to provide power for multiple NIUs or a single NIU with expanded capabilities. The circuit voltage of 150 volts permits greater distances between supply locations (or longer transmission lines).

> **Wiring Methods** – Only listed BM, CM, MP coaxial cables can be used.



Coaxial cables are not required to be installed in raceways.

FIGURE 1-15

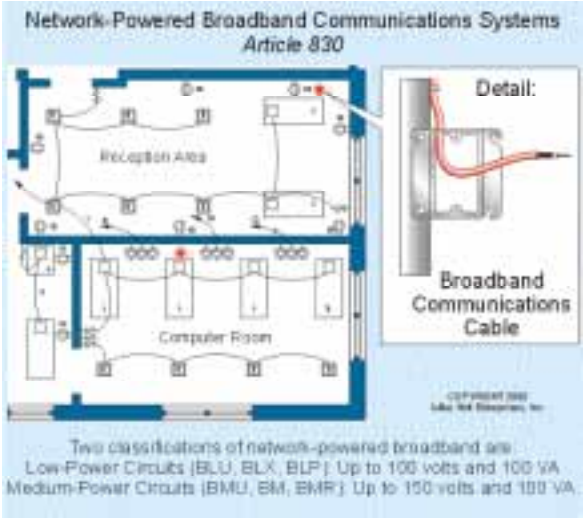


FIGURE 1-16

Unit 2. NEC Introduction [Article 90]

CODE ARRANGEMENT [90-3]

General Requirements – The general requirements of Chapters 1 through 4 apply to all installations, except for communications wiring covered in Chapter 8.

> **Author's Comment:** Only those Sections of Article 300 referenced in Sections 725-3, 760-3, and 770-3 apply to low-voltage or limited-energy wiring.

Special Requirements - The general requirements of Chapters 1 through 4 apply to all Chapters 5 through 7 wiring system, unless a specific rule in Chapter 7 modifies the general requirements or adds additional requirements. Sections 725-3, 760-3, and 770-3 modify the general rule and specify that only those Sections in Articles 300 referenced in Articles 725-, 760, and 770 apply to low-voltage or limited-energy wiring.

Example. Article 720 does not modify the general requirements, therefore all of the requirements of Chapter 3 apply systems and equipment operating at less than 50 volts.

Communications Systems – Chapter 8 contains the requirements for communications circuits such as telephone, satellite dishes, TV antennas, CATV, and network-powered broadband communications systems. The requirements of Chapter 8 are independent of Chapter 1 through 7 requirements, unless a *Code* Section in Chapter 8 makes a specific reference to those general requirements.

Tables – Chapter 9 contains tables that apply to limited-energy systems, such as Table 11 for Class 2 and 3 power limitations, and Table 12 for Fire Alarm power limitations.

ENFORCEMENT OF THE NATIONAL ELECTRICAL CODE [90-4]

The *Code* specifies the inspector's responsibilities; these include interpretation of the Code rules, determining approval of equipment, granting special permission, waiver of rules for new material requirements, and ensuring that equipment is installed properly.

Interpretation of NEC rules – Electrical inspectors have the responsibility to interpret the Code, but the inspector must have a Code rule to base the interpretation on. Electrical inspectors do not have the authority to require an electrical installation to exceed NEC requirements.

Approval of equipment and materials – The *Code* requires some equipment to be listed for its use, but it does not require all equipment to be listed. The electrical inspector determines the suitability of equipment and approves its use. The basis of equipment approval is often the listing by National Recognized Testing Laboratories (NRTL) [90-7 and 110-2]. However, the NEC requires low-voltage and limited-energy cables installed *indoors* to be listed [725-71, 770-50, 800-49, 820-49, 830-54 and 830-55]. As a result, there are currently no low-voltage or limited-energy cables listed for installations underground, outdoors, or in wet locations. Inspectors permit (approve) nonlisted cables to be installed underground, outdoors, or in wet locations where the manufacturer has identified them as suitable for this purpose, **Fig. 2-1**.

Granting of special permission – Section 90-4 gives the electrical inspector authority to permit alternate methods when an installation is not covered by the Code, or where noncompliance is necessary. But this is only permitted where equivalent electrical safety can be achieved. There will be occasions when the electrical inspector will need to grant special permission, simply so the low-voltage or limited-energy system can perform its intended function or purpose.

Ensure that equipment is installed properly – It is the inspector's responsibility to ensure that electrical equipment is installed and used in accordance with the equipment's listing or labeling instructions [1 10-3(b)]. In addition, the inspector is responsible for detecting field modification of listed equipment that could compromise the equipment's listing [90-71.

PRODUCT EVALUATION FOR SAFETY [90-7]

Evaluation of products for safety is performed by Nationally Recognized Testing Laboratories (NRTL) that publish a list of equipment that meets nationally recognized test standards. Product listing decreases the need for inspectors to re-inspect or evaluate the electrical equipment at the time of installation. Listing and labeling by NRTL is the primary basis for equipment approval by electrical inspectors [90-4 and 1l0-2J.

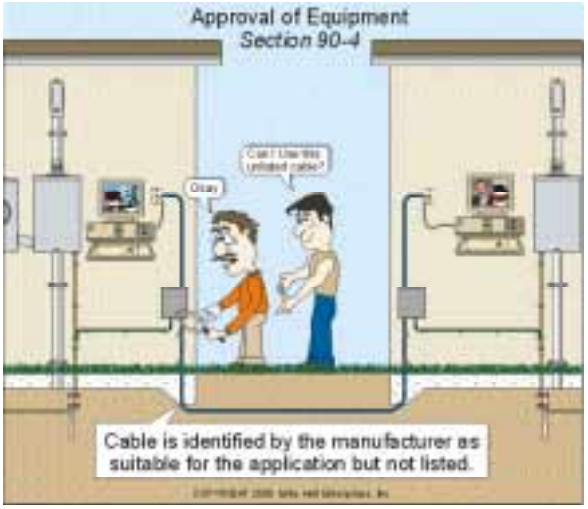


FIGURE 2-1

Unit 3. NEC Definitions [Article 100]

Article 100 contains definitions of terms often used throughout the *Code*. The official dictionary of the NFPA is the IEEE *Standard Dictionary of Electrical and Electronic Terms* (ANSI/IEEE 100-1997). In addition, definitions are also located throughout the Code in some of the articles. Some important definitions for the application of low-voltage and limited-energy systems are as follow.

> **Note:** Definitions below marked with (*) are not contained in the *National Electrical Code.*

Approved: "Approved" means acceptable to the authority having jurisdiction, which is usually the electrical inspector. Many think that if the equipment is listed or labeled, then it is approved. This is not the case [90-4, 90-7 and 110-21, see Fig. 2-1.

> ***Example***: Section 110-12(a) specifies that unused openings in electrical equipment must be closed with an *approved* (not a listed) fitting that provides protection equivalent to the wall of the equipment.

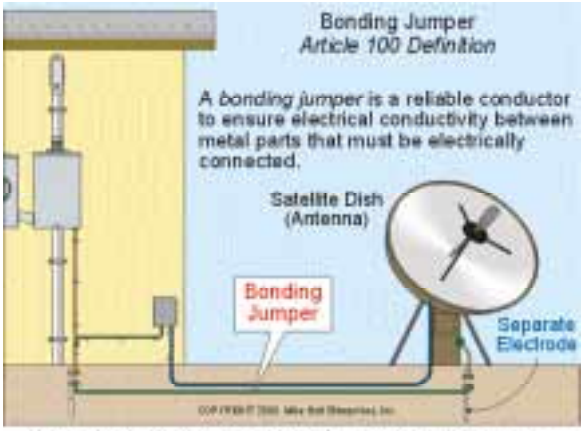


FIGURE 3-1 If a separate grounding electrode is used at the antenna, a bonding jumper run to the power grounding electrode system is required, See Section 810-21(j).

Bonding/Bonded: Bonding means to electrically join or tie together. Bonding is important for the purpose of ensuring that metal parts are properly grounded by a Tow-impedance path.

> ***Example***: Section 810-21(d) requires satellite entrance cable to be earth grounded by a No. 10 or larger copper conductor run to the building or structure grounding electrode system. If the grounding conductor is run in a metal raceway, then both ends of the metal raceway must be effectively *bonded* to the grounding conductor.

Bonding Jumper: A reliable conductor to ensure electrical conductivity between metal parts that must be electrically connected. The NEC does not have any requirement for the color of the bonding jumper, but traditionally electricians use a green insulated wire, or a black wire marked with green tape. Telephone and CATV companies generally use a gray insulated conductor.

> ***Example***: Section 810-21(d) states that a *bonding jumper*, not smaller than No.6 copper, must be connected between a radio, television, or HAM equipment grounding electrode and the power grounding electrode system, where separate electrodes are used, **Fig. 3-1**.

***Broadband**: Transmission facilities capable of handling a wide range of frequencies simultaneously, permitting multiple channels. Coaxial and optical fiber cables are inherently broadband.

Labeled: Equipment or materials with a label, symbol, or other identifying mark, applied by a Nationally Recognized Testing Laboratory (NRTL) acceptable to the inspector. Labeled and listed equipment provides the basis for inspector approval of the equipment. Many are familiar with the testing laboratory labels on electrical equipment, which may be in the form of a sticker, decal, printed label, or molded into the product itself [90-4, 90-7, 110-2, and 110-3], **Fig. 3-2.**

> **Author's Comment:** According to Section 110-3(b) listed or labeled equipment must be installed, used, or both, in accordance with any instructions included in the listing or labeling.

Listed: "Listed" means that the equipment or material is on lists published by Nationally Recognized Testing Laboratories that maintain periodic inspection of production of listed equipment or material. The material listing indicates that appropriate designated standards have been met, or the material has been tested and found suitable for use in a specified manner. The *Code* does not require all electrical equipment to be listed, but some rules do specifically require listed material/equipment.

> **Author's Comment:** Sections 725-71, 760-31, 770-50, 800-50, and 820-50 specify that low-voltage and limited-energy cables installed within buildings must be listed. However, UL Standard 444 *does not* test low-voltage or limited-energy cables for direct burial, exposure to ultraviolet rays of the sun, or standing water because these cables are intended to be installed indoors. *NEC* requirements drive the UL standards, and currently there is no *NEC* requirement to list these types of low-voltage and limited-energy cables for outdoor use.

Cable manufacturers produce "gel-filled" cables that *they consider suitable* for installation underground or in wet locations. There's no uniform marking on the cable jacket to indicate this purpose; for instance West Penn Wire marks its cables "AQC", which stands for their registered trade mark - Aqua Seal, whereas other manufacturers use different markings.

> **Author's Comment:** The suitability of communications cables installed in wet locations or exposed to the direct rays of the sun is generally not a safety *Code* issue. But it could be for fire protection or security systems wiring installed outdoors. As users become more informed on the needs of low-voltage and limited-energy systems, it is likely that the *Code* will be changed to require that all cable types be listed and labeled for their intended application or purpose.

***Plenum Cable:** A cable that's listed for exposed installation in plenums without the need for conduit because the insulation and jacket compounds have low flame-spread and low smoke characteristics. This type of cable is required when installed in a space used to move environmental air, such as the space above a suspended ceiling for return air, **Fig. 3-3**.

Note: Sometimes the label is on the box or instructions that come with the material.

FIGURE 3-2

FIGURE 3-3

Unit 4. General Installation Requirements

Note: None of the requirements in Article 110 apply to communications circuits (*NEC* Chapter 8), but some apply to Chapters 6 and 7 wiring systems 190-31.

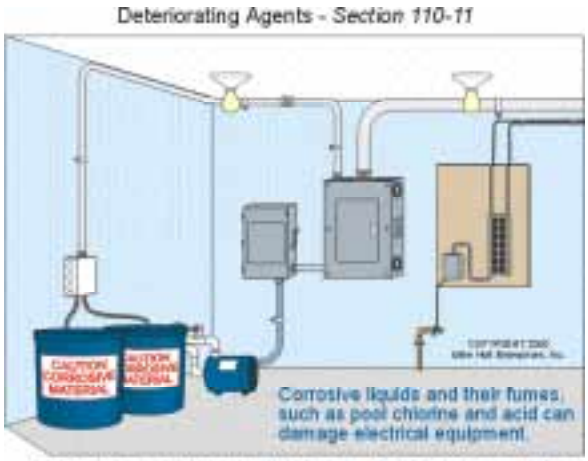


FIGURE 4-1 All electrical equipment must be suitable for the conditions and environment they are installed in. See Section 300-6.

FIGURE 4-1

Approval of Equipment [110-21

The authority having jurisdiction must approve all electrical equipment 190-41 and this includes low-voltage and limited-energy equipment and cables (see Article 100 for the definition of approved) [see Fig. No.1 in Unit 2].

Equipment Listing Instructions [110-3(b)]

All electrical equipment must be installed, and/or used according to its listing and labeling instructions. Equipment that is not listed or labeled can still be used, but the electrical inspector must approve its use.

> **Author's Comment:** Section 800-4 requires equipment intended to be electrically connected to a telecommunications network to be listed for the purpose, and the equipment installations must comply with Section 110-3(b).

Deteriorating Agents [110-11]

Low-voltage and limited-energy equipment must be suitable for the environment such as moisture, solar exposure, gases, fumes, vapors, excessive temperatures, or any other agent that could have a detrimental effect on the equipment or conductors. In addition, electrical equipment approved for use in dry locations must be protected from the weather during the building construction period, **Fig. 4-1**.

Mechanical Execution of Work [110-12]

Electrical systems including low-voltage and limited-energy systems must be installed in a neat and workmanlike manner. This rule is also contained in the following Code Sections, **Fig. 4-2:**

System	Section
• CATV, MATV, and CCTV	820-6
• Circuits Less Than 50 volts	720-12
• Class 1, Class 2, and Class 3	725-7
• Fire Alarm	760-8
• Optical Fiber Cables and Raceways	770-8
• Network Broadband	830-7
• Telecommunications	800-6

Note: *MAIW - Master Antenna Television Systems, CCTV - Closed Circuit Television System*

Author's Comment: The National Electrical Contractors Association (NECA), in conjunction with other organizations is currently developing *National Electrical Installation Standards*™ to define the intent of the *Code* rules.

Protection of Internal Parts [110-12(c)]

Special care must be taken to protect the internal parts of electrical equipment to guard against damage or contamination by foreign material such as paint, plaster, cleaners, etc.

Conductor Terminations [110-14(a)]

Connection of conductors to terminals shall ensure a mechanically and electrically sound connection without damaging the conductors. Terminations shall be made by means of pressure connectors (including set-screw type), solder lugs, or splices to flexible leads. Terminals intended for more than one conductor and terminals used to connect aluminum must be listed and identified for the purpose.

Conductor Splices [110-14(b)]

Low-voltage cables and conductors must be spliced using listed connectors. The standard practice of twisting the wires together and covering them with electrical tape does not meet the requirement of this Section.

Author's Comment: A box or conduit body is not required at each conductor splice, connection point, junction point, or pull point for low-voltage and limited-energy circuits.

Manufacturer's Markings [110-21]

Electrical equipment must be marked with the manufacturer's identification. Additional markings required by other *Code* sections could include voltage, current, wattage, or other ratings and these markings must withstand the intended environment involved.

Working Space [110-26]

For the purpose of safe equipment operation and maintenance, all electrical equipment must have sufficient access and working space, **Fig. 4-3**.

Question: Does low-voltage and limited-energy systems require the same working space as power conductors and equipment?

Answer: Section 110-26 requires working space for all systems. However, the generally accepted practice is not to require working space for low-voltage and limited-energy systems, but to install these systems so as not to encroach on the working space requirements of the power equipment.

Width. The working space in front of equipment must be a minimum of 30 inches wide, but in no case less than the width of the equipment.

Depth. Equipment must be installed so that the working space from the low-voltage and limited-energy equipment to nearby higher voltage equipment is not less than 3 feet (measured from the enclosure front) for 120/240 volt or

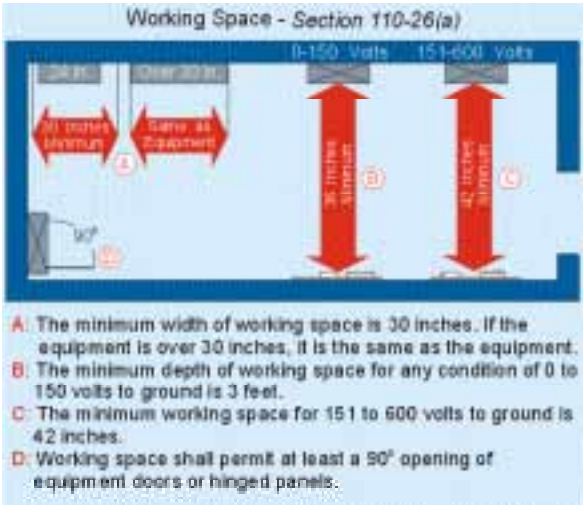


FIGURE 4-3

208Y1120 volt systems. For 480Y1277 volt systems, the working space must not be less than 3 feet from low-voltage or limited-energy equipment. In all cases, the working space must be of sufficient width, depth, and height to permit a 900 opening of all equipment doors.

Dedicated Space [110-26(1)]

The "dedicated equipment space" for electrical equipment was revised to require dedicated space the width and depth (footprint) of the equipment from the floor to a height of *6 feet* (was 25 feet) above the equipment, or to the structural ceiling, whichever is lower. No piping, ducts, or equipment foreign to the electrical installation shall be located in this zone, **Fig. 4-4.**

> **Author's Comment:** Low-voltage and limited-energy equipment cannot be installed within the dedicated space above and below panelboards or switchboards [11 0-26(f)].

Protection Against Physical Damage [170-27(b)]

Electrical equipment must not be installed where it can be exposed to physical damage. Enclosures or guards must be used to protect electrical equipment that could be exposed to physical damage. Exposure to physical damage is subject to interpretation by the electrical inspector.

Sound Systems [640-4]

Sound system equipment such as amplifiers, rectifiers, and loudspeakers must be located or protected to guard against physical damage, which might result in fire or personal hazard.

Safety-Control Equipment [725-8]

Where damage to remote-control circuits introduces a direct fire or life hazard, all conductors shall be installed in rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, electrical metallic tubing, Type MC cable, or be suitably protected from physical damage.

Fire Alarm Power-Limited Circuits [760-52(b)]

Power-limited fire alarm circuit conductors and cables shall be installed in such a way that maximum protection against physical damage is afforded.

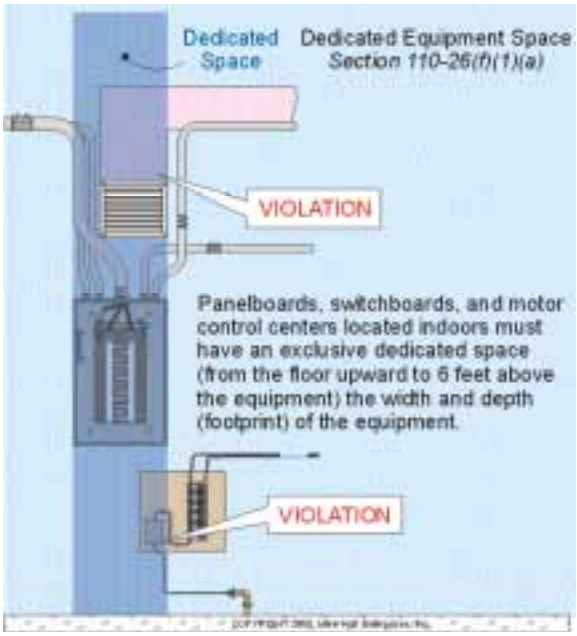


FIGURE 4-4

Unit 5. Understanding Grounding Requirements

The purpose of the *National Electrical Code* is for the practical safeguarding of persons and property from hazards arising from the use of electricity [90-1(a)]. The proper application and installation of equipment grounding will significantly reduce the hazards that exist in the use of electricity.

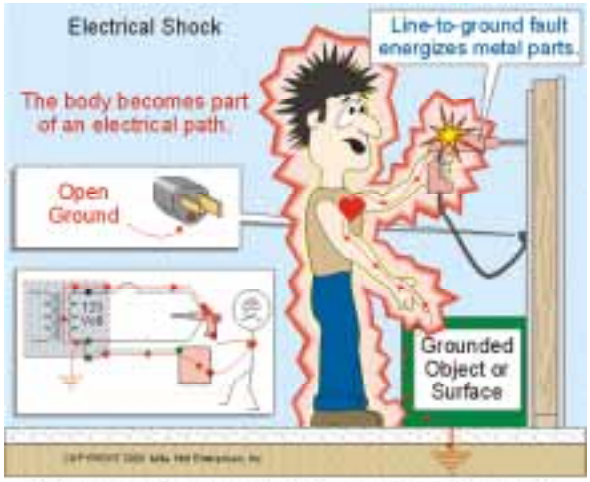
Article 250 of the NEC covers the general rules and specific requirements of when systems are required to be grounded, the locations of grounding connections, the size and types of grounding conductors, bonding conductors, and electrodes, and the methods of grounding and bonding. To better apply the *NEC's* grounding rules, you must understand that there are two different methods of grounding and that they serve different purposes: "Safety Grounding" and "Earth Grounding."

Safety Grounding (Equipment Grounding) [250-2(b)]

The purpose of grounding electrical metal enclosures is to remove dangerous voltage (potential) to protect against electric shock and/or electrocution of persons in contact with energized metal parts, due to a ground-fault. In addition, the fault must be removed quickly before a fire develops.

Electric Shock. People die when voltage pushes electrons through their bodies, particularly through the heart. If a person makes contact between an object that has voltage and another object that is grounded, current will flow through those contact points. Humans are susceptible to death when exposed to currents as low as 20 mA (20/1,000 ampere) for a fraction of a second, **Fig. 5-1.**

To remove the dangerous voltage, the circuit overcurrent protection device must open quickly to clear the ground-fault. To open the overcurrent protection device, the grounding path must have an impedance that is low enough to permit ground-fault current to reach a level of at least five times (preferably 10 times) the overcurrent protection device's rating. This can be accomplished by bonding metal parts to each other and then bonding the metal parts to the system



Death can occur in less than 1/6th of a second if the touch potential is as little as 50 volts and the current flow is as little as 50 milliamperes.

FIGURE 5-1

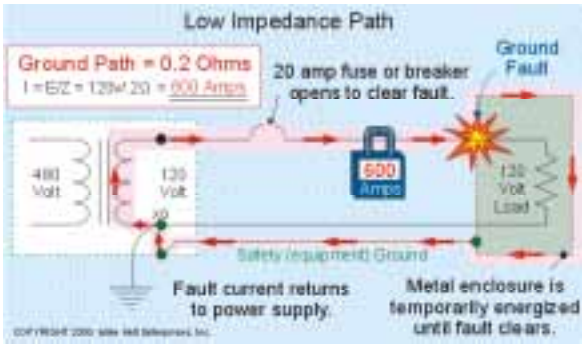


FIGURE 5-2

grounded conductor (neutral) resulting in a low ground-fault return path, **Fig. 5-2.**

Danger: The earth is a high impedance path for ground-fault current and cannot be used for equipment grounding [250-2(d) and 250-541. The high impedance of the earth results in very low current flow during ground-fault conditions and the ground-fault not clearing. If a grounding electrode (earth) were used as the equipment grounding conductor, the maximum current that could flow would be a function of the ground-fault voltage divided by the earth's impedance, or I = E/Z, **Fig. 5-3.**

FIGURE 5-3

Safety grounding is not required for the metal parts of equipment and electrical raceways for low-voltage systems that operate at less than 50 volts [250-20(a)1, **Fig. 5-4.** However, metal raceways for low-voltage and limited-energy circuits that may become energized by higher voltage systems must be bonded in accordance with Section 250-92(b).

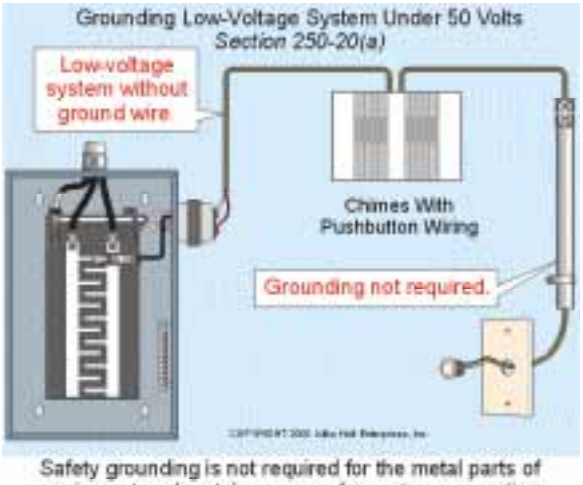


FIGURE 5-5

Safety grounding is not required for the metal parts of equipment and metal raceways for systems operating at less than 50 volts.

Fire Hazard. In addition to electric shock, electrical current can create a fire. Fire is caused by heat, and heat is a function of current squared times resistance (12R). If the grounding path has a high resistance, the ground-fault current might not be of sufficient magnitude to open the circuit protection device to clear the fault. This will result in dangerous voltage on all metal parts, and ground-fault current flowing (generating heat) for a period of time that could cause a fire, **Fig. 5-5.**

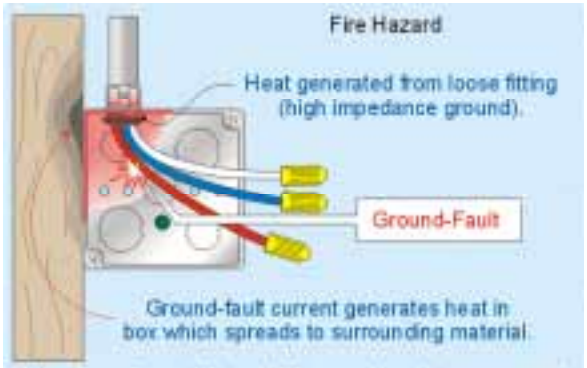


FIGURE 5-5

If the grounding path has a high enough resistance, ground-fault current might not be of sufficient magnitude to open the circuit protection device to clear the fault which could result in a fire.

> **Author's Comment:** This happened at the MGM Grand hotel in Las Vegas in 1980. Eighty-four people died because of a poor grounding path. There was a ground-fault, but the grounding path impedance was so high that it did not allow enough current to trip the circuit protection device. This ground-fault current continued to heat the metal raceway until it ignited nearby combustible materials.

Earth Grounding [250-2(a)]

Earth grounding is the intentional connection to earth through a ground connection or connections of sufficiently low impedance to prevent the destruction of electrical components, as well as electric shock that can occur from superimposed voltage from lightning, voltage transients, and contact with higher voltage systems. In addition, earth grounding helps prevent the build-up of static charges on equipment and material as well as establishing a zero voltage reference point to ensure the proper performance of sensitive electronic and communications systems equipment, **Fig. 5-6.**

Author's Comment: Failure to properly earth ground communications systems has led to $500 million dollars of property or equipment damage annually due to lightning and power surges, according to insurance industry data.

The impedance of the earth ground is dependent on the resistance of the electrodes, the termination resistance, contact resistance of the electrodes to the adjacent earth, and the resistance of the body of earth surrounding the electrodes. Most of the resistance comes from the resistivity of the soil, which the electrode is in contact with. Minerals, moisture content and temperature affect soil resistivity.

Earth Grounding and Bonding of Communications Systems

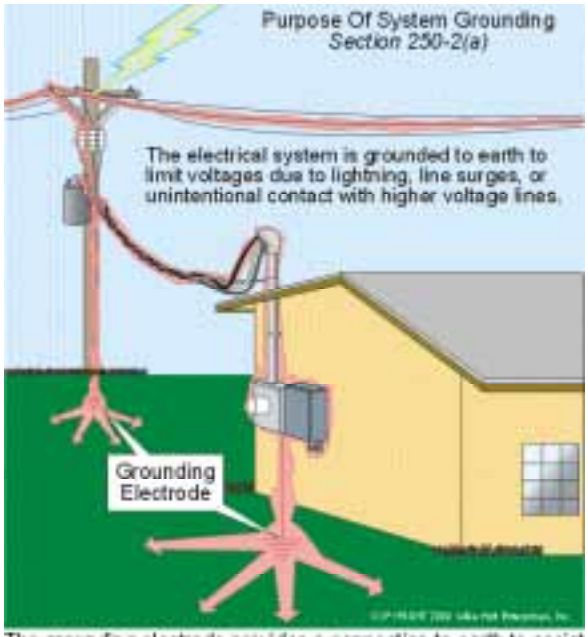
The *National Electrical Code* required earth grounding of telecommunications [800-40(b)], antennas and lead-in cables [810-21(f)], CATV [820-40(b)], and network-powered broadband communications systems [830-40(b)]. This is accomplished by bonding the communications systems to the building earth ground, Fig. 5-7.

The communications systems must be bonded to any of the following earth ground locations, **Fig. 5-8:**

1. Building or structure grounding electrode system as described in Section 250-50.
2. Interior metal water pipe meeting the requirements of Section 250-104(a). The limitation of 5 feet in Section 250-50 does not apply.
3. Metal service raceway.
4. Service equipment enclosure.
5. Building or structure grounding electrode conductor.
6. Metal enclosure enclosing the building or structure grounding electrode conductor.
7. Accessible bonding means such as six inches of No.6 copper conductor connected to the service equipment or raceway [250-92(b)].

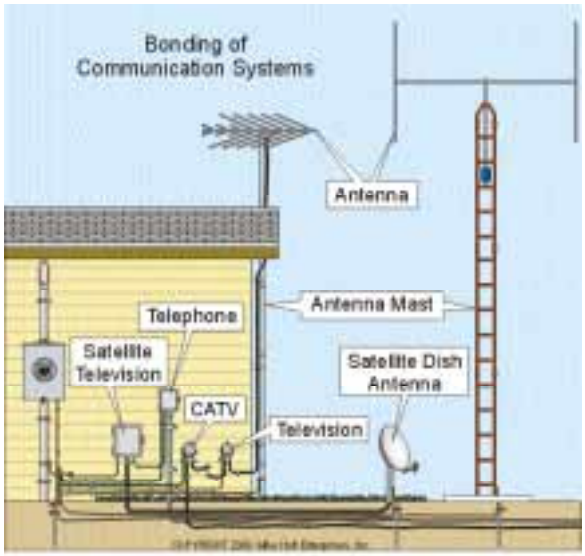
Author's Comment: When an electrode such as a ground rod is installed for the communications systems, it must be bonded with a No.6 copper or larger bare or insulated conductor to the grounding electrode system at the building or structure served, **Fig. 5-9.**

Termination. Earth grounding termination to the grounding electrode must be done by exothermic welding, listed lug, listed pressure connector, or by listed clamp. Earth grounding



The grounding electrode provides a connection to earth to assist lightning to dissipate into the earth without severely damaging the electrical equipment.

FIGURE 5-6



Metal parts of communications systems must be bonded to the building grounding electrode system.

FIGURE 5-7

buried in the earth must be listed for direct burial and marked “DB” [800-40(c), 820-40(c), and 830-40(c)].

Metal Raceway. If the earth conductor is rnn in a metal raceway, then both ends of the metal raceway must be bonded to the earth-grounding conductor F800-40(a)(5), 810-21(d), 820 40(a)(5), and 830-40(a)(5)].

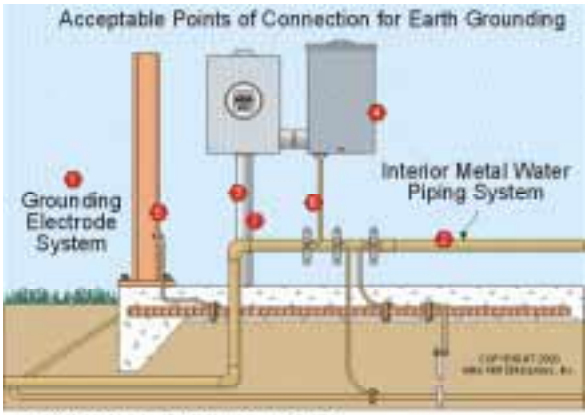


FIGURE 5-5

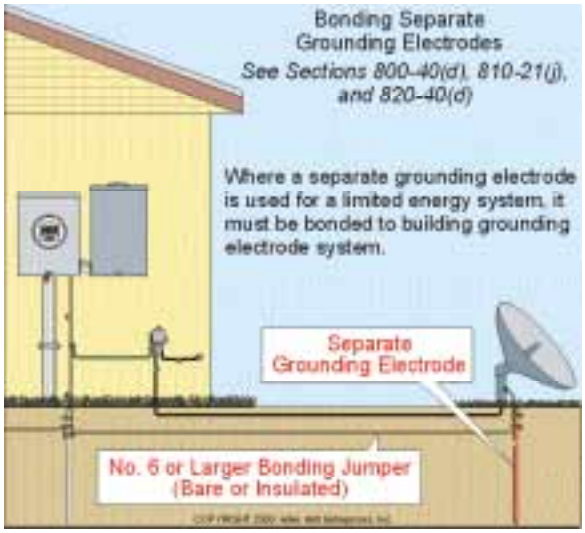


FIGURE 5-5

Unit 6. Earth Grounding of Communications Systems

All of the following communications systems must be earth grounded. The most effective method is to bond them to a common point at the building grounding electrode system.

Low-Voltage Lighting - Article 411

Listed low-voltage lighting systems that comply with Article 411 are not required to be grounded [411-5(a)].

Intrinsically Safe Systems - Article 504

Safety Ground - Intrinsically safe apparatus, associated apparatus, cable shields, metal enclosures, and raceways must be safety grounded by the use of an equipment grounding conductor [504-50(a)]. In addition, locknut-bushings and double-locknuts shall not be depended upon for bonding purposes, but bonding jumpers with proper fittings or other approved means of bonding shall be used. Such means of bonding shall apply to all intervening raceways, fittings, boxes, enclosures, etc., between Class I hazardous locations and the point of grounding for service equipment or point of grounding of a separately derived system [504-60].

Earth Ground - Where connection to a grounding electrode is required by the equipment instructions, the grounding electrode shall be as specified in Section 250-50. A separate ground rod cannot be used for this purpose, if electrodes specified in Section 250-50 are available [504-50(b)].

Sound (Audio) Systems - Article 640

Safety Ground - Circuits Not Over 50 Volts - Safety or earth grounding *is not required* for metal raceways and enclosures that contain sound circuits that operate at less than 50 volts [250-112(i)] unless the cables are exposed to lightning [725-54(c)].

System Ground - Circuits 60 Volts – Sound circuits that operate at 60 volts to ground must have their metal enclosures and raceways grounded in accordance with Section 250-30 for separately derived systems. In addition an equipment grounding conductor must be provided in accordance with Section 530-72(b) [640-7].

Safety Ground - Circuits Over 50 Volts – Safety or earth grounding is required for metal raceways and enclosures that contain sound circuits that operate at over 50 volts.

Low- Voltage circuits less than 50 volts - Article 720

Grounding is not required for low-voltage systems that operate at less than 50 volts, unless the primary exceeds 150 volts to ground, the primary supply is ungrounded, or the secondary conductors are installed as overhead conductors outside the building [720-10 refers to 250-20(a)].

Class 1, 2 and 3 Circuits - Article 725

Safety Ground - Circuits Over 5O Volts – Class 1 circuits that operate at over 50 volts must have their metal enclosures and raceways grounded to clear fault current in accordance with Article 250 U25-6].

Safety Ground - Circuits Not Over 50 Volts –Safety grounding is not required for metal equipment or raceways that contain circuits that operate at not over 50 volts [250-20(a), 250-86, and 250-112(i)], [see **Fig. 5-4**, p.18].

Earth Ground - Shielded Class 2 or 3 twisted-pair conductors that extend beyond the building structure and are exposed to lightning must be earth grounded in accordance with Section 800-33 for telecommunications systems and coaxial cable must be grounded in accordance with Section 820-33 for CATV systems [725-54(c)].

> **Author's Comment:** Class 2 and Class 3 cables installed outdoor not exposed to lightning (installed underground) do not need to be grounded, **Fig. 6-1**.

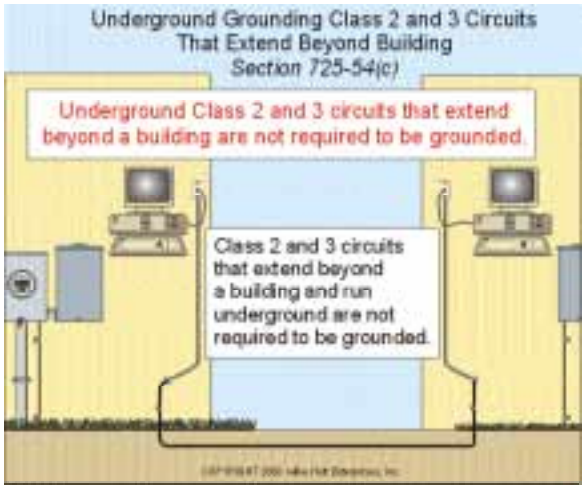


FIGURE 6-1

FIGURE 6-2

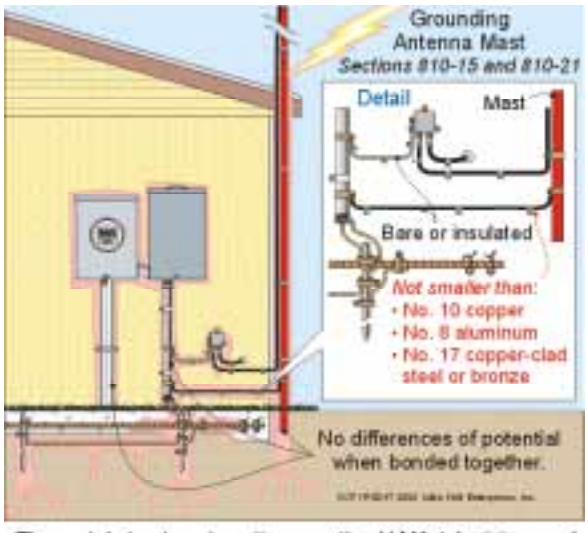


FIGURE 6-3

Fire Alarm Signaling Systems - Article 760

Safety Ground - Circuits Over 50 Volts -Metal equipment, metal raceways, and cables containing nonpower-limited fire alarm circuit over 50 volts must be installed using Chapter 3 wiring method and must be safety grounded in accordance with Article 250 [760-6].

Safety Ground - Circuits Not Over 50 Volts - Power-limited fire alarm circuits that operate at less than 50 volts are not required to be safety grounded [250-112(i)].

Telecommunications (Telephone) Systems - Article 800

Earth Ground - The metallic sheath of telephone cable and primary protectors must be grounded to the earth (electrode) as close as practicable to the point of entrance of the phone cable to the building or structure [800-331. The earth grounding is accomplished by bonding the telephone's grounding block to an acceptable earth ground with a No.14 or larger insulated copper conductor run in as straight a line as practicable [800-40(a)], **Fig. 6-2.**

Outdoor Antenna, Satellite, and Other Receiving Systems [Article 8101

Proper grounding of antenna mast and lead-in cables is somewhat effective in protecting receiving equipment from voltage surges, as well as voltage transients that result from lightning.

Mast - The metal structure that supports radio, HAM, television and satellite receiving antennas must be grounded to an acceptable earth ground [810-15] with a No.10 copper bare or insulated conductor run in as straight a line as practicable [810-21], **Fig. 6-3.**

Author's Comment: If the mast is not properly grounded, the Low Noise Block (LNB), as well as the dc rotor motors that control the positioning larger satellite dishes often will be destroyed by voltage surges caused by nearby lightning strikes.

Lead-in Cable – Each conductor (coaxial, control, and signal conductors) of a lead-in from an "outdoor antenna" must be provided with a listed antenna discharge unit (grounding block). The antenna discharge unit must be located outside or inside as near as practicable to the entrance of the conductors to the building and it must not be located near combustible material [810-20]. The discharge unit must be grounded to an acceptable earth ground [810-21(f)] with a No. 10 copper bare or insulated conductor run in as straight a line as practicable [810-21], **Fig. 6-4.**

Author's Comment: If each conductor of a lead-in from an outdoor antenna is not properly earth grounded, the receiver can be destroyed by voltage surges caused by nearby lightning strikes.

CATV Systems [Article 820]

Earth Ground – The metallic sheath of CATV cable entering a building or structure must be grounded to the earth as close as practicable to the point of entrance to the building or structure [820-33]. The earth grounding is accomplished by bonding the Cat's grounding block to an acceptable earth ground with a No.14 or larger insulated copper conductor run in as straight a line as practicable to the earth [820-40(a)].

Author's Comment: CATV systems are often terminated at a location that is not near the electrical service, and since most new homes have nonmetallic water piping systems, CATV systems require that an *insulated* No. 14 grounding conductor run to an acceptable earth ground, **Fig. 6-5.**

CCTV and MATV Systems

Earth Ground – Closed circuit television (CCTV) and master antenna television (MATV) circuits within a building do not have to be grounded to the earth. However coaxial cable that extends beyond the building structure and is exposed to nearby lightning must be earth grounded [810-2]. The metal sheath of coaxial cables (exposed to nearby lighting) that enters a building or structure must be grounded to an acceptable earth ground as close as practicable to the point of entrance to the separate building or structure [820-33]. The earth grounding is accomplished by bonding the CCTV grounding block to an accept able earth ground with a

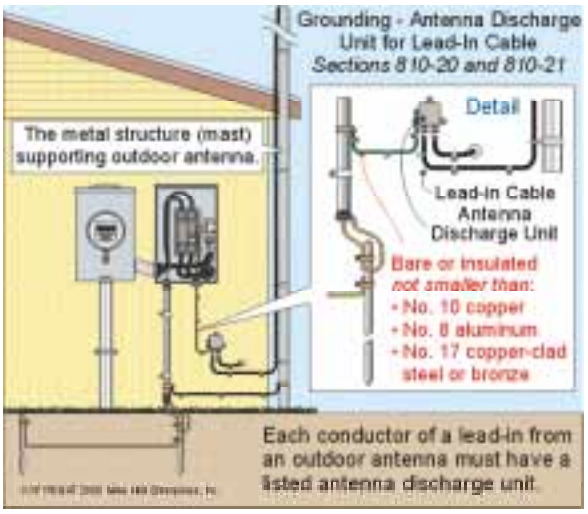


FIGURE 6-5

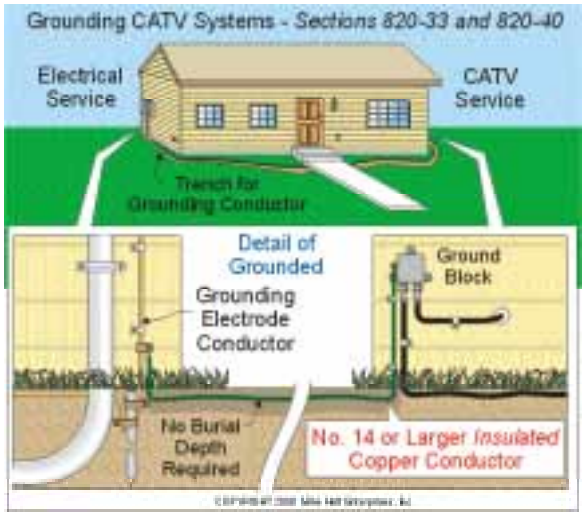


FIGURE 6-6

No.14 or larger insulated copper conductor run in as straight a line as practicable [820-40(a)], **Fig. 6-6**.

Network-Powered Broadband Communications Systems - Article 830

Earth Ground Cable – The metallic sheath of network-powered broadband communications systems cable entering a building or structure must be grounded to the earth as close as practicable to the point of entrance to the building or structure [830-33]. The earth grounding is accomplished by bonding the NPBCS cable (grounding block) to an acceptable earth ground with a No.14 copper to a maximum No.6 copper conductor (depending on the current-carrying capacity coaxial shield) run in as straight a line as practicable 1830-401.

Earth Ground Metal Raceway – Metal raceways used for network power broadband entrance cable must be bonded to an acceptable earth ground with a No.14 copper to a maximum No.6 copper conductor depending on the current-carrying capacity coaxial shield [830-40 and 830-43(c) Exception].

CCTV Extended Beyond Building or Structure
Sections 820-33 and 820-40

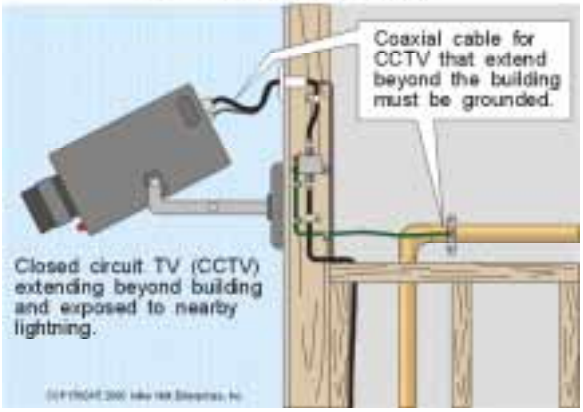


FIGURE 6-6

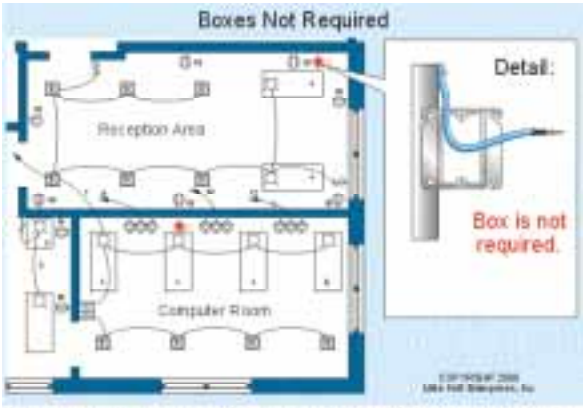
Unit 7. General Wiring Requirements

The general wiring method requirements contained in Article 300 do not apply to low-voltage or limited-energy system, unless a specific reference is made in Chapter 7 [725-3, 760-3 and 770-31 or Chapter 8 [90-3] to a specific Section in Article 300.

Boxes Not Required

A box or conduit body *is not required* at each conductor splice, connection point, junction point, or pull point for low-voltage and limited-energy circuits, **Fig. 7-1.**

> **Author's Comment:** Low-voltage and limited-energy devices in fire resistant walls, floors, and ceiling, must be installed in metal outlet boxes or fire rated nonmetallic outlet boxes [300-21]. For example, fire rated outlet boxes must be used when cable or phone devices are installed in fire rated residential garage walls [300-21].

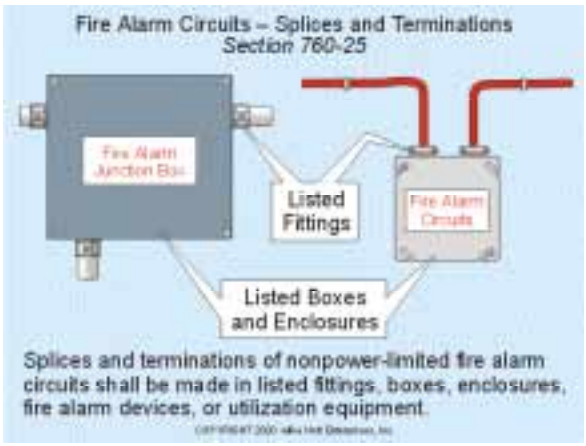


A box or conduit body is not required at each conductor splice, connection point, junction point, or pull point for low-voltage or limited-energy circuits (except for Class 1 and fire alarm).

FIGURE 7-1

Boxes Required

Outlet boxes must be used for Class I circuits [725-25] and fire alarm circuits [760-25, 760-30(a) and 760-52(b)(1)], **Fig. 7-2.**



Splices and terminations of nonpower-limited fire alarm circuits shall be made in listed fittings, boxes, enclosures, fire alarm devices, or utilization equipment.

FIGURE 7-2

Cable Listing and Marking

Low-voltage and limited-energy cables installed *within a building* must be listed as being suitable for the purpose, **Fig. 7-3.**

Table 7-1 indicates acceptable cables for each type of system.

The "CM" of CMP indicates communication system cable, the "P" in CMP indicates that this cable is suitable for use in environmental air spaces.

FIGURE 7-3

	CL2	CL3	FPL	NFPL	OF	CM	MP	CATV	BL	BM	Chapter 3
Article 720 – Circuits Less than 50 volts											●
Article 725 – Class 1 Remote-Control, Signaling											●
Article 725 – Class 2 Remote-Control, Signaling	●	●				●					
Article 725 – Class 3 Remote-Control, Signaling		●				●					
Article 760 – Fire Alarm Power-Limited Circuits				●							
Article 760 – Fire Alarm Power-Limited Circuits			●	●			●				●
Article 770 – Optical Fiber Cables						●					
Article 800 – Telecommunications Systems						●	●				
Article 820 – Cable - Television (CATV)						●		●			
Article 820 – Network Low-Powered Broadband									●		
Article 820 – Network Medium-Powered Broadband		●				●	●			●	

CL2 - Class 2 Cable [725-71]
CL3 - Class 3 Cable [725-71]
FPL - Power-Limited Fire Alarm Cable [760-71]
NFPL - Nonpower-Limited Fire Alarm Cable [760-31]
CM - Communications Cable [800-53]*
OF - Optical Fiber Cable [770-71]
MP - Multipurpose Cable (Coaxial) [800-50]*
CATV - CATV Cable [820-53]*
BL - Broadband Low-Power Cable [830-55]*
BM - Broadband Medium-Power Cable [830-55]*
* Listing and marking are not required where the length of the cable within the building measured from its point of entrance does not exceed 50 feet [800-50 Exc. 3, 820-50 Exc. 3, and 830-55(c) Exc. 4].

TABLE 7-1

The *Code* may require additional marking for low-voltage and limited-energy cables, depending on the intended use of the cable such as:

The P suffix stands for plenum rating. Plenum cables are listed for use in environmental air space (dropped ceiling space used for return air) and they have adequate fire-resistant and low smoke-producing characteristics.

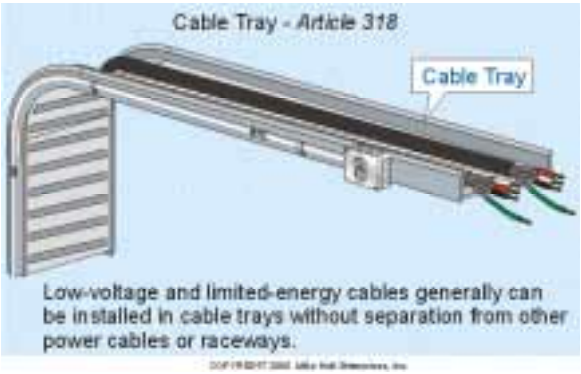


FIGURE 7-4

• The **R** suffix stands for riser rating. Riser cables are listed for use in vertical shafts (risers) and they have fire-resistant characteristics to prevent the carrying of fire from floor to floor.

• The X suffix indicates that a cable is listed for use in dwellings and in raceways.

Cable Tray [Article 318]

A cable tray system is a unit or assembly of units or sections, and associated fittings, forming a structural system used to securely fasten or support cables and raceways. The following rules must be complied with when installing low-voltage or limited-energy cable within a cable tray, **Fig. 7-4**:

• *CATV Cables [Article 820]* - The NEC does not contain any reference to permit the installation of CATV, MATV, or CCTV cables within a cable tray [3l8-3(a)].

• *Class] Control and Signaling Conductors [Article 725]* - Class 1 control and signaling conductors must be installed using a Chapter 3 wiring method in accordance with the requirements of Article 318 [725-3(d)].

• *Class 2 and Class 3 Cables [Article 725]* - Class 2 and Class 3 cables marked: PLTC, MPP MPR, MPG, MR CMP CMR, CMG, CM, CL3P, CL3R, CL3, CL2l, CL2R, or CL2 can be installed in cable trays [318-3(a), 725-3(d), 725-61(c), and 725-71].

• *Fire Alarm Conductors [Article 760]* - Non-power-limited fire alarm circuit conductors must be installed using a Chapter 3 wiring method in accordance with the requirements of Article 318 [318-3(a) and 760-28(c)].

• *Instrumentation Tray Cables Type ITC [Article 727]* - Instrumentation tray cables are permitted to be installed in cable trays at industrial establishments [318-3(a), 727-3, and 727-4(1)].

• *Network-Powered Broadband Communications Systems* - The NEC does not contain any reference to permit the installation of BL or BM cables in cable trays [318-3(a)].

• *Optical Fiber Cables [Article 770]* - Any listed optical fiber cable can be installed in a cable tray [318-3(a) and 770-52(a)].

• *Radio and Television Cables [Article 810]* - The NEC does not contain any reference to permit the installation of radio and television cables in cable trays.

• *Sound (Audio) Systems [Article 640]* - Class 2 and Class 3 cables marked: PLTC, MPP, MPR, MPG, MR, CMP, CMR, CMG, CM, CL3P, CL3R, CL3, CL2R, CL2R, or CL2 can be installed in cable trays [318-3(a), 640-3(c), 7253(d) 725-61(c), and 725-71].

• *Telecommunications Cables [Article 800]* - Telecommunications cables marked: MPP, MPR, MPG, MR, CMR, CMR, CMG, and CM can be installed in cable trays [318-3(a) and 800-52(d)].

> **Author's Comment:** Low-voltage and limited-energy cables can be installed in cable trays without separation from power raceways or cables, see the "Separation" section in this Chapter.

Computer Rooms

The general requirement is that cables installed within raised floors of computer rooms shall be listed for data processing rooms and be marked Type DP. Type DP cable is constructed to have adequate fire-resistance characteristics suitable for use under a computer room raised floor [645-5(d)]. The following types of low-voltage and limited-energy cables are also permitted to be used beneath computer room raised floors, and these cables are not required to be Type DP or plenum rated [645-5(d)(5)(c)], **Fig. 7-5:**

System	Cable Type
• CATV, MATV, CCTV	Type CATV
• Control and Signaling	Type CL2, CL3, and PLTC
• Optic Fiber	Types OFC and OFN
• Fire Alarm	Types NPLF and FPL
• Network-Powered Broadband	No Code Rule
• Sound (Audio)	Type CL2, CL3, and PLTC
• Telecommunications	Types CM and MP

> **Author's Comment:** The *NEC* does not require the grounding of the metal structure that supports a raised computer floor. However, a green insulated single conductor cable No. 4 and larger marked "For use in cable trays" or "For CT use" can be installed within a raised floor area for high-frequency RF bonding of the metal raised floor pedestals [645-5(d)(5)(c)]. This technique is used to minimize radio frequency interference (RFI), often known as "electrical noise," that can disrupt communications circuits.

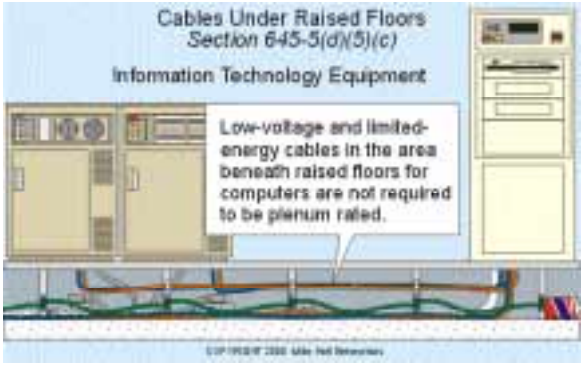


FIGURE 7-3

Equipment Access

Access to equipment must not be prohibited by an accumulation of cables that prevent the removal of suspended ceiling panels. Cables must be located so that the suspended ceiling panels can be moved to provide access to electrical equipment, **Fig. 7-6.**

Note: See the support section in this Chapter for the requirements for proper cable supports.

System	Section
• CATV MATV, CCTV	820-5
• Control and Signaling (Class 2 and 3)	725-5
• Optical Fiber	770-7
• Fire Alarm	760-5
• Network-Powered Broadband	830-6
• Radio and Television	No Code Rule
• Sound (Audio)	640-5
• Telecommunications	800-5

FIGURE 7-6 Cables must be located so that the suspended ceiling panels can be moved to provide access to electrical equipment. Note: Violation, cables must be properly supported.

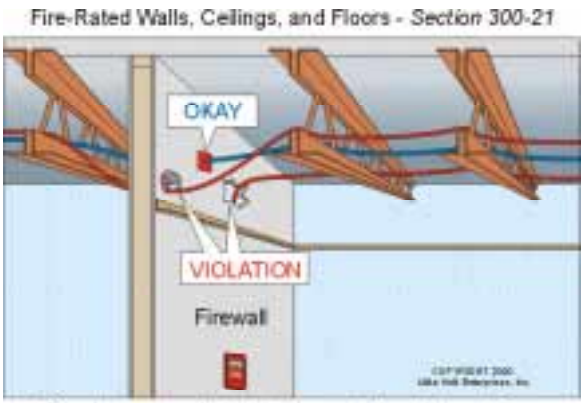


FIGURE 7-7 Openings around electrical penetrations through fire-resistant rated walls, partitions, floors, or ceilings are required to be firestopped using approved methods to maintain the fire resistance rating.

Fire Rated Walls / Ceilings / Floors

Low-voltage and limited-energy cables must be installed so that they don't increase the spread of fire or smoke [300-21]. This means that openings in fire-rated walls, floors, and ceilings must be sealed with an approved fire-stop material. The installation of fire-stop materials must be done in accordance with the specific instructions supplied by the manufacturer for the specific type of wiring method (raceway or cable), and construction material (drywall, brick, etc.), **Fig. 7-7.**

> **Author's Comment:** When low-voltage and limited-energy devices are installed fire resistant walls, floors, and ceiling, metal outlet boxes or fire rated nonmetallic outlet boxes must be used to maintain the fire resistant rating of the assembly, **Fig. 7-7.**

System	Section
• CATV	820-3(b)
• Control and Signaling (Class 2 and 3)	725-3(a)
• Optical Fiber	770-3(a)
• Fire Alarm	760-3(a)
• Network-Powered Broadband	830-3(a) and 830-58(b)
• Sound (Audio)	640-3(a)
• Telecommunications	800-52(b)

> **Author's Comment:** Many times fire stopping is enforced by the structural inspector during framing inspection, and local building Codes often contain specific fire-stopping requirements.

Identification

Fire Alarm Circuits [Article 760] - Fire alarm circuits must be identified at all terminal and junction locations. The identification must be in a manner that will prevent unintentional interference with the fire alarm circuits during testing and servicing [760-10], **Fig. 7-8**.

Intrinsically Safe Systems [Article 504] - Permanently affixed labels with the wording "Intrinsic Safety Wiring" must be placed on raceways containing intrinsically safe cables. The labels must be visible after installation and placed so that they may be readily traced through the entire length of the installation in both the classified as well as the unclassified area [504-80(b)].

Lighting Fixtures, Recessed

Low-voltage incandescent recessed fixtures must have thermal protection and be identified as thermally protected [410-65(c)]. In addition, low-voltage fixtures that are "Type IC" can be installed in contact with thermal insulation [410-66(b)].

Manhole Installations

Low-voltage and limited-energy cables installed in manholes shall be installed in accordance with Section 370-52 Cabling Work Space, and Section 370-55 Access to Manholes.

Mixing Low-Voltage and Limited-Energy Cables and Conductors

• *Class 1 Conductors* – Class 1 control circuits and power conductors associated with the same equipment can occupy the same raceway, but Class 1 circuits cannot occupy the same cable, enclosure, or raceway with other low-voltage or limited-energy circuits, **Fig. 7-9**.

• *Optical Fiber Cable* – Nonconductive optical fiber cable can occupy the same raceway, cable tray, or enclosure with power, or any other low-voltage or limited-energy cable that operates at 600 volts or less [770-52], **Fig. 7-10**.

• *Nonpower-Limited Fire Alarm Conductors* – Nonpower-limited fire alarm conductors can be installed in the cable, enclosure, or raceway with power conductors used solely for supplying power to the equipment to which fire alarm conductors are connected [760-26 and 760-28(c)].

• *Other Low-Voltage and Limited-Energy Conductors* - To provide protection to those who might come in contact with low-voltage or limited-energy wiring, conductors for these systems must be separated from power, Class 1, nonpower-limited fire alarm conductors so that they are not accidentally energized by the higher voltage power conductors.

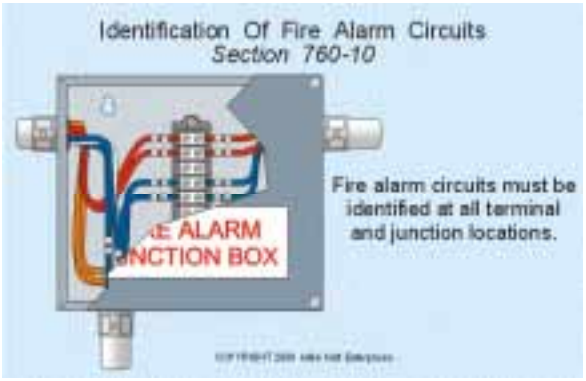


FIGURE 7-8

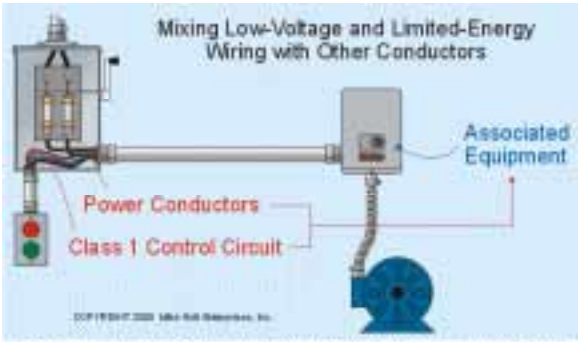


FIGURE 7-9

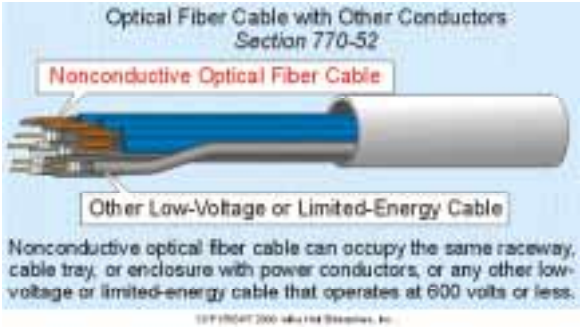


FIGURE 7-10

The following Code sections prohibit the mixing of low-voltage and limited-energy conductors with power, Class 1, or nonpower-limited fire alarm circuit conductors:

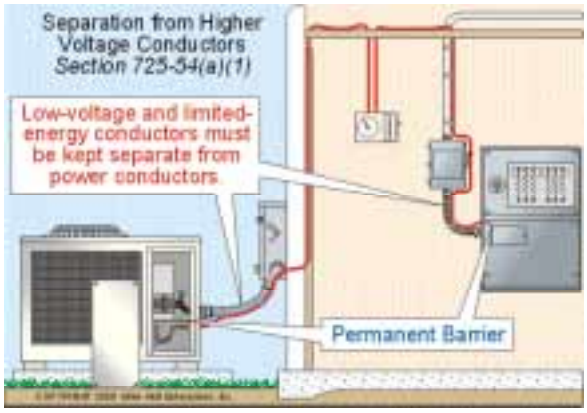


FIGURE 7-11

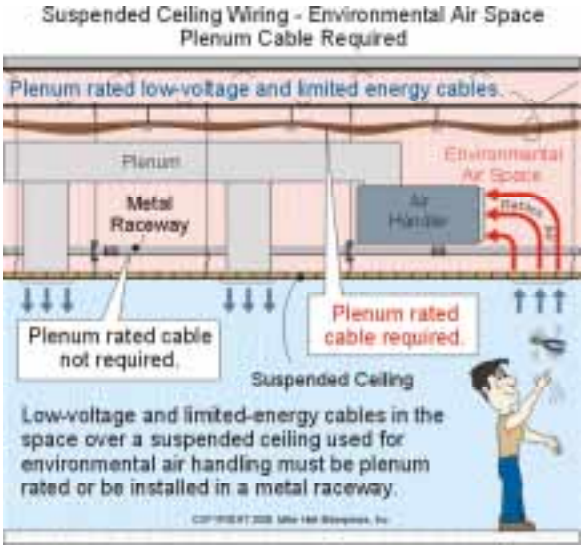


FIGURE 7-12

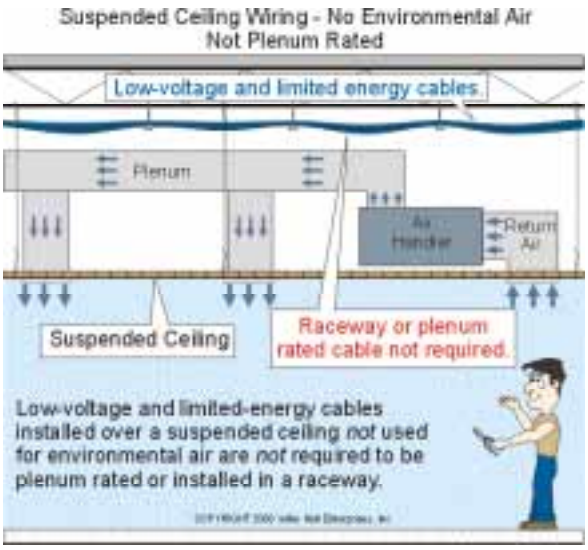


FIGURE 7-13

System	Sections
• CATV, MATV, CCTV	820-lO(f)(1)
• Control and Signaling (Class 2 and 3)	725-54(a)(1) **Fig. 7-11**
• Fire Alarm (Power-Limited)	760-54(a)(1)
• Intrinsically Safe	504-30(a)(2)
• Instrument Tray Cable	727-5
• Network-Powered (medium power)	830-58(c)
• Radio and Television	810-18(c) and 810-70
• Sound (Audio)	640-9(c)
• Telecommunications	800-52(a)(1)

Exceptions to the above *Code* sections permit power conductors to terminate onto listed low-voltage and limited-energy equipment, if the power conductors maintain a minimum of 0.25 inch separation from the low-voltage and limited-energy conductors.

Plenum Cable

Low-voltage and limited-energy cables installed in ducts, plenums, and dropped ceiling spaces used to move environmental air must be either plenum rated or installed in a metal raceway, **Fig. 7-12.**

System	Sections
• CATV, MATV, CCTV	820-51(a)
• Control and Signaling (Class 2 and 3)	725-61(a)
• Fire Alarm	760-61(a)
• Network-Powered Broadband	830-54(b) and 830-55(b)
• Optical Fiber	770-53(a)
• Radio and Television	No Code Rule
• Sound (Audio)	640-9(c) and 725-61(a)
• Telecommunications	800-53(a)

Note: *The PLTC cable is not manufactured as a plenum rated cable.*

Author's Comment: Where cable tics are used to secure, low-voltage and limited-energy cables must be plenum rated!

Plenum Rating Not Required – Low-voltage and limited-energy cables are not required to be plenum rated when installed in the space over a suspended ceiling that is not used for air handling. In addition, low-voltage and limited-energy cables do not have to be plenum rated if they are installed in habitable rooms or areas of a building the primary purpose of which is not air handling [300-22(c) Exception No.31, **Fig. 7-13.**

Plenum Raceways

Nonmetallic raceways installed in ducts, plenums, and other spaces used for environmental air must be listed for plenum spaces [770-6 and 800-51], and the cables installed in the nonmetallic raceways must be plenum rated [770-53(a) and 800-53(a)].

> ***Author's Comment:*** Listed nonmetallic plenum rated raceways must be installed in accordance with Article 331 - Electrical Nonmetallic Tubing [770-6 and 800-48]. However, the NEC does not make any reference to plenum rated raceways in Articles 725, 760, 810, 820 or 830.

Raceway Not Required - The following low-voltage and limited-energy cables are not required to be installed in raceways, **Fig. 7-14:**

System	Section
• CATV	90-3
• Control and Signaling (Class 2 and 3)	725-3
• Optical Fiber Cables	770-3
• Power-limited Fire Alarm Cables	760-3
• Radio and Television	90-3
• Sound (Audio) Systems (Class 2 or 3 Cables)	640-23

Raceway Required – The following low-voltage and limited-energy system must be installed in a Chapter 3 wiring method, and raceway conductor fill limitations apply [300-17].

System	Section
• Circuits in Compliance with Article 720	300-17
• Class 1 Control and Signaling	725-28
• Class 2 and 3 Control and Signaling	725-8(b)*
• Fire Alarm Nonpower-Limited	760-28
• Fire Alarm Power-Limited	760-52(b)*
• Optical Fiber Cables (installed with power conductors)	770-6
• Sound (Audio)	640-23
• Telecommunications	800-48

**Class 2 and 3 cables for control and signaling, and power- limited fire alarm cables subject to physical damage must be protected*

The requirements of raceway conductor fill only apply when the low-voltage or limited-

Raceways are not required for low-voltage and limited-energy cables for sound, communication, control, or signaling circuits located in places of assembly, motion picture and TV studios, theaters, and audience areas.

FIGURE 7-14

Raceway conductor fill requirements only apply when the low-voltage or limited-energy circuit require a Chapter 3 wiring method.

FIGURE 7-15

energy circuit utilizes Chapter 3 wiring methods (such as Class 1 conductors for control, signaling, or other uses such as sound systems), **Fig. 7-15.**

FIGURE 7-16 Where practicable, a separation of at least 6 feet shall be maintained between communication cables and lightning protection conductors.

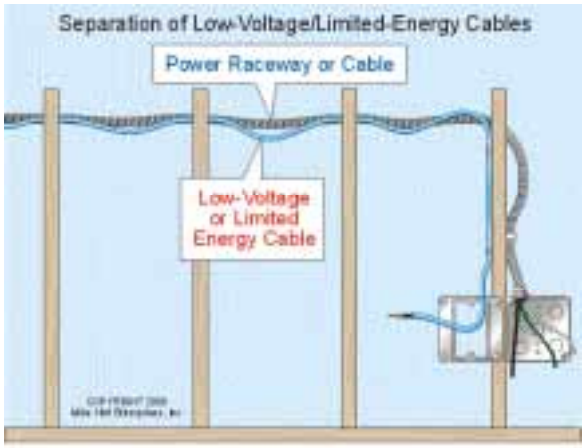


FIGURE 7-17 Separation is not required between low-voltage or limited-energy cables, and raceways or cables containing power conductors.

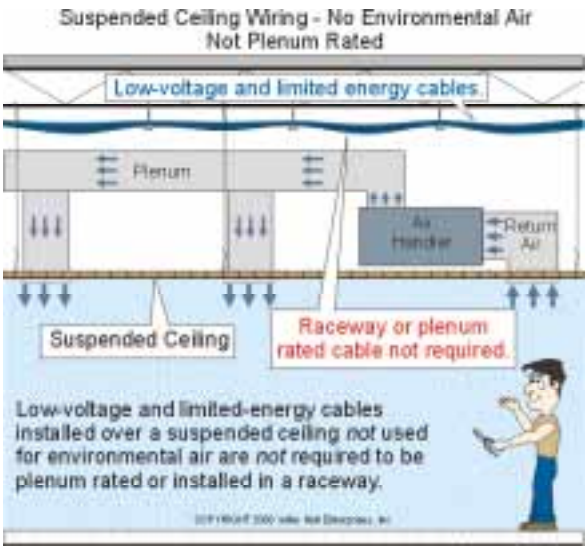


FIGURE 7-18

Author's Comment: In order to maintain cable performance, many contractors install low-voltage and limited-energy cables in accordance with the BICSI Cabling Installation Manual (Chapter 4). This installation guideline suggests that raceway runs be limited to 100 feet, no more than two 90-degree bends be installed in one run, and also recommends a maximum pull force of 25 pounds for each Category 5 cable and 100 pounds for each optical fiber cable.

Separation from Lightning Protection Conductors

Where practicable, a separation of at least 6 feet shall be maintained between communications cables (NEC Chapter 8) and lightning protection conductors, **Fig. 7-16.**

System	Section
• CATV	820-10(f)(3)
• Network-Powered Broadband	830-10(i)(3)
• Radio and Television	810-18
• Telecommunications	800-13

Separation from Raceways or Cables

Two inches of separation is required between low-voltage or limited-energy conductors and power conductors. However, separation is not *required* between low-voltage or limited-energy cables, and raceways or cables containing power conductors, **Fig. 7-17**.

System	Sections
• CATV, MATV, CCTV	820-52(a)(2) Exception No.1
• Control and Signaling (Class 2 and 3)	725-54(a)(3) Exception No.1
• Fire Alarm	760-54(a)(3) Exception No.1
• Intrinsically Safe	504-30(a)(2) Exception No.1
• Network-Powered Broadband	830-58(a)(2) Exception No. I
• Radio and Television	810-18(b) Exception No.1
• Telecommunications	800-52(a)(2) Exception No.1

Note: Outside buildings and similar structure power conductors must maintain 4 inches of separation from low-voltage and communications conductors [225-14(c) and 830-10(i)(1)]. Network-powered broadband cables installed underground must be kept 12 inches from power conductors.

Service Masts

Service masts can only be used for the support of power service drop conductors [230-2381. In addition, aerial cables for radio, TV, or CATV cannot be attached to the electric service mast [810-12 and 820-10(c)] and receiving antennas cannot be attached to the electric service mast [810-12], **Fig. 7-18.**

> ***Author's Comment:*** Community antenna system coaxial cables complying with Article 820 and the supporting messengers shall be permitted at a height of not less than 10 feet above swimming and wading pools, diving structures, and observation stands, towers, or platforms [230-24(d) and 680-8].

Support

Low-voltage and limited-energy cables must be supported by the building structure in such a manner that the cables will not be damaged by normal building use, **Fig 7-19.** These cables cannot be strapped, taped, or attached to electrical raceways, **Fig. 7-20.**

System	Sections
• CATV, MATV, CCTV	820-6, 820-10(c) and 820-52(e)
• Control and Signaling (Class 2 and 3)	725-7 and 725-54(d)*
• Fire Alarm	760-8 and 760-54(d)
• Optical Fiber	770-8
• Network-Powered Broadband	830-7 and 830-58(d)
• Radio and Television	810-12
• Telecommunications	800-6 and 800-52(e)

* Class 2 cable can be supported to the raceway that supplies the power to the equipment controlled by the Class 2 cable [300-1 1(b)(2) and 725-54(d) Exception], **Fig. 7-21.**

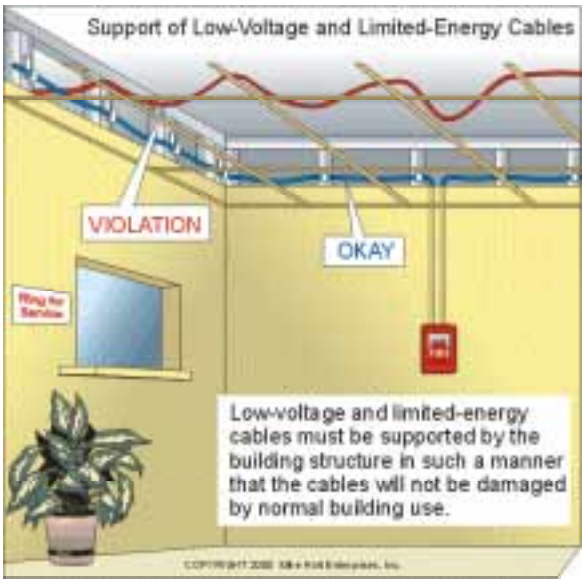


FIGURE 7-19

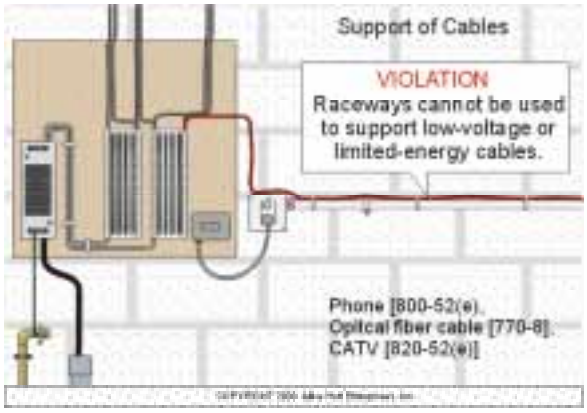
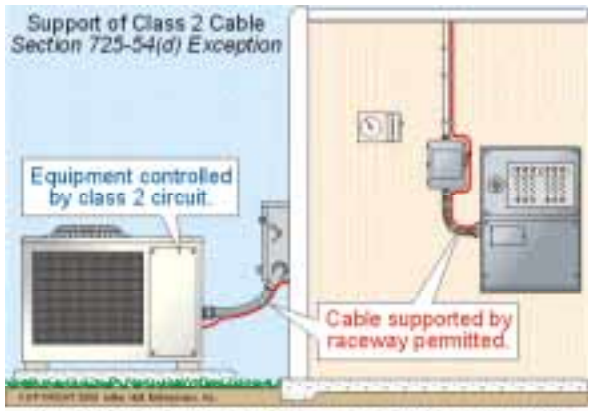


FIGURE 7-20



Class 2 control cables can be supported by the raceway that supplies power to the equipment controlled by the Class 2 cable

FIGURE 7-21

Author's Comment: Section 300-11(a) does not permit electrical wiring to be secured to ceiling support wires, but it does permit independent support wires secured at both ends to be used for the support of electrical wiring. Technically this rule does not apply to low-voltage or limited-energy cables because there is no reference to Section 300-11(a) in Chapter 7 or Chapter 8, **Fig. 7-22.**

Computer Room Raised Floors – Low-voltage and limited-energy cables installed under the raised floors of information technology equipment rooms are not required to be secured in place [645-5(e)]. When a cable passes through an opening in the computer raised floor, it must be protected against abrasions, and the opening must minimize the entrance of debris beneath the raised floor [645-5(b)], **Fig. 7-23.**

Underground Installations – The burial depth requirements of Section 300-5 do not apply to the following low-voltage and limited-energy cables, except landscape lighting [Article 4111, Fig. 7-24.

System	Section
• CATV	90-3
• Control and Signaling (Class 2 and 3)	725-3
• Optical Fiber	770-3
• Fire Alarm	760-3
• Network-Powered Broadband	90-3
Telecommunications	90-3