THE COMPLETE

UNDERSTANDING THE NATIONAL ELECTRICAL CODE®

2023 STUDY GUIDE

500–820

A PRACTICAL GUIDE TO ELECTRICAL SAFETY AND CODE COMPLIANCE

CLEAR EXPLANATIONS

PRACTICE QUESTIONS

REAL-WORLD APPLICATIONS

Michael Hamilton

THE ULTIMATE GUIDE TO ELECTRICAL SAFETY AND COMPLIANCE

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Author's Commentary: *This article groups safety rules for specialized electrical equipment and installations that need extra attention. It covers welders, audio and IT systems, and water environments—focusing on proper wiring, protection, bonding, and GFCI safeguards.*

— Michael Hamilton

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ABOUT THIS TEXTBOOK

Michael Hamilton's Illustrated Guide to Understanding the National Electrical Code®, Volume 2, based on the 2023 NEC®

Michael Hamilton's *Illustrated Guide to Understanding the National Electrical Code®, Volume 2*, based on the 2023 *NEC®* textbook gives you the tools you need to grasp the technical requirements of the *National Electrical Code* (*NEC*), Articles 500 through 820, and also includes the complete volume of a two-part program.

This textbook is easy to use because of Michael Hamilton's straightforward and informative writing style. Like all of Michael Hamilton textbooks, this one is loaded with full-color illustrations and photographs that demonstrate how the requirements of the *National Electrical Code* are put into practice. The images provide a visual representation of the topics being discussed, helping you better understand the *Code* rules in action.

This textbook explains not only proper electrical installations, but also hazards, warnings, or potential dangers related to improper work, and points out possible conflicts or confusing *NEC* requirements. At times a rule can appear puzzling or difficult to interpret until you see its practical application. Where this may be the case, you'll find extra material to help you better grasp the rule. Our goal is to help the electrical industry understand the current *NEC*, point out areas that may need refinement, and encourage all *Code* users to be part of the ongoing process that helps create a better *NEC* for the future.

Chapters 5 through 8 of the *NEC* are specialized and technical, and require a complete understanding of the *Code* rules and requirements in Chapters 1 through 4. We recommend that you complete the Volume 1 textbook before moving on to Volume 2. In addition, we highly recommend that you use both books along with the accompanying videos. They contain additional *Code* insights and expert explanations from a panel of industry professionals that provide further understanding of the intricacies of the *Code* rules and their application.

Author's Commentary: Staying aligned with the *Code*'s requirements should be a shared goal for everyone in the electrical profession—whether you're an installer, contractor, inspector, engineer, or instructor. This textbook is here to help you reach that goal.

— Michael Hamilton

The Scope of This Textbook

This textbook, *Michael Hamilton's Illustrated Guide to Understanding the National Electrical Code®, Volume 2, based on the 2023 NEC®*, covers the general installation requirements contained in the *NEC* from Articles 500 through 820 (*NEC* Chapters 5 through 8) along with relevant content from Chapter 1.

This program is based on 120/208V, 120/240V, or 277/480V, single-phase and three-phase solidly grounded alternating-current systems, using 90°C insulated copper conductors sized to 60°C rated terminals for 100A and less rated circuits, and with 75°C rated terminals for over 100A rated circuits, unless otherwise indicated in the text.

How to Use This Textbook

This textbook is intended to be used along with the *NEC* and not as a replacement for it. Be sure to have a copy of the 2023 *National Electrical Code* to reference as you study. You will notice that we have paraphrased a great deal of the wording, and some of the article and section titles appear different than those in the actual *Code* book. We believe doing so makes it easier to understand the content of the rule, so keep that in mind when comparing this textbook to the *NEC*.

Always compare what is being explained in this textbook to what the *Code* book says. Get with others who are knowledgeable about the *NEC* to discuss any topics you find difficult to understand or join our free *Code* Forum at www.MichaelHamilton.com/forum to post your question.

Format. This textbook follows the *Code* format, but it does not cover every requirement. For example, it does not include every article, section, subsection, exception, or informational Note. So, do not be concerned if you see that the textbook contains Exception 1 and Exception 3, but not Exception 2.

Cross-References. Many *NEC* rules refer to requirements located in other sections of the *Code*. This textbook does the same with the intention of helping you develop a better understanding of how the *NEC* rules relate to one another. These cross-references are indicated by *Code* section numbers in brackets, an example of which is "[90.4]."

Author's Commentary: Reading the *Code* with purpose and comparing it to real-world applications will deepen your understanding and make you a more confident professional.

— Michael Hamilton

Informational Notes. Items labeled as *Informational Notes* in the *NEC* are flagged in this book as "Note."

Exceptions. Provisions called out as exceptions in this text will be marked "EX" so they stand out clearly.

Before you dive into the text, take a few minutes to look over the excellent illustrations and real-world examples provided. They're designed to help you build a stronger grasp of the *Code*. Be sure to use the practice questions to check your knowledge—and don't hesitate to review the material more than once to really lock in your understanding.

Technical Questions

As you study this textbook, you'll quickly find that you don't have to know every explanation, example, calculation, or comment.

Avoid frustration, and don't be overly hard on yourself. Keep in mind, this is the *National Electrical Code*, and at times the best approach is to explain an idea just enough to make it perfectly clear. If something still confuses you, check out a trusted *Code* forum or discussion group. You'll find plenty of experienced electrical professionals willing to help.

Textbook Corrections

We are committed to delivering you a top-quality resource with the fewest possible errors, and we take great care to keep our textbooks accurate. Still, even the best references can have occasional mistakes.

The most current information we have is available on our website. For any issues you find, whether it's something confusing, access problems, or suggestions to improve this text, please check the list of updates there.

To see known errors, visit our corrections section online.

If you believe you've spotted an error (typographical, mathematical, technical, and so on) in this book or in the Answer Key, and it isn't listed on the website, please send us an email. Include the book title, page numbers, print date, and any other details that can help us make the fix.

Key Features

The layout and design of this textbook include special elements and visual cues that make it easier to navigate the content and improve your learning.

QR Code

Scan this **QR Code** with your smartphone to open a webpage that features sample videos demonstrating key concepts—along with a video panel captured during our recording sessions.

For a complete list of all videos that accompany this product, call (632) 263-8322.

Caution, Warning, and Danger Icons

These icons draw attention to important safety information.

Caution

Caution: Highlights a situation that could cause damage to property or equipment.

Warning

Warning: Points out a situation that could result in serious property damage or personal injury.

Danger

Danger: Indicates a condition that could lead to severe injury or death.

Formulas

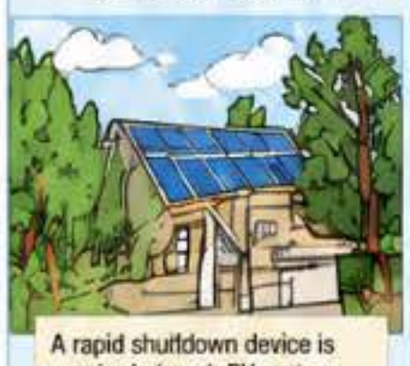
$$P = I \times E$$

Formulas are highlighted in green on a gray bar so they're easy to spot.

$$P = I \times E$$

Solar Photovoltaic (PV) Systems | 690.7

Solar Photovoltaic (PV) System Connected to a Utility



A rapid shutdown device is required at each PV system where specified in 690.12.

Figure 690–30

PV System and Charge System CONTINUOUS

Continuous Load:
- Automatic doors
- Refrigerators
- Emergency systems
- Life support
- Sump pumps
- Security systems

Comply with 690.56 and 690.57(B)(2) for continuous and backfeed load applications.

Figure 690–31

PV System and Energy Storage System (ESS)

ESS installation requires compliance with 690.64 through 690.66, 706.15, and 706.30 and depends on the operating mode used at the system.

Figure 690–32

Energy Storage Systems (ESS) SUPPLY ONLY

ESS installation must follow 690.64 through 690.66, 706.30(B)(2), and Table 706.30(B)(2).

Figure 690–33

More Information: The illustrations in this group relate to other sections of the NEC and include only key highlights.

Figures 690–30 through 690–33

Full-Color, Detailed Educational Graphics. High-quality color graphics assist with visualizing the complex language of the *NEC* and demonstrate how the rules are used in real-world situations. This makes a big difference in reinforcing learning.

Examples. Real-world application questions and answers are displayed in framed yellow boxes.

When you see an ellipsis (• • •) at the bottom of the example, expect the continuation on the next page.

Code Change text. Underlined wording indicates updates to the *Code* for the 2023 *NEC*.

Code Rule Headers. The *Code* rule being covered is identified with a chapter color bar and white text. Chapters are visually coded and modular to make it easier to move through each part of the textbook.

Author's Commentary: These notes offer extra background details to help you better understand the context.

— Michael Hamilton

701.3 | ALL — 7 Legally Required Standby Systems

Legally Required Standby Systems

Figure 701–2

701.4 | General, not Ratings

This article deals with legally required standby systems from the perspective of how those systems are installed. All descriptive information in this article is general. The ratings listed in Part I and Tables 700.11 and 701.1 refer to other articles and are not part of this article.

701.7 Tests and Maintenance

(A) General. Systems must be kept in ready-to-operate condition at all times. The owner or a designated agent is responsible for testing the system and replacing or repairing parts that are needed to maintain reliable performance.

(B) Periodic Testing. Legally required standby systems must be tested, and results recorded, at least monthly for three consecutive years on a log and maintained for inspection by the code official.

Author's Commentary:

Performing the testing often helps you catch issues sooner so faults can be resolved quickly, minimizing downtime. Exceptional measures are needed when essential systems require continuous readiness.

— Michael Hamilton

701.5 Transfer Equipment

Emergency systems that need to automatically activate and transfer the load must use automatically operated transfer equipment.

701.8 Generater Sets

Transfer equipment must be suitable for safely moving the selected loads. The system must be properly installed and maintained.

Figure 701–4

ADDITIONAL PRODUCTS TO HELP YOU LEARN

Understanding the 2023 National Electrical Code, Volume 2 Videos

Among the finest ways to learn from this textbook is to study it together with the matching video series. The videos give you a 360° exploration of each subject area featuring expert insights from Michael Hamilton along with commentary from leading industry professionals. Viewing them will boost your comprehension and make the material easier to retain.

Topics included in the videos:

- ***Special Occupancies and Special Equipment***
- ***Limited Energy and Communications Systems***

If you'd like these companion videos to enhance your study of this textbook, contact our office or send an e-mail.

Understanding the 2023 National Electrical Code, Volume 1 Training Program

Our top-rated Understanding the *2023 NEC* Volume 1 program has assisted thousands of electricians in mastering the *Code* with ease. Volume 1 spans Articles 90–480 and leads learners through the most important rules while showing how those rules are applied in real life. Vivid, full-color graphics appear throughout the book to support visual learning and clarify key ideas being taught; the videos deliver more detail as Michael and his panel discuss each topic, its significance, and its use on the job. When you must know the *Code*, this program is the most effective way to build knowledge—there's no other product like it. This program includes:

- ***Understanding the NEC—Volume 1*** textbook
- ***Understanding the NEC Workbook, Articles 90-480***
- ***Bonding and Grounding*** textbook
- *General Requirements DVD*
- *Wiring and Protection DVD*
- *Bonding and Grounding DVDs (4)*
- *Wiring Methods and Materials DVDs (3)*
- *Equipment for General Use DVD*

To order, visit our website.

Solar Photovoltaic Systems Training Program

When most people think about solar photovoltaic systems and the *Code*, Article 690 usually comes to mind. Yet numerous other aspects of solar PV are addressed in the *NEC*. While Article 690 provides the rules related to wiring the array, it doesn't explain how to connect the array to the rest of the system. The *2023 Code* updates resulted in significant revisions, including rewritten key articles and many additions, plus changes to rules that affect PV systems across the *NEC*. Even if you're already experienced, you'll want to study these updates.

Michael Hamilton's Understanding NEC Requirements for Solar Photovoltaic and Energy Storage Systems is essential reading for anyone who designs, installs, services, and inspects solar PV and energy storage systems. Beyond Article 690 and 691 revisions, this program also offers an in-depth review of the key articles that govern installation, wiring, and system interconnection.

This program includes:

Understanding NEC Requirements for Solar Photovoltaic and Energy Storage Systems textbook

- *Understanding NEC Requirements for Solar Photovoltaic and Energy Storage Systems DVDs (3)*

For more information, visit our website.

HOW TO USE THE *NATIONAL ELECTRICAL CODE*

The original *NEC* document was developed in 1997 as a result of the united efforts of various insurance, electrical, architectural, and other cooperative intersets. The National Fire Protection Association (NFPA) has sponsored the *National Electrical Code* since 1911.

The purpose of the *Code* is the practical safeguarding of persons and property from hazards arising from the use of electricity. It isn't intended as a design specification or an instruction manual for untrained persons. It is, in fact, a standard that contains the minimum requirements for an electrical installation that's essentially free from hazard. Learning to understand and use the *Code* is critical to you working safely; whether you're training to become an electrician, or are already an electrician, electrical contractor, inspector, engineer, designer, or instructor.

The *NEC* was written for qualified persons: those who understand electrical terms, theory, safety procedures, and electrical trade practices. Learning to use the *Code* is a lengthy process and can be frustrating if you don't approach it the right way. First, you'll need to understand electrical theory and if you don't have theory as a background when you get into the *NEC*, you're going to struggle. Take one step back if necessary and learn electrical theory. You must also understand the concepts and terms in the *Code* and know grammar and punctuation in order to understand the complex structure of the rules and their intended purpose(s). The *NEC* is written in a formal outline which many of us haven't seen or used since high school or college so it's important for you to pay particular attention to this format. Our goal for the next few pages is to give you some guidelines and suggestions on using your *Code* book to help you understand that standard, and assist you in what you're trying ta accomplish and, ultimately, your personal success as an electrical professional!

Language Considerations for the *NEC*

Terms and Concepts

The *NEC* contains many technical terms, and it's crucial for *Code* users to understand their meanings and applications. If you don't understand a term used in a rule, it will be impossible to properly apply the *NEC* requirement. Article 100 defines those that are used generally in two or more articles throughout the *Code*; for example, the term "Dwelling ha'a| "dweliing unit" you can't properly identify its *Code* requirements. Another example worth mentoining is the term "Outlet." For many people it has always meant a receptacle—not so in the *NEC*!

Many *Code* articles use terms unique to that specific article, and the definitions of those terms only apply to that given article. Definitions for them are usually found in the beginning of the article. For example, Section 250.2 contains the definitions of terms that only apply to Article 250—Grounding and Bonding. Whether definitions are unique to a specific article, or apply throughout the *NEC*, is indicated at the beginning of the definitions (xxx.2) section of the article. For example,

Article 690 contains definitions (in 690.2) that apply ONLY to that article while Article 705 introduces definitions (in 705.2) that apply throughout the entire *Code*.

Small Words, Grammar, and Punctuation

Technical words aren't the only ones that require close attention. Even simple words can make a big difference to the application of a rule. Is there a comma? Does it use "or," "and," "other than," "greater than," or "smaller than"? The word "or" can imply alternate choices for wiring methods. A word like "or" gives us choices while the word "and" can mean an additional requirement must be met.

An example of the important role small words play in the *NEC* is found in 110.26(C)(2), where it says equipment containing overcurrent, switching, "or" control devices that are 1,200A or more "and" over 6 ft wide require a means of egress at each end of the working space. In this section, the word "or" clarifies that equipment containing any of the three types of devices listed must follow this rule. The word "and" clarifies that 110.26(C)(2) only applies if the equipment is both 1,200A or more and over 6 ft wide.

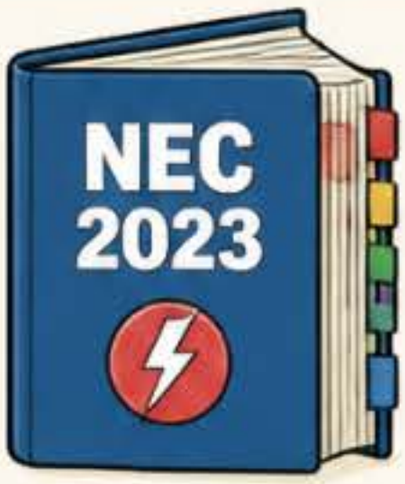
NEC Style and Layout | How to Use the *National Electrical Code*

Rules depend heavily on grammar and punctuation to convey their intended meaning. A comma placed in a different spot can completely change a rule's requirement in 250.28(A), where it states a main bonding jumper shall be a wire, bus, screw, or another approved conductor. If the comma between "bus" and "screw" is removed, only a "bus screw" could be used. That single comma creates a major shift in what the rule allows.

Slang Terms or Technical Jargon

Professionals in the trades across the country use local slang that might puzzle someone from another region. Because of that, it can be difficult to be sure everyone understands these terms the same way. To ensure consistency, check the official definitions and application notes before using any term. For instance, "pigtail" commonly describes a short conductor that connects a device to a splice, while "pigtail" is also the name of an insulated light socket with pre-attached leads. Although "splice" and "tap" mean similar things, they can create confusion. The *Code* keeps the meaning of every term clear and consistent so electricians everywhere interpret them the same way, no matter where they work.

NEC Style and Layout



To use the *Code* effectively, it helps to understand how it is organized and how its writing style works. The 2023 *National Electrical Code* is structured using twelve major components.

1. Table of Contents
2. Chapters—Chapters 1 through 9 (major categories)
3. Articles—The chapters contain subdivistions called articles that address specific subjects
4. Parts—Articles break down the subject matter they cover
5. Sections—Divisions used to further organize the article subject matter
6. Tables and Figures—Show the mandatory requirements of a rule
7. Exceptions—Alternatives to the main rule in the *Code*
8. Informational Notes—Explanatory material for a specific rule (not a requirement)
9. Tables—Applicable as referenced in the *NEC*
10. Annexes—Additional explanatory information such as tables and references (not a requirement)
11. Index
12. Changes to the *Code* from the previous edition

1. Table of Contents. The Table of Contents displays the layout of the chapters, articles, and parts along with the page numbers. It gives an excellent overview and is best used periodically to see how the sections of the *NEC* connect with one another. When you need to find a rule on a specific subject, the quickest way is to check the Table of Contents first.

2. Chapters. There are nine chapters, each divided into articles. The articles fall into one of four groups: General Requirements (Chapters 1 through 4), Specific Requirements (Chapters 5 through 7), Communications Systems (Chapter 8), and Tables (Chapter 9).

Chapter 1—General
Chapter 2—Wiring and Protection
Chapter 3—Wiring Methods and Materials
Chapter 4—Equipment for General Use
Chapter 5—Special Occupancies
Chapter 6—Special Equipment
Chapter 7—Special Conditions
Chapter 8—Communications Systems (Telephone, Data, Satellite, Cable TV, and Broadband)
Chapter 9—Tables—Conductor and Raceway Specifications

3. Articles. The *NEC* includes roughly 140 articles, each dedicated to a particular subject. It starts with Article 90, the introduction to the *Code*, which explains the purpose and coverage of the *NEC*, what it does not cover, and how it is arranged. It also provides information on enforcement, required workmanship and permits, and the rules for writing and presenting the *Code*. Article 90 also details the interpretation process, examines equipment for safety, wiring planning, and information on measurement units. Here are a few articles you'll find in the *NEC*.

- ☑ Article 110—Requirements for Electrical Installations
- ☑ Article 250—Grounding and Bonding
- ☑ Article 300—General Requirements for Wiring Methods and Materials
- ☑ Article 430—Motors, Motor Circuits, and Motor Controllers
- ☑ Article 500—Hazardous (Classified) Locations
- ☑ Article 680—Swimming Pools, Fountains, and Similar Installations
- ☑ Article 725—Remote-Control, Signaling, and Power-Limited Circuits
- ☑ Article 800—General Requirements for Communications Systems

HOW TO USE THE *NATIONAL ELECTRICAL CODE* | NEC Style and Layout

4. Parts. Large subjects are broken into parts. Since the parts of a *Code* article are not shown in the section numbers, we often add the word "part" in front of an *NEC* rule. For instance, Table 110.34(A) includes working space clearance data for electrical equipment. If we are not careful, this table might seem like it applies only to wiring methods, but Table 110.34(A) is in Part II, which covers installations rated "Over 1,000 Volts, Nominal." The standards for working clearances for systems of 1,000 volts, nominal, or less are found in Table 110.26(A)(1) which is in Part II—1,000 Volts, Nominal, or Less.

5. Sections. Every *NEC* rule is called a "*Code* Section." A *Code* section may be divided into lower levels; the first level of division is written in parentheses like (A), (B), ..., then are second level divisions in parentheses like (1), (2), ..., and finally third level divisions as lowercase letters such as (a), (b), and so on.

For example, the rule requiring all receptacles in a dwelling unit bathroom to be GFCI protected is located in Section 210.8(A)(1) which is in Chapter 2, Article 210, Section 8, first level subdivision (A), and second level subdivision (1).

Author's Commentary: According to the *NEC Style Manual*, first and second level subdivisions must have titles. A title for a third level subdivision is allowed but not required.
— Michael Hamilton

Within the industry, some people use the term "Article" when talking about a *Code* section. For example, someone might say "Article 210.8," meaning "Section 210.8." Sections in this text show the word "Section" at the start of the sentence, followed by the exact section number. For instance, Section 210.8(A) is written simply as 210.8(A).

6. Tables and Figures. Many *NEC* requirements are organized in tables that list *Code* rules in a systematic way. These tables are very important since they help you read the rules carefully and understand their purpose, uses, and limits. Notes often appear in or below tables; always read them as part of the rule text. For example, Note 1 for Table 300.5 explains how to measure the cover when buying cables and raceways, and Note 5 clarifies what to do if solid rock is encountered.

7. Exceptions. Exceptions are *NEC* requirements or permissions that provide another method to meet a specific rule. There are two types of exceptions—mandatory and permissive. When a rule has multiple exceptions, those with mandatory conditions are listed before the permissive exceptions.

Mandatory Exceptions. A mandatory exception uses the phrases "shall" or "shall not." The word "shall" in this context means that if you use the exception, you must follow it exactly. The phrase "shall not" means it is not allowed.

Permissive Exceptions. A permissive exception uses words like "shall be permitted," meaning it is allowed (but not required) to do it this way.

8. Informational Notes. An Informational Note gives background information to help explain a rule or assist, but it is not part of the *Code* requirement.

9. Tables. Chapter 9 contains tables used as references in the *NEC*. They help calculate raceway size, conductor fill, the radius of raceway bends, and conductor voltage drop.

10. Informative Annexes. Annexes are not part of the *Code* requirements and are included for informational purposes only.

- Annex A. Product Safety Standards
- Annex B. Application Information for Ampacity Calculation
- Annex C. Raceway Fill Tables for Conductors and Fixture Wires of the Same Size
- Annex D. Examples
- Annex E. Types of Construction
- Annex F. Critical Operations Power Systems (COPS)
- Annex G. Supervisory Control and Data Acquisition (SCADA)
- Annex H. Administration and Enforcement
- Annex I. Recommended Tightening Torques
- Annex J. ADA Standards for Accessible Design

11. Index. The Index at the back of the *NEC* helps find a specific rule by using helpful index keywords.

12. Changes to the *Code*. Updates to the *NEC* are shown like this:

- Rules that were changed since the previous edition have a gray background in the revised text.
- New rules arer't gray but have a gray "N" in the left margin of the section number.
- Moved rules are shown as new with a gray "N" in the left margin of the section number.
- Deleted rules have a bullet • in the left margin showing where the rule was in earlier editions. The bullet appears only where one or more full paragraphs were removed. If there is no bullet with a number, a single word, group of words, or sentence was removed.
- A Δ symbol marks text deletions and figure/table revisions.

How to Locate a Specific Requirement | How to Use the *National Electrical Code*

How to Locate a Specific Requirement

Finding exactly what you need in the *Code* depends on several factors. For some subjects, your background with the *NEC* may lead you to the right rule right away. Seasoned professionals often know generally which requirements to consult, so they go directly to the appropriate rule. Less experienced readers might first review the Table of Contents to identify where a topic is covered. Either way, most people review the Table of Contents, the Index, and electronic search features available in digital versions of the *Code*.

Here's a straightforward example: Suppose you want to know the maximum number of service disconnects allowed by *NEC*.

Using the Table of Contents. If you're familiar with the *Code*, use the Table of Contents. Look under Article 230, which covers "Services," and because this article is split into parts (eight sections, eight parts total), you can jump directly to the section titled "Service Equipment Disconnecting Means" in Part VI.

Author's Commentary:
The number "70" comes before all page numbers here because the NEC is printed to follow NFPA Standard Number 70.
— Michael Hamilton

Using the Index. If you use the Index (arranged alphabetically) to look up "service disconnect," you won't see a direct entry. Try "disconnecting means." That points you to "services," and the Index provides the exact location: Article 230, Part VI. Since the *NEC* doesn't list a page number in the Index, you'll still need the Table of Contents or a quick reference flip to find Article 230, then continue flipping through until you reach Part VI.

Many people say the *NEC* confuses them because they only skim through it. Once you gain experience reading the *Code* and expand your grasp of terms, concepts, and industry practices, you'll navigate it much more easily and with greater confidence.

With enough exposure to *NEC* topics, you'll notice that lots of words and phrases show up repeatedly across different articles. For example, the word "solar" first appears in *Code* Article 690 (Solar Photovoltaic Systems). The term "marina" signals information in Article 555. Sometimes a key article points you to a specific requirement somewhere else in the *Code*. For instance, compliance might be stated in another article "in accordance with 230.x." Don't think of those cross-references as a "circle," but rather as a map directing you to exactly where you need to look.

Customizing Your *Code* Book

You can make your *Code* book work better for you by highlighting and underlining the important *NEC* requirements. Preprinted adhesive tabs are handy for marking key articles and sections that you refer to often. Still, learn to use your *Code* book actively to prepare for tests and exams, since some tests don't permit sticky tabs. For more details about organizing your *Code* book, visit

Highlighting. When reading or searching for answers, mark the *NEC* requirements that matter most to you. Use a bright color like yellow for general items and a different color for highly priority topics you want to find fast. Be sure to highlight words in the Index and the Table of Contents as well.

Underlining. Underline or circle important key words and phrases in the *Code* with a red or blue pen (not a pencil) using a straight ruler or other edge to keep lines straight and neat. This is an efficient approach to help you identify important requirements quickly. A ruler or another straightedge is also useful for finding information in tables.

Interpretations

Electrical industry professionals often enjoy lively discussions when debating *Code* requirements. These conversations are valuable because they help everyone better understand how to apply the *NEC* and its requirements. If you decide to join one of these discussions, avoid assuming that you already know the real *Code* intent without checking first. Professionals frequently mention a requirement that isn't tied to a specific section after digesting numerous interpretations. This helps everyone involved really grasp the idea and become more informed about *NEC* issues so that you feel confident joining fie the code-change process and helping to improve it!

Become Involved in the *NEC* Process

Changing the *Code* is a two-year process with many participants who work to keep the *NEC* accurate and up to date. If you have a strong understanding of the *Code*, why not get involved? You'll learn something new, enjoy the experience more, and see how you can also contribute. Rather than just watching from the sidelines, take part in the process and help make it even better!

DEFINITIONS | From Michael Hamilton Publications

Instead of remaining on the sidelines while others shape the rules, you have the option to step up and get involved by submitting proposals or contributing directly to the code's development. In 2023, there were 3,730 Public Input submissions and 1,930 comments. Hundreds of adjustments and several brand-new articles were incorporated to ensure that the NEC stays current with emerging technology and continues moving us toward a safer, more efficient electrical future.
Below is an overview of how the process works:

STEP 1—Public Input Stage

Public Input. The revision cycle begins when the NEC accepts Public Input (PI)—a formal notice to anyone with an interest in proposing changes—to submit an existing standard or a new committee-approved draft standard. After the submission window closes, the committee convenes its First Draft Meeting to address all Public Input received.

First Draft Meeting. At this First Draft (FD) Meeting, the Technical Committee reviews and responds to every item of Public Input. They may use that input to create First Revisions to the standard. The First Draft package includes the opening consensus of the committee by simple majority. However, to place a proposal on the Technical Committe's ballot, it must be supported by a formal ballot.

Committee Ballot on First Draft. The First Draft, produced during the First Draft Meeting, is sent out for ballot. To be included in the First Draft, a proposal must receive approval from at least two-thirds of the Technical Committee.

First Draft Report Posted. All ballot-passed First Revisions are compiled and released as the First Draft Report on the NFPA website. This report serves as the official record of the Input Stage and is available to everyone for review and

whether to submit a Notice of Intent to Make a Motion (NITMAM) for further consideration.

STEP 2—Public Comment Stage

Public Comment. Once the First Draft Report is available, anyone can submit a Public Comment over a specified period on both the First Draft Report and the First Draft itself. When the Public Comment period closes, the Technical Committee convenes its Second Draft Meeting.

Second Draft Meeting. After the Public Comment period ends and the committee has reviewed all proposed revisions, the Second Draft Meeting takes place. At this meeting, the Technical Committee evaluates the First Draft and may issue additional revisions to the draft Standard. All Public Comments official action and response to each one. These actions are documented in the Second Draft.

Comments are considered, and the Technical Committee provides an action and response to each Public Comment. These actions result in the Second Draft.

Committee Ballot on Second Draft. The Second Revisions developed at the Second Draft Meeting are balloted. To appear in the Second Draft, a revision must be approved by at least two-thirds of the Technical Committee.

Second Draft Report Posted. Second Revisions which pass ballot are ultimately compiled and published as the Second Draft Report on the document's NFPA website. This report serves as documentation of the Comment Stage and is published for public review.

Once published, the public can review the Second Draft Report to decide whether to submit a Notice of Intent to Make a Motion (NITMAM) for further consideration.

STEP 3—NFPA Technical Meeting (Tech Session)

Following completion of the Public Input and Public Comment stages, there's further opportunity for debate and discussion of issues through the NFPA Technical Meeting that takes place at the NFPA Conference & Expo®. These motions are attempts to change the resulting final Standard from the committee's recommendations published as the Second Draft.

STEP 4—Council Appeals and Issuance of Standard

Issuance of Standards. When the Standards Council convenes to issue an NFPA standard, it also hears any related appeals. Appeals are an important part of ensuring that all NFPA rules have been followed and that due process and fairness have continued throughout the standards development process. The Standards Council considers appeals based on the written record and by conducting live hearings during which all interested parties can participate. Appeals are decided on the entire record of the process, as well as all submissions and statements presented.

After deciding all appeals related to a standard, the Standards Council, if appropriate, proceeds to issue the Standard as an official NFPA Standard. The decision of the Standards Council is final subject only to limited review by the NFPA Board of Directors. The new NFPA standard becomes effective twenty days following the Standards Council's action of issuance.

DEFINITIONS | From Michael Hamilton Publications

Tentative Interim Amendment—(TIA)

Standards occasionally undergo last-minute changes. Maybe an editor discovers a mistake that could affect an electrical installation, or an issue arises in the field that needs immediate attention and can't wait until the next *Code* cycle. When that happens, a Tentative Interim Amendment, or "TIA," may be proposed for consideration.

The NFPA issues a TIA because it hasn't completed the full standards-making process. By nature, it is temporary and only appears in selected editions of the standard. A TIA automatically becomes a Public Input of the proposed text for the next edition of the standard. At that point, it is open to all the steps of the standards development process.

Author's Commentary:

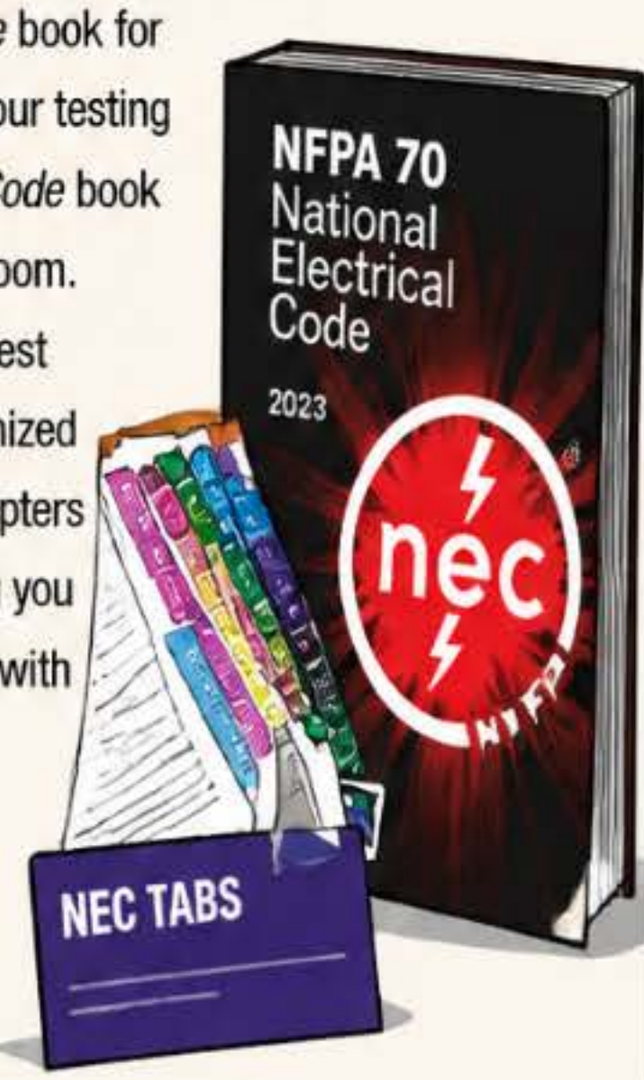
- You can submit proposals, comments, and TIAs for consideration on the NFPA website at nfpa.org. From the homepage, look for "Codes & Standards," then choose "Standards Development," and click "How the Process Works." If you come across something in the *Code* that you think should be changed, I encourage you to get involved.

— Michael Hamilton

2023 *Code* Book and Tabs

The best way to use your *Code* book is to make it a quick-reference tool—just like the tabs that are my most popular. If you're using your *Code* book for an exam, confirm with your testing authority that a tabbed *Code* book is allowed in the exam room. Also included is the newest version of our tabs, organized by color to match the chapters in this textbook—helping you cross-reference the text with the *NEC* with ease.

Order your tabs today.



ARTICLE 90 INTRODUCTION TO THE *NATIONAL ELECTRICAL CODE*

Introduction to Article 90—Introduction to the *National Electrical Code*

Article 90 begins by stating clearly that the *National Electrical Code* (*NEC/Code*) is not a design specification or a training text. Its sole aim is to promote the practical protection of *people* and property from the dangers that *electricity* presents. This does not mean that installations will necessarily be the most convenient, or the easiest to adapt to in the future, nor imply that.

Understanding where to locate the rules that apply to a given installation can be challenging. While there is no single method that works for every situation, you are not expected to immediately gain confidence by knowing where to begin your research after studying this manual.

Article 90 then goes on to outline the scope and organization of the *NEC*. This balance gives you the information you need to grasp how the *Code* is arranged and what it covers.

Most electrical systems fall under the first four chapters of the *NEC* (the chapters that apply in general) and require working knowledge of Chapter 9 tables. Gaining familiarity with these parts of the *Code* is essential. Chapters 5, 6, and 7 cover much of the *Code* body but only to special occupancies, special equipment, or special conditions. The first four chapters, however, include the rules found in Chapter 8.

Chapter 8 addresses the communication systems—radio and television devices, satellite receivers, antenna systems, twisted-pair conductors, and general cable wiring. Communications rules are found in Chapter 8 (radio and television devices, satellite receivers, antenna systems, twisted-pair conductors, and general cable wiring). Specialized requirements in other chapters may refer to these communications rules.

90.1 Purpose of the *NEC*

(A) Practical Safeguarding. The goal of the *National Electrical Code* is to ensure electrical installations are performed in a way that protects people and property by reducing risks related to electricity. The *NEC* is not intended as a design specification or a training manual for untrained or unqualified persons.

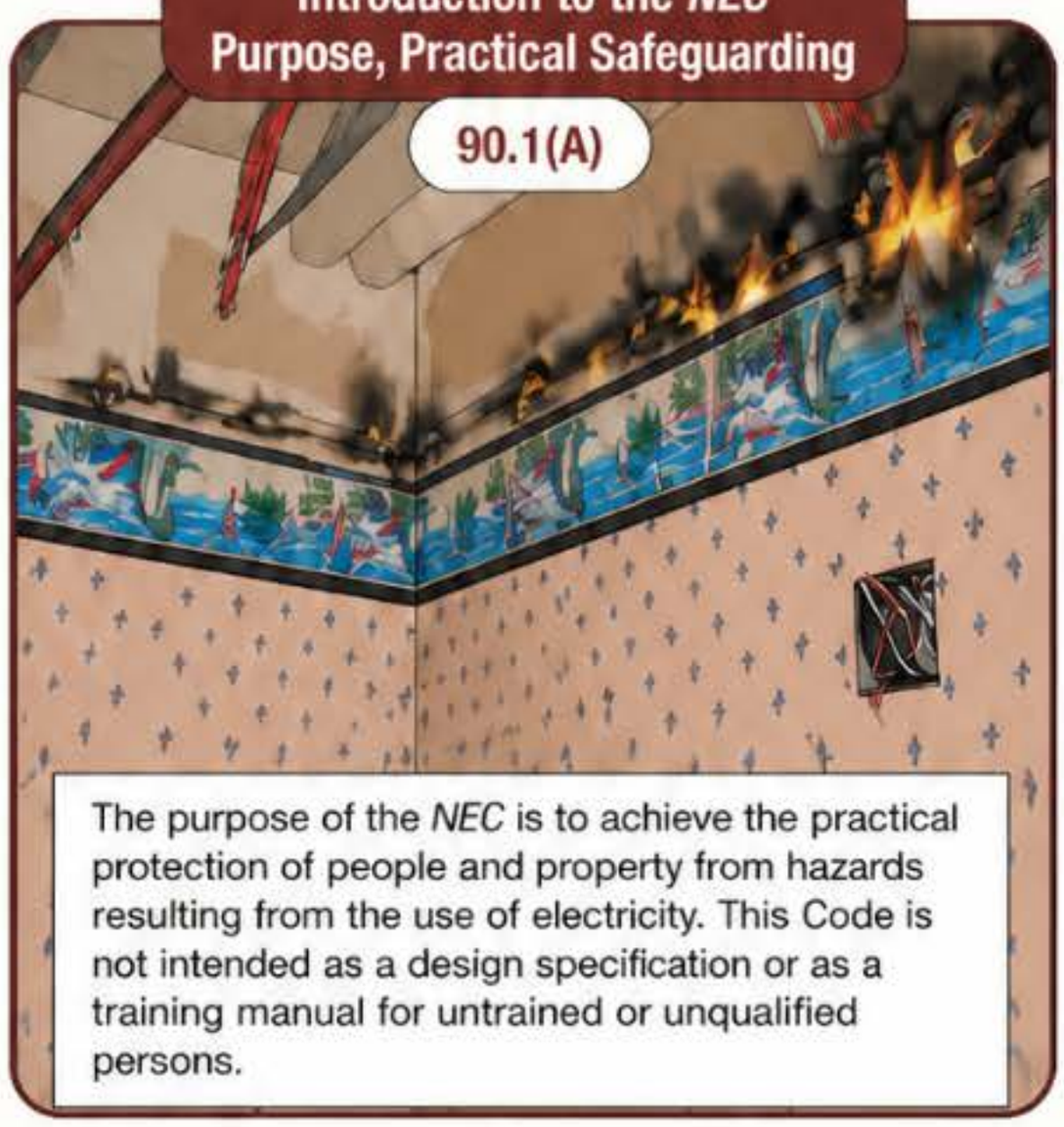
▶ **Figure 90–1**

Author's Commentary:

The *Code* is meant for individuals who are trained and knowledgeable in electrical theory, electrical systems, construction methods, and the installation and operation of electrical equipment.

— Michael Hamilton

Introduction to the *NEC* Purpose, Practical Safeguarding



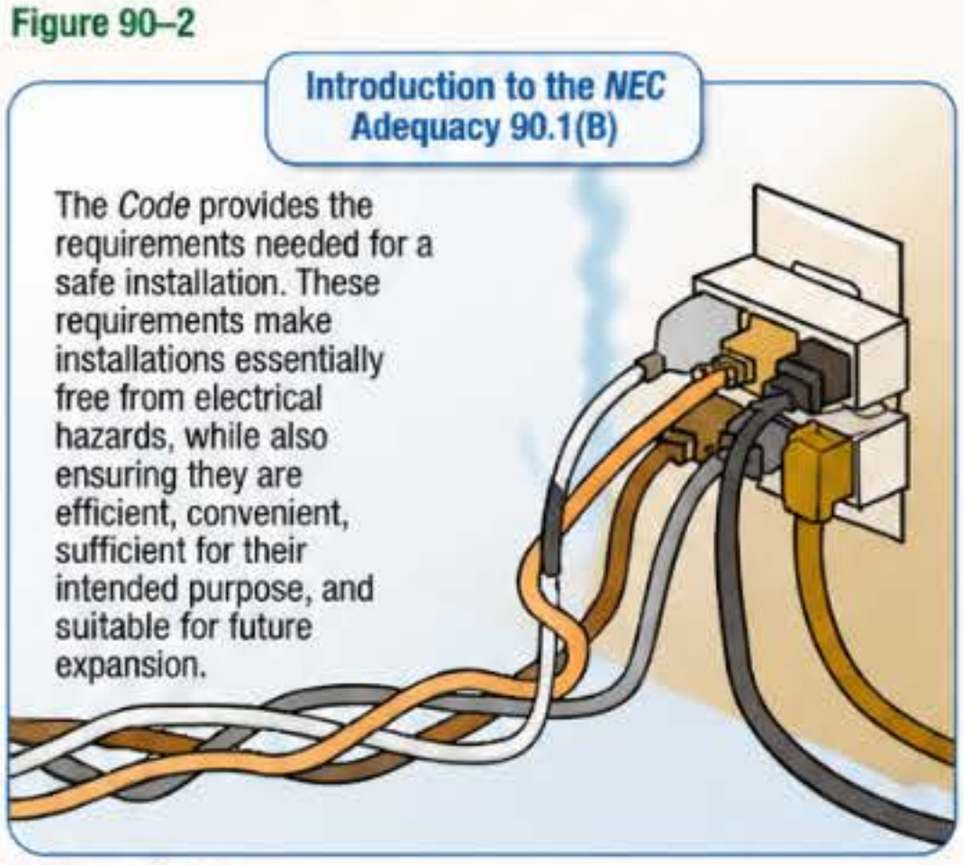
The purpose of the *NEC* is to achieve the practical protection of people and property from hazards resulting from the use of electricity. This Code is not intended as a design specification or as a training manual for untrained or unqualified persons.

▶ **Figure 90–1**

90.2 Introduction to the *National Electrical Code*

(B) Adequacy. Electrical installations must comply with the provisions the *NEC* esttablises to protect people and property. Whenever an installation follows the *Code*, it is considered essentially free of electrical dangers.

These provisions are intended to make installations dependable, convenient to operate, sufficiently capable for the intended use, and appropriate for dependable service or future growth. **Figure 90–2**



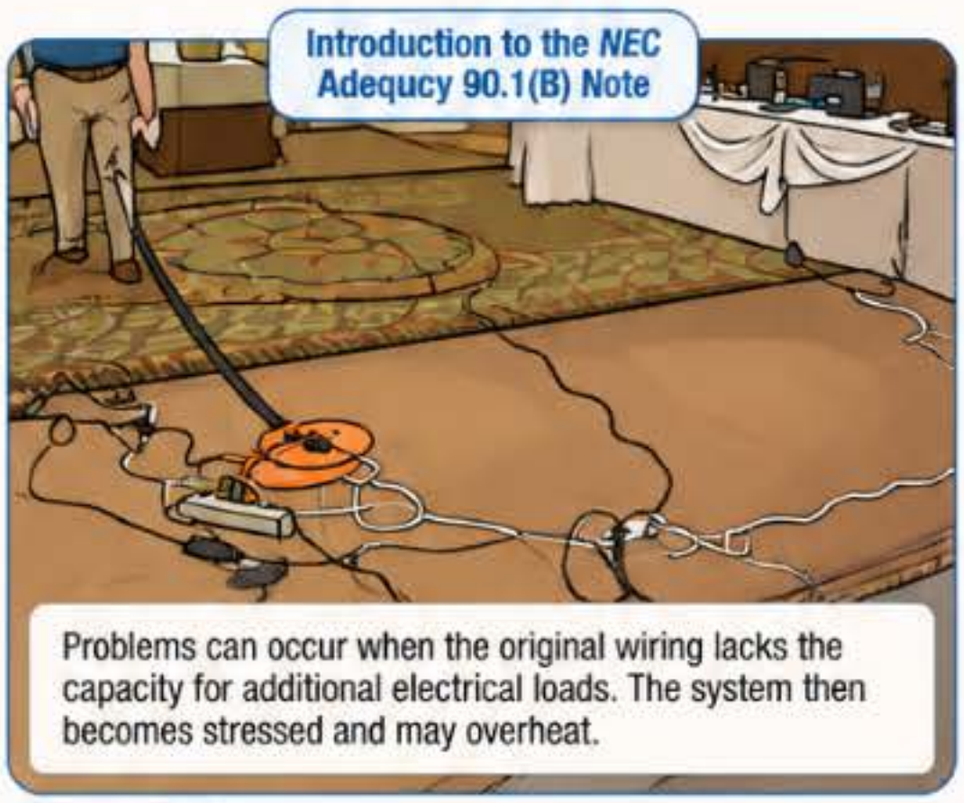
▸ Figure 90–2

Author's Commentary:

Concerns such as managing energy use, keeping equipment in service, ensuring high-quality power, and accommodating future increases in demand are not treated within the scope of the *NEC*.

— Michael Hamitton

Note: Hazards often happen because initial wiring does not provide enough capacity for later electrical additions, causing systems to become overloaded. **Figure 90–3**



▸ Figure 90–3

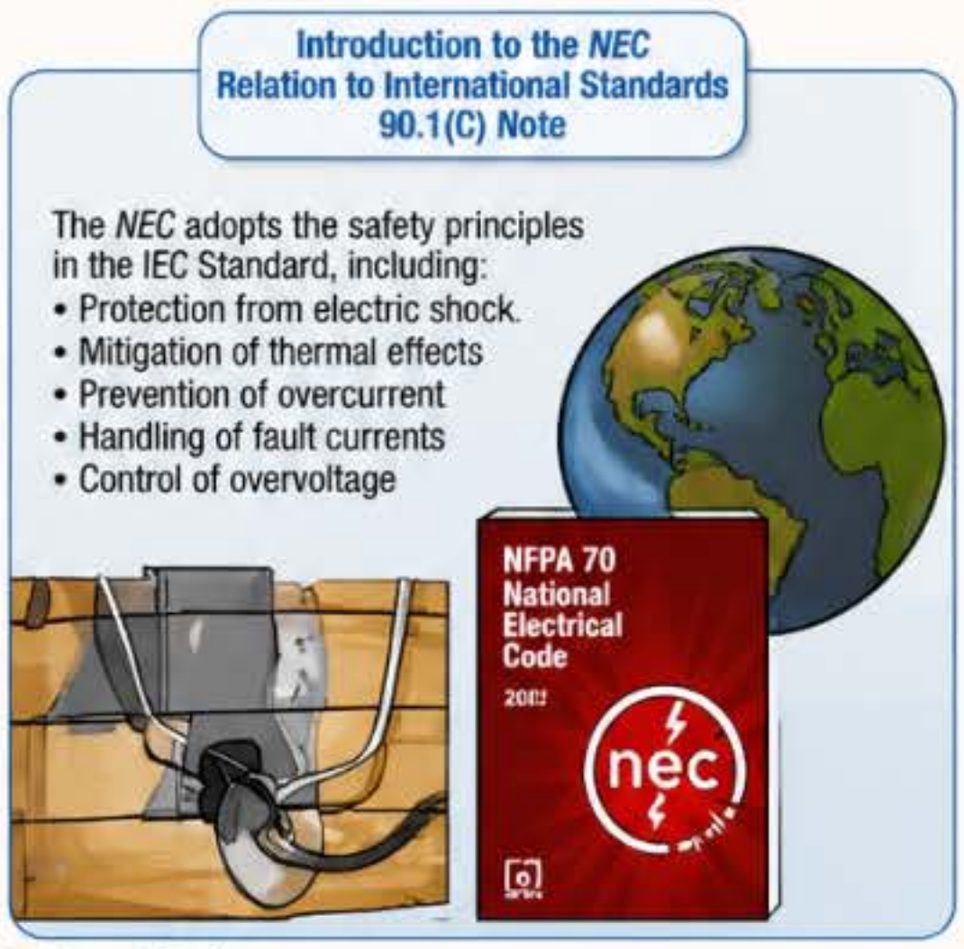
Author's Commentary:

The *NEC* is not limited to present installations or systems. It does not demand that equipment be designed or installed to handle future loads. That said, electricians (who usually care about safety and *Code* compliance) also consider what customers need both now and in the years ahead. To meet those needs, systems are designed and installed to exceed the minimum *NEC* requirements.

— Michael Hamilton

(C) Relation to International Standards. The *NEC* incorporates the basic safety principles found in the International Electrotechnical Commission (IEC) Standard.

Note: IEC 60364-1, Section 131, sets forth core protection principles against electric shock, safeguards against thermal effects, guards against overcurrent, protection against fault currents, and measures against overvoltage. All identified risks are addressed through *NEC* requirements. **Figure 90–4**



▸ Figure 90–4

90.2 Scope of the *NEC*

(A) What is Covered by the *NEC*. The *NEC* covers the installation and removal of electrical conductors, equipment, and raceways; signaling and communication conductors and equipment; and raceways along with optical fiber cables and raceways. **Figure 90–5**

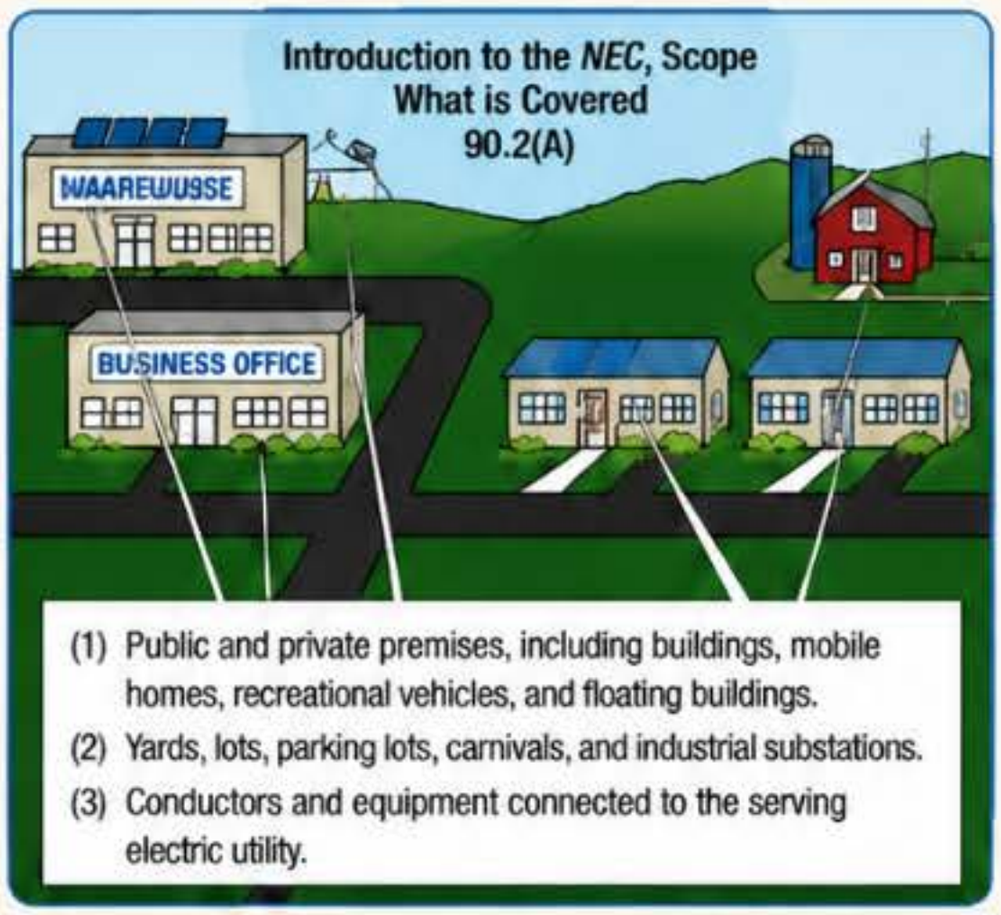


Figure 90–5

(1) Public and private premises including buildings, mobile homes, recreational vehicles, and floating buildings.

(2) Yards, lots, parking lots, carnivals, and industrial substations.

(3) Conductors and equipment connected to the serving electric utility.

(4) Installations used by a serving electric utility such as office buildings, warehouses, garages, machine shops, recreational buildings, and other electric utility buildings that are not an integral part of a utility's generating plant, substation, or control center. ▸**Figure 80–6**

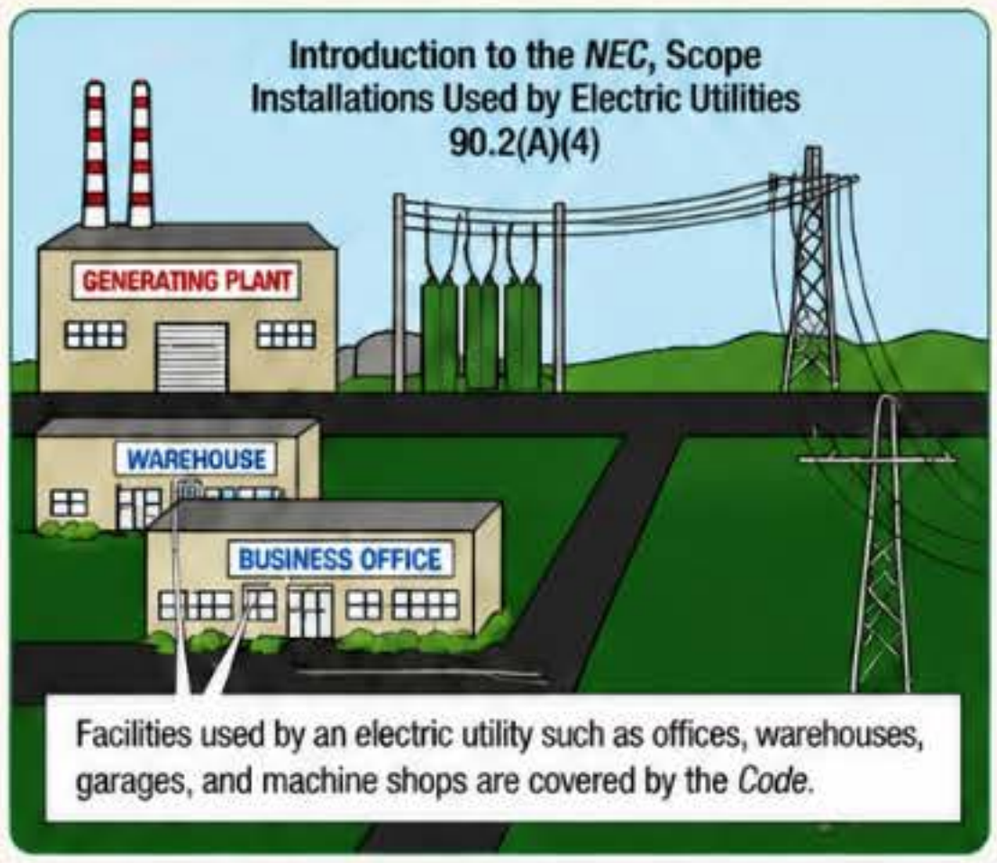


Figure 90–6

(5) Installations supplying shore power to watercraft in marinas and boatyards, including systems that monitor leakage current. ▸**Figure 90–7**

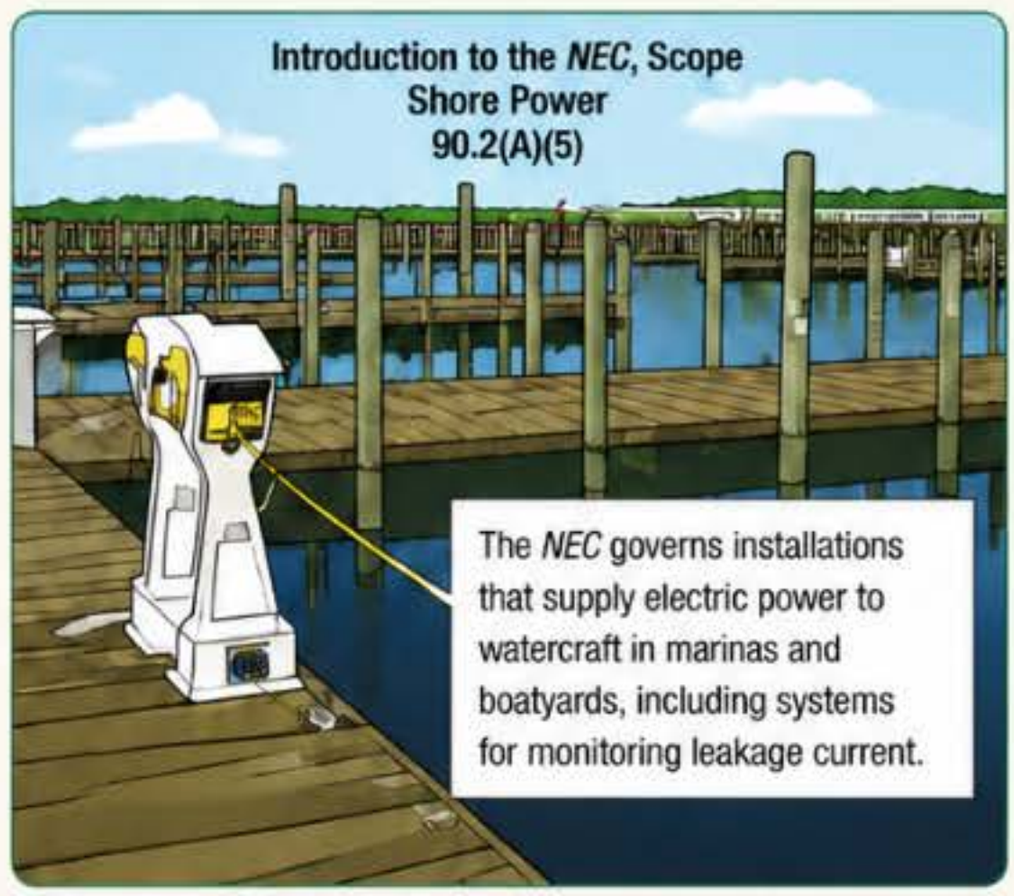


Figure 90–7

Author's Commentary:

- The updated text in Article 90's scope, 90.2(A)(5), makes it clear to include the power cable located between the pedestal and the boat within the coverage of the *NEC*, but there are no specific rules in Article 555 addressing that power-supply cord.
- The language in 555.35(B) requires leakage-detection equipment to sense leakage current from boats and sends that information to the load side of the marina's power pedestal.

— Michael Hamilton

(6) Installations used to export electric power from vehicles to premises wiring or for bidirectional current flow. ▸**Figure 90–8**

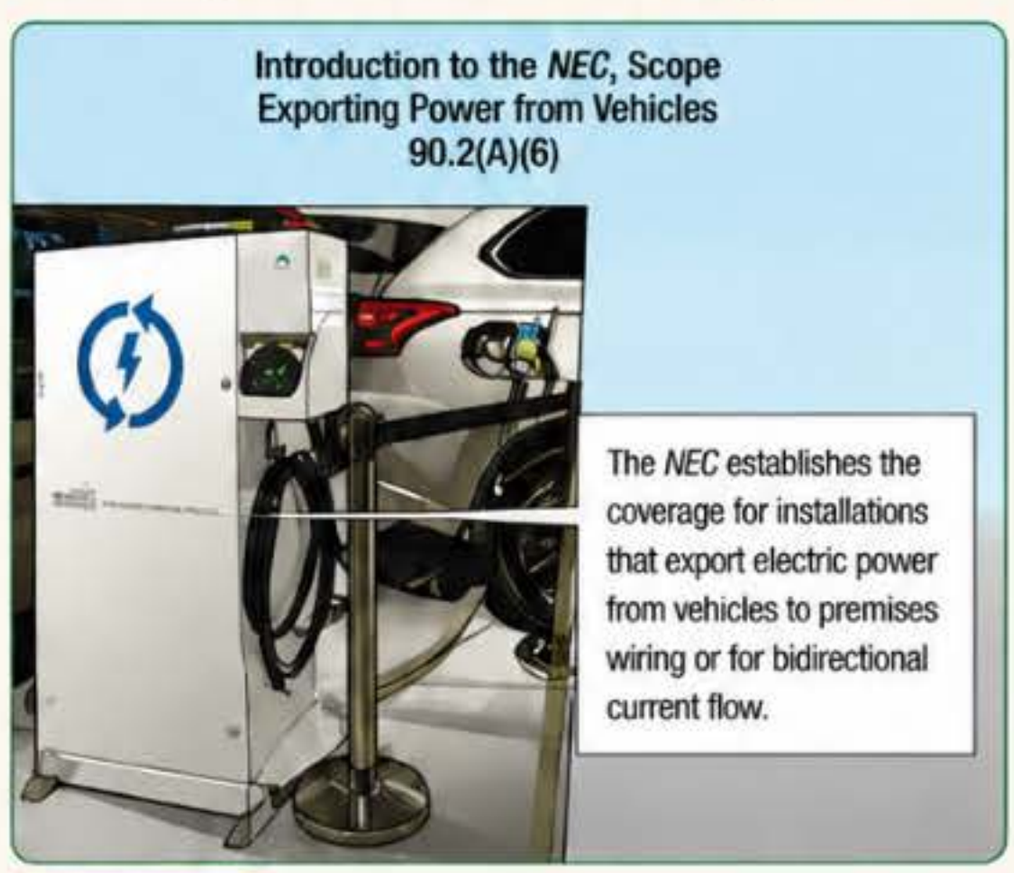


Figure 90–8

90.3 | Introduction to the *National Electrical Code*

Author's Commentary:
An EV battery system can be arranged "bidirectionally," meaning it has the ability to act as a reserve or secondary source of power to energize building circuits when the primary supply fails. The guidelines that govern such use are found in Article 625.

— Michael Hamilton

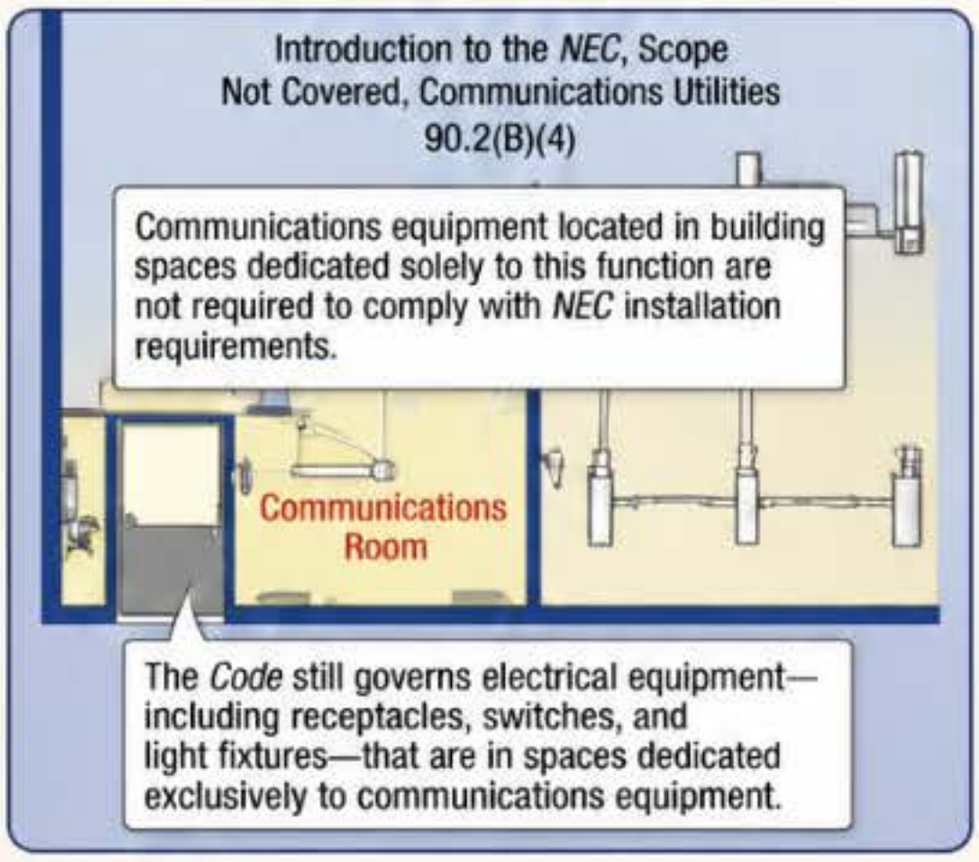
(B) What Is Not Covered by the *NEC*. The *Code* does not address the installation of electrical or communication systems in the following situations:

(1) Transportation Vehicles. The *NEC* excludes installations on ships and watercraft other than floating structures, and motor vehicles other than mobile residences and recreational vehicles.

(2) Mining Equipment. The *Code* excludes systems used in underground mining, along with power and communications for self-propelled mining machines and the related electrical hauling equipment.

(3) Railways. The *NEC* does not apply to railroad power systems, signaling, energy storage, or communications wiring.

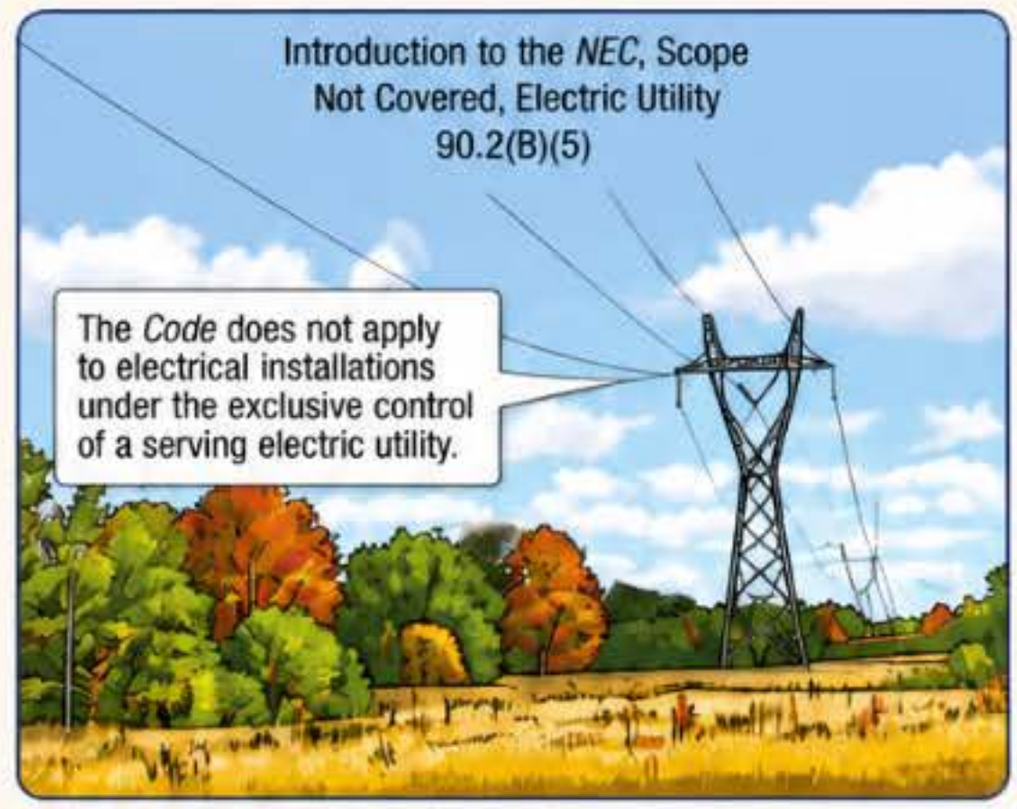
(4) Communications Utilities. The *Code* does not govern installations under the sole control of communications utilities in building areas used exclusively for such purposes or in outdoor locations. **Figure 90–9** illustrates this case.



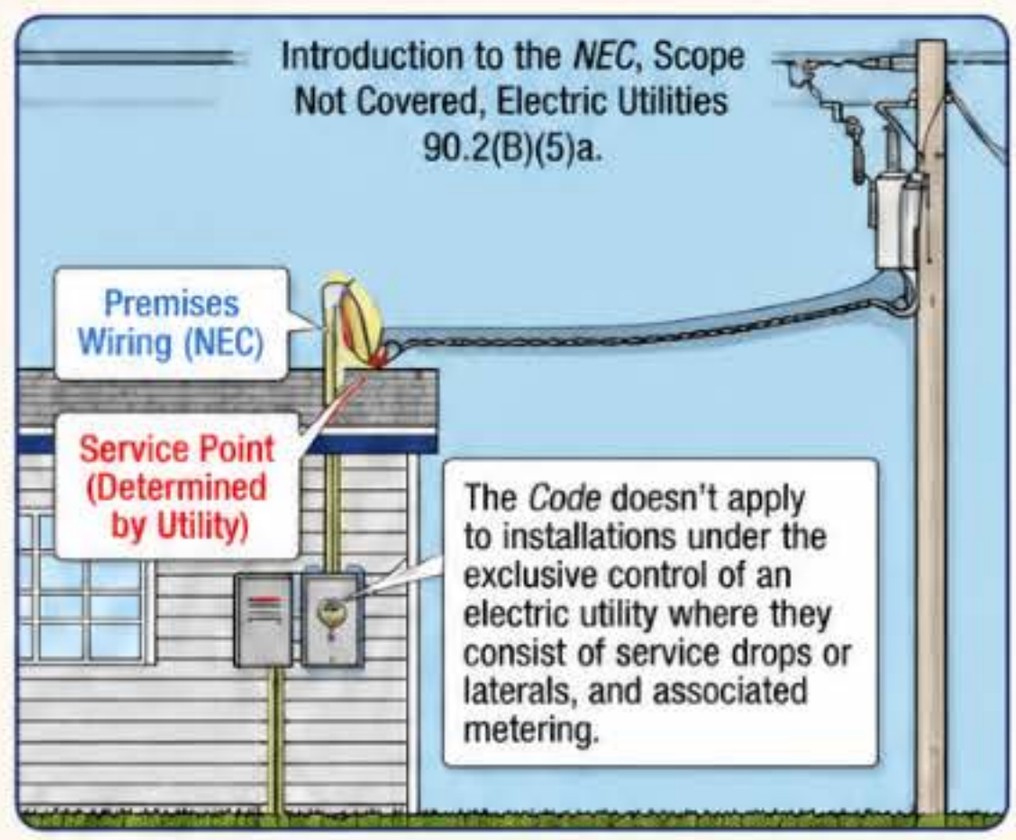
▲ Figure 90–9

(5) Electric Utilities. The *NEC* does not apply to electrical installations under the exclusive control of a serving electric utility in situations such as these: **Figure 90–10**.

a. Include service drops, service laterals, and the associated metering equipment. **Figure 90–11** illustrates this case.



▲ Figure 90–10



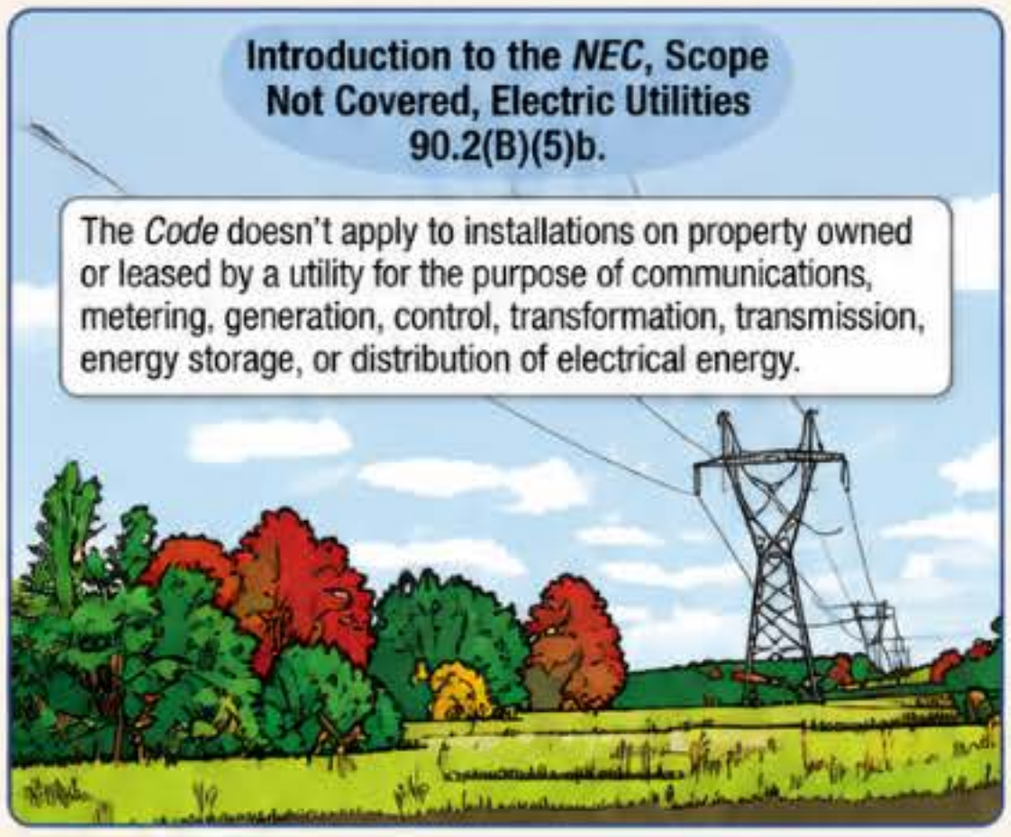
▲ Figure 90–11

b. Are on property owned or leased by the utility for the purpose of communications, metering, generation, control, transformation, transmission, energy storage, or distribution of electricity. **Figure 90–12** shows an example.

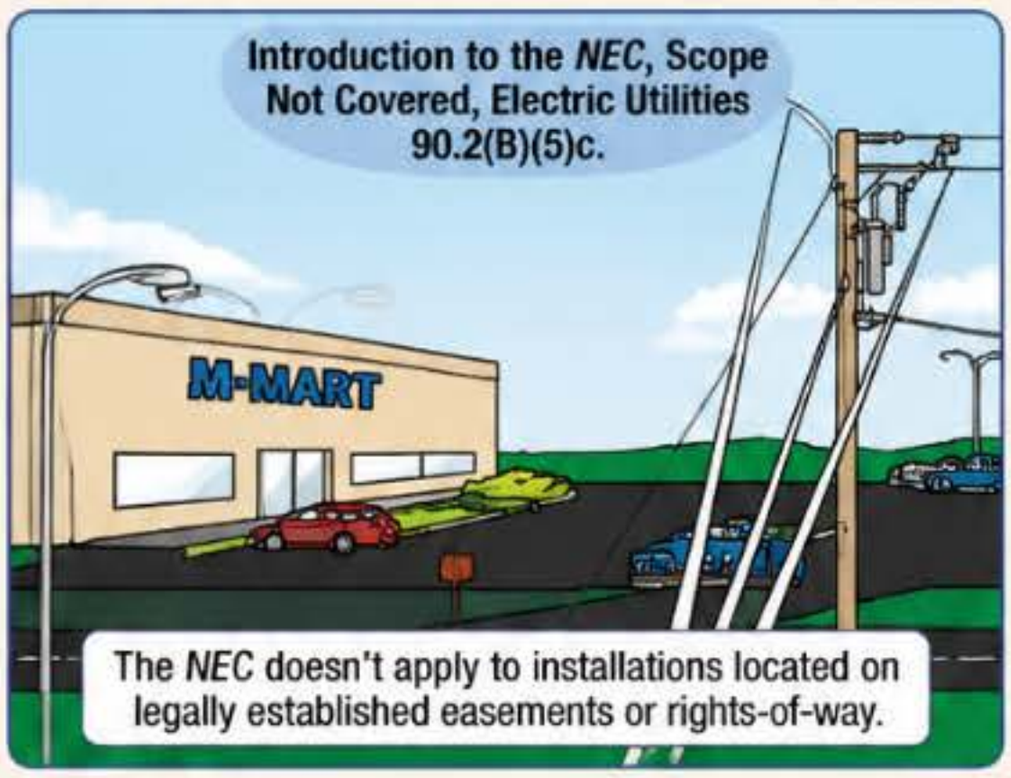
c. Are located in legally established easements or rights-of-way. **Figure 90–13** provides an example.

90.3 Code Arrangement

General Requirements. The *Code* is organized with an introductory portion, followed by nine chapters, and then by informative annexes. Chapters 1 through 4 present general conditions. **Figure 90–14** shows this organization.



▶ **Figure 90–12**



▶ **Figure 90–13**

Introduction to the *NEC*, Code Arrangement 90.3

General Requirements
- Ch 1 - General
- Ch 2 - Wiring and Protection
- Ch 3 - Wiring Methods & Materials
- Ch 4 - Equipment for General Use

Chapters 1 through 4 generally apply to all applications.

Special Requirements
- Chapter 5 - Special Occupancies
- Chapter 6 - Special Equipment
- Chapter 7 - Special Conditions

Chs 5 through 7 may supplement or modify the requirements in Chapters 1 through 7.

- **Ch 8 - Communications Systems**
  Ch 8 requirements are not subject to requirements in Chapters 1 through 7, unless there is a specific reference in Ch 8 to a rule in Chapters 1 through 7.
- **Chapter 9 - Tables**
  Ch 9 tables are applicable as referenced in the *NEC* and are used for calculating raceway sizes, conductor fill, and voltage drop.
- **Annexes A through J**
  Annexes are for information only and are not enforceable.

The *NEC* is divided into an introduction and nine chapters, followed by informative annexes.

▶ **Figure 90–14**

The requirements contained in Chapters 5, 6, and 7 apply to special occupancies, special equipment, or other special conditions, which may supplement or modify the requirements contained in Chapters 1 through 7, but not Chapter 8.

Chapter 8 contains the requirements for communications systems (twisted wire, antennas, and coaxial cable) which are not subject to the general requirements of Chapters 1 through 4, or the special requirements of Chapters 5 through 7, unless a specific reference in Chapter 8 is made to a rule in Chapters 1 through 7.

Chapter 9 consists of tables applicable as referenced in the *NEC*. The tables are used to calculate raceway sizing, conductor fill, the radius of raceway bends, and conductor voltage drop.

Annexes are not part of the requirements of the *Code* but are included for informational purposes. There are ten annexes:

- Annex A. Product Safety Standards
- Annex B. Application Information for Ampacity Calculation
- Annex C. Raceway Fill Tables for Conductors and Fixture Wires of the Same Size
- Annex D. Examples
- Annex E. Types of Construction
- Annex F. Critical Operations Power Systems (COPS)
- Annex G. Supervisory Control and Data Acquisition (SCADA)
- Annex H. Administration and Enforcement
- Annex I. Recommended Tightening Torques
- Annex J. ADA Standards for Accessible Design

90.4 Enforcement

The *NEC* is intended to be suitable for enforcement by governmental bodies that exercise legal jurisdiction over electrical installations for power, lighting, signaling circuits, and communications systems such as: ▶ **Figure 90–15**

Signaling circuits include:

- Article 725. Remote-Control, Signaling, and Power-Limited Circuits
- Article 760. Fire Alarm Systems
- Article 770. Optical Fiber Cables

Communications systems which include:

- Article 810. Radio and Television Equipment (Satellite Antenna)
- Article 820. Community Antenna Television and Radio Distribution Systems (Coaxial Cable)

90.4 | Introduction to the *National Electrical Code*

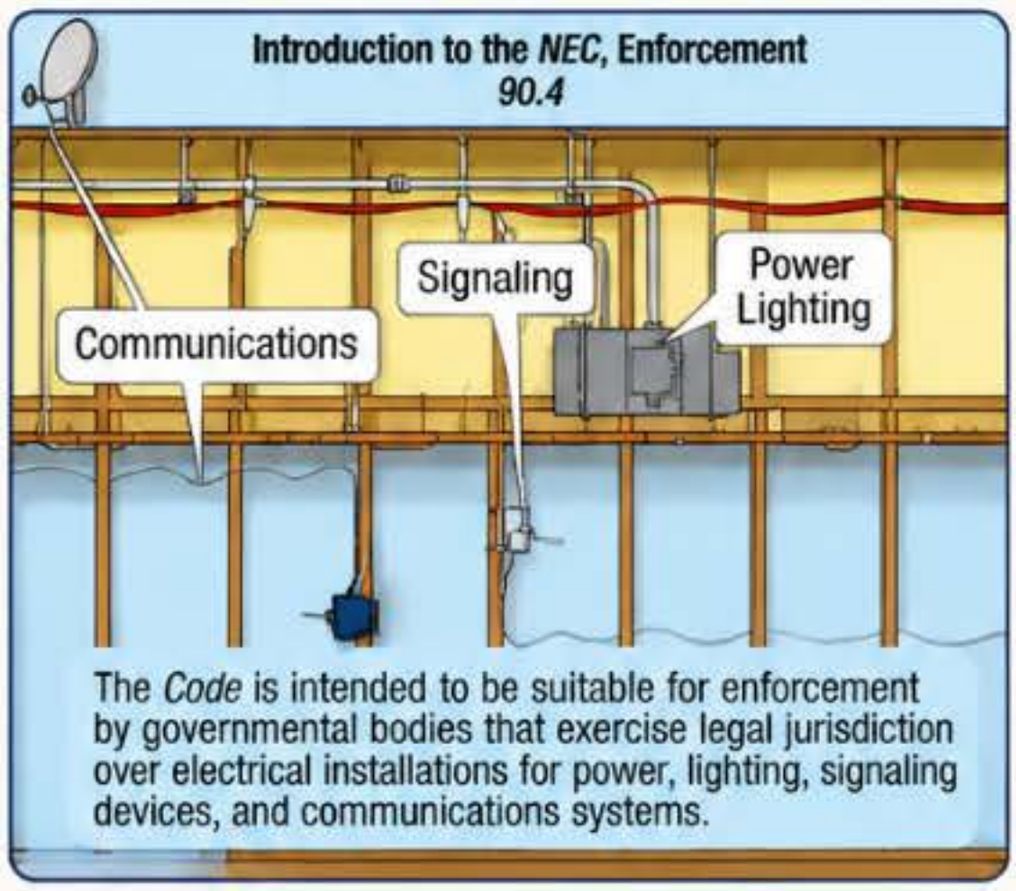


Figure 90–15

Author's Commentary:

- Once adopted (in part, wholly, or amended), the *National Electrical Code* becomes statutory law for the adopting jurisdiction and is thereby considered a legal document.

Enforcement. The enforcement of the *NEC* is the responsibility of the authority having jurisdiction, who is responsible for interpreting requirements, approving equipment and materials, waiving *Code* requirements, and ensuring equipment is installed in accordance with listing instructions. ■ **Figure 90–16**

Author's Commentary:

- "Authority Having Jurisdiction" is defined in Article 100 as the organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure. See 90.4 and 90.7 for more information.
- "Approved" is defined in Article 100 as acceptable to the authority having jurisdiction; usually the electrical inspector.

Interpretation. The authority having jurisdiction is responsible for interpreting the *NEC*.

Author's Commentary:

- The authority having jurisdiction's decisions must be based on a specific *Code* requirement. If an installation is rejected, the AHJ is legally responsible for informing the installer of the specific *NEC* rule that was violated.
- The art of getting along with the AHJ consists of doing good work and knowing what the *Code* says (as opposed to what you think it says). It is also useful to know how to choose your battles when the inevitable disagreement does occur.

Approval of Equipment and Materials. Only the authority having jurisdiction has the authority to approve the installation of equipment and materials. ■ **Figure 90–17**

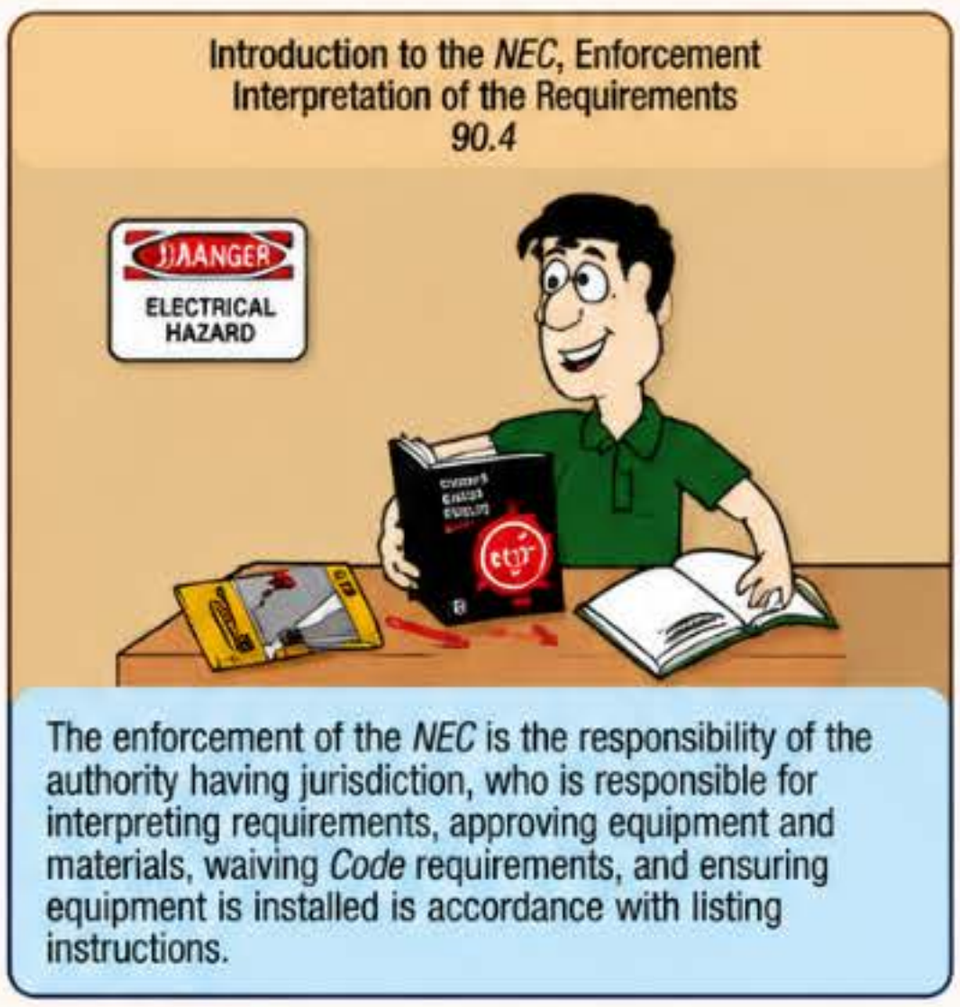


Figure 90–16

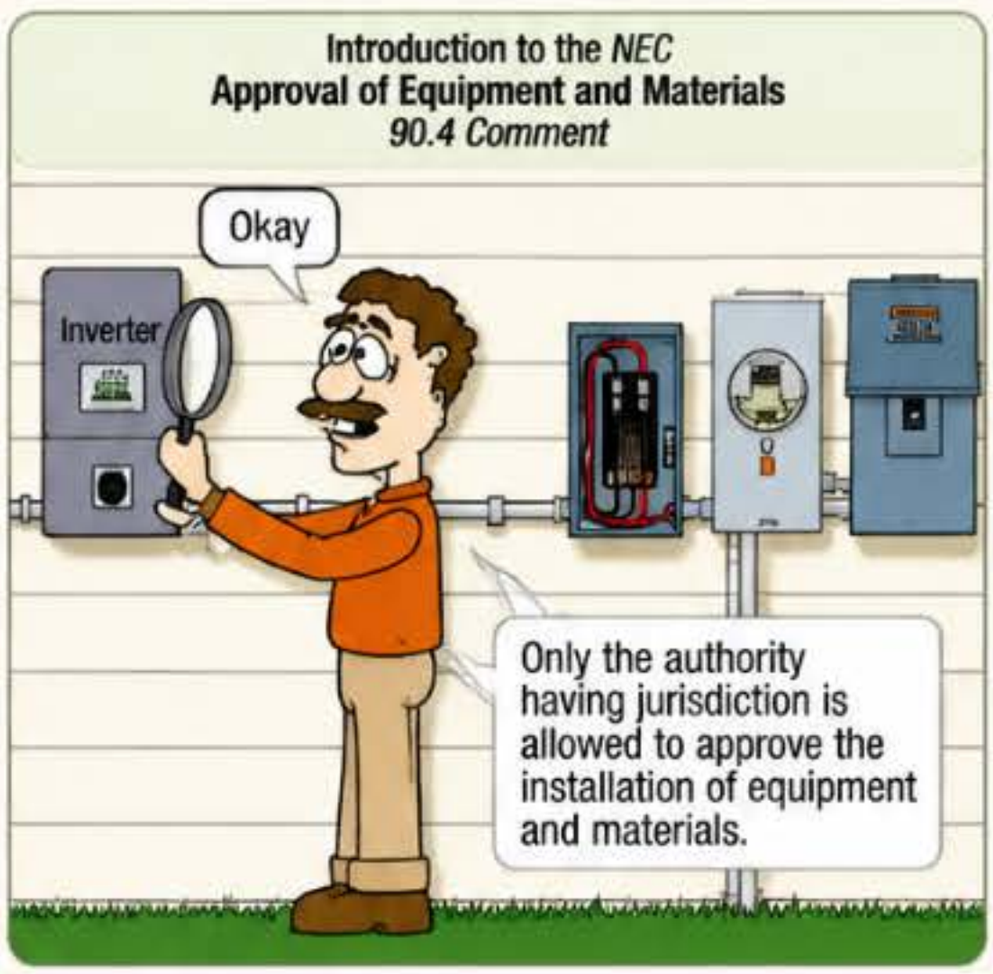


Figure 90–17

DEFINITIONS | From Michael Hamilton Publications

Author's Commentary:

In practice, the AHJ commonly approves testing equipment accepted by a recognized testing body such as Underwriters Laboratories, Inc. (UL). The *NEC* does not mandate listing of every item, yet many state and local regulations adopt sections 90.7, 110.2, and 110.3 as well as the terms in Article 100 like "Approved," "Identified," "Labeled," and "Listed."

Under the *Code*, the AHJ decides whether listed equipment is acceptable. This means the agency may reject an installation of listed equipment or authorize the use of some unlisted equipment. With more highly scrutinized societies today, gaining permission to use unlisted equipment is becoming harder.

— Michael Hamilton

Approval of Alternate Means. Through a special allowance, the authority having jurisdiction may sanction alternate methods that provide equivalent safety when dependability is demonstrated and preserved.

Author's Commentary:

The term "Special Permission," defined in Article 100, means the written consent of the AHJ.

— Michael Hamilton

Waiver of Product Requirements. If the *Code* specifies products, construction methods, or materials that are not available at the time the *NEC* is adopted, the AHJ can permit substitution with items that were allowable under the earlier *Code* edition.

Author's Commentary:

There are times when testing laboratories require several years to establish product standards that meet new *NEC* product requirements. Therefore, it can take years for those products to be manufactured and marketed.

— Michael Hamilton

90.5 Mandatory Requirements and Explanatory Material

(A) Mandatory Requirements. The words "shall" or "shall not" signify a mandatory requirement.

Author's Commentary:

To simplify reading, this text uses "must" for "shall" and "must not" for "shall not."

— Michael Hamilton

(B) Permissive Requirements. Where the *Code* uses "shall be permitted" it means the action is allowed, but not required. Permissive rules are often found as exceptions to general requirements.

Author's Commentary:

For easier reading, the phrase "shall be permitted" (as found in the *NEC*) is replaced here with "is permitted" or "are permitted."

— Michael Hamilton

(C) Explanatory Material. References to other standards or information related to a *Code* rule are included under "Informational Notes." Such notes exist for informational purposes only and have no enforceable status as an *NEC* requirement.

For example, Informational Note No. 3 in 210.19(A)(1) suggests that voltage drop in a circuit should not exceed 3 percent; however, this is guidance only—not a *Code* requirement.

Author's Commentary:

For convenience of the reader, this text labels "Informational Notes" as "Notes."

— Michael Hamilton

CAUTION

Informational notes are not enforceable, but notes in tables are. Within this textbook, notes inside tables will be called "table notes."

(D) Informative Annexes. Annex material in the back of the *Code* is provided for information purposes only and has no enforceable effect as *NEC* requirements.

90.7 Examination of Equipment for Product Safety

Product evaluation for *Code* compliance, approval, and safety is generally performed by a nationally recognized testing laboratory in accordance with established testing standards.

Except to detect modifications or damage, factory-installed internal wiring of equipment that has been processed by a qualified testing laboratory does not need retesting for *NEC* compliance at the time of installation. **Figure 90-18**

Note 1: The requirements of Article 300 do not apply to the integral components of electrical equipment. See 110.3(B).

90.7 | Introduction to the *National Electrical Code*

▶ **Figure 90–18**

Note 2 "Listed" is defined in Article 100 as equipment or materials included in a list published by a testing laboratory acceptable to the authority having jurisdiction. The listing organization must periodically inspect the production of listed equipment or material to ensure it meets appropriate designated standards and is suitable for a specified purpose.

Author's Commentary:

Equipment that is "listed" has already been examined by an approved testing laboratory. Inspectors do not need to open the equipment to look at internal wiring or construction, unless there is a reason to believe it has been modified or damaged.

— Michael Hamilton

ARTICLE 90 PRACTICE QUESTIONS

Please use the **2023** ***Code*** book to answer the following questions.

Article 90—Introduction to the *National Electrical Code*

1. The *NEC* is _____.
   (a) intended to be a design manual
   (b) meant to be used as an instruction guide for untrained persons
   (c) for the practical safeguarding of persons and property
   (d) published by the Bureau of Standards

2. Compliance with the *Code* and proper maintenance result in an installation that is essentially _____.
   (a) free from hazards
   (b) not efficient or convenient
   (c) not adequate for good service or future expansion
   (d) all of these

3. Compliance with the provisions of the *NEC* will result in _____.
   (a) good electrical service
   (b) an efficient electrical system
   (c) an electrical system essentially free from hazard
   (d) all of these

4. The *Code* contains provisions considered necessary for safety, which will not necessarily result in _____.
   (a) efficient use
   (b) convenience
   (c) good service or future expansion of electrical use
   (d) all of these

5. Electrical hazards often occur because the initial _____ did not provide for increases in the use of electricity and therefore wiring systems become overloaded.
   (a) inspection
   (b) owner
   (c) wiring
   (d) builder

6. Hazards often occur because of _____.
   (a) overloading of wiring systems by methods or usage not in conformity with the *NEC*
   (b) initial wiring not providing for increases in the use of electricity
   (c) manufacturing defects
   (d) overloading of wiring systems by methods or usage not in conformity with the *NEC* and initial wiring not providing for increases in the use of electricity

7. Which of the following systems shall be installed and removed in accordance with the *NEC* requirements?
   (a) Signaling conductors, equipment, and raceways
   (b) Communications conductors, equipment, and raceways
   (c) Electrical conductors, equipment, and raceways
   (d) all of these

8. The *NEC* applies to the installation of _____.
   (a) electrical conductors and equipment within or on public and private buildings
   (b) signaling and communication conductors
   (c) optical fiber cables
   (d) all of these

ARTICLE 90 PRACTICE QUESTIONS

9. This *Code* covers the installation of _____ for public and private premises, including buildings, structures, mobile homes, recreational vehicles, and floating buildings.
   (a) optical fiber cables
   (b) electrical equipment
   (c) raceways
   (d) all of these

10. Installations supplying _____ power to ships and watercraft in marinas and boatyards are covered by the *NEC*.
   (a) shore
   (b) primary
   (c) secondary
   (d) auxiliary

11. Installations used to export electric power from vehicles to premises wiring or for _____ current flow are covered by the *NEC*.
   (a) emergency
   (b) primary
   (c) bidirectional
   (d) secondary

12. The *NEC* does apply to installations in _____.
   (a) floating buildings
   (b) mobile homes
   (c) recreational vehicles
   (d) all of these

13. The *NEC* does not cover electrical installations in ships, watercraft, railway rolling stock, aircraft, or automotive vehicles.
   (a) True
   (b) False

14. The *Code* covers underground mine installations and self-propelled mobile surface mining machinery and its attendant electrical trailing cable.
   (a) True
   (b) False

15. The *Code* does not cover installations under the exclusive control of an electrical utility such as _____.
   (a) service drops and laterals
   (b) electric utility office buildings
   (c) electric utility warehouses
   (d) electric utility garages

16. Installations of communications equipment that are under the exclusive control of communications utilities and located outdoors or in building spaces used exclusively for such installations _____ covered by the *NEC*.
   (a) are
   (b) are sometimes
   (c) are not
   (d) may be

17. Chapters 1 through 4 of the *NEC* apply _____.
   (a) generally to all electrical installations
   (b) only to special occupancies and conditions
   (c) only to special equipment and material
   (d) all of these

18. Chapters 5, 6, and 7 apply to special occupancies, special equipment, or other special conditions and may supplement or modify the requirements in Chapters 1 through 7.
   (a) True
   (b) False

19. Chapters 5, 6, and 7 of the *NEC* apply to _____.
   (a) special occupancies
   (b) special equipment
   (c) special conditions
   (d) all of these

20. Communications wiring such as telephone, antenna, and CATV wiring within a building shall not be required to comply with the installation requirements of Chapters 1 through 7, except where specifically referenced in Chapter 8.
   (a) True
   (b) False

21. Installations shall comply with the material located in the *NEC* Annexes because they are part of the requirements of the *Code*.
   (a) True
   (d) False

22. The _____ has the responsibility for deciding on the approval of equipment and materials.
   (a) manufacturer
   (b) authority having jurisdiction
   (c) testing agency
   (d) the owner of the premises

DEFINITIONS | From Michael Hamilton Publications

23. The authority having jurisdiction has the responsibility for _____.

(a) offering interpretations of rules
(b) making decisions on the acceptance of equipment and materials
(c) consenting to particular requirements in the *Code* and allowing alternative methods that meet safety objectives
(d) all of these

24. If the *NEC* requires new products that are not yet available when a new edition goes into effect, the _____ may allow the use of those products to comply with the most recent previous edition of the *Code* adopted by that jurisdiction.

(a) electrical engineer
(b) master electrician
(c) authority having jurisdiction
(d) permit holder

25. In the *NEC*, the word(s) "_____" indicate a mandatory requirement.

(a) shall
(b) shall not
(c) shall be permitted
(d) shall or shall not

26. When the *Code* uses "_____," it means the identified actions are allowed but not required, and they may be options or alternative methods.

(a) shall
(b) shall not
(c) shall be permitted
(d) shall or shall not

27. Explanatory material, such as references to other standards, references to related sections of the *NEC*, or information related to a *Code* rule, are included in the form of Informational Notes.

(a) True
(b) False

28. Nonmandatory Informative Annexes contained in the back of the *Code* book are _____.

(a) for information only
(b) not enforceable as a requirement of the *Code*
(c) enforceable as a requirement of the *Code*
(d) for information only and not enforceable as a requirement of the *Code*

29. It is the intent of the *NEC* that factory-installed wiring of listed equipment need not be inspected at the time of installation of the equipment, except to detect alterations or damage.

(a) external
(b) associated
(c) internal
(d) all of these

30. Factory-installed _____ wiring of listed equipment need not be inspected at the time of installation of the equipment, except to detect alterations or damage.

(a) external
(b) associated
(c) internal
(d) all of these

Notes

CHAPTER 1 GENERAL RULES

Introduction to Chapter 1—General Rules

Before you can make sense of the *2023 NEC*, you must first become familiar with its general rules, concepts, definitions, and requirements. Chapter 1 includes two major topics: Article 100, which establishes definitions that promote consistent understanding when *Code*-related matters are discussed, and Article 110, which presents the general requirements that must be correctly applied to the *2023 NEC*.

After gaining an understanding of Chapter 1, some of the *Code* requirements that might be confusing to many will become much clearer. Articles 100 and 110 will make more sense because you will have the foundation from which the rules are built on, understood, and correctly applied.

- **Article 100—Definitions.** Article 100 is organized into three parts. Part I contains definitions of terms used throughout the *Code* for systems operating at 1,000 volts or less, whether they are current (AC) or direct current (DC). Part II provides definitions of terms applied to systems operating above 1,000 volts, whether AC or DC, and also includes terms not within the scope of this text. Part III includes definitions applicable to "Hazardous (Classified) Locations" as found in Chapter 5 of the 2023 *NEC*.

  This article overall only includes terms used in more than one article. Standard terms such as volt, voltage drop, ampere, impedance, and resistance are not included in Article 100. If the 2023 *NEC* does not define a term, you should consult a dictionary or a code reference recognized by the authority having jurisdiction.

  Definitions are usually placed at the start of an article. When this occurs, the terms apply solely within that article. These terms are uniform in their placement, and the definitions given for a particular article number will be preceded by ".2." For instance, definitions specific to the photovoltaic (PV) systems article appear in 690.2.

- **Article 110—Requirements for Electrical Installations.** This article contains the general requirements that apply to all types of electrical installations.

Notes

ARTICLE 100 DEFINITIONS

Introduction to Article 100—Definitions

Have you ever had a conversation with someone only to discover that what you said and what he or shene h teeard were completely different? That stituation comes up often when people use the same words but attach different meanings to them. This is why the definitions of key *NEC* terms are provided at the beginning of the *Code* (Article 100), and again at the start of every other article.

If we all share a clear understanding of important terms, we can communicate more effectively and avoid confusion. Words taken out of context can create more trouble than clarity.

Because the *NEC* exists to safeguard people and property, it's essential that you can clearly express and understand the language being used. Review and study Article 100 until you are confident you know the definitions presented.

100 Definitions

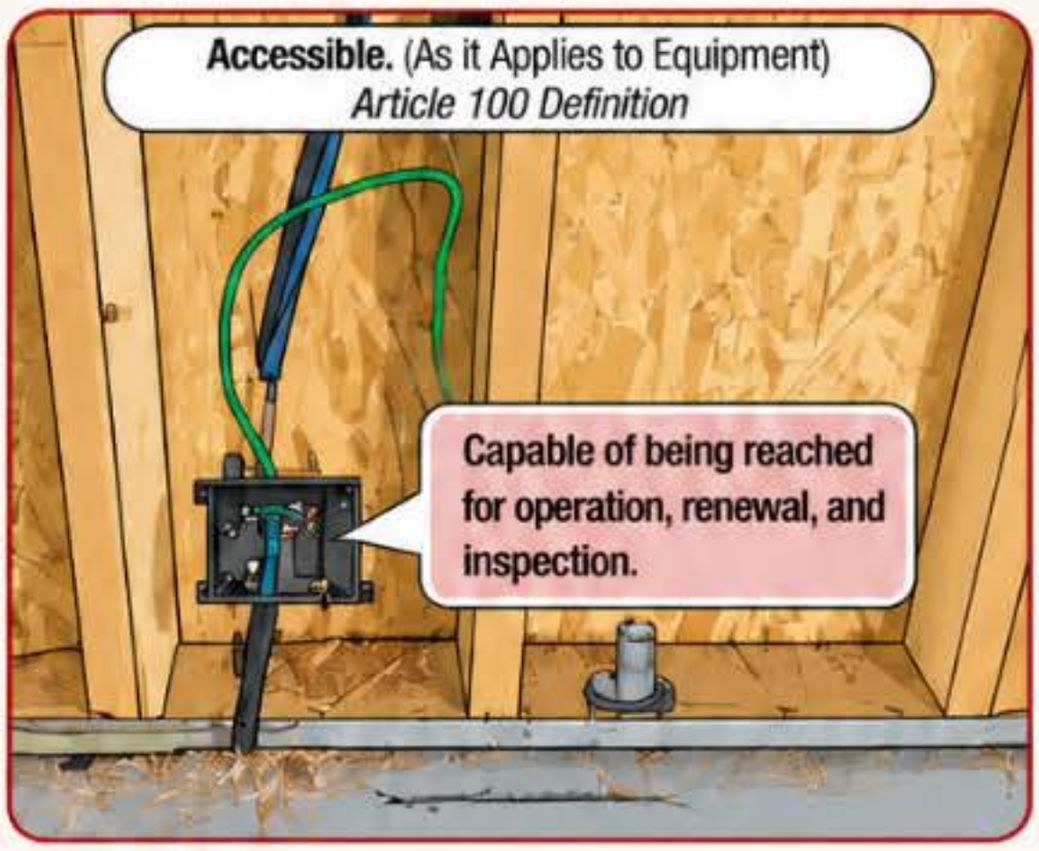
Scope. This article contains definitions that are vital to applying this *Code*; it does not include general or technical terms from other *codes* and standards. In general, any term used in two or more articles is defined in Article 100.

Definitions are also found in the two sections of other articles.

- Part I of this article contains definitions intended to apply wherever the terms are used throughout the *NEC*.
- Part II contains definitions applicable to Hazardous (Classified) Locations.

Accessible (as applied to equipment). Capable of being reached for operation, renewal, and inspection. ▶ **Figure 100–1**

Accessible, Readily (Readily Accessible). Capable of being reached quickly for operation, renewal, or inspection without requiring those to whom ready access is necessary to use tools (other than keys), climb over or under obstructions, remove obstacles, resort to using portable ladders, and so forth. ▶ **Figure 100–2**



▶ **Figure 100–1**

Note: The use of keys for locks on electrical equipment, and locked doors to electrical equipment rooms and vaults is a common practice and permitted by the *NEC*. ▶ **Figure 100–3**

Adjustable-Speed Drive System. A combination of an adjustable speed drive, its associated motor(s), and any other equipment associated with the two.

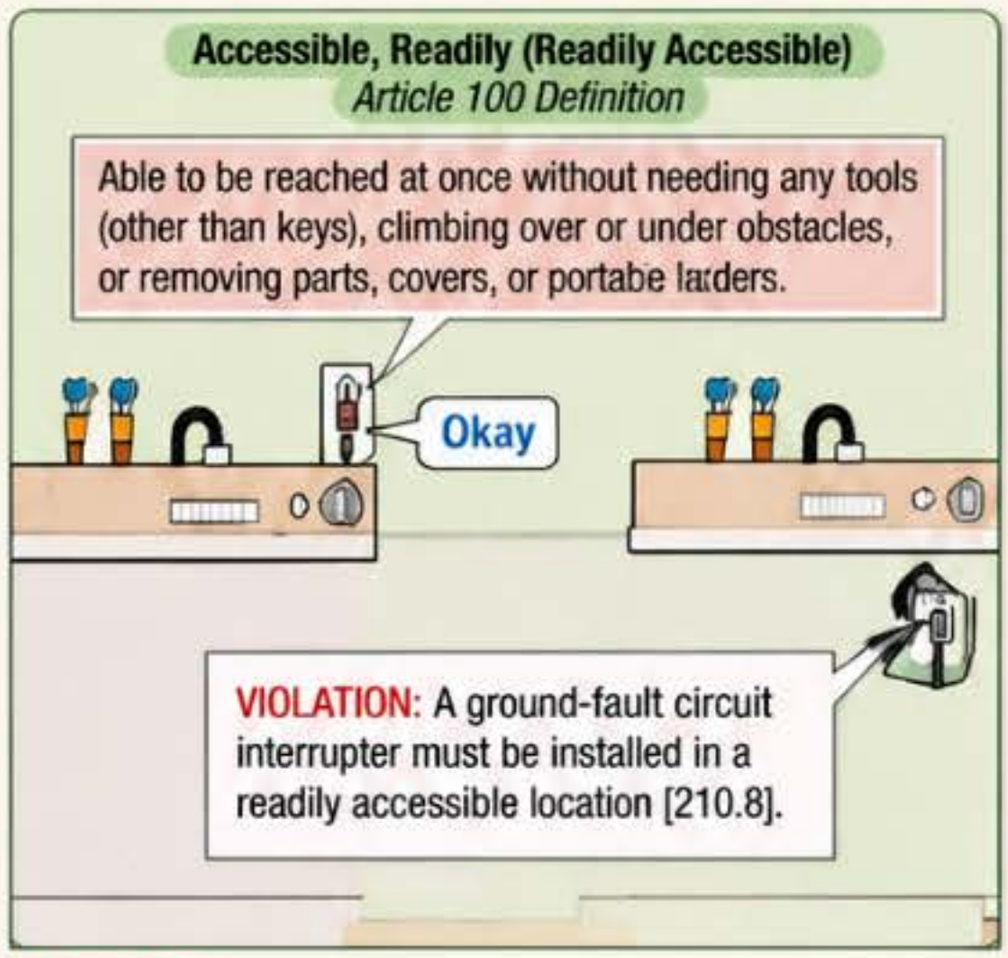


Figure 100-2

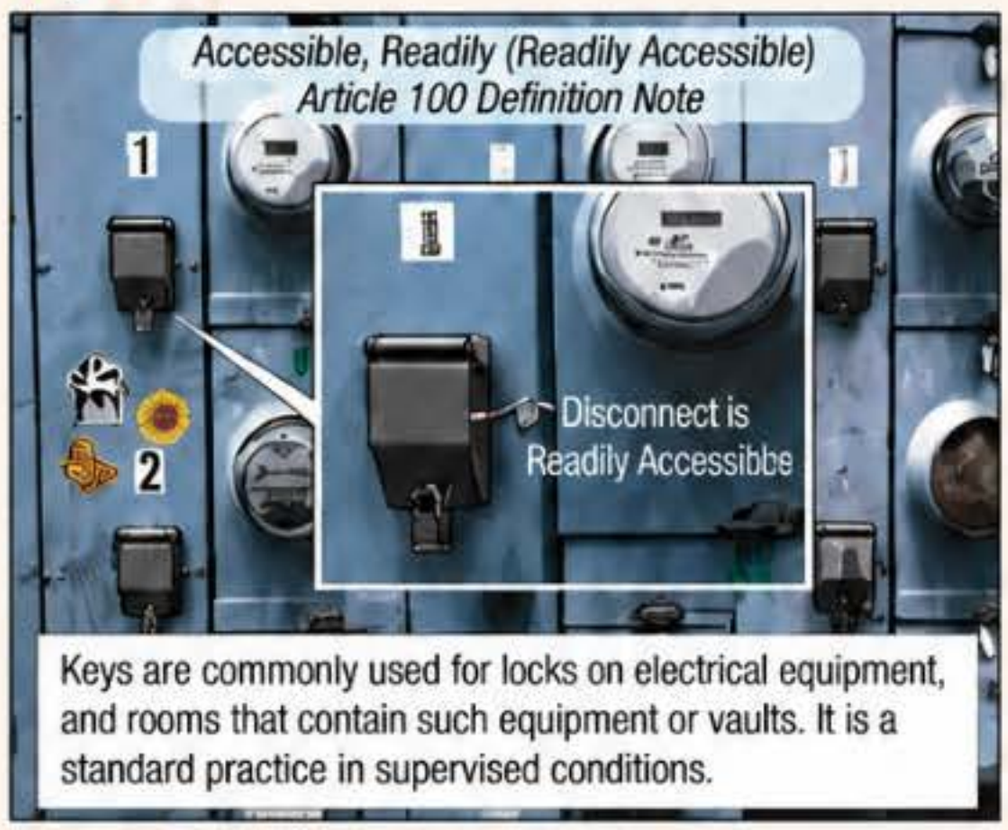


Figure 100-3

Author's Commentary:

- An adjustable-speed drive is a type of equipment that lets you change how fast an electric motor runs. Variable-speed drives are also known as "variable-frequency drives (VFDs)."
- A variable-frequency drive is a kind of electronic controller that changes the alternating-current motor's frequency and voltage, which in turn adjusts the motor's speed and power demands.

Ampacity. The current, in amperes, that a conductor can continuously carry under the conditions of its use without exceeding its temperature rating. Figure 100-4

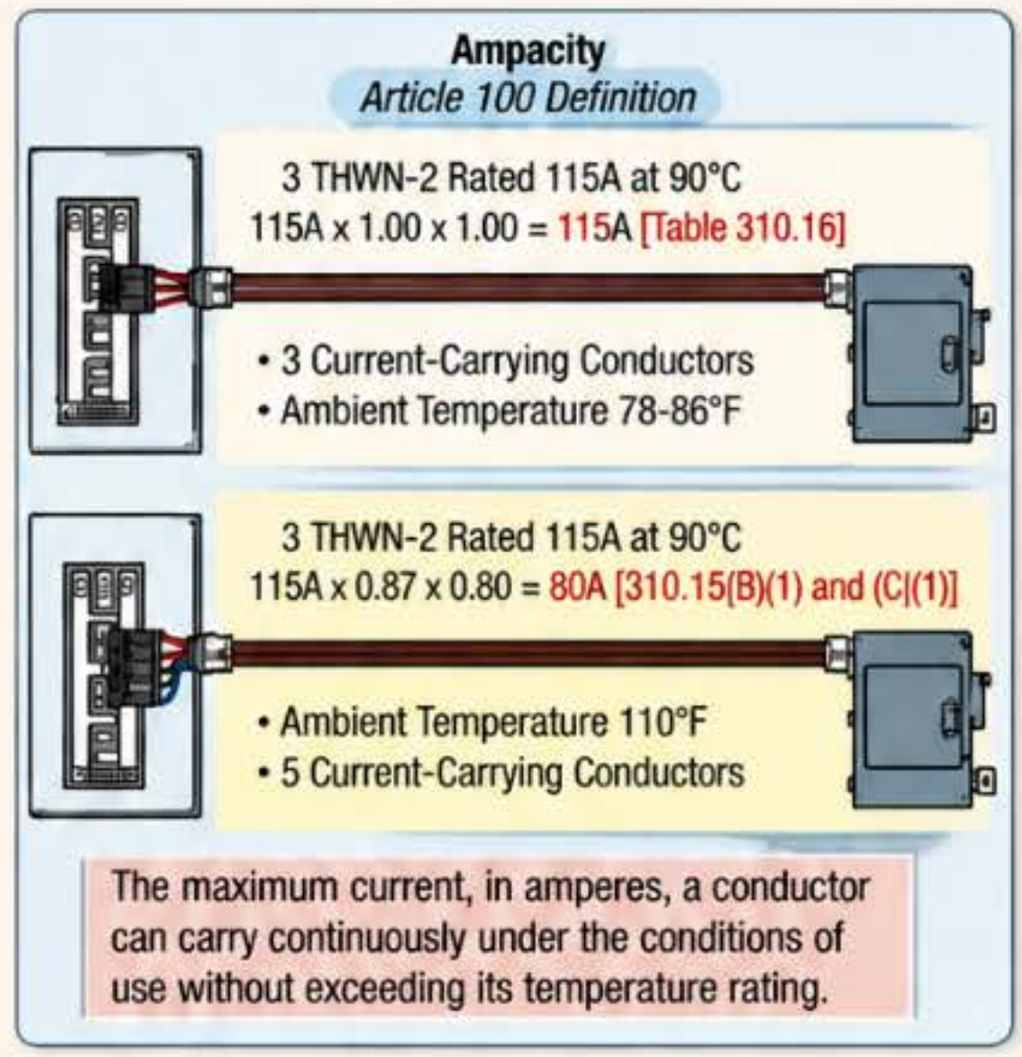


Figure 100-4

Author's Commentary:

- See 310.10 and 310.15 for complete details and examples.

Appliance [Article 422]. Electrical equipment, other than industrial equipment, built in standardized sizes. Examples of appliances include ranges, ovens, cooktops, réfrigerators, drinking water coolers, and beverage dispensers.

Approved. Acceptable to the authority having jurisdiction; usually the electrical inspector. Figure 100-5

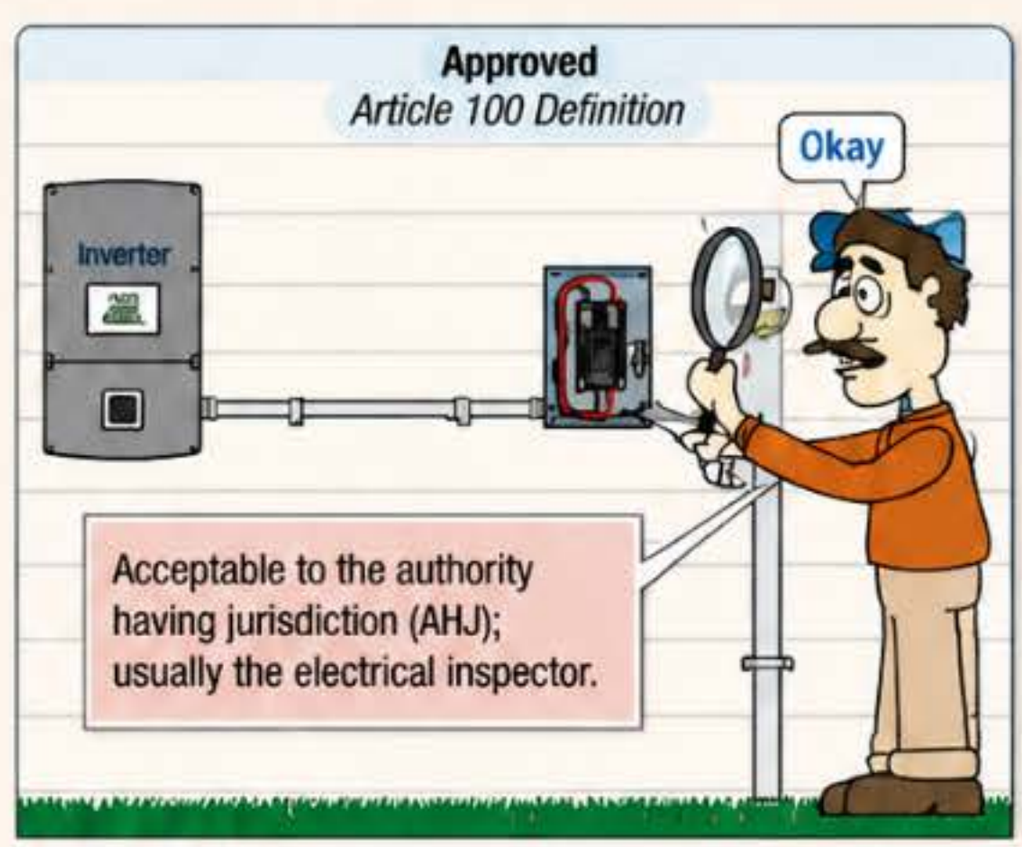


Figure 100-5

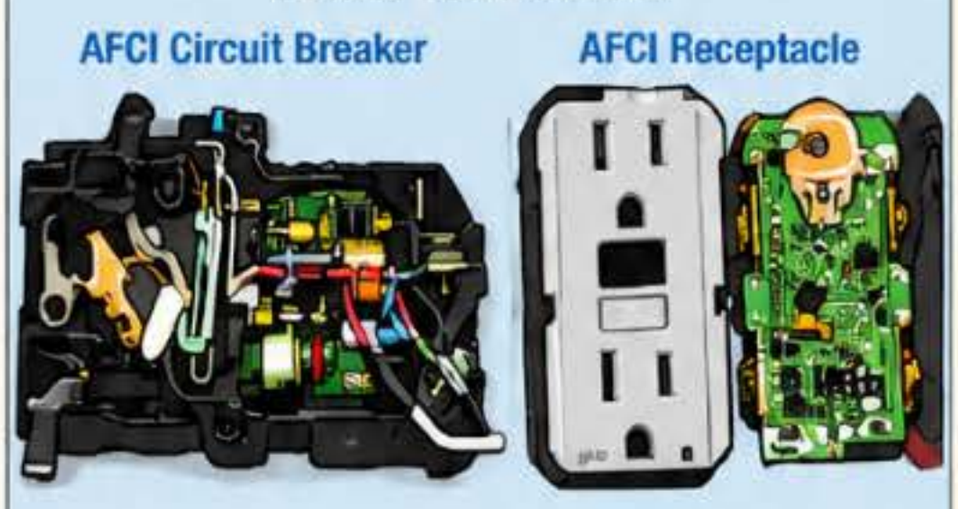
Author's Commentary:

A product listing is not the same as an approval. However, a listing can support approval. Refer to Articles 90.4, 90.7, 90.21, and 110.2, along with the definitions in this article for "Authority Having Jurisdiction," "Listed," and "Listed Product."

— Michael Hamilton

Arc-Fault Circuit Interrupter (AFCI). This device is designed to remove power from a circuit when it senses current waveform patterns that are unique to an arcing fault. ▸ **Figure 100-6** and ▸ **Figure 100-7**

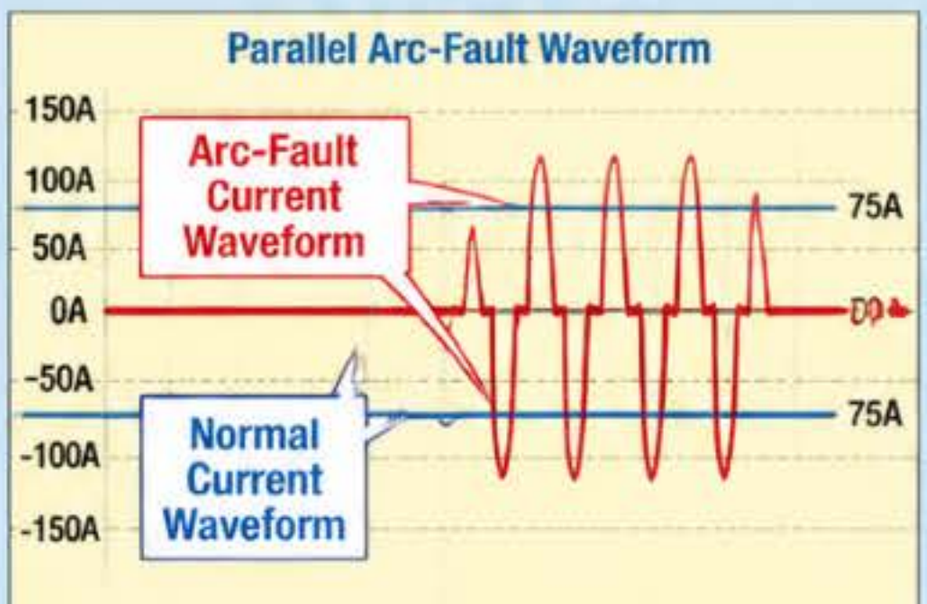
Arc-Fault Circuit Interrupter (AFCI)
Article 100 Definition



A device intended to de-energize the circuit when it detects the current waveform characteristics unique to an arcing fault.

▸ **Figure 100-6**

Arc-Fault Circuit Interrupter (AFCI)
Article 100 Definition



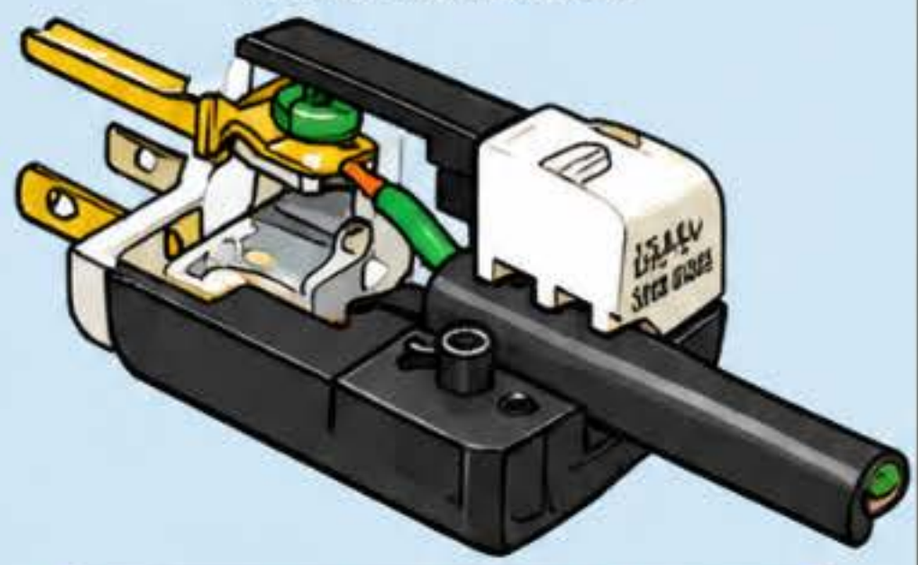
▸ **Figure 100-7**

Attachment Fitting. A device that, by insertion into a locking support and mounting receptacle, establishes a connection between the conductors of the attached utilization equipment and the branch-circuit conductors connected to the locking support and mounting receptacle.

Note: An attachment fitting is different from an attachment plug because no cord is associated with the fitting. An attachment fitting used with a locking support and mounting receptacle secures the associated utilization equipment in place and supports its weight.

Attachment Plug (Plug Cap), (Plug). A wiring device at the end of a flexible cord that is intended to be inserted into a receptacle to make an electrical connection. ▸ **Figure 100-8**

Attachment Plug (Plug Cap), (Plug)
Article 100 Definition



A wiring device at the end of a flexible cord intended to be inserted into a receptacle in order to make an electrical connection.

▸ **Figure 100-8**

Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure. See Articles 90.4 and 90.7 for more information.

Note: The authority having jurisdiction may be a federal, state, or local government department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor or health department, a building official, electrical inspector, or someone else with statutory authority. In some situations, the property owner or their agent assumes the role, and at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

Author's Commentary:

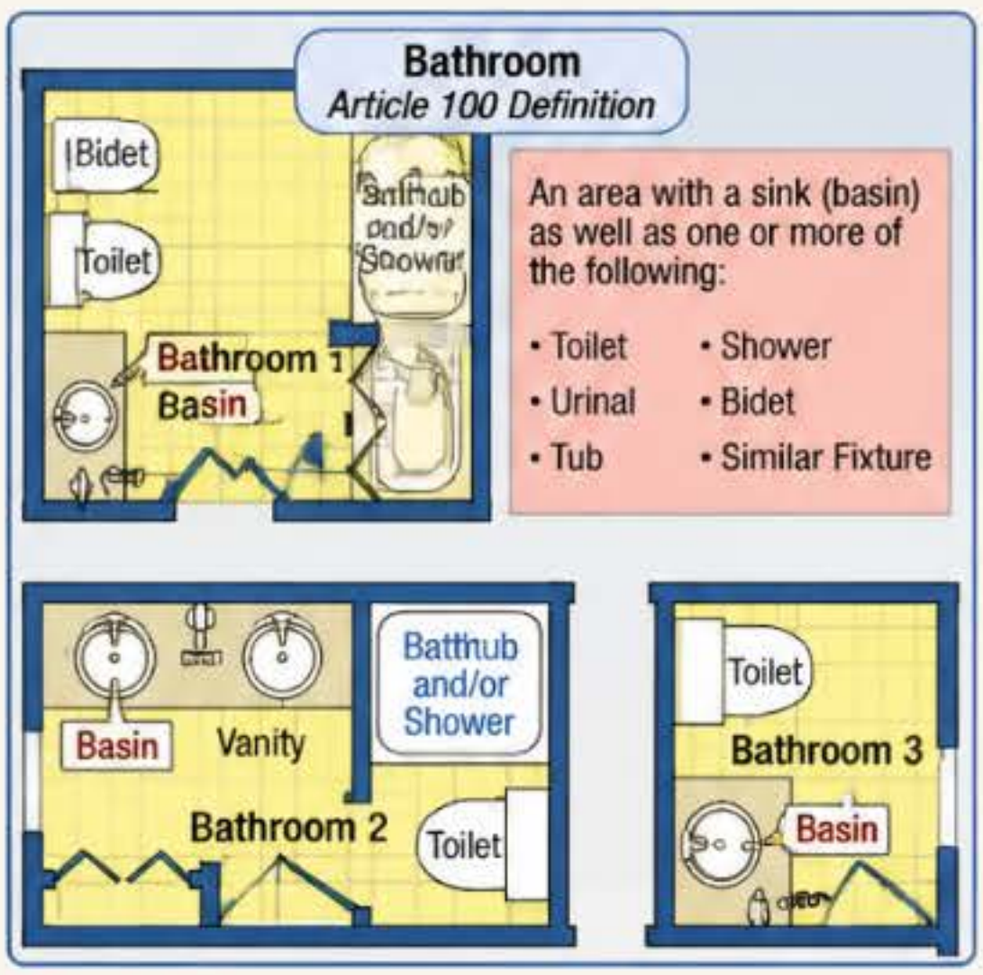
Electrical inspectors usually have legal authority granted by statute. When no state, local, or federal rules apply, the person operating the premises—or their representative—is typically viewed as the authority.

To be considered the "authority having jurisdiction," a person should generally have at least some background in electrical work, such as formal engineering training or holding an electrical contractor's license. In some states, obtaining a license satisfies this requirement. Membership, certifications, and participation in recognized electrical organizations such as the International Association of Electrical Inspectors (IAEI) support an individual's qualifications. For details about these organizations, visit www.IAEI.org.

— Michael Hamilton

Automatic. Operating without the need for manual action.

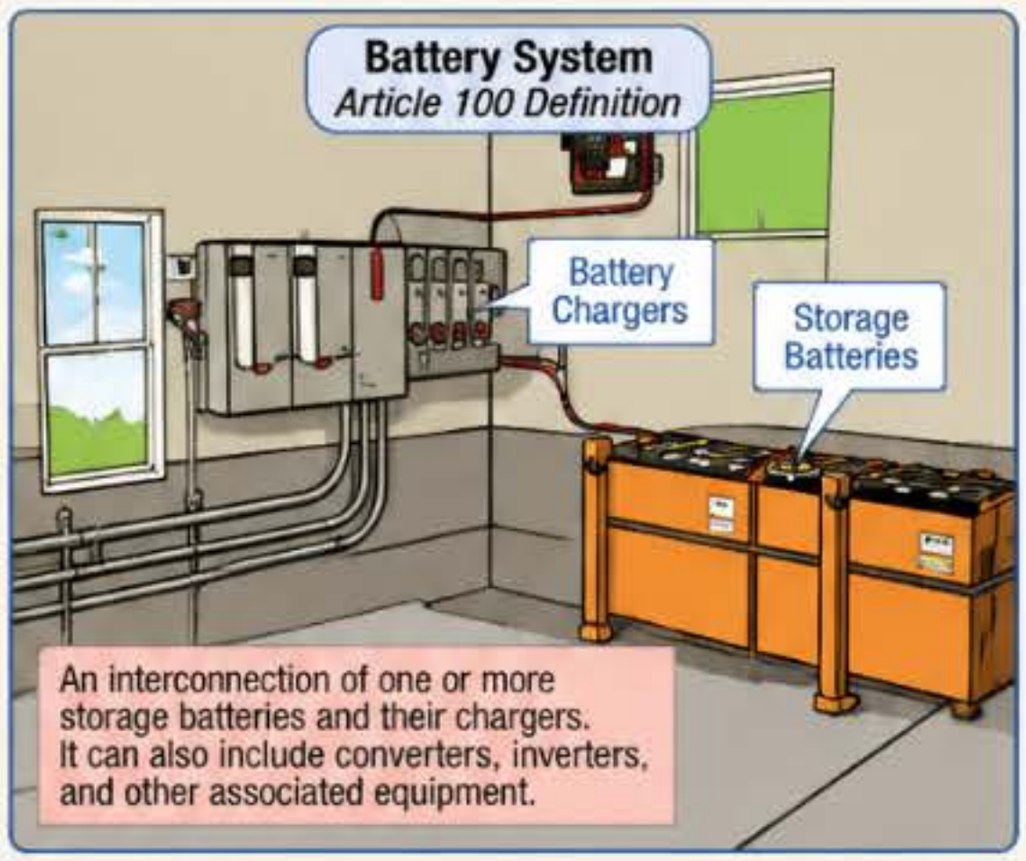
Bathroom. A room that includes a sink (basin) as well as one or more of the following: a toilet, urinal, tub, shower, bidet, or a comparable plumbing fixture. ▸Figure 100–9



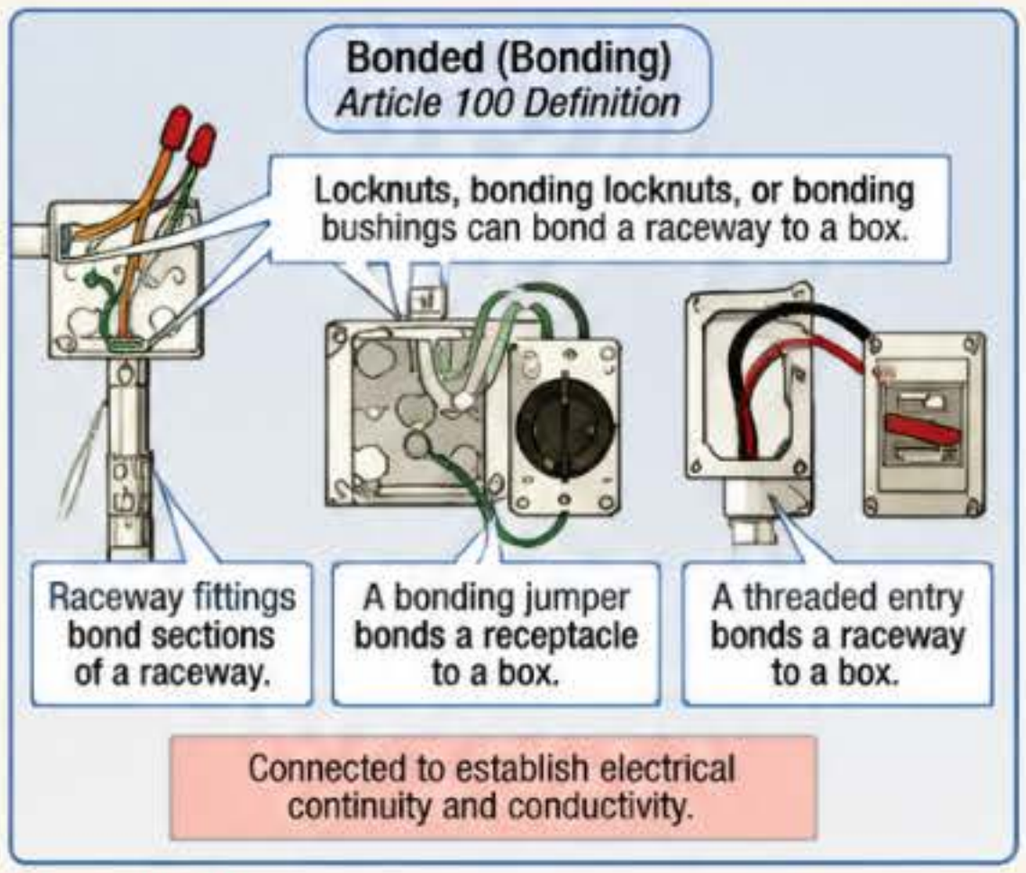
▸Figure 100–9

Battery System. A connection of one or more storage batteries paired with their chargers. It may also include converters, inverters, and other related equipment. ▸Figure 100–10

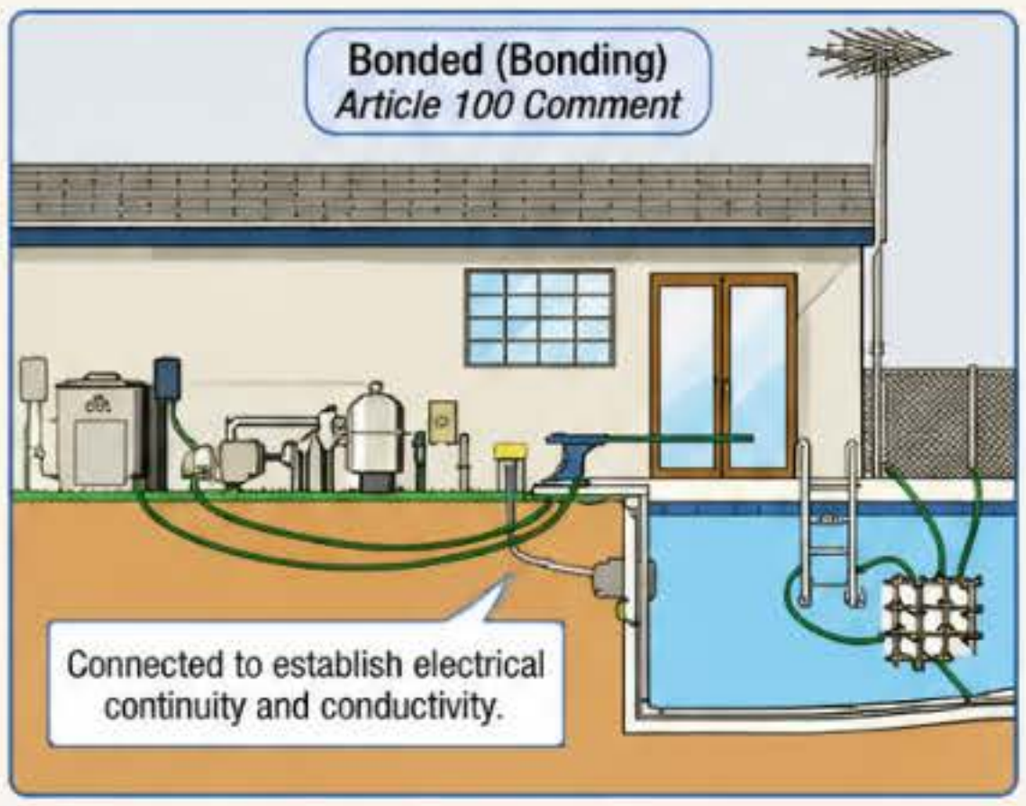
Bonded (Bonding). Connected to establish electrical continuity and conductivity. ▸Figure 100–11 and ▸Figure 100–12



▸Figure 100–10



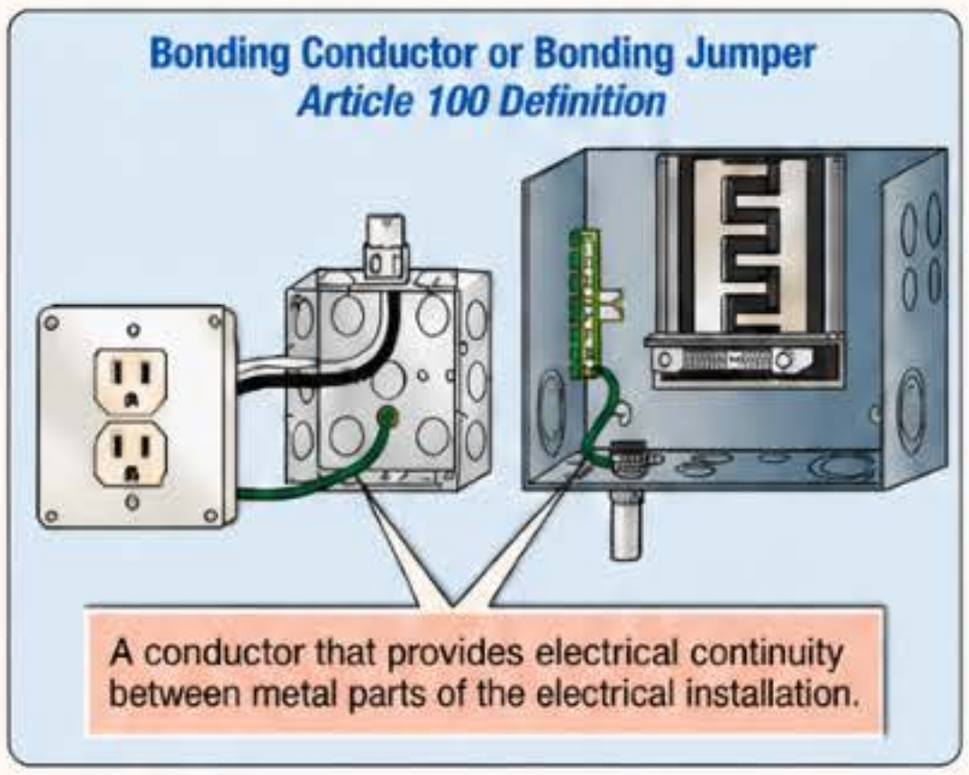
▸Figure 100–11



▸Figure 100–12

DEFINITIONS | From Michael Hamilton Publications

Bonding Conductor or Jumper: A conductor that provides electrical continuity between metal parts of the electrical installation. ▸ Figure 100–13



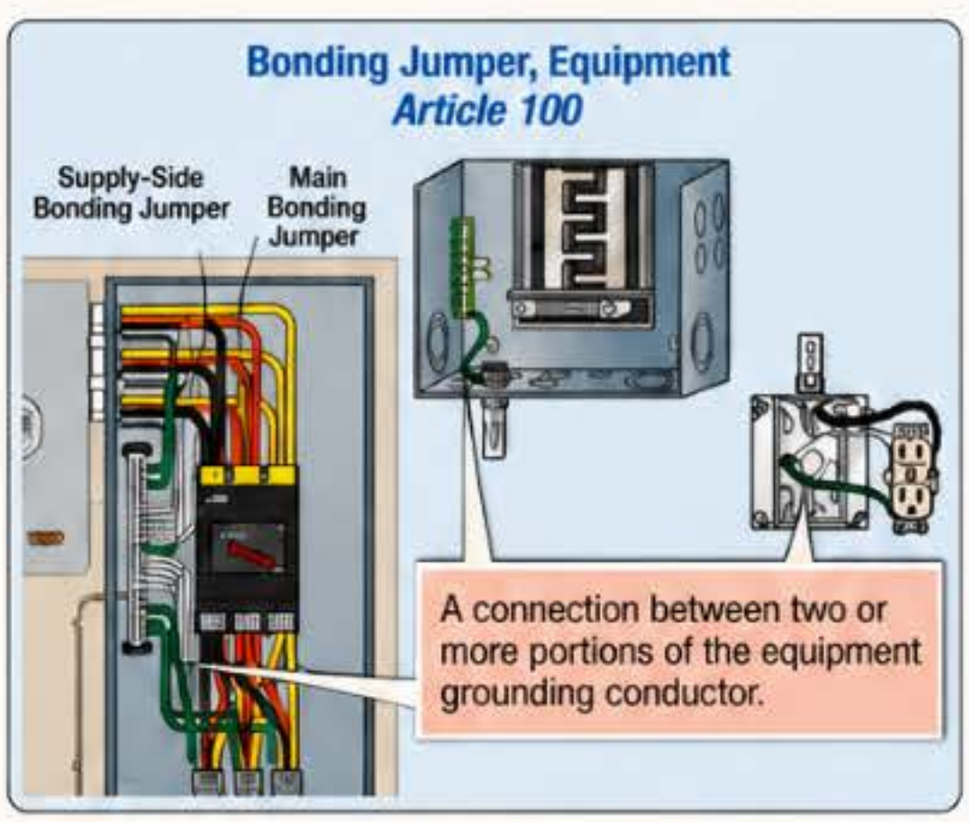
▸ Figure 100–13

Author's Commentary:

- You may hear either "bonding conductor" or "bonding jumper." Both names are short-hand for a small length of wire that creates electrical conductivity between metal components.

— Michael Hamilton

Bonding Jumper, Equipment: A connection between two or more portions of the equipment grounding. ▸ Figure 100–14

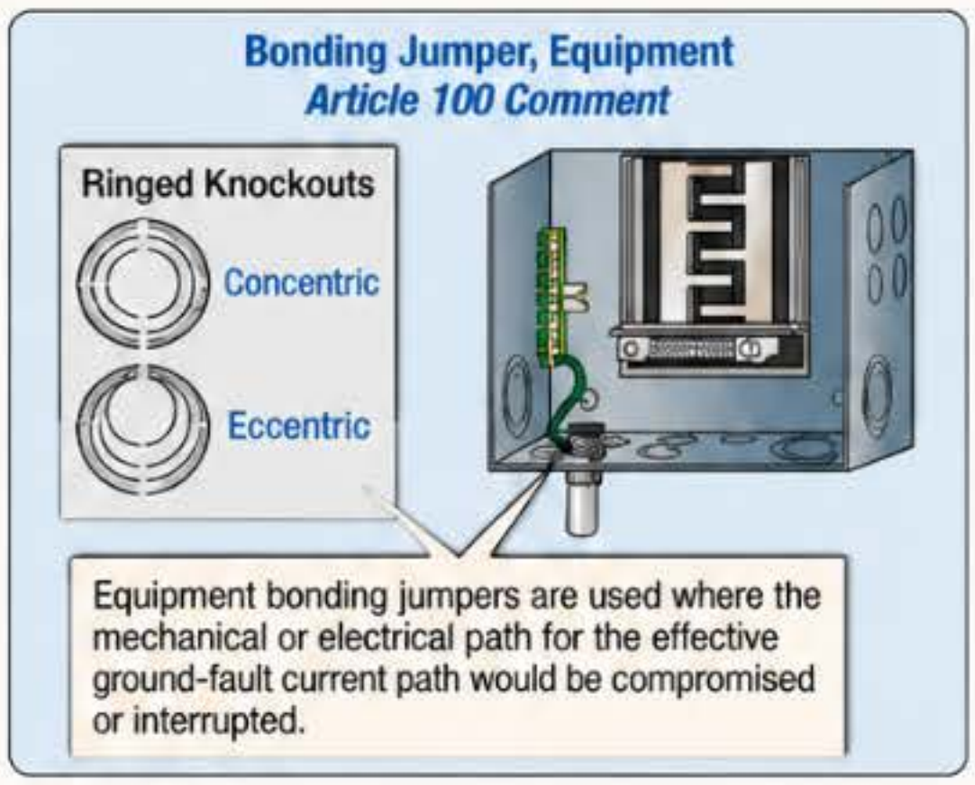


▸ Figure 100–14

Author's Commentary:

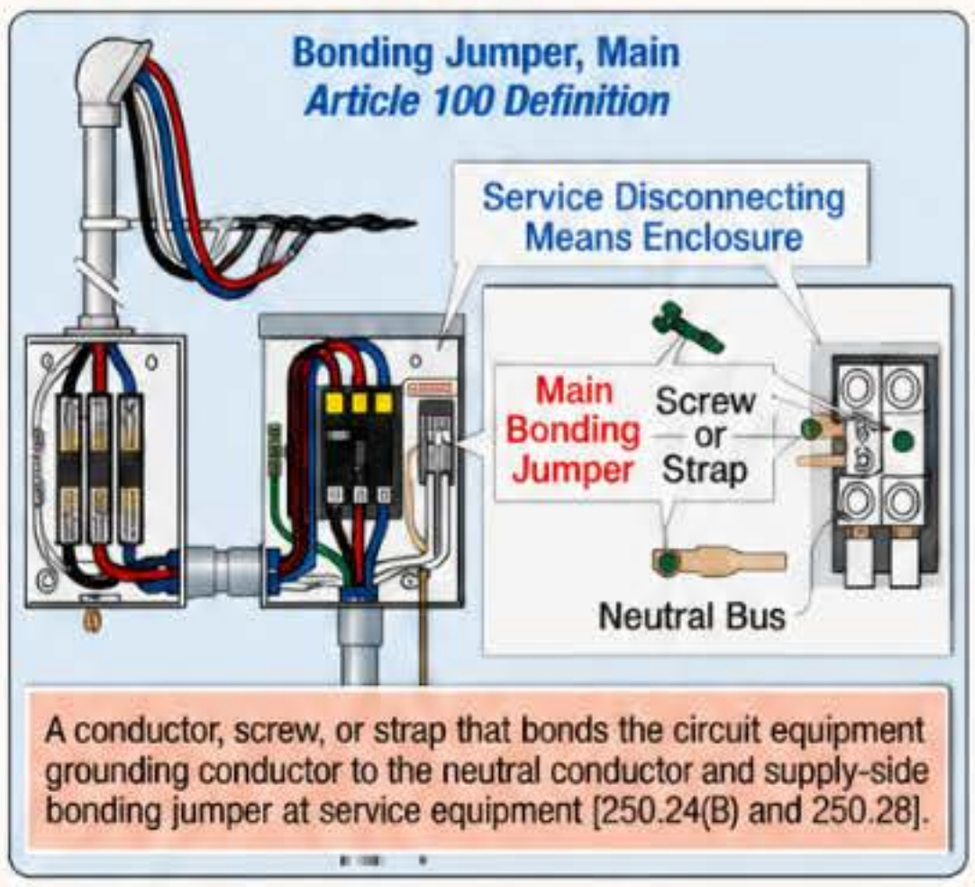
- Equipment bonding jumpers are installed where the current path for a ground-fault—whether mechanical or electrical—could be weakened or broken.

— Michael Hamilton

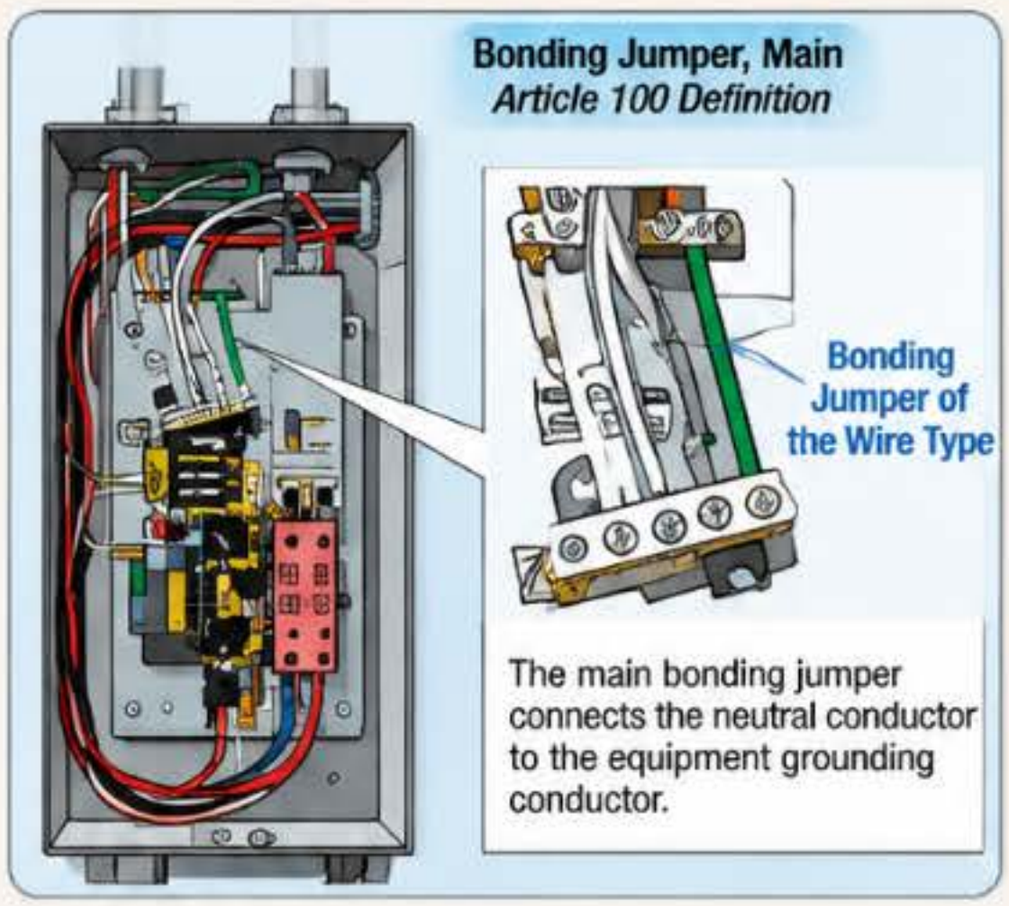


▸ Figure 100–15

Bonding Jumper, Main: A conductor, screw, or strap used to connect the circuit equipment grounding conductor to the neutral conductor or to the supply-side bonding jumper at the service equipment in accordance with 250.24(B). ▸ Figure 100–16 and ▸ Figure 100–17

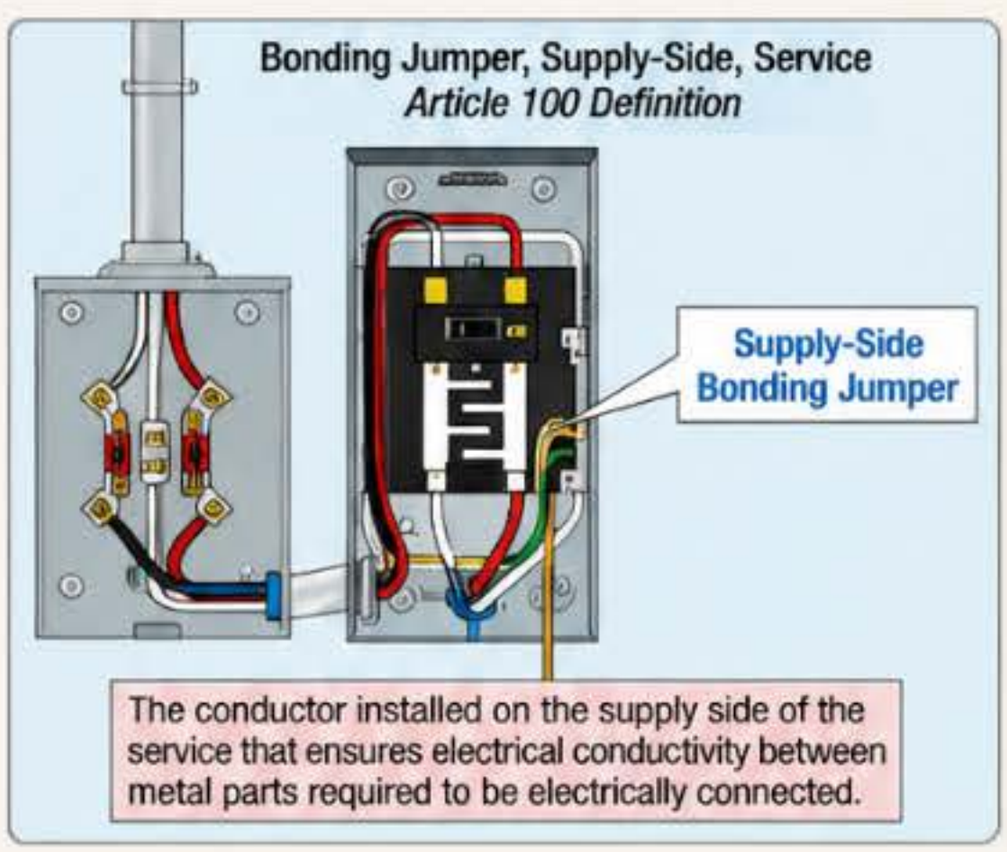


▸ Figure 100–16



▶ Figure 100–17

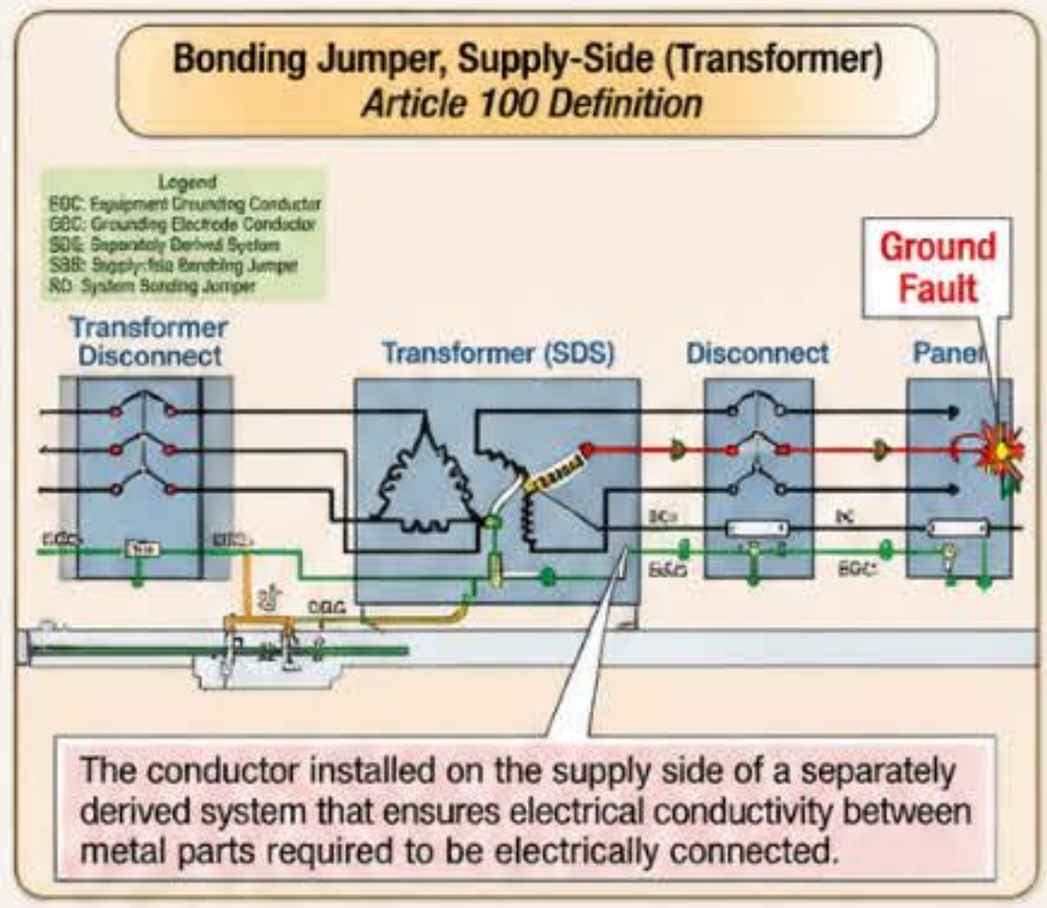
Bonding Jumper, Supply-Side. The conductor installed on the supply side of a service or separately derived system that ensures conductivity between metal parts required to be electrically connected. ▶Figure 100–18, ▶Figure 100–19, and ▶Figure 100–20



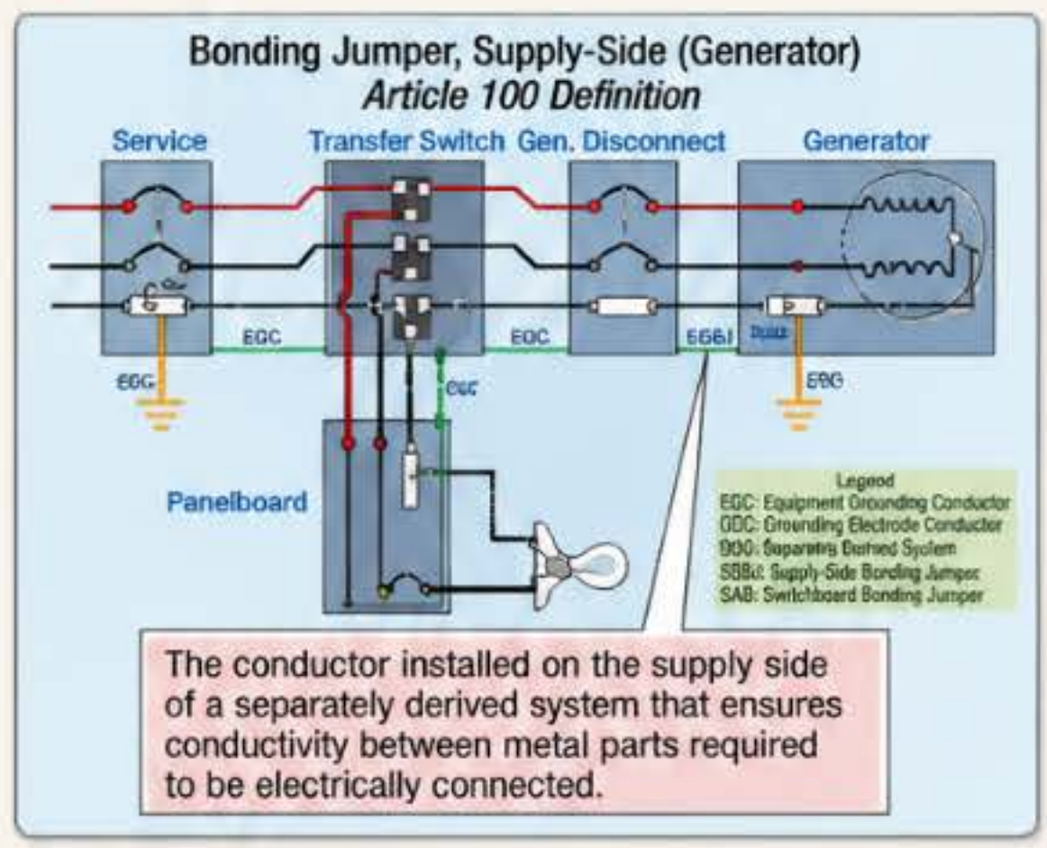
▶ Figure 100–18

Bonding Jumper, System. The connection between the neutral conductor or grounded-phase conductor and the supply-side bonding jumper or equipment grounding conductor, or both, at a transformer. ▶Figure 100–21

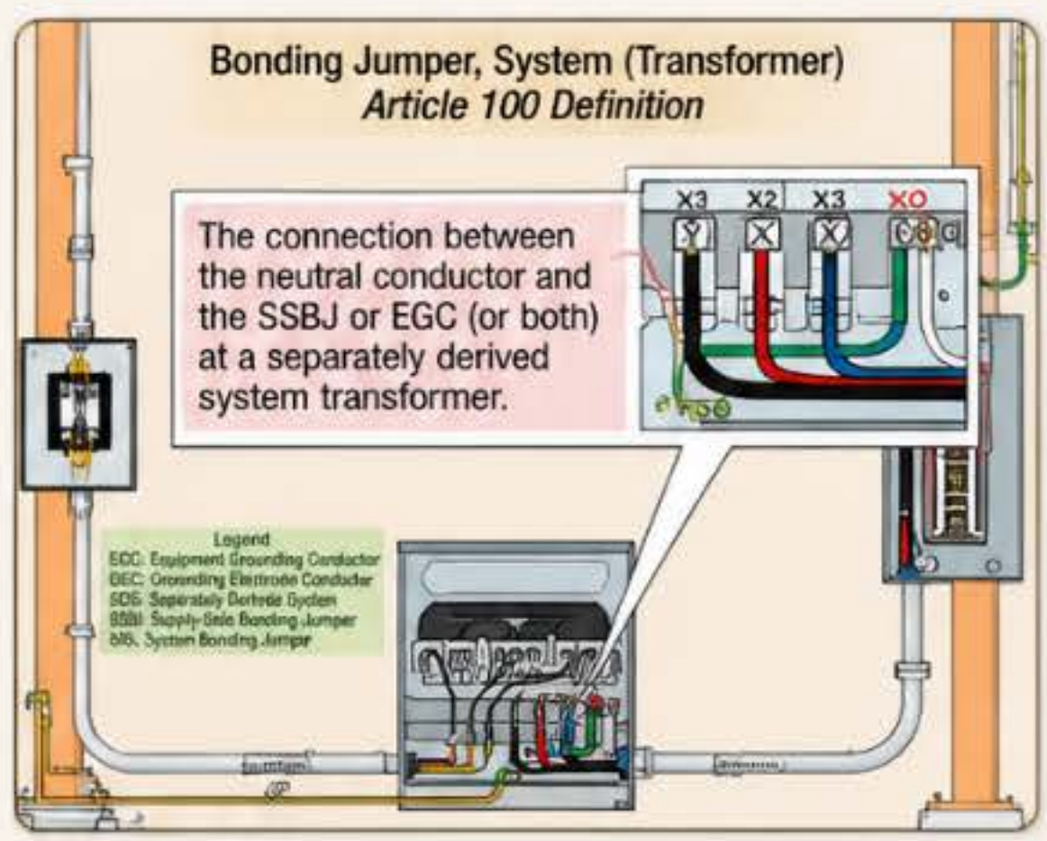
Branch Circuit. The conductors between the final overcurrent device and the receptacle outlets, lighting outlets, or other outlets as defined in this article. ▶Figure 100–22



▶ Figure 100–19



▶ Figure 100–20



▶ Figure 100–21

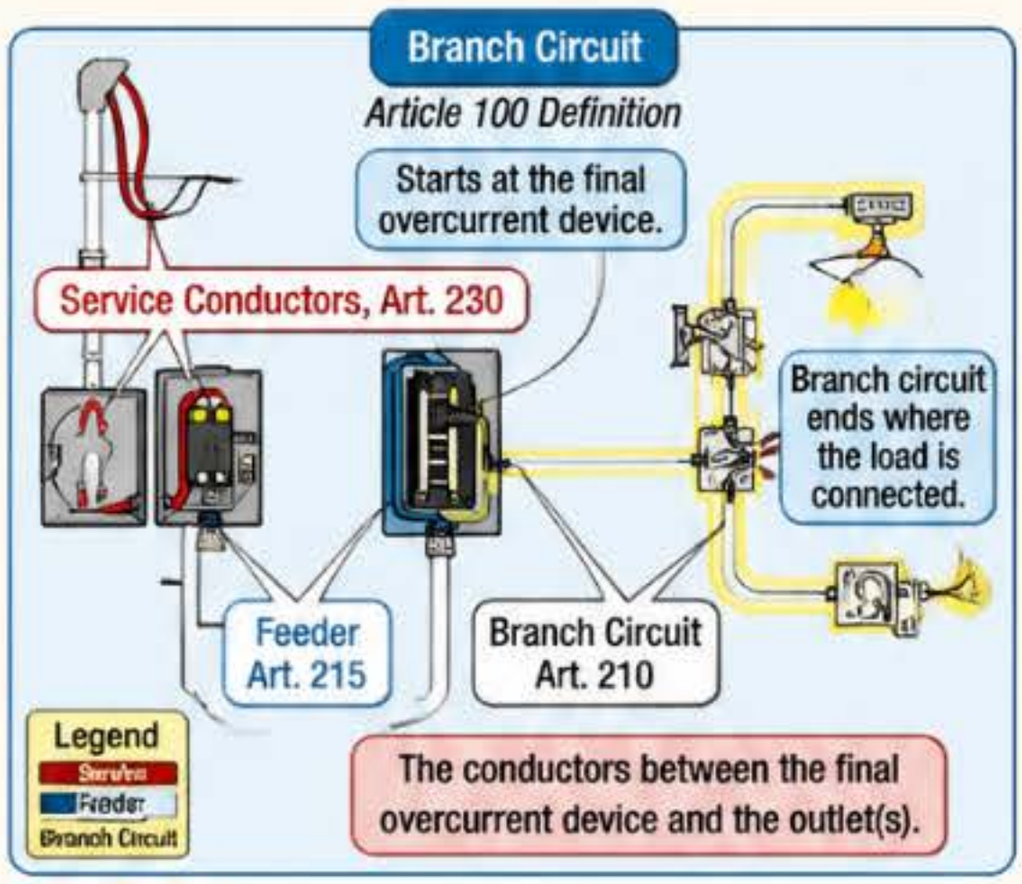


Figure 100-22

Branch Circuit, Individual (Individual Branch Circuit). A branch circuit that only supplies one load.

Branch Circuit, Multiwire (Multiwire Branch Circuit). A branch circuit consisting of two or more circuit phase conductors with a common neutral conductor. There must be a voltage between the phase conductors and an equal difference of voltage from each phase conductor to the common neutral conductor. *Figure 100-23

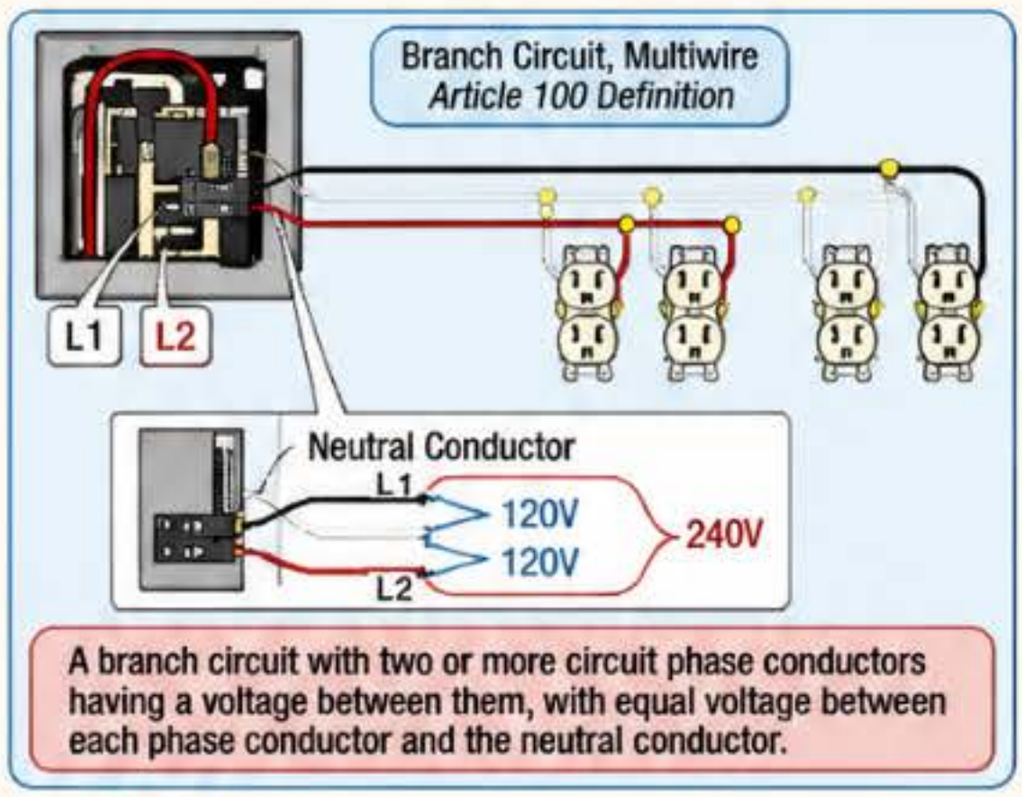


Figure 100-23

Author's Commentary:

Multiwire branch circuits offer the advantage of fewer conductors within a raceway which can result in smaller raceways, and reduced material and labor costs. In addition, multiwire branch circuits can reduce circuit voltage drop by as much as 50 percent. Because of the dangers associated with the use of multiwire branch circuits and the need for extra care, the *NEC* contains additional requirements to ensure a safe installation. See 210.4, 300.13(B), and 408.41 in this textbook for details.

— *Michael Hamilton*

as 50 percent. Because of the dangers associated with the use of multiwire branch circuits and the need for extra care, the *NEC* contains additional requirements to ensure a safe installation. See 210.4, 300.13(B), and 408.41 in this textbook for details.

▶ Hazard of an Open Neutral

Example: *A 3-wire, single-phase, 120/240V multiwire circuit supplies a 1,200W, 120V hair dryer and a 600W, 120V television.*

Figure 100-24

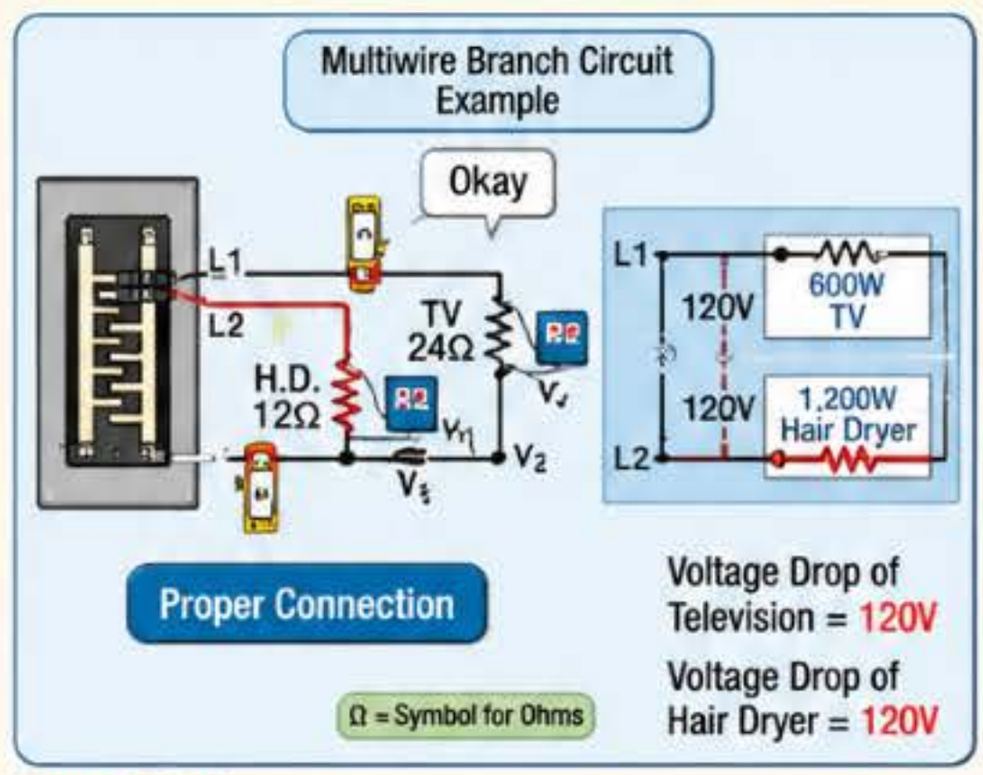


Figure 100-24

If the neutral conductor of the multiwire circuit is interrupted, it will cause the 120V television to operate at 160V and consume 1,067W of power (instead of 600W) for only a few seconds before it burns up. *Figure 100-25

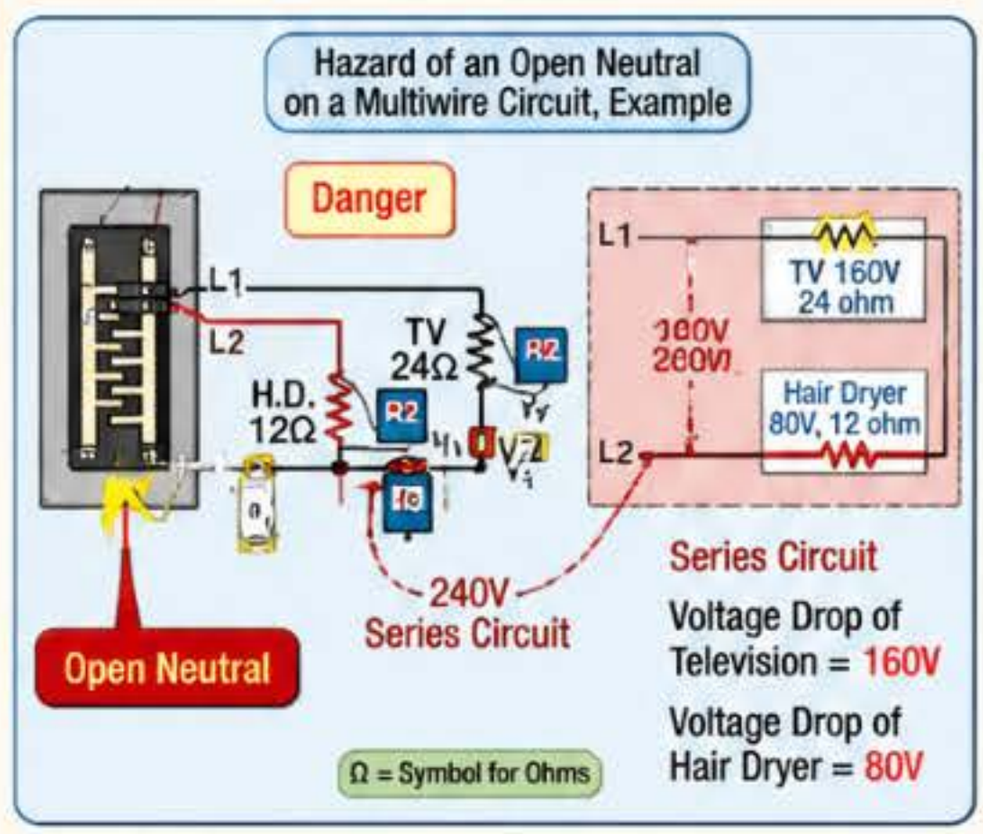


Figure 100-25

• • •

Solution:

Step 1: *Determine the resistance of each appliance.*

R = E²/P

R of the hair dryer = 120V²/1,200W
R of the hair dryer = 12 ohms

R of the television = 120V²/600W
R of the television = 24 ohms

Step 2: *Determine the current of the circuit.*

I = Volts/Resistance
Volts = 240V
R = 36 ohms (12 ohms + 24 ohms)

I = 240V/36 ohms
I = 6.70A

Step 3: *Determine the operating voltage for each appliance.*

Volts = I × R
I = 6.70A
R = 12 ohms for hair dryer and 24 ohms for TV

Voltage of hair dryer = 6.70A × 12 ohms
Voltage of hair dryer = 80V
Voltage of television = 6.70A × 24 ohms
Voltage of television = 160V

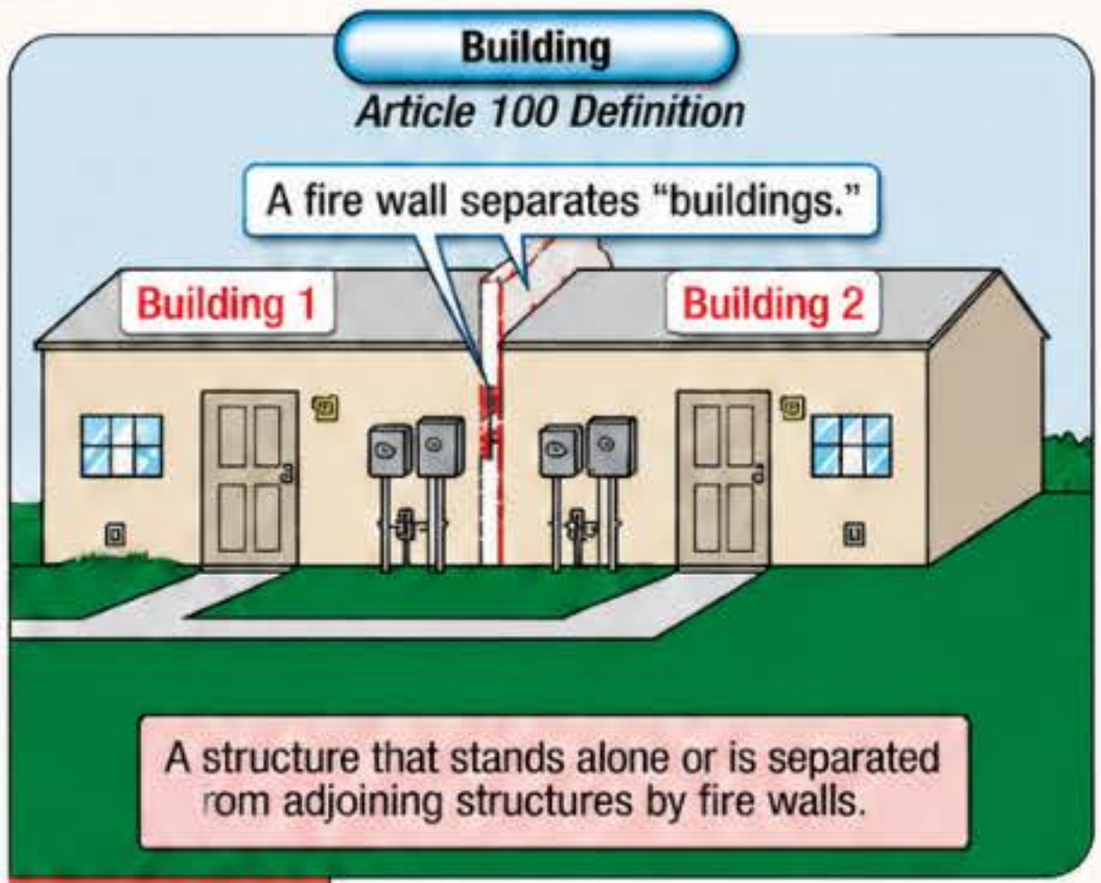
Answer: *160V*

Warning

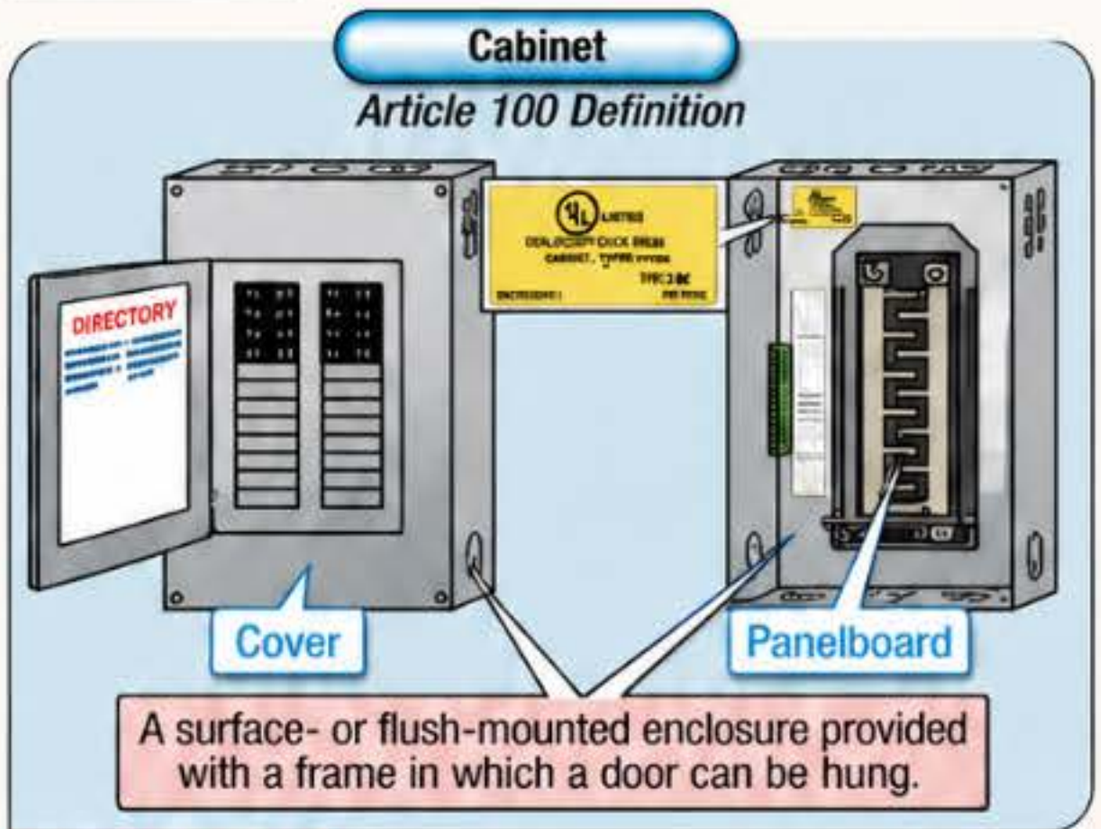
Failure to terminate the phase conductors to separate phases can cause the neutral conductor to become overloaded because the current from the phase conductors is additive and the insulation can be damaged or destroyed. by excessive heat. Conductor overheating is exclusive the service life of insulation, which creates the potential for arcing faults and can ultimately lead to fires. It is not known just how long conductor insulation lasts, but heat does decrease its life span.

Building. A structure that stands alone or is separated from adjoining structures by fire walls. ▸Figure 100–26

Cabinet. A surface-mounted or flush-mounted enclosure provided with a frame in which a door can be hung. ▸Figure 100–27



▸Figure 100–26



▸Figure 100–27

Author's Commentary:

- Cabinets are used to enclose panelboards. See the definition of "Panelboard" in this article.

— Michael Hamilton

Cable, Coaxial. A cylindrical assembly containing a conductor centered inside a metallic shield, separated by a dielectric material, and covered by an insulating jacket. ▸Figure 100–28

Cable, Optical Fiber. An assembly of optical fibers. ▸Figure 100–29

Note: A field-assembled optical fiber cable is an assembly of one or more optical fibers within a jacket. The jacket is installed like a raceway into which the optical fibers are inserted.

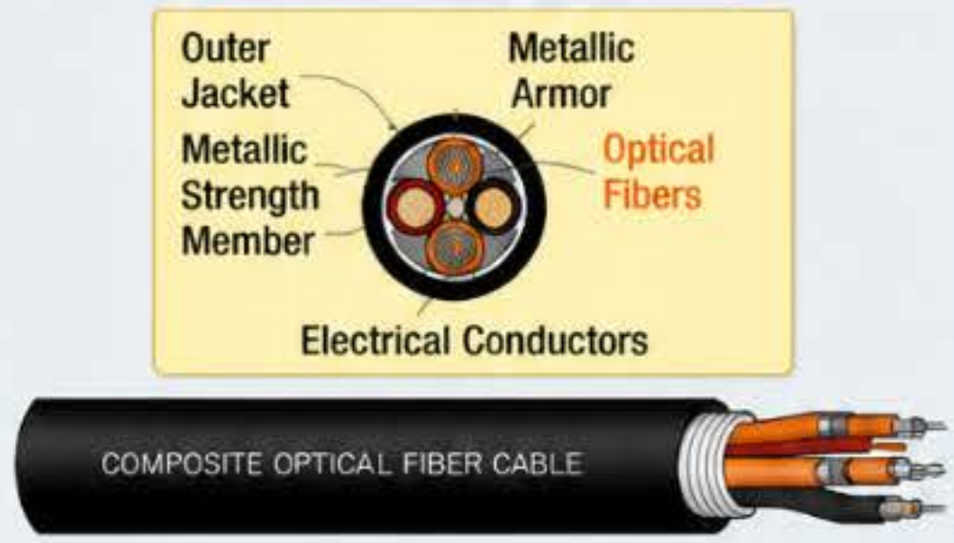
DEFINITIONS | From Michael Hamilton Publications

Cable, Coaxial (CATV)
Article 100 Definition

A cylindrical assembly containing a conductor centered inside a metalliic shield, separated by a dielectric material, and covered by an insulating jacket.

▸ Figure 100–28

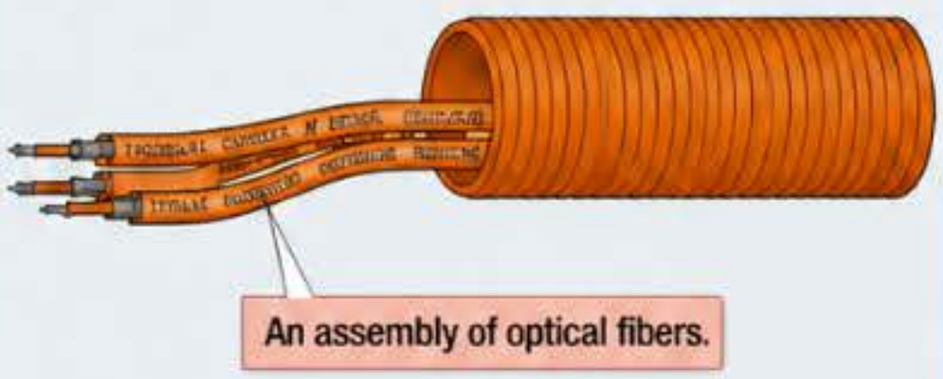
Cable, Optical Fiber, Composite
Article 100 Definition



A cable containing optical fibers and current-carrying electrical conductors.

▸ Figure 100–30

Cable, Optical Fiber
Article 100 Definition and Note

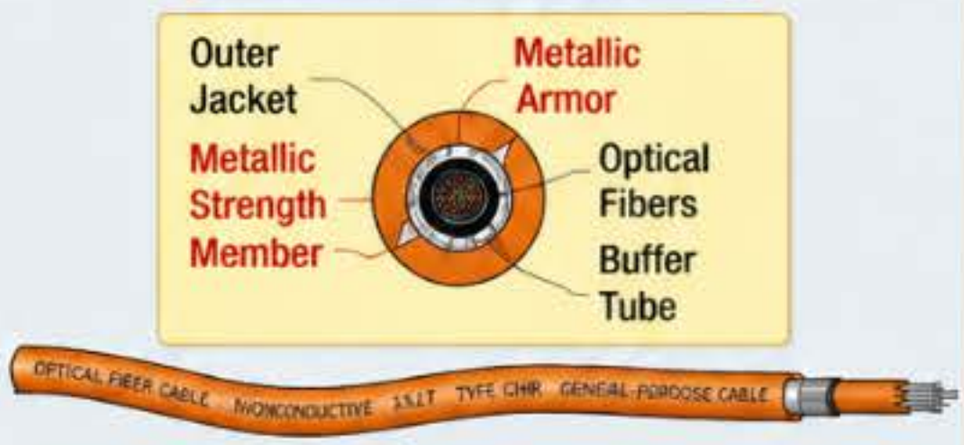


An assembly of optical fibers.

Note: A field-assembled optical fiber cable is an assembly of one or more optical fibers within a jacket. The jacket is installed like a raceway and then the optical fibers are inserted into the jacket.

▸ Figure 100–29

Cable, Optical Fiber, Conductive
Article 100 Definition



An optical fiber cable containing conductive members such as metallic strength members, metallic vapor barriers, and metallic armor or sheath.

▸ Figure 100–31

Cable, Optical Fiber, Composite. A cable containing optical fibers and current-carrying electrical conductors. ▸ Figure 100–30

Author's Commentary:

- Article 770 permits the use of composite optical fiber cables only where the optical fibers and current-carrying electrical conductors are functionally associated [770.133(A)].

Cable, Optical Fiber, Conductive. An optical fiber cable containing conductive members such as metallic strength members, metallic vapor barriers, or metallic armor or sheath. ▸ Figure 100–31

Author's Commentary:

- Conductive components in an optical fiber cable help provide mechanical support, moisture protection, and electromganetic shielding.

— Michael Hamiiton

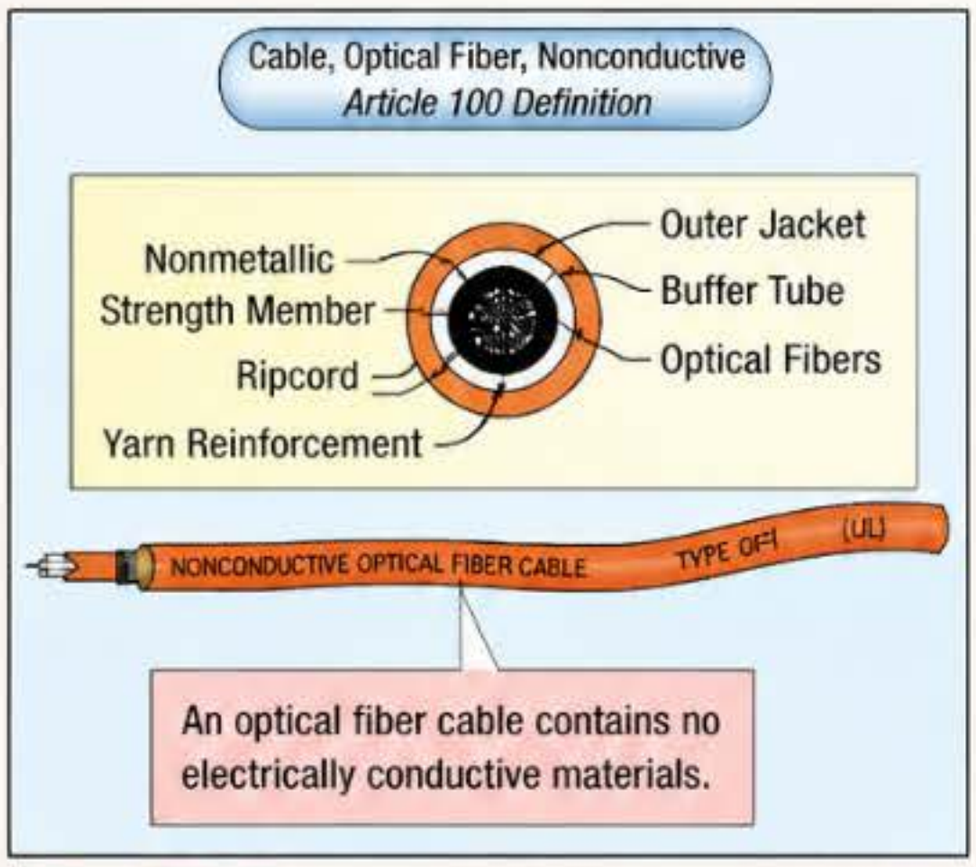
Cable, Optical Fiber, Nonconductive. An optical fiber cable without any electrically conductive materials. ▸ Figure 100–32

Cable Routing Assembly. A channel or channels (with their fittings) that support and route communications wires and cables, and optical fiber, data, Class 2, Type PLTC, and power-limited fire alarm cables in plenum, riser, and general-purpose applications. ▸ Figure 100–33

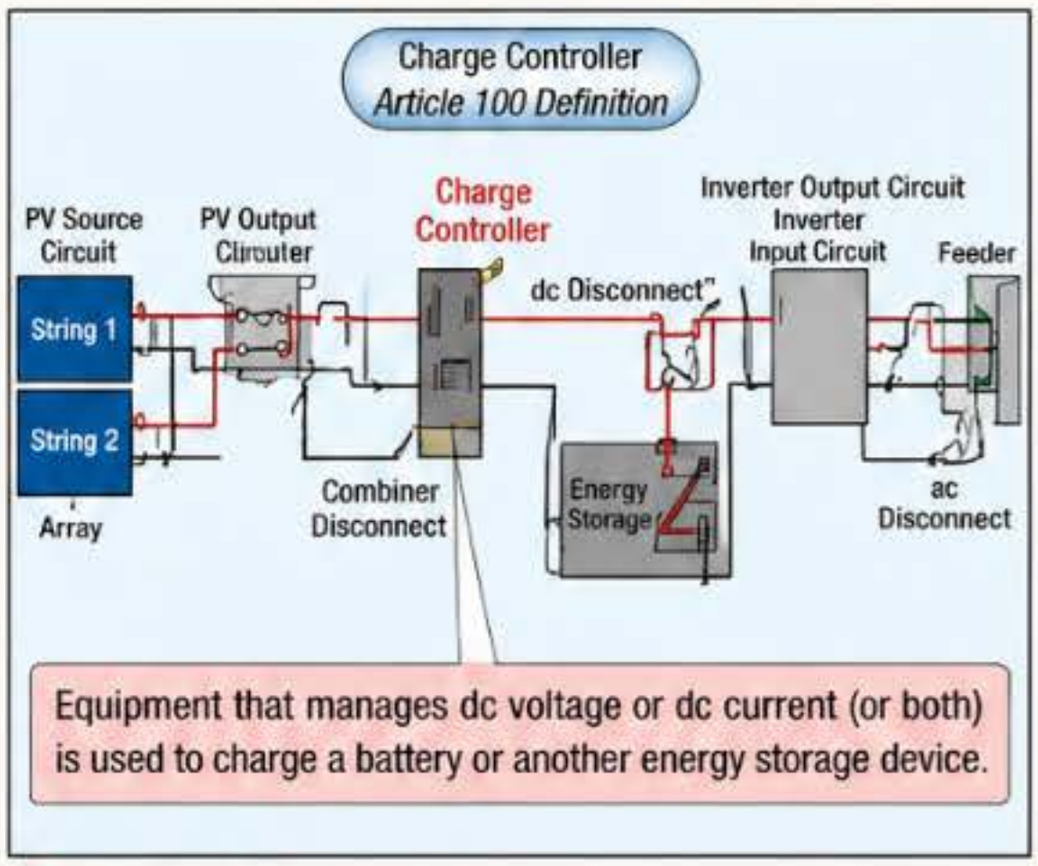
Author's Commentary:

- Cable routing systems are typically U-shaped troughs, either open-top or enclosed, designed to hold and guide cables. They are not considered raceways.

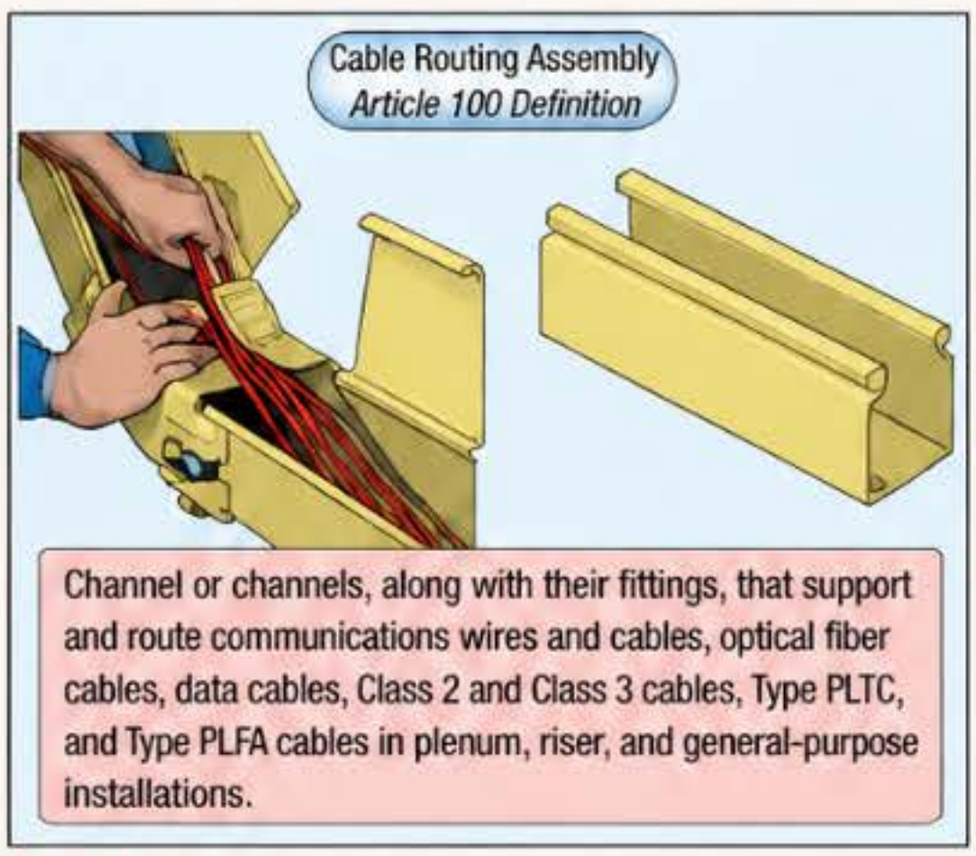
— Michael Hamilton



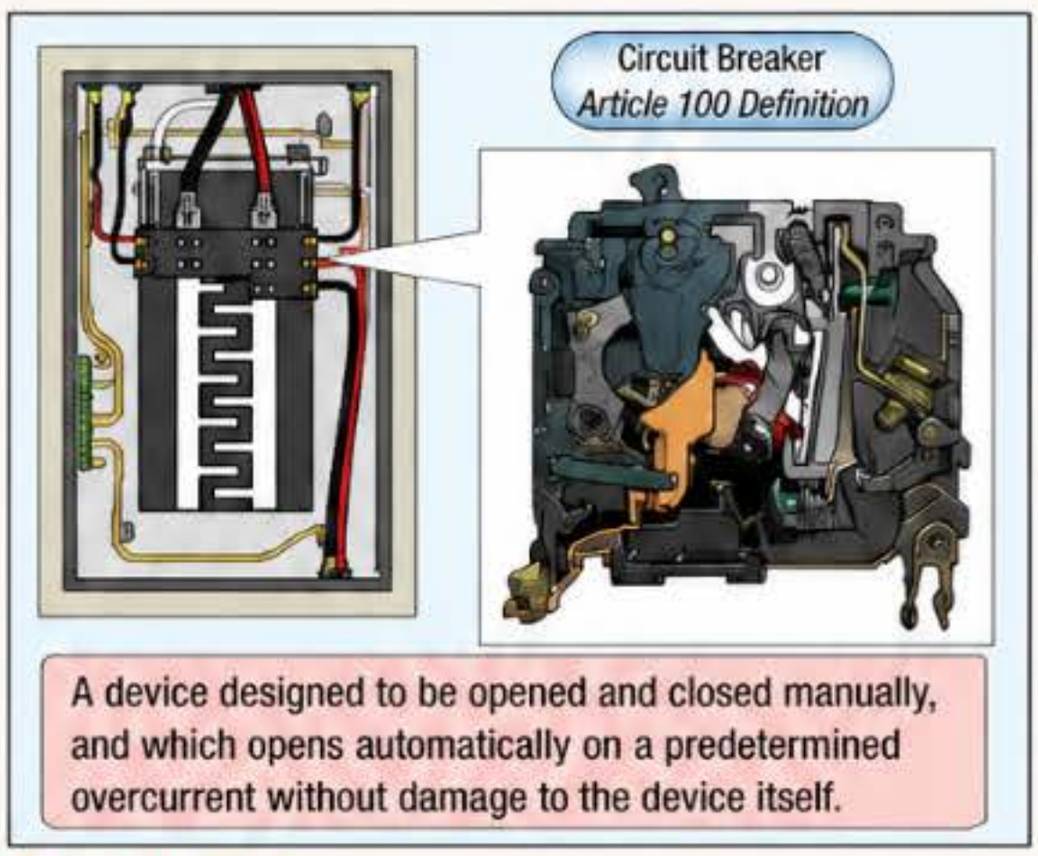
▶ Figure 100–32



▶ Figure 100–34



▶ Figure 100–33



▶ Figure 100–35

Charge Controller. Equipment that manages dc voltage or dc current (or either or both). It is used to charge a battery or another energy storage device. ▶ Figure 100–34

Circuit Breaker. A device that can be opened and closed by hand and which automatically opens at a specific overcurrent without suffering damage. Circuit breakers are available in various configurations, such as adjustable trip (electronically controlled), instantaneous trip/motor-protective circuit protectors, and inverse time. ▶ Figure 100–35

Circuit Breaker, Adjustable. Adjustable circuit breakers enable the breaker to trip at different settings for current, time (or both), within a defined operating range.

Circuit Breaker, Instantaneous Trip. Instantaneous trip breakers operate only on the basis of electromagnetic forces and are used for motors. These are sometimes referred to as "motor-circuit protectors." This type of device does not provide overload protection. Only short-circuit and ground-fault protection are provided; overload protection must be supplied separately.

Author's Commentary:

Instantaneous trip circuit breakers do not have an intentional time delay and are responsive to current surges, vibration, and mechanical shock. Therefore, they should not be employed in locations where these conditions are regularly encountered.

— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

Circuit Breaker, Inverse Time. This kind of circuit breaker is intentionally built to slow its tripping response when an overcurrent is present.

The intention is to offset the rush of inrush current that occurs during the normal start-up of devices like vacuum cleaners or air conditioners and to prevent unwanted "nuisance tripping."

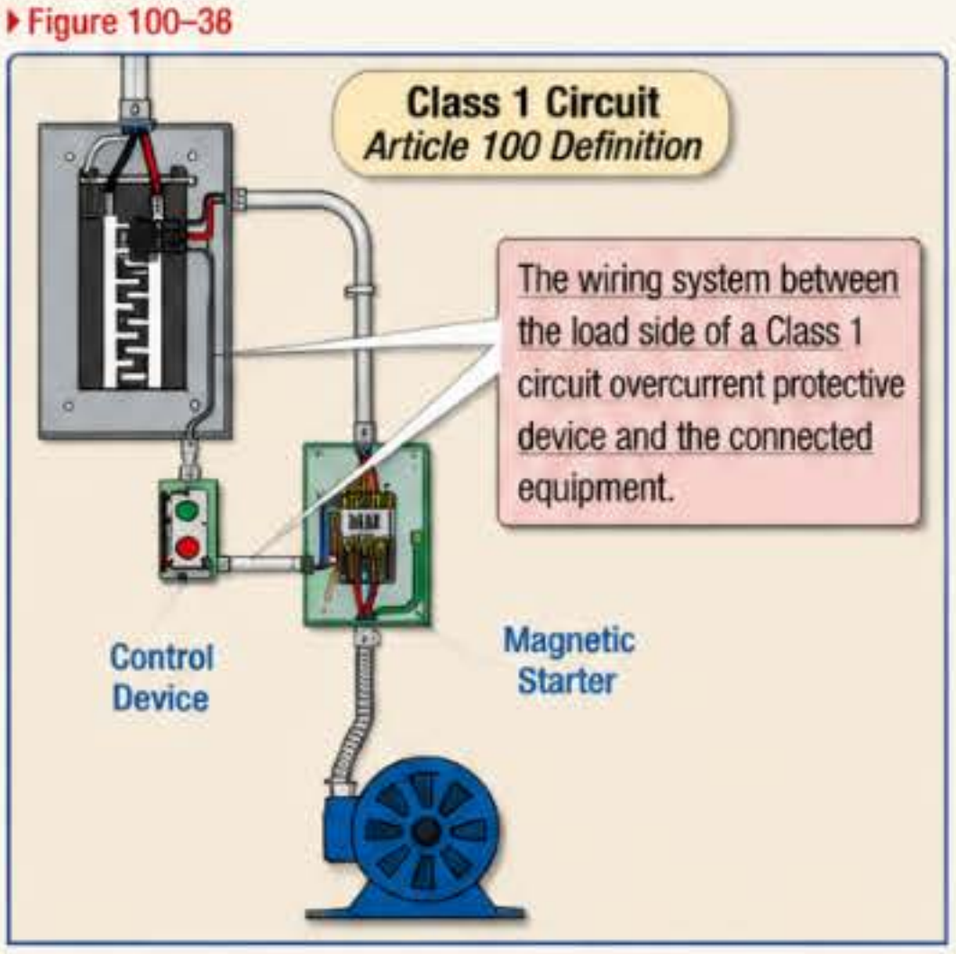
Author's Commentary:

Inverse time breakers work on the principle that the higher the current, the faster the breaker opens. They deliver everyday overcurrent protection under overload, short-circuit, or ground-fault conditions. This type is the most commonly purchased circuit breaker installed in panels.

— Michael Hamilton

Class 1 Circuit. The wiring system between the load side of a Class 1 circuit overcurrent protective device and the connected equipment.

▸ Figure 100–38



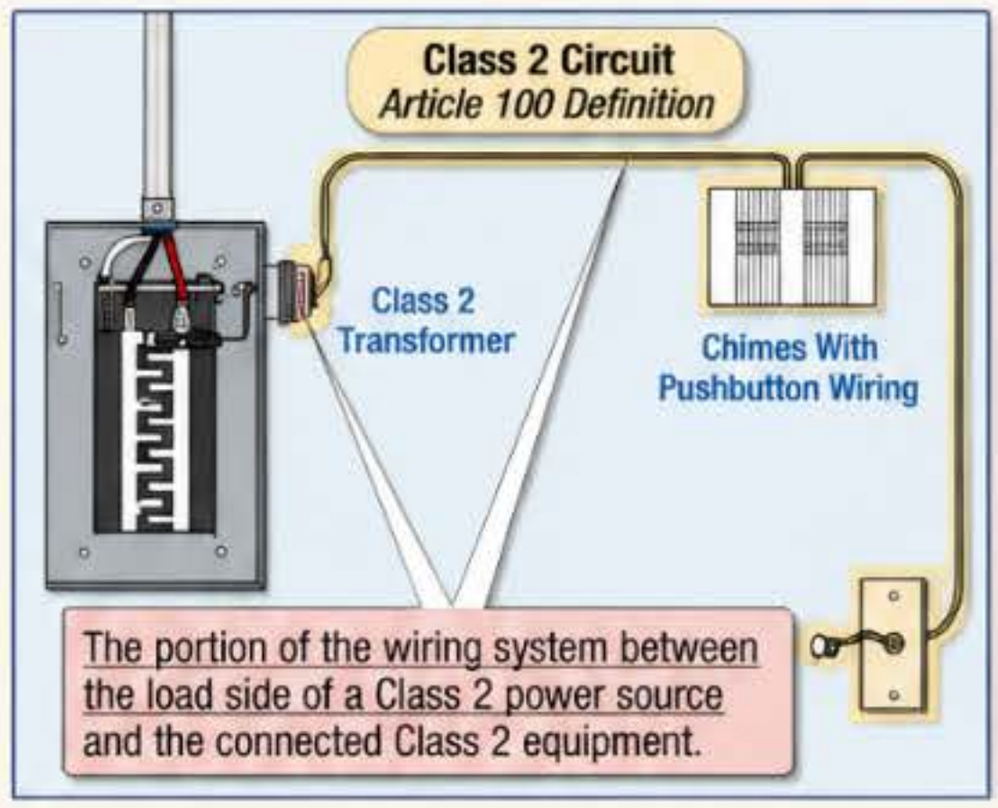
▸ Figure 100–36

Note: See 725.41 for the voltage and power limitations of Class 1 circuits.

Class 2 Circuit. The portion of the wiring system between the load side of a Class 2 power supply and the connected Class 2 equipment.

▸ Figure 100–37

Due to power limitations of its power supply, a Class 2 circuit is considered safe from a fire initiation standpoint and provides acceptable electric shock protection.



▸ Figure 100–37

Author's Commentary:

- Class 2 circuits are considered safe because they are limited to 100 VA for systems operating at 30V or less, and to 5 mA for systems over 30V [715.121(A) and Chapter 9, Table 11(A)].
- Class 2 circuits typically serve low-energy, low-voltage loads such as thermostats, programmable controllers, burglar alarms, and security devices. This category also includes twisted-pair or coaxial cables that connect computers for local networks (LANs), power over ethernet applications (POE), and programmable controller I/O circuits [725.121(A)(3) and 725.121(A)(4)].

— Michael Hamilton

Class 3 Circuit. The portion of the wiring system between the load side of a Class 3 power supply and the connected Class 3 equipment.

▸ Figure 100–38

Author's Commentary:

- Class 3 circuits are used when the power demand exceeds 30 VA but does not go beyond 100 VA [Chapter 9, Table 11(A)].

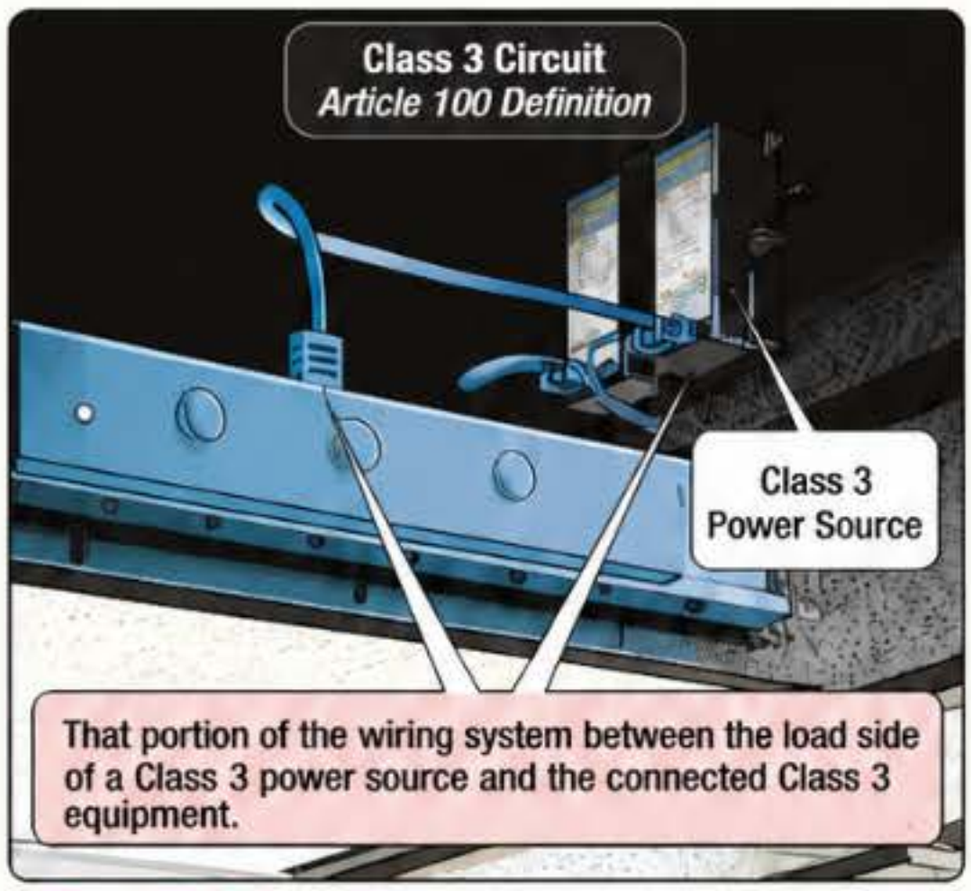
— Michael Hamilton

Clothes Closet. A nonhabitable roonn or enclosed space intended mainly for storing clothing and apparel. ▸ Figure 100–39

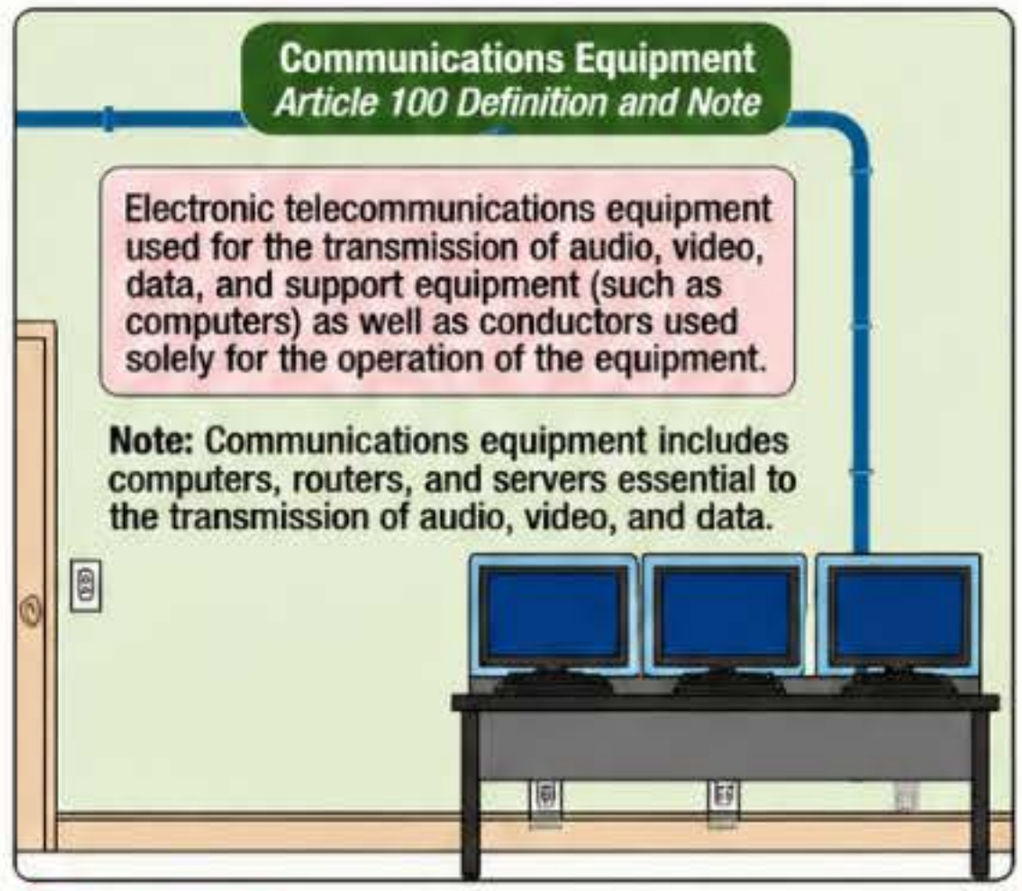
Author's Commentary:

The definition of a "Clothes Closet" clarifies how overcurrent protection device requirements [240.24(D)] and lighting requirements [410.16] apply within clothes closets.

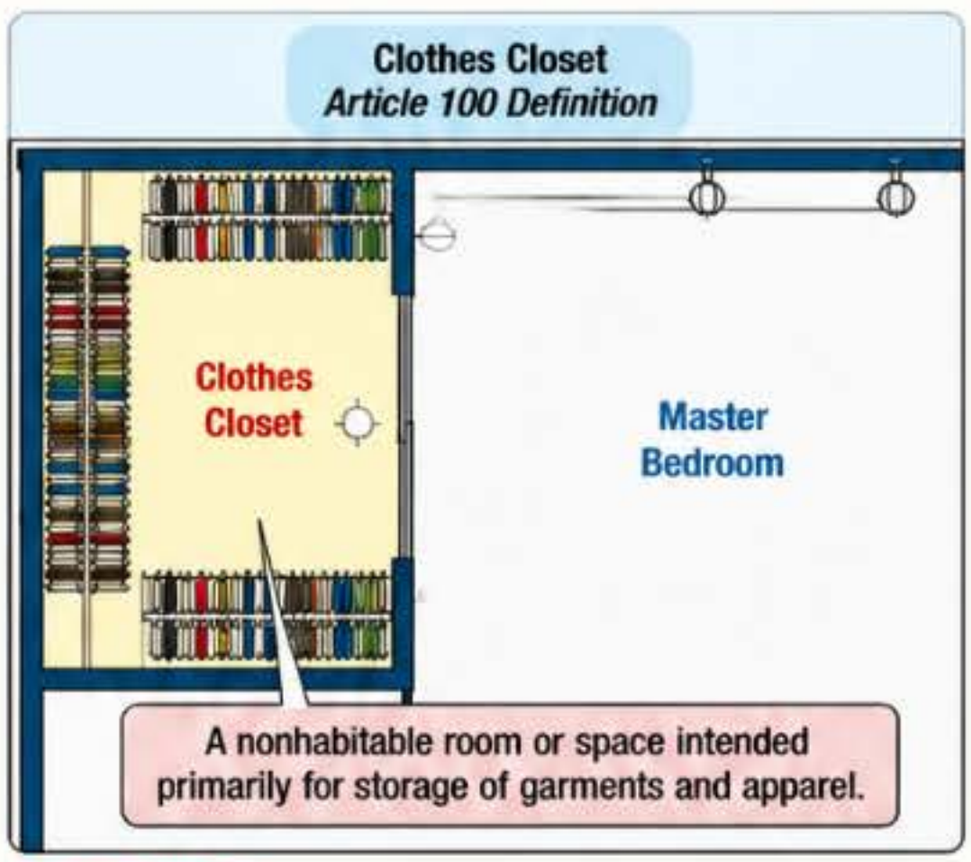
— Michael Hamilton



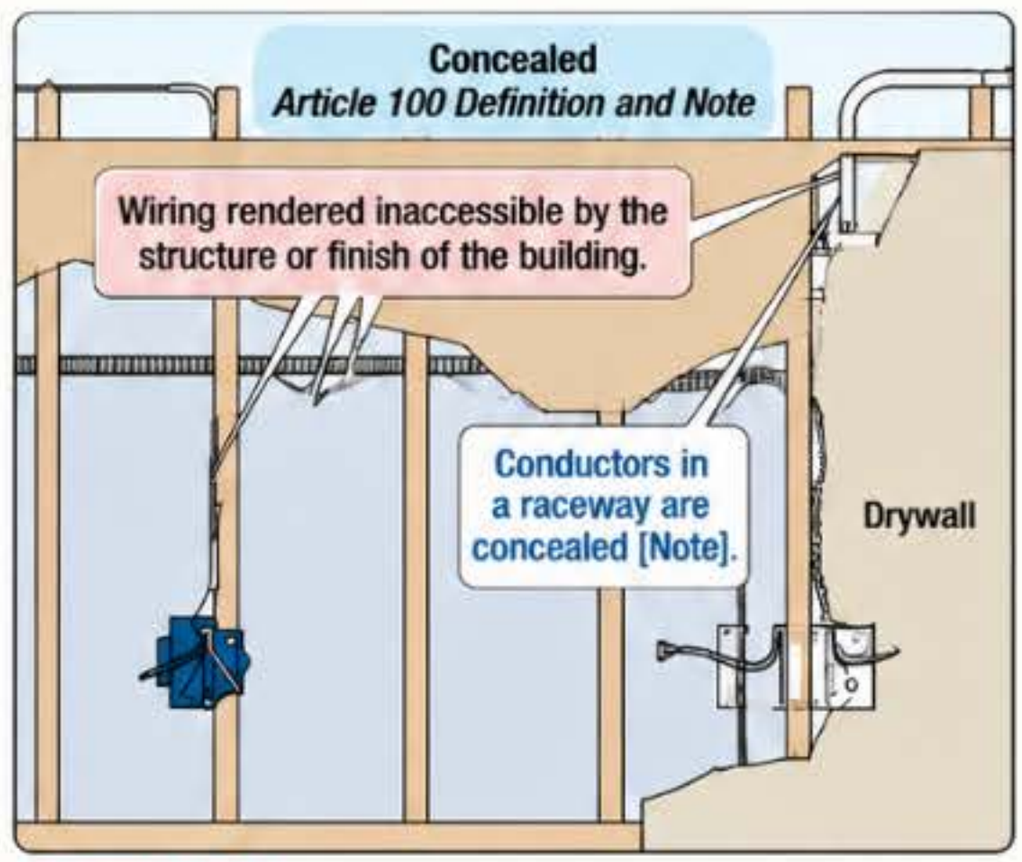
▶ Figure 100–38



▶ Figure 100–40



▶ Figure 100–39



▶ Figure 100–41

Communications Equipment. Electronic telecommunications equipment used for the transmission of audio, video, and data including support equipment (such as computers) and the conductors used solely for the operation of the equipment.

Note: Communications equipment includes the computers, routers, and servers essential to the transmission of audio, video, and data. ▶Figure 100–40

Concealed. Rendered inccessible by the structure or finish of the building. ▶Figure 100–41

Note: Conductors in a concealed raceway are considered concealed even though they may be made accessible by withdrawing them from the raceway.

Author's Commentary:

- Wiring behind panels designed to allow access, such as removable ceiling tile and wiring in accessible attics, is not regarded as concealed; it is treated as exposed. See the definition of "Exposed" (as applied to wiring methods).
- Boxes are not permitted to be concealed by the finish of the building. ▶Figure 100–42

— Michael Hamilton

Conduit Body. A fitting installed in a conduit or tubing system that provides access to conductors through a removable cover. ▶Figure 100–43

Continuous Load. A load where the maximum current is expected to exist for 3 hours or more continuously such as in schools, office buildings, stores, or parking lot lighting.

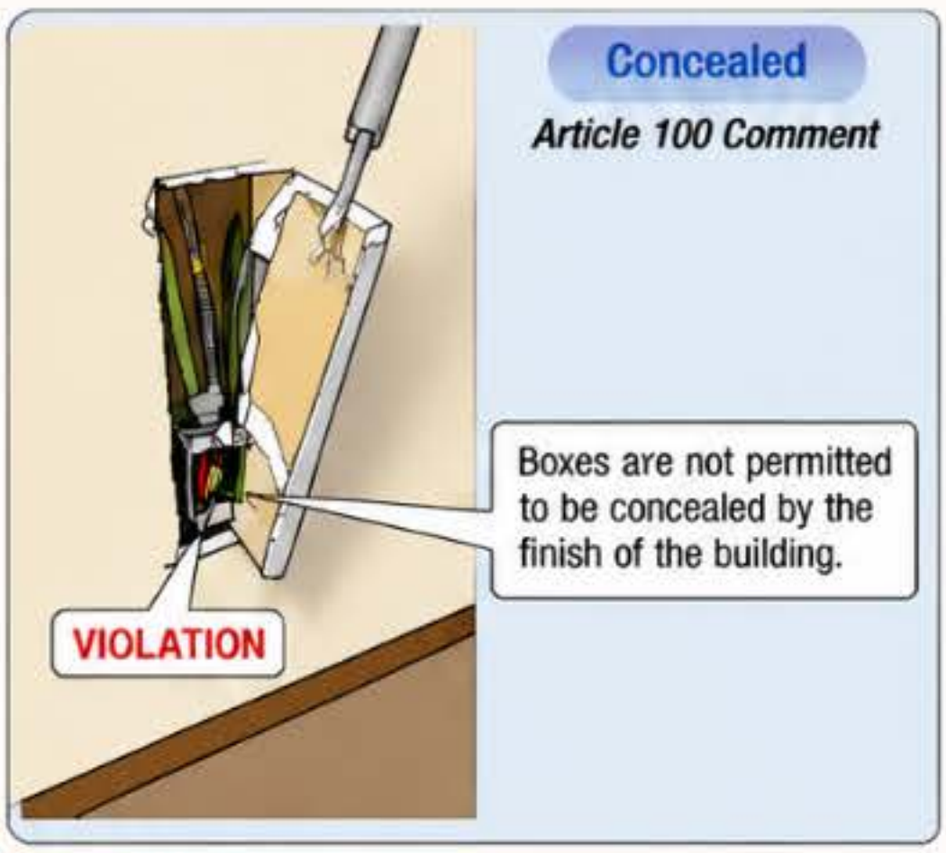


Figure 100–42

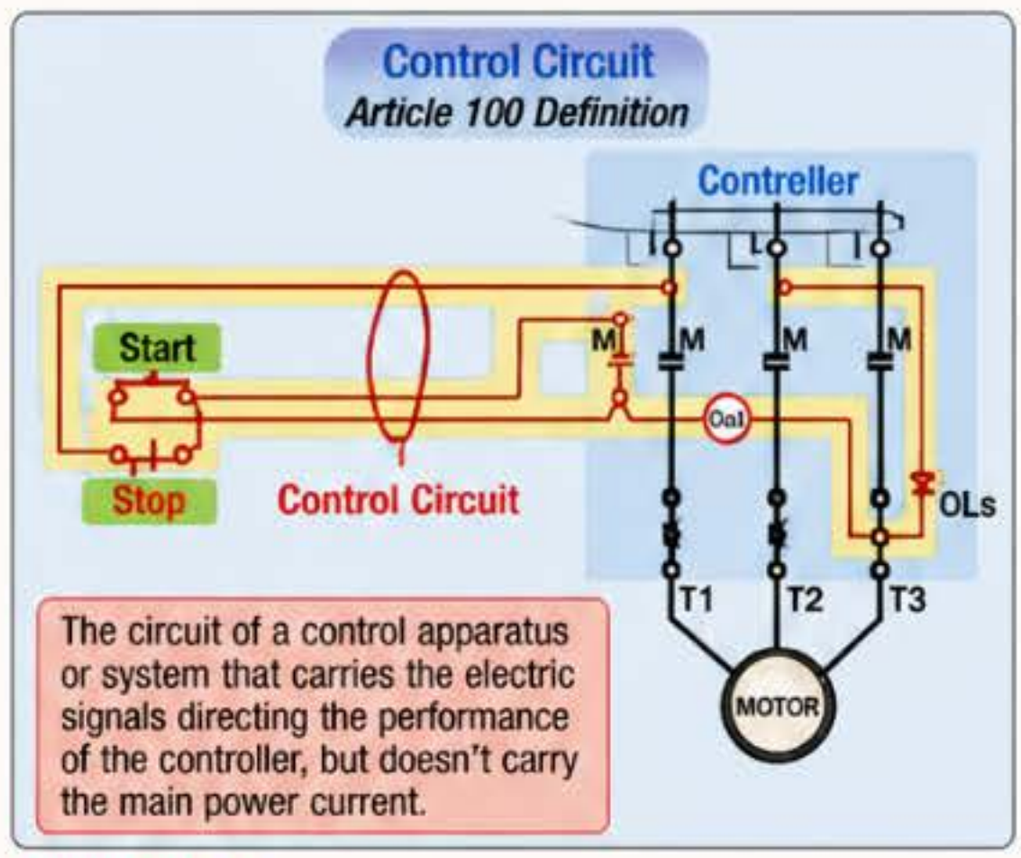


Figure 100–44

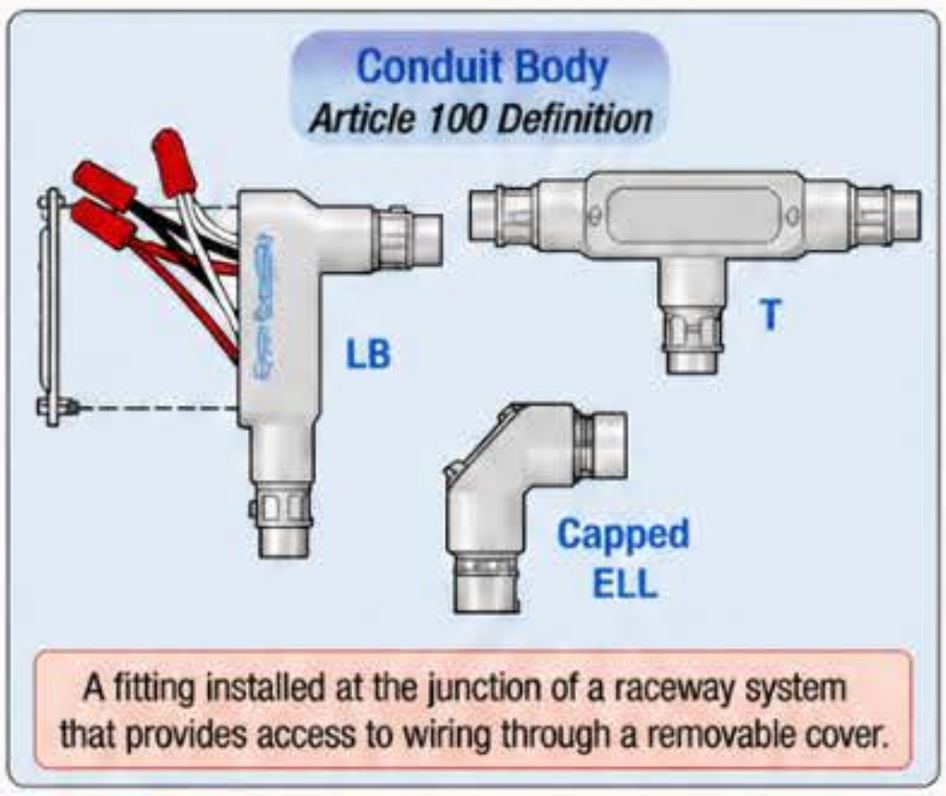


Figure 100–43

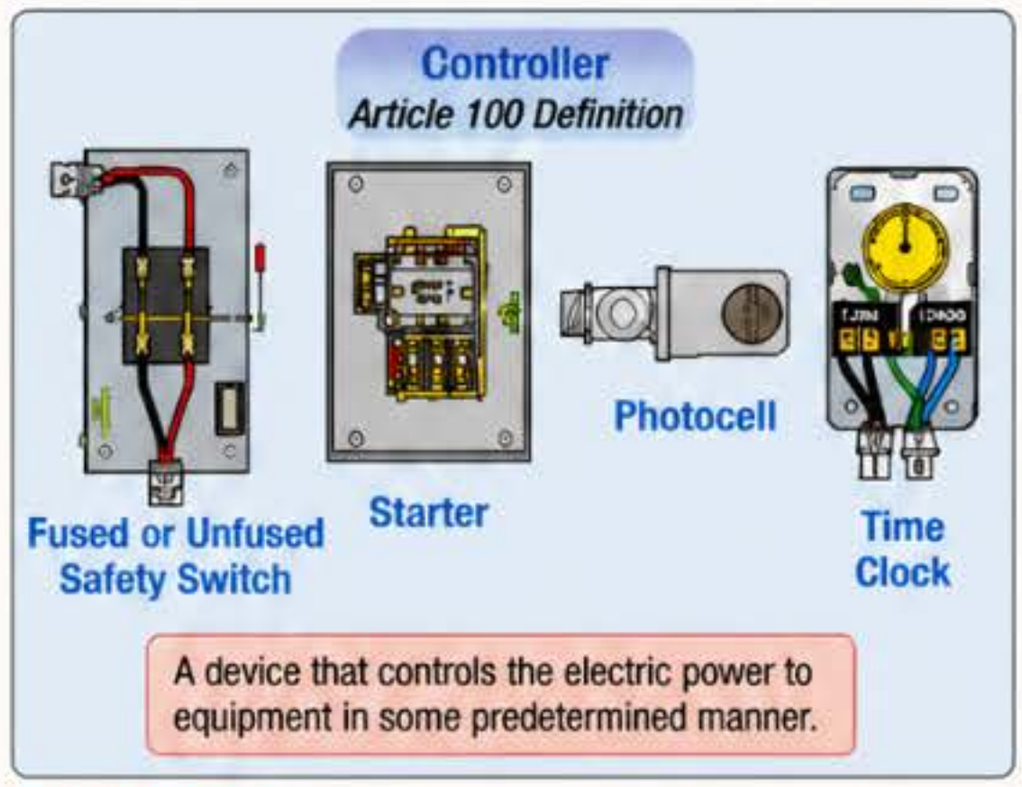


Figure 100–45

Control Circuit. The circuit of a control apparatus or system that carries the electric signals directing the performance of a controller but does not carry the main power current. ▸Figure 100–44

Controller. A device that controls the electric power delivered to electrical equipment in some predetermined manner. This includes time clocks, lighting contactors, photocells, and equipment with similar functions. ▸Figure 100–45

Coordination, Selective (Selective Coordination). Localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices. Selective coordination includes all currents from overloads, short circuits, or ground faults. ▸Figure 100–46

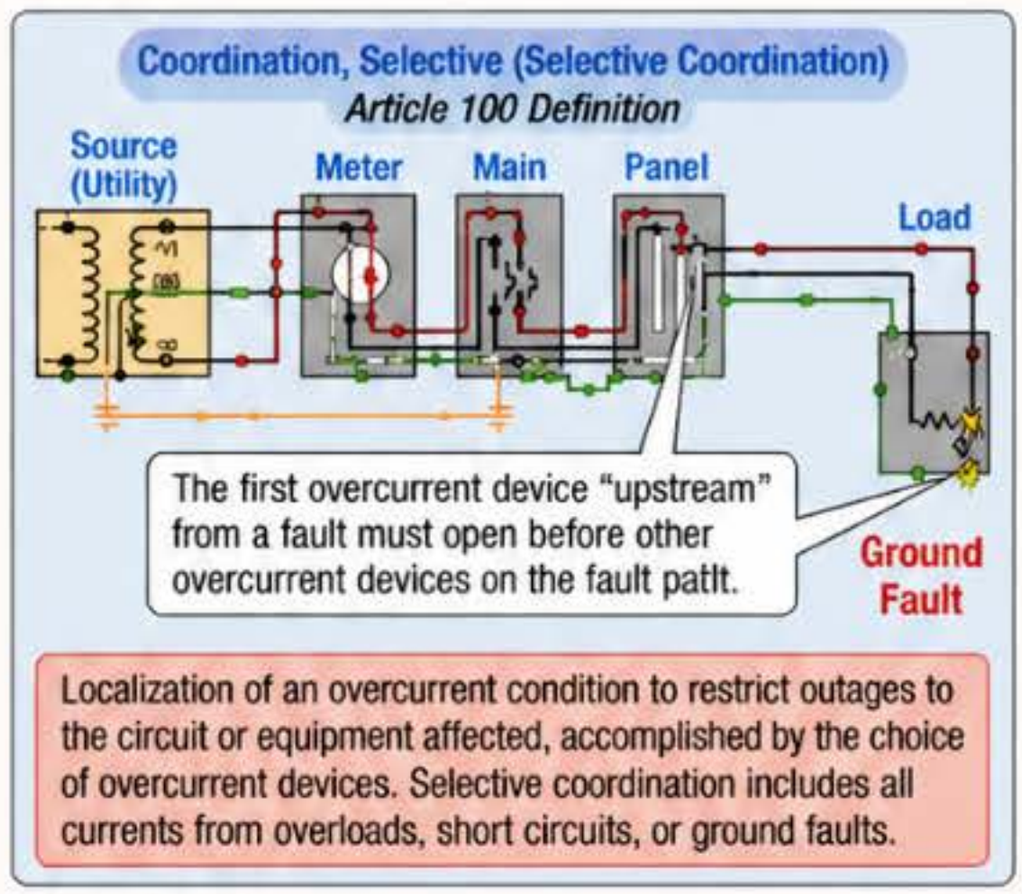


Figure 100–46

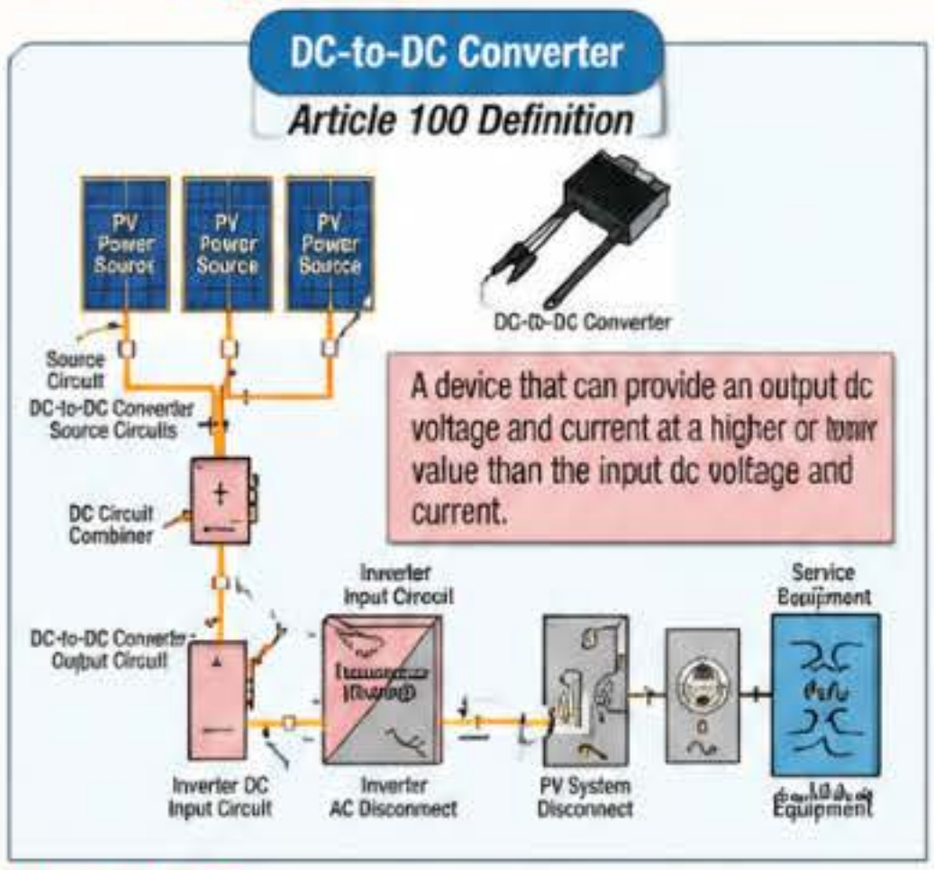
100 DEFINITIONS

Author's Commentary:

Selective coordination means the overcurrent protection scheme confines the interruption to a specific circuit rather than to the entire electrical system. For example, if someone plugs in a space heater and draws a total of 20A on a 25A circuit, or if a short circuit or ground fault occurs with selective coordination, the only breaker or fuse that will open is the one protecting just that branch circuit. Coordinating overcurrent protection for an electrical system is especially important in healthcare facilities and data centers where the loss of power ahead of the troubled circuit can have dire consequences—including loss of life.

— Michael Hamilton

DC-to-DC Converter. A device that can provide an output dc voltage and current at a higher or lower value than the input dc voltage and current.
current. ▶ **Figure 100–47**



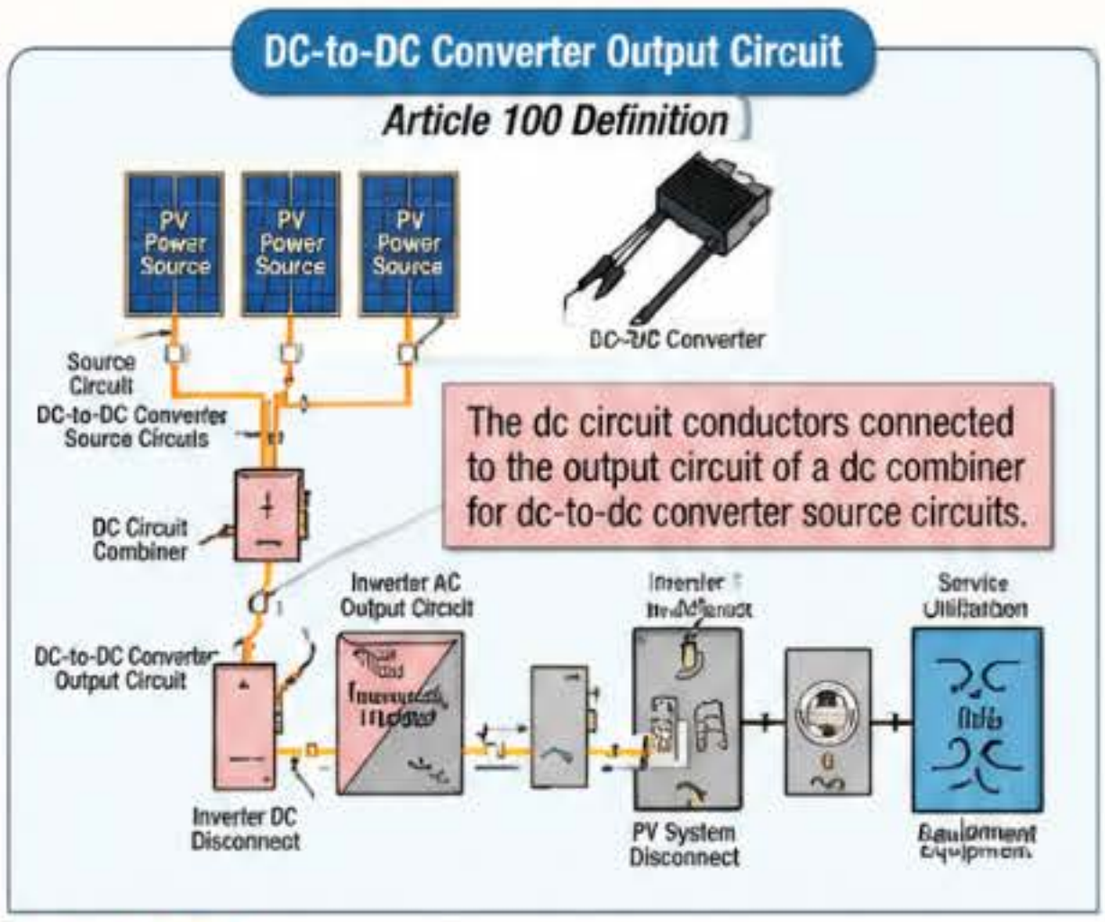
▲ **Figure 100–47**

Author's Commentary:

- DC-to-DC converters are intended to maximize the output of independent PV modules and reduce losses due to variances between modules' outputs. They are directly wired to each module and are bolted to the module frame or the PV rack.
- A dc-to-dc converter enables a PV inverter to automatically maintain a fixed circuit voltage, the optimal point for dc/ac conversion by the inverter, regardless of circuit length and individual module performance.

— Michael Hamilton

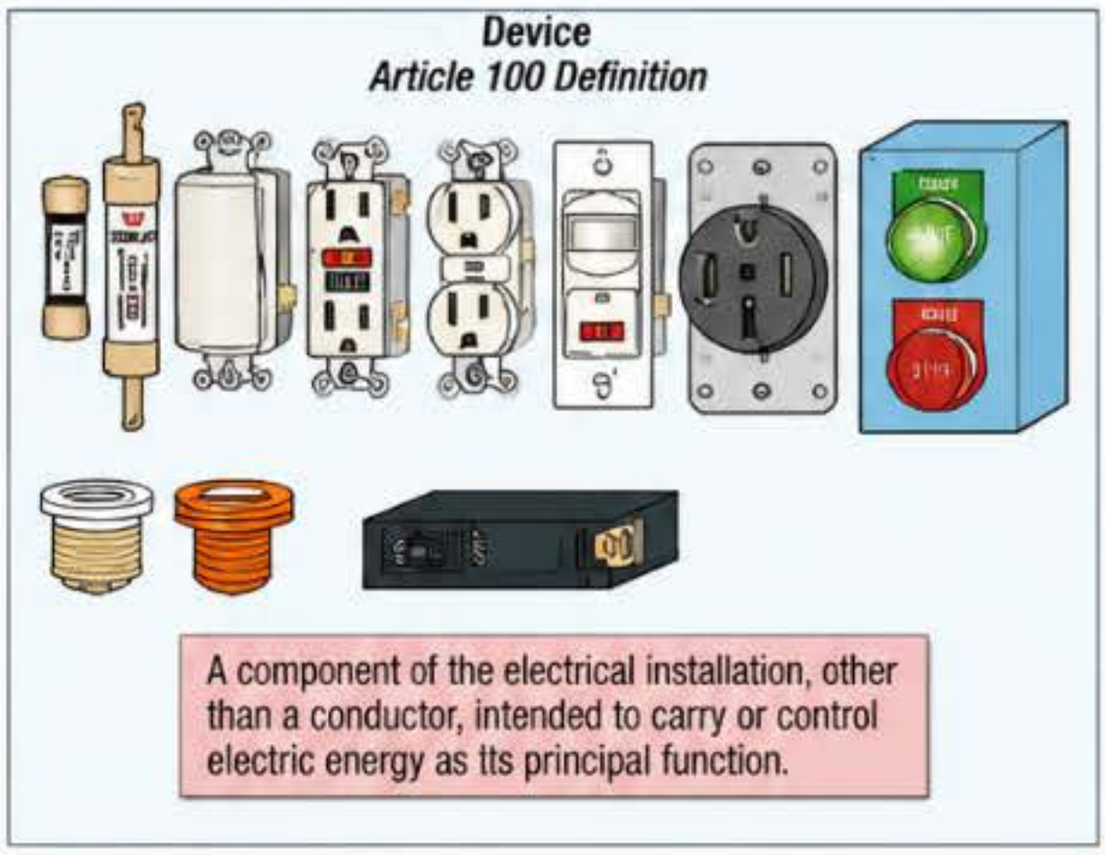
DC-to-DC Converter Output Circuit. The dc circuit conductors connected to the output circuit of a dc combiner for dc-to-dc converter source circuits. ▶ **Figure 100–48**



▲ **Figure 100–48**

Demand Factor. The ratio of the maximum load demand to the total connected load.

Device. A component of an electrical installation, other than a conductor, intended to carry or control electric energy as its principal function. ▶ **Figure 100–49**



▲ **Figure 100–49**

Author's Commentary:

- Devices generally do not consume electric energy and include receptacles, switches, illuminated switches, circuit breakers, fuses, time clocks, controllers, attachment plugs, and so forth. Some (such as illuminated switches, contactors, or relays) consume very small amounts of energy and are still classified as a device based on their primary function.

— Michael Hamilton

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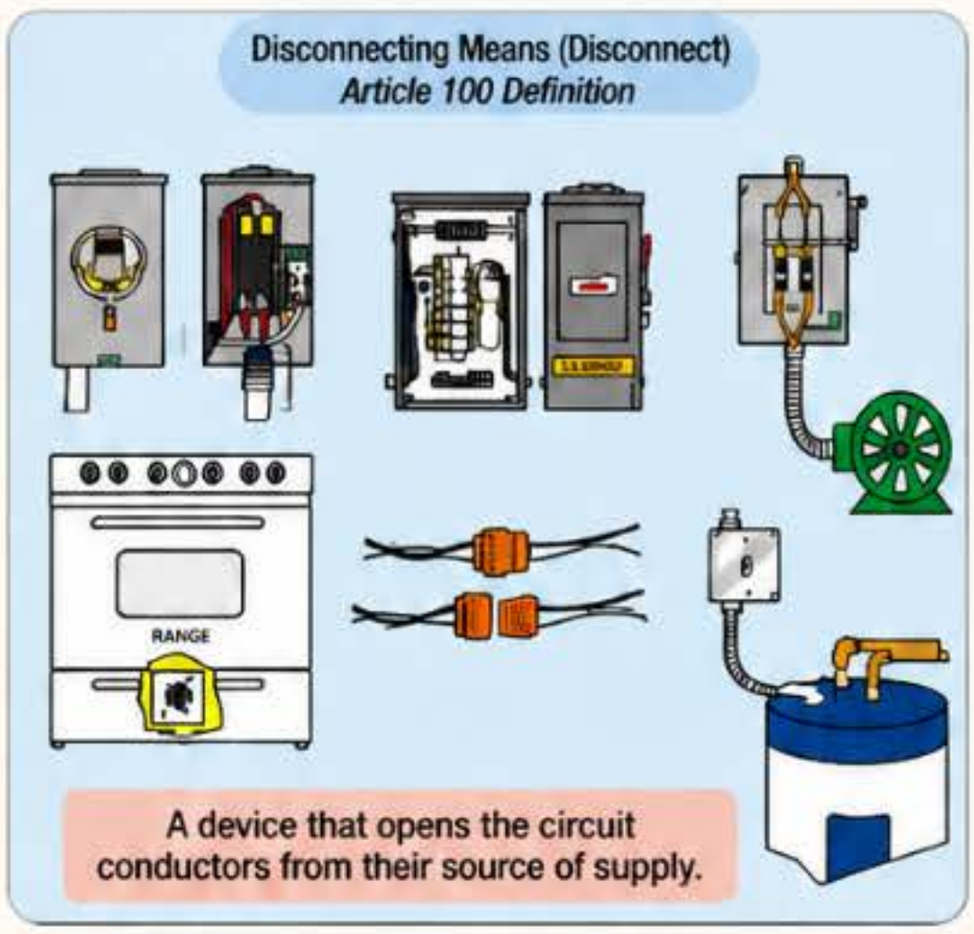
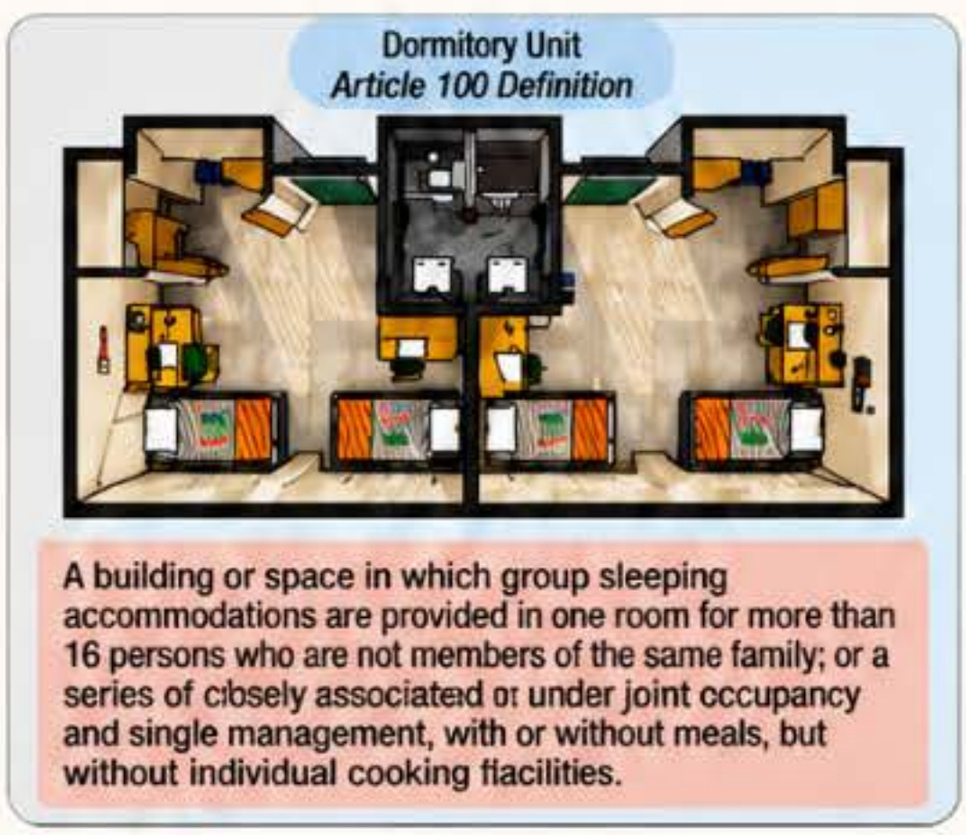
Disconnecting Means (Disconnect). Equipment whose purpose is to physically separate the conductors of a circuit from their source of electrical energy. Common forms include switches, pullout fittings, and circuit breakers. ▸Figure 100–50



▸Figure 100–50

Dormitory Unit. A building or portion of a building that provides group sleeping accommodations in a single room for more than 16 occupants who are not members of the same family; or a set of closely related rooms under common management, with or without meal service, but without individual cooking facilities. ▸Figure 100–51



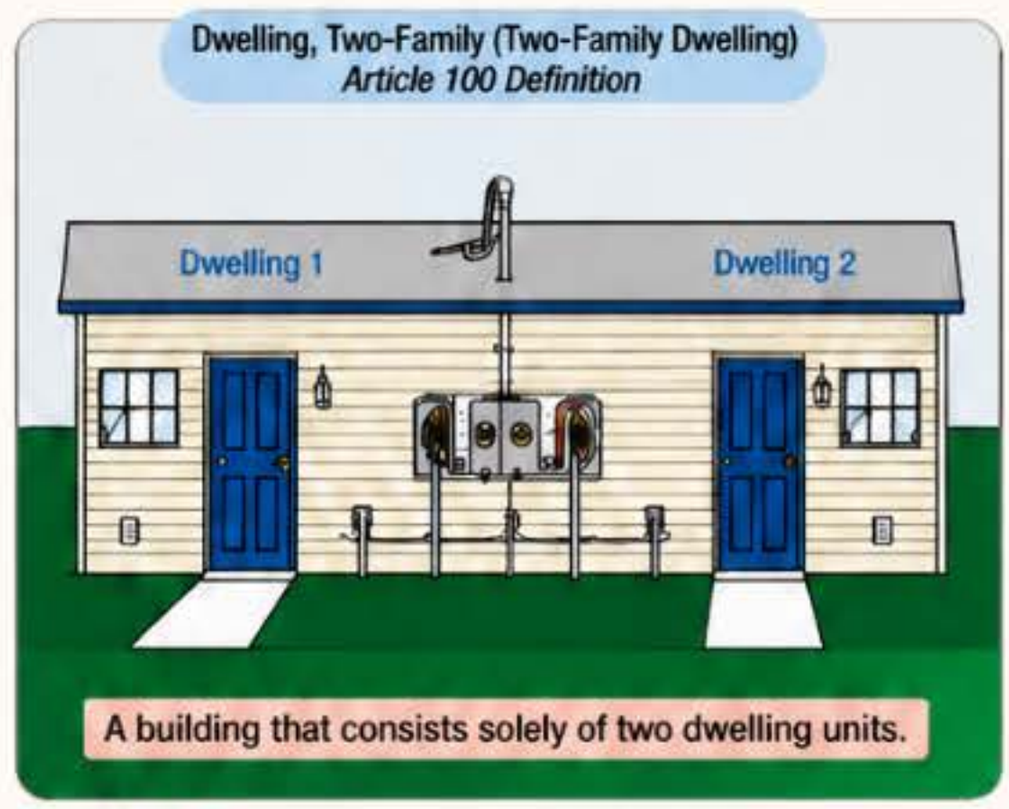
▸Figure 100–51

Duty, Continuous (Continuous Duty). Operation at a substantially constant load for an indefinite amount of time.

Duty, Varying (Varying Duty). Operation at loads, and for intervals of time, which may both be subject to wide variation.

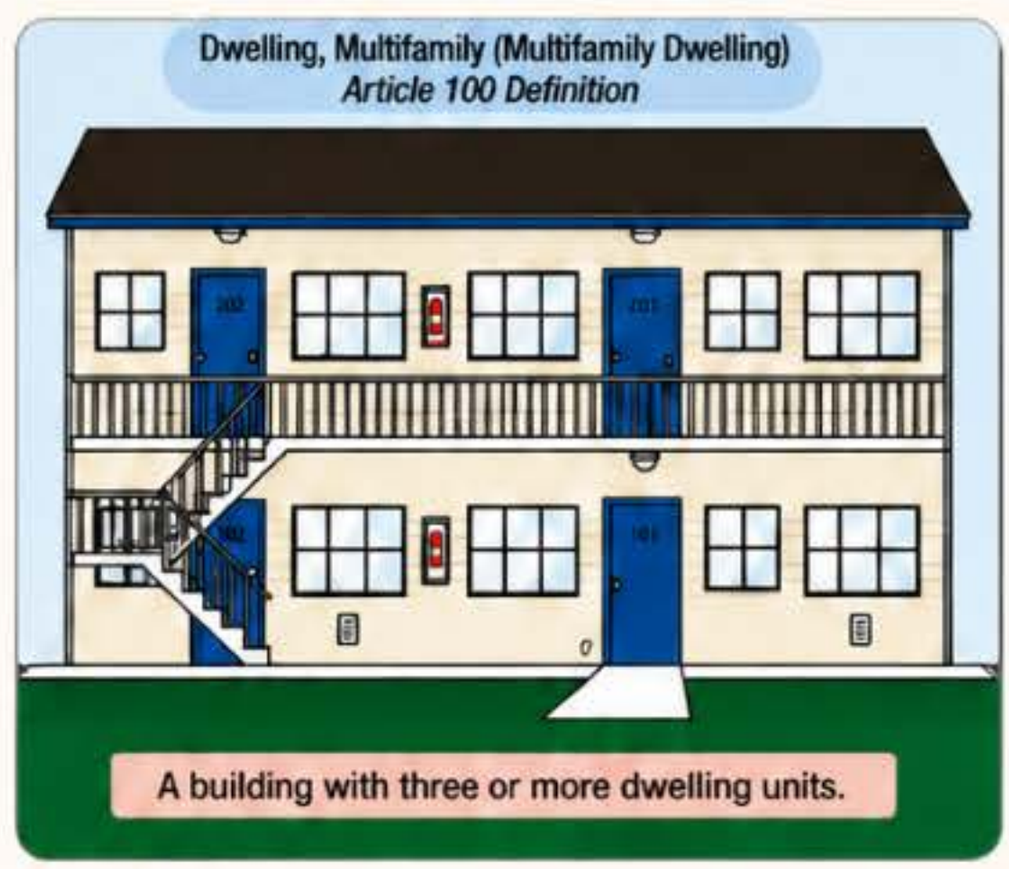
Dwelling, One-Family (One-Family Dwelling). A building that consists solely of one dwelling unit.

Dwelling, Two-Family (Two-Family Dwelling). A building that consists solely of two dwelling units. ▸Figure 100–52



▸Figure 100–52

Dwelling, Multifamily (Multifamily Dwelling). A building that contains three or more dwelling units. ▸Figure 100–53

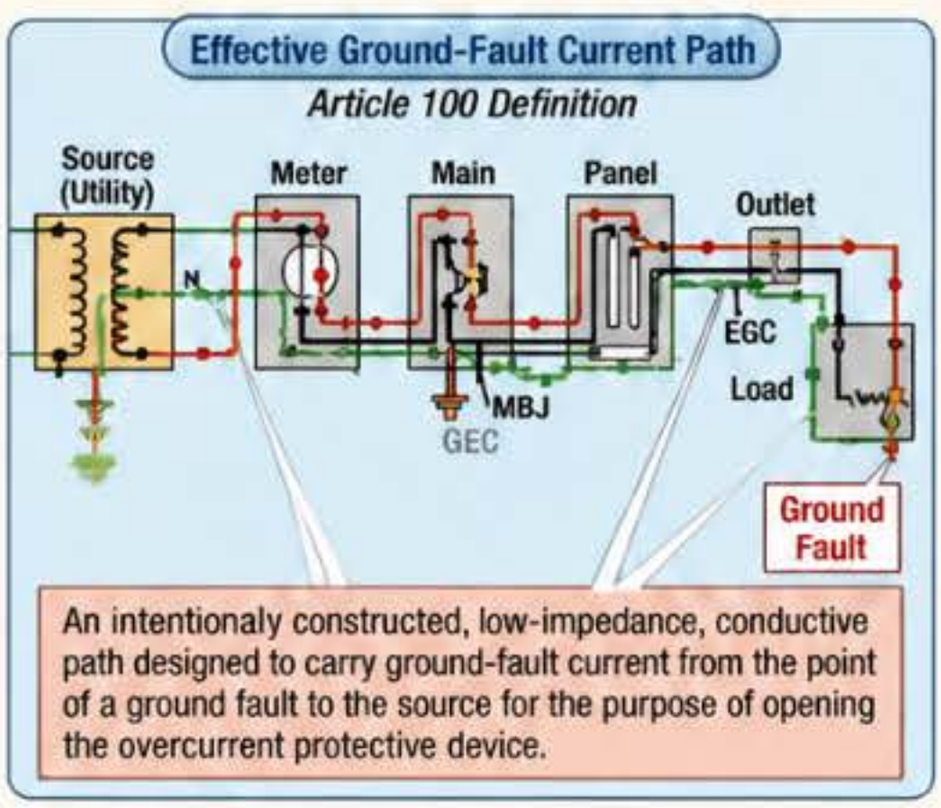


▸Figure 100–53

Dwelling Unit. A space that provides independent living facilities with space for eating, living, sleeping, and permanent provisions for cooking and sanitation. ▸Figure 100–54

▶ Figure 100–54

Effective Ground-Fault Current Path. An intentionally constructed low-impedance conductive path designed to carry ground-fault current from the point of a ground fault to the source for the purpose of opening the circuit overcurrent protective device. **2023 NEC 100–55**



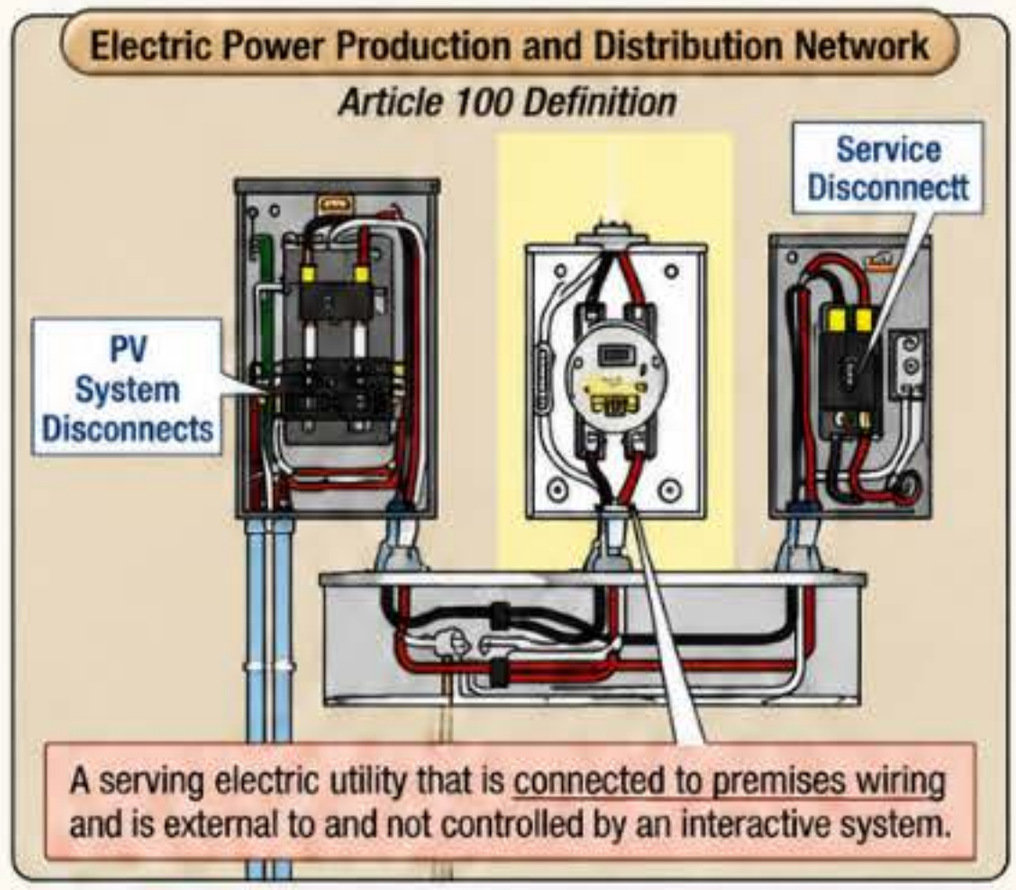
▶ Figure 100–55

Author's Commentary:

- The effective ground-fault current path is intended to help remove dangerous voltage from a ground fault by opening the circuit overcurrent protective device.

— Michael Hamilton

Electric Power Production and Distribution Network. A serving electric utility that is connected to premises wiring and is not controlled by an interactive system. **2023 NEC 100–56**



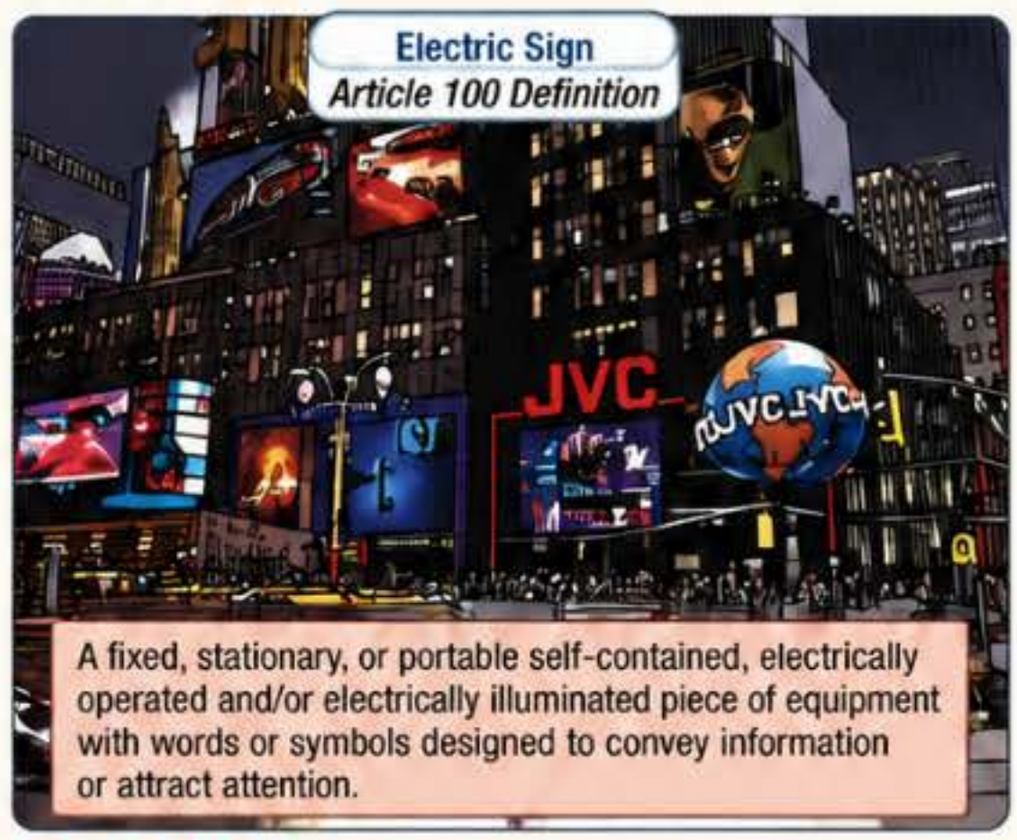
▶ Figure 100–56

Author's Commentary:

- An interactive system is an electric power production system that operates in parallel with, and may deliver power to, the serving electric utility. An example is a PV system interactively connected in parallel to the utility by an interactive inverter.

— Michael Hamilton

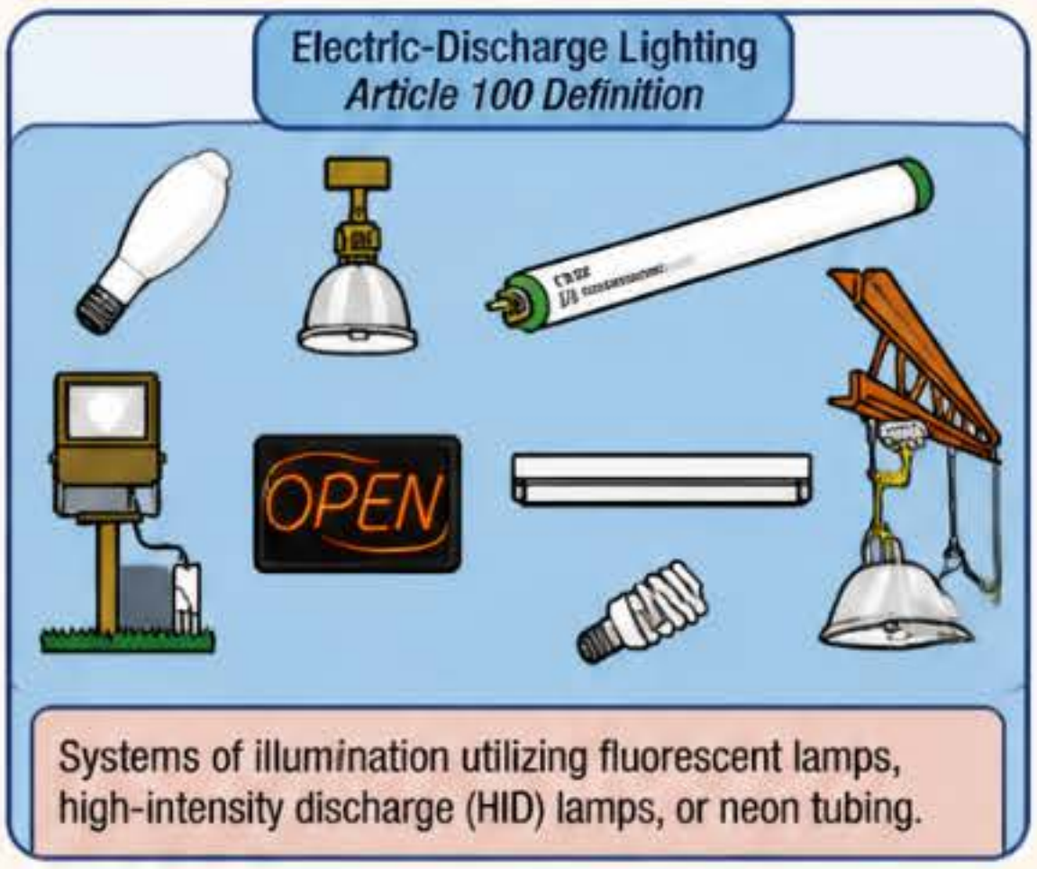
Electric Sign (Article 600). A fixed, stationary, or portable self-contained, electrically operated and/or electrically illuminated piece of equipment with words or symbols designed to convey information or attract attention. **2023 NEC 100–57**



▶ Figure 100–57

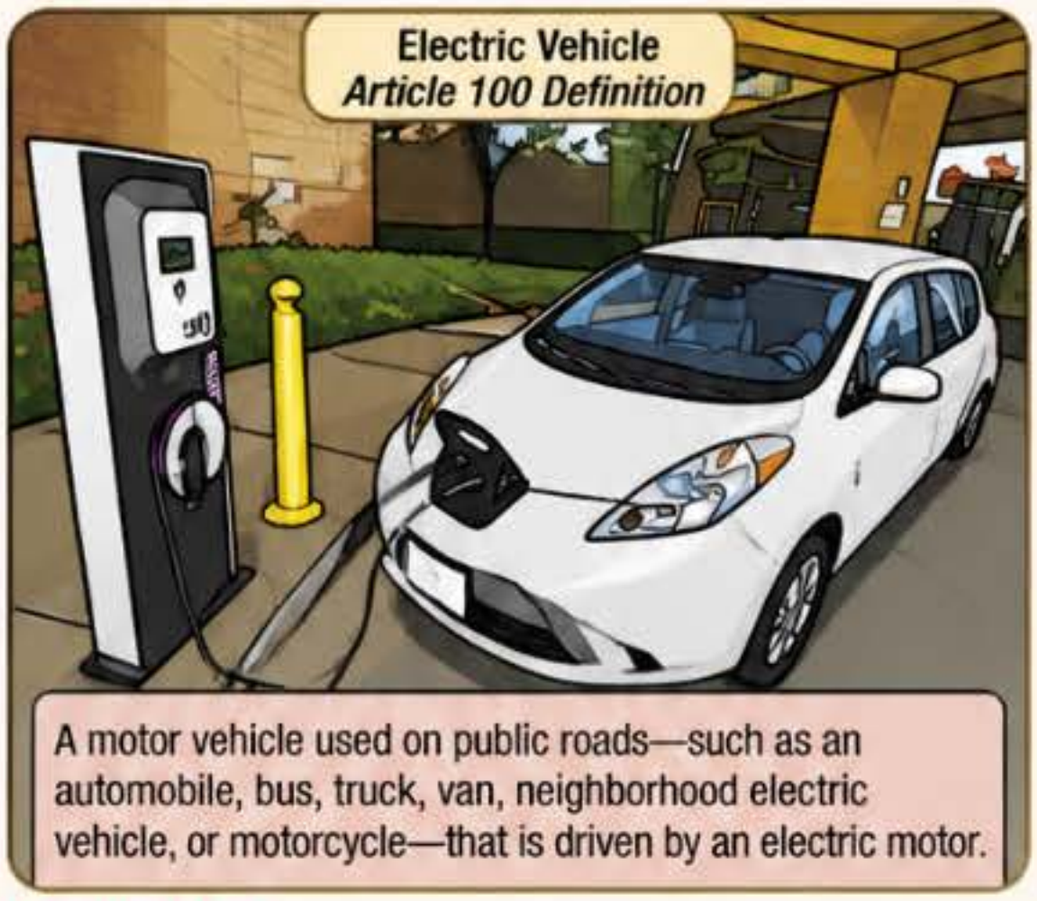
Electric-Discharge Lighting. Systems of illumination utilizing fluorescent lamps, high-intensity discharge (HID) lamps, or neon tubing. **2023 NEC 100–58**

DEFINITIONS | From Michael Hamilton Publications



▶ Figure 100–58

Electric Vehicle. A motor vehicle used on public roads—such as an automobile, bus, truck, van, neighborhood electric vehicle, or motorcycle—that is driven by an electric motor. ▶ Figure 100–59



▶ Figure 100–59

Off-road, self-propelled electric industrial trucks, hoists, lifts, transporters, golf carts, airline ground support equipment, tractors, and boats are not considered electric vehicles.

Author's Commentary:

- *This category includes plug-in hybrid vehicles that have both an electric motor and a combustion engine used to recharge the electric motor in accordance with Article 625.*

— Michael Hamilton

Electrical Datum Plane. The notional elevation above a body of water at which electrical equipment can be set up and the associated wiring connections can be made.

Author's Commentary:

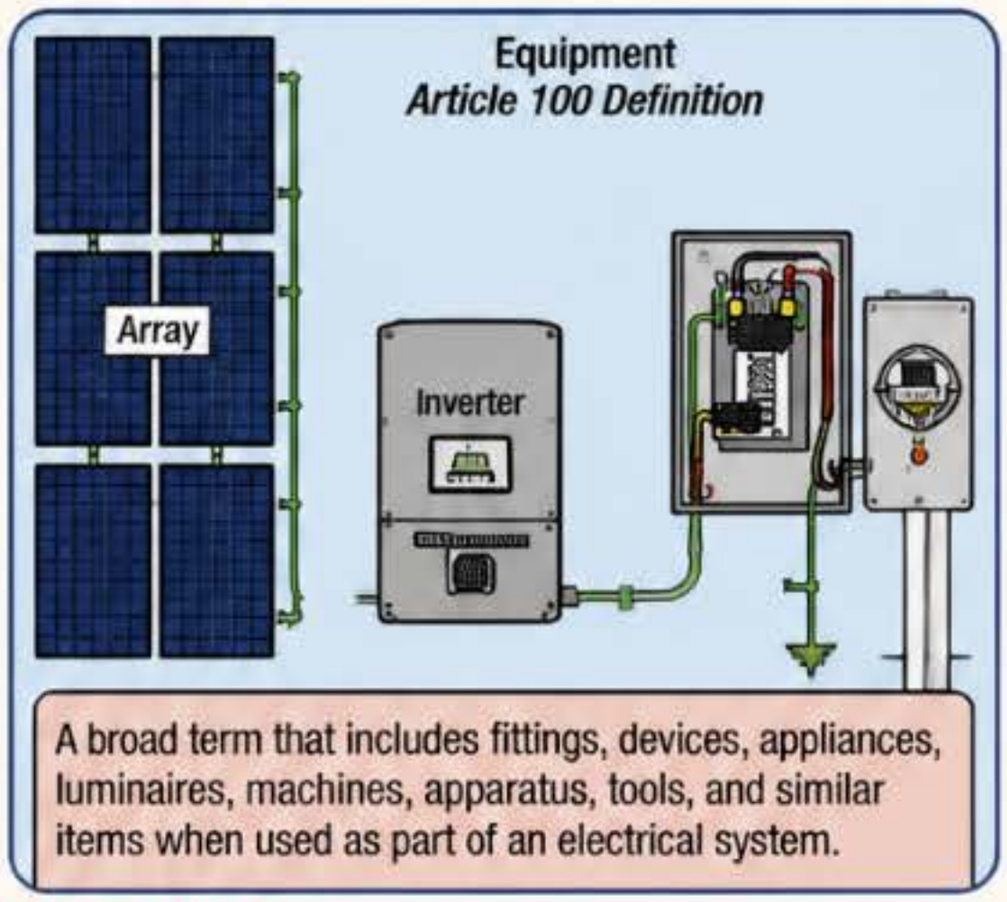
- *The earlier text stated the particular elevations that served as the electrical datum plane for each requirement. Those detailed numbers appear in 682.5 since they apply only to this article and not to other provisions that use this term.*

— Michael Hamilton

Enclosed. Surrounded by a case, housing, fence, or wall(s) that prevents energized components from being touched accidentally.

Energized. Connected to a voltage source.

Equipment. A broad term that includes fittings, appliances, machines, luminaires, tools, and similar items when used as part of—or connected within—an electrical installation. ▶ Figure 100–60



▶ Figure 100–60

Exposed (as applied to live parts). Able to be contacted accidentally or approached more closely than the safe distance. ▶ Figure 100–61

Note: This term covers parts that are not properly guarded, insulated, or otherwise protected for the intended conditions of use—such as line-side lugs in a meter socket or panelboard.

Exposed (as applied to wiring methods). Mounted on or attached to the surface of a building or behind panels intended to allow access. ▶ Figure 100–62

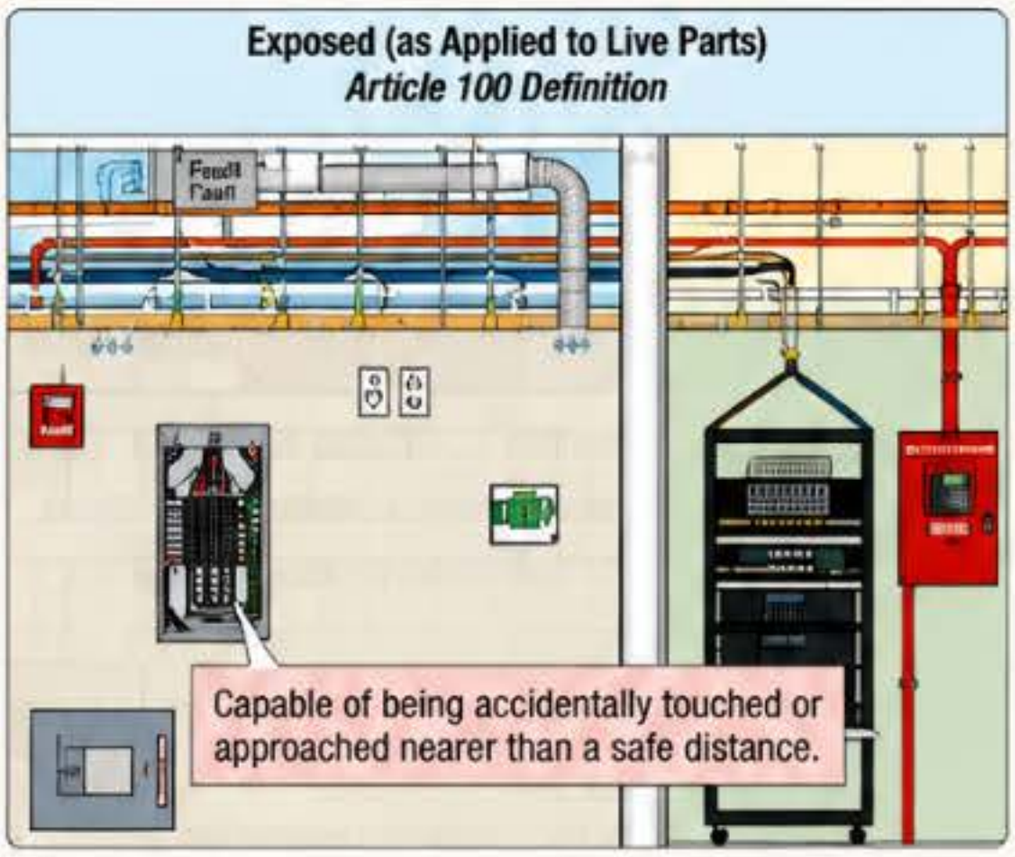


Figure 100–61

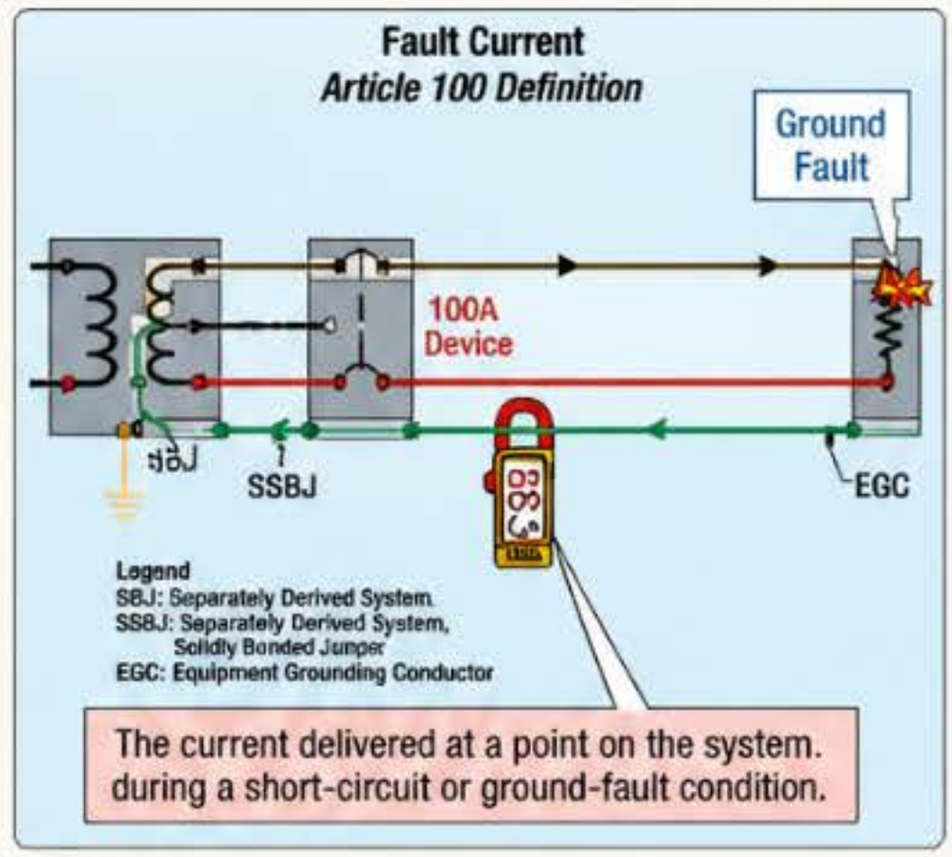


Figure 100–63

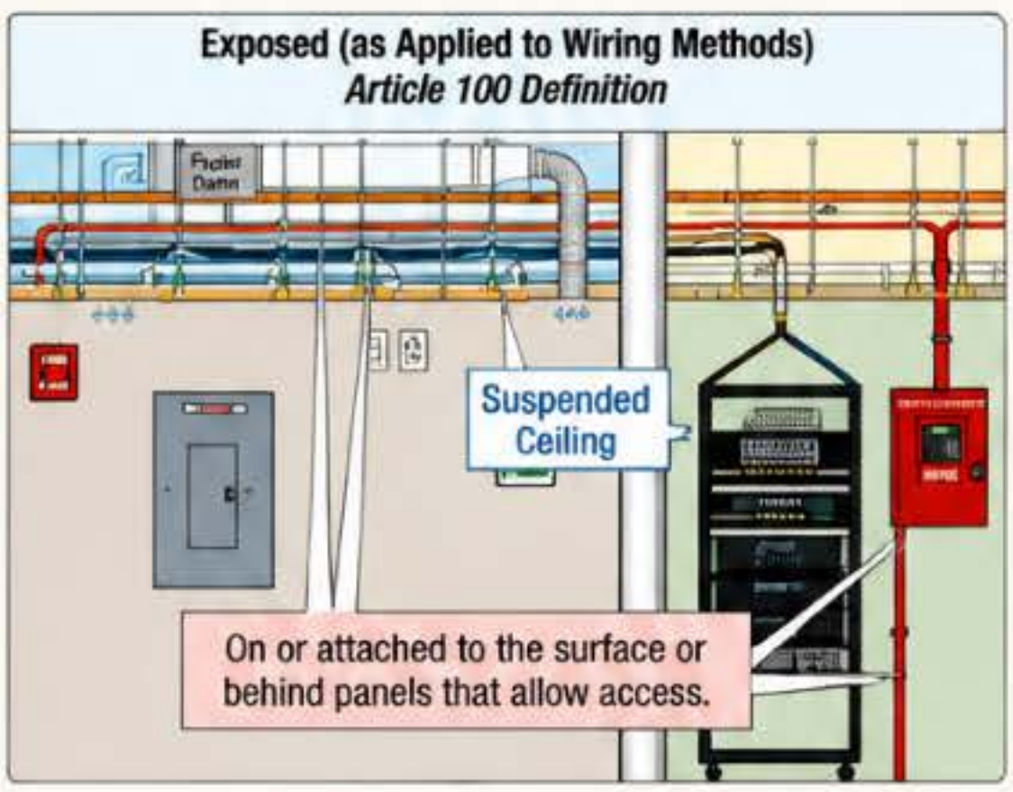


Figure 100–62

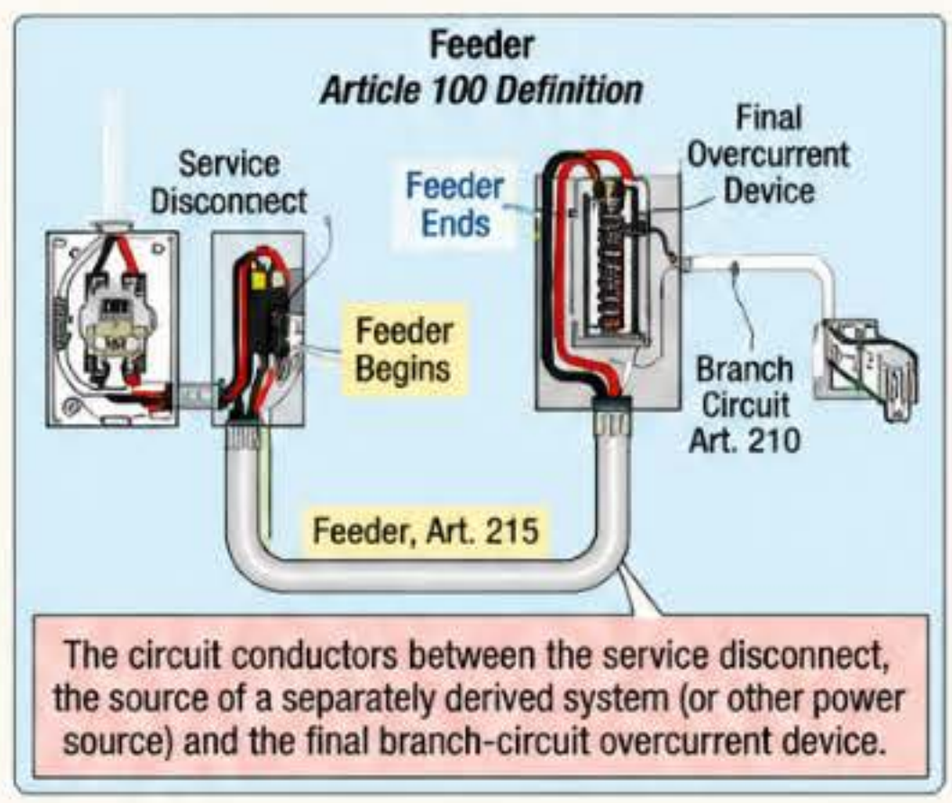


Figure 100–64

Fault Current. The current delivered at a point on the system during a short-circuit condition. Figure 100–63

Note: A short circuit can occur during abnormal conditions such as a fault between circuit conductors or a ground fault.

Feeder. The conductors between the service disconnect, a separately derived system (typically a transformer), or other power-supply source and the final branch-circuit overcurrent device. Figure 100–64

Author's Commentary:

- An "other power-supply source" includes solar PV systems or conductors from generators. Figure 100–65

— Michael Hamilton

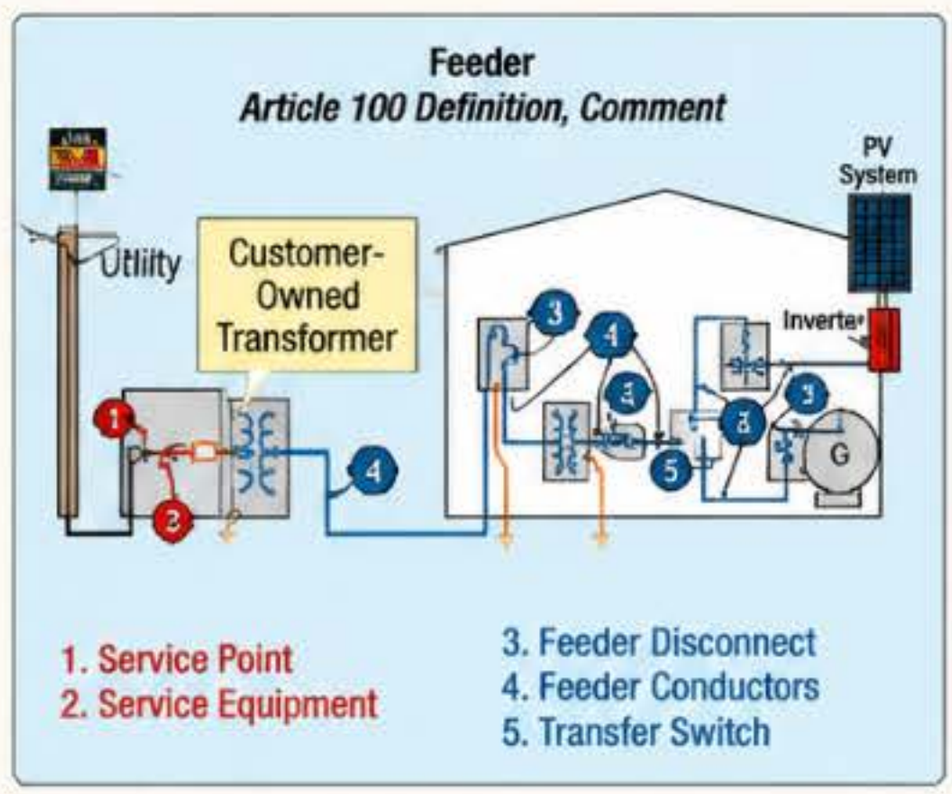
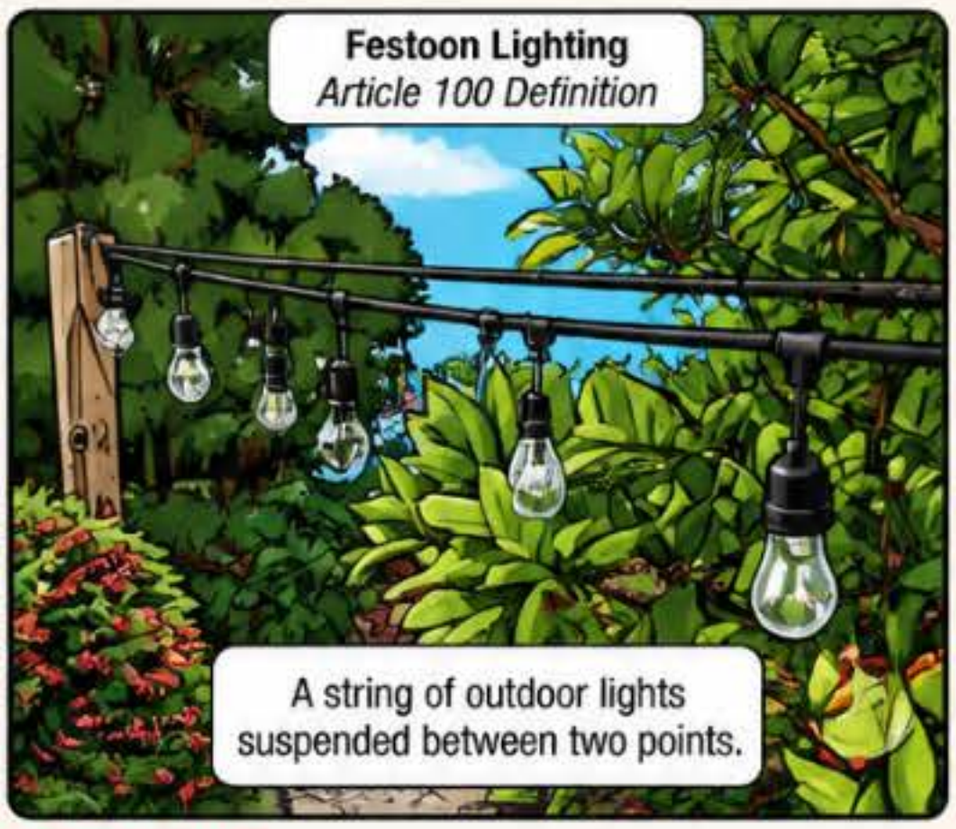


Figure 100–65

Festoon Lighting. A string of outdoor lights suspended between two points. ▸Figure 100–66



▸Figure 100–66

Field Evaluation Body (FEB). An organization or part of an organization that performs field evaluations of electrical equipment and materials.

Field Labeled (as applied to evaluated products). Equipment or materials which have a label, symbol, or other identifying mark of a field evaluation body (FEB) indicating the equipment or materials were evaluated and found to comply with the requirements described in the accompanying field evaluation report.

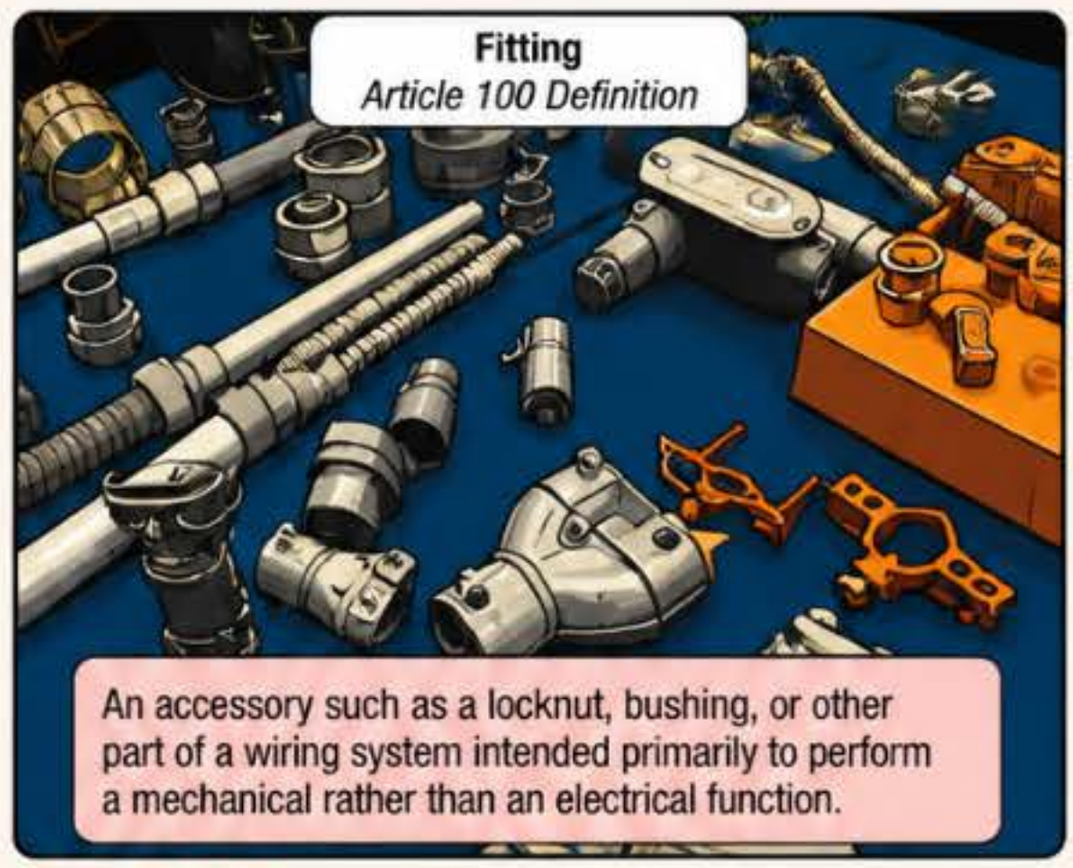
Fitting. An accessory such as a locknut, bushing, or other part of a wiring system that is primarily intended to perform a mechanical rather than an electrical function. ▸Figure 100–67

Free Air (as applied to conductors). An open or ventilated environment that allows for heat dissipation and air flow around a conductor. ▸Figure 100–68

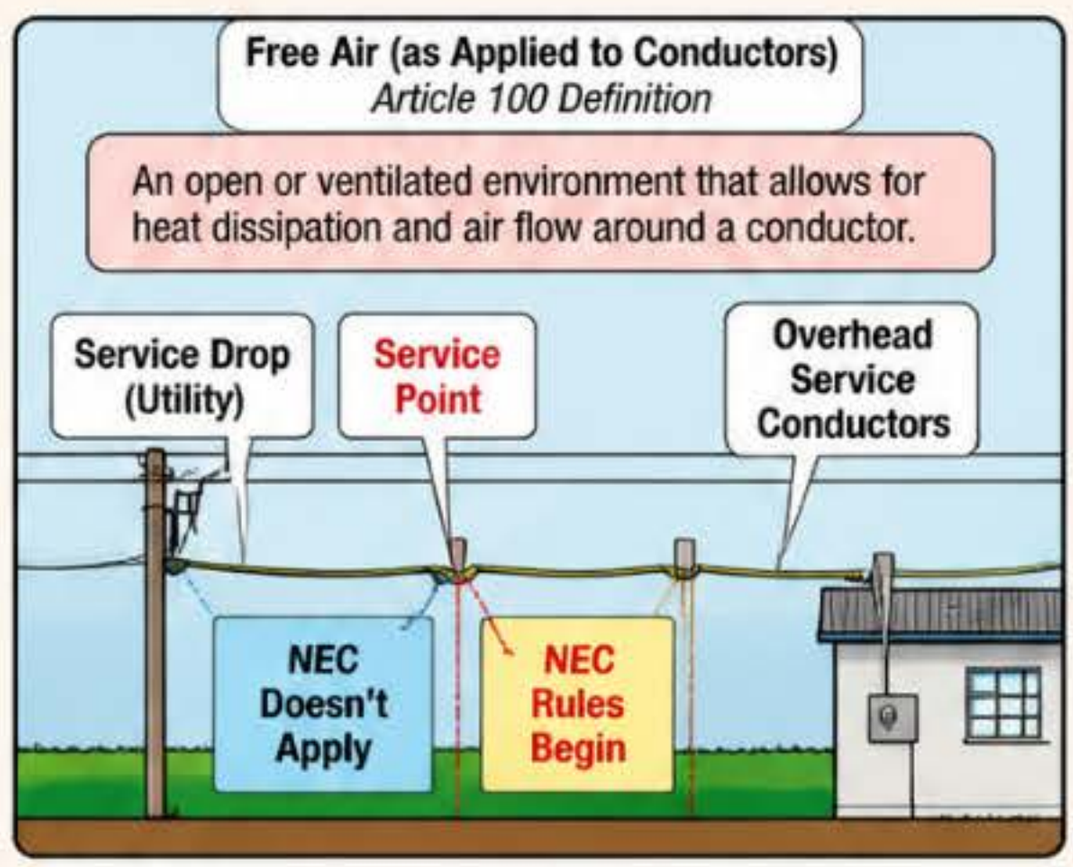
Garage. A building or portion of a building where self-propelled vehicles can be kept.

Generating Capacity, Inverter. The sum of parallel-connected inverters' maximum continuous output power at 40°C in watts or kilowatts.

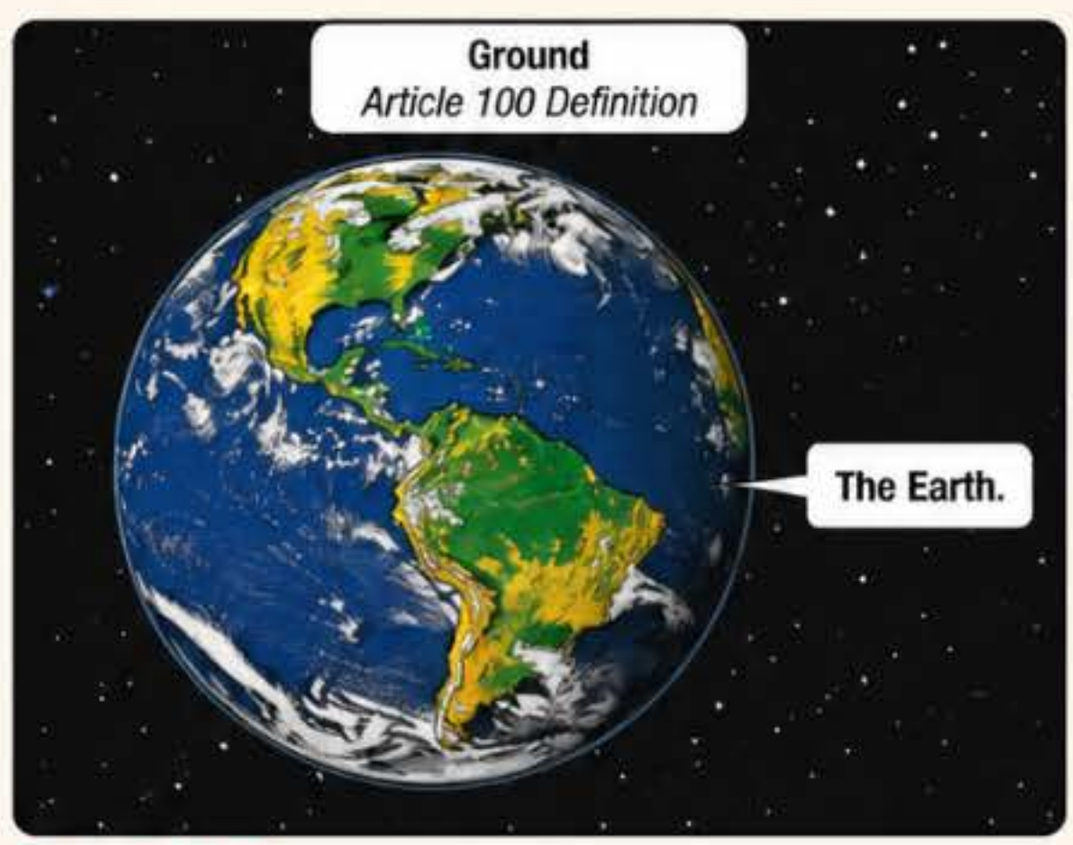
Ground. The Earth. ▸Figure 100–69



▸Figure 100–67

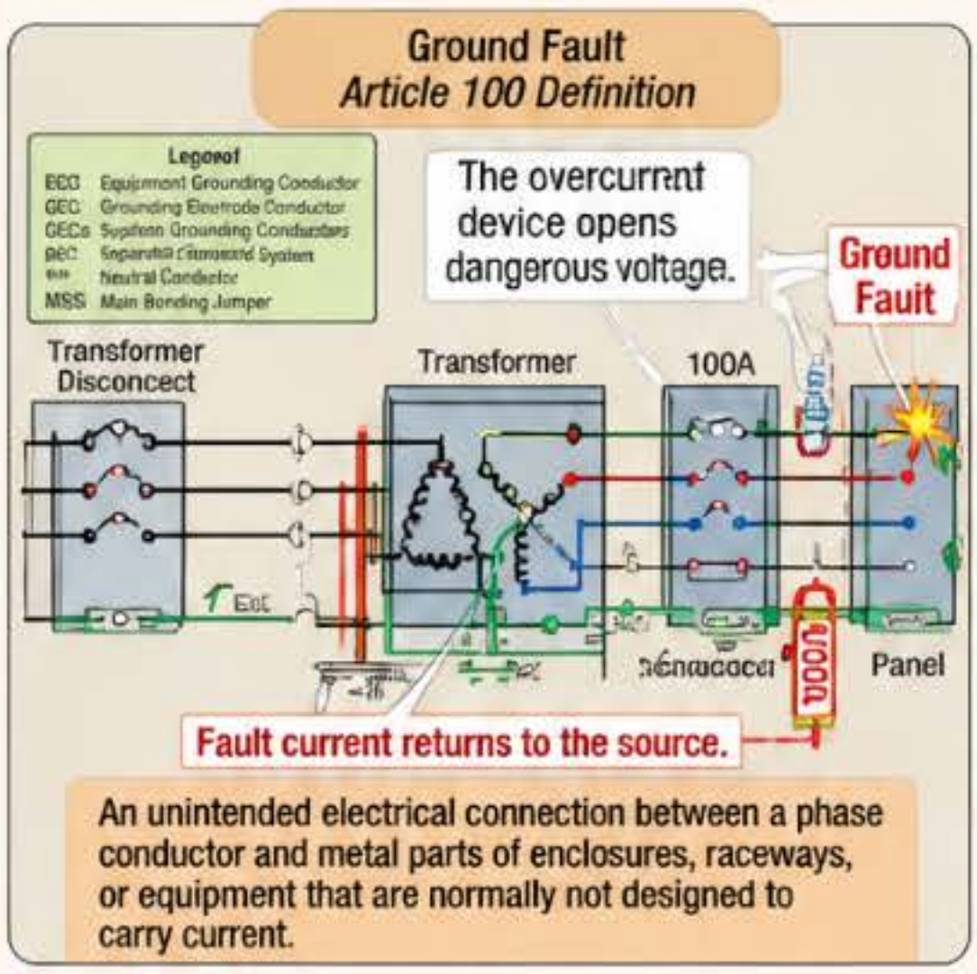


▸Figure 100–68



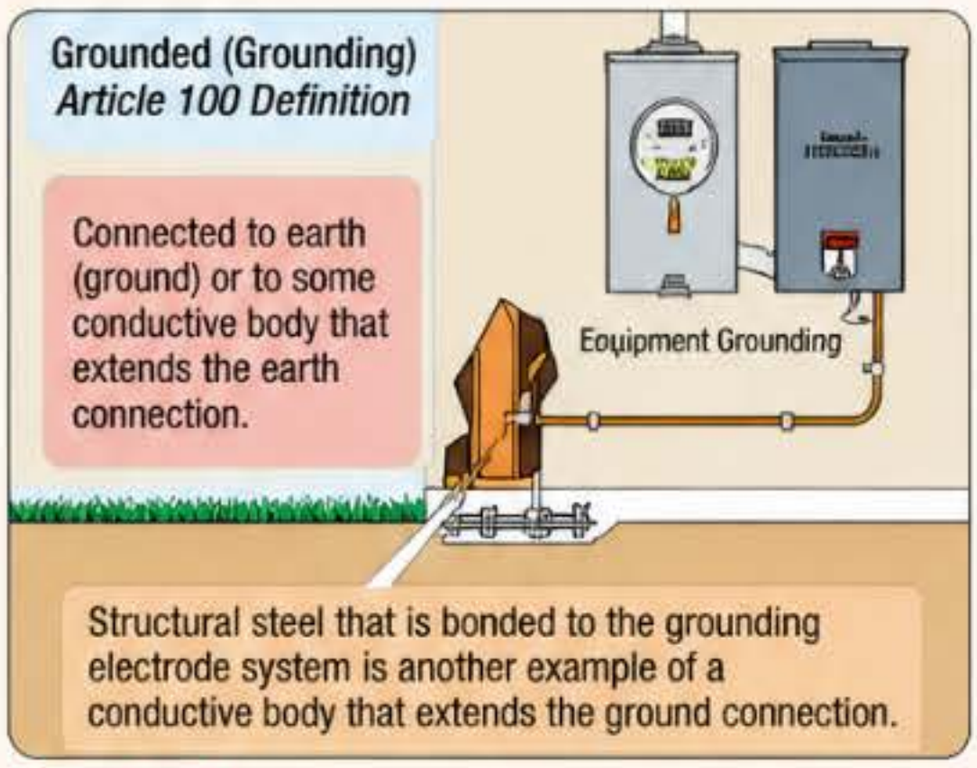
▸Figure 100–69

Ground Fault. An unintended electrical link between a phase conductor and metal parts of enclosures, raceways, or equipment that are normally not current-carrying.
▸Figure 100–70



▸Figure 100–70

Grounded (Grounding). Connected to earth (ground) or to a conductive body that extends the earth connection.
▸Figure 100–71



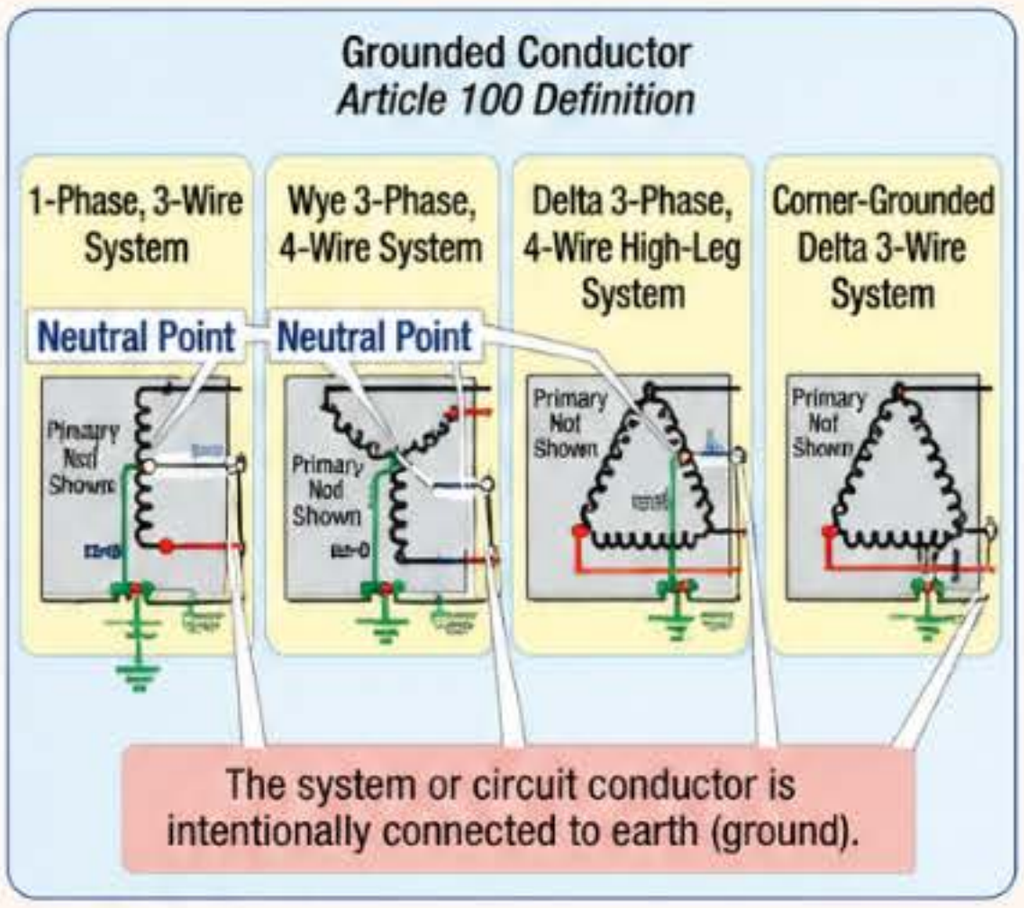
▸Figure 100–71

Author's Commentary:

- An example of a "body that extends the ground (earth) connection" is a termination to structural steel that is bonded to the earth either directly or by terminating to another grounding electrode in accordance with 250.52.

— Michael Hamilton

Grounded Conductor. A system or circuit conductor that is intentionally connected to earth (ground).
▸Figure 100–72



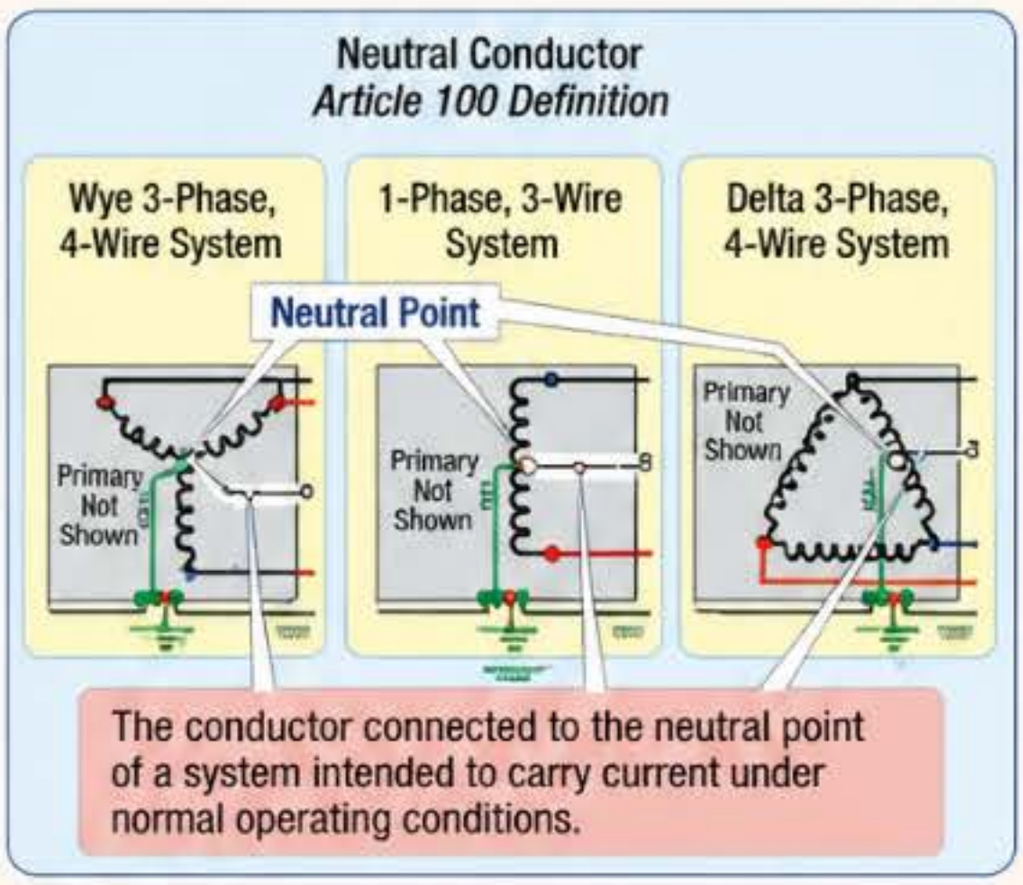
▸Figure 100–72

Note: Although an equipment grounding conductor is grounded, it is not considered a grounded conductor.

Author's Commentary:

- There are two types of grounded conductors: neutral conductors and grounded-phase conductors. A system where the transformer secondary is wye-connected with the neutral point grounded will have a neutral.

— Michael Hamilton



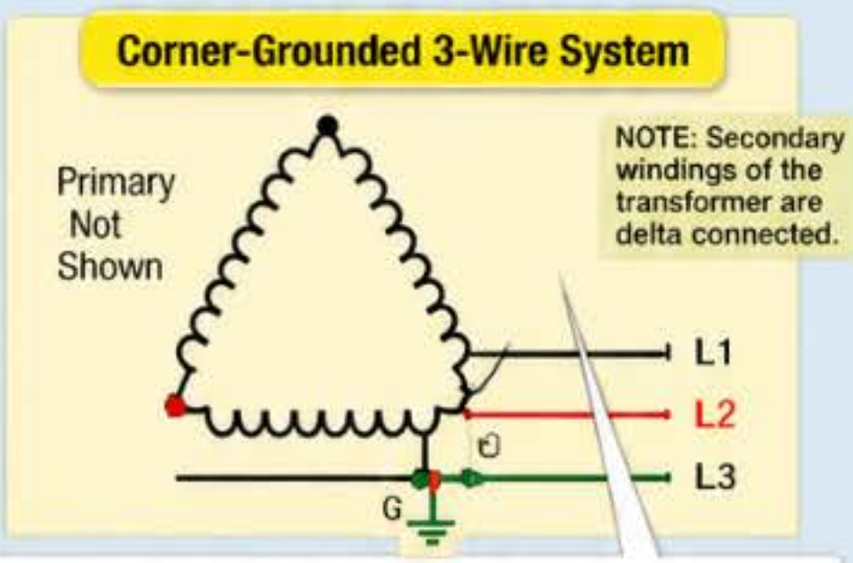
▸Figure 100–73

Author's Commentary:

In a system where the transformer secondary is delta connected and only one corner of the windings is bonded to earth, a grounded-phase conductor is provided.

— Michael Hamilton

Grounded Conductor, Corner-Grounded Delta
Article 100 Definition, Comment

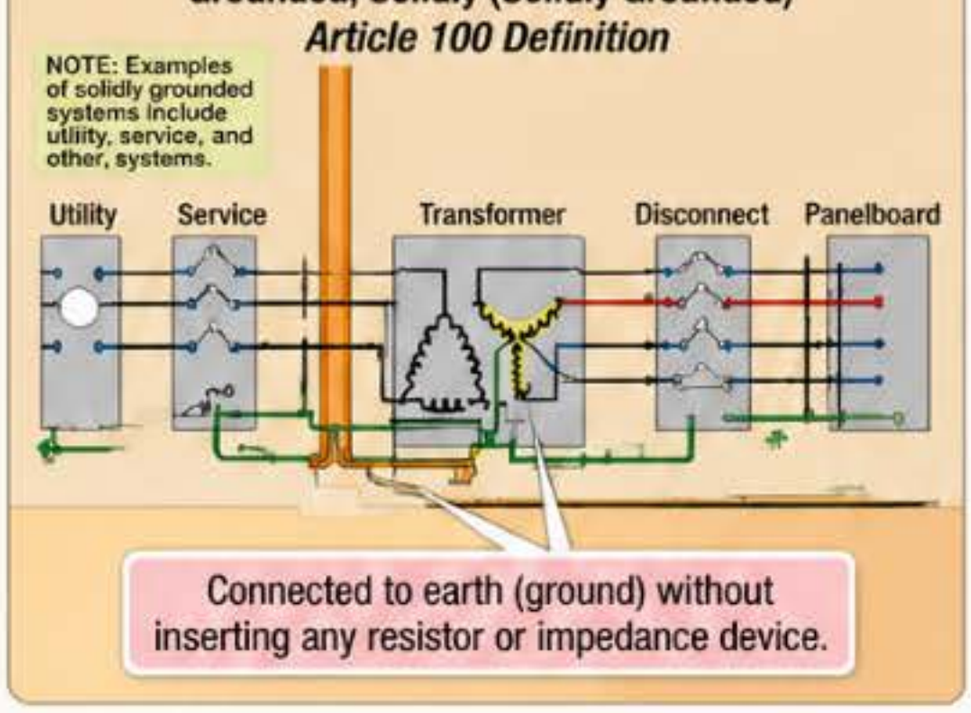


A system in which the transformer secondary is delta connected with a single corner winding grounded provides a grounded-phase conductor.

▸ Figure 100–74

Grounded, Solidly (Solidly Grounded). A system connected directly to earth (ground) without adding any resistor or impedance in the grounding path. ▸ Figure 100–75

Grounded, Solidly (Solidly Grounded)
Article 100 Definition

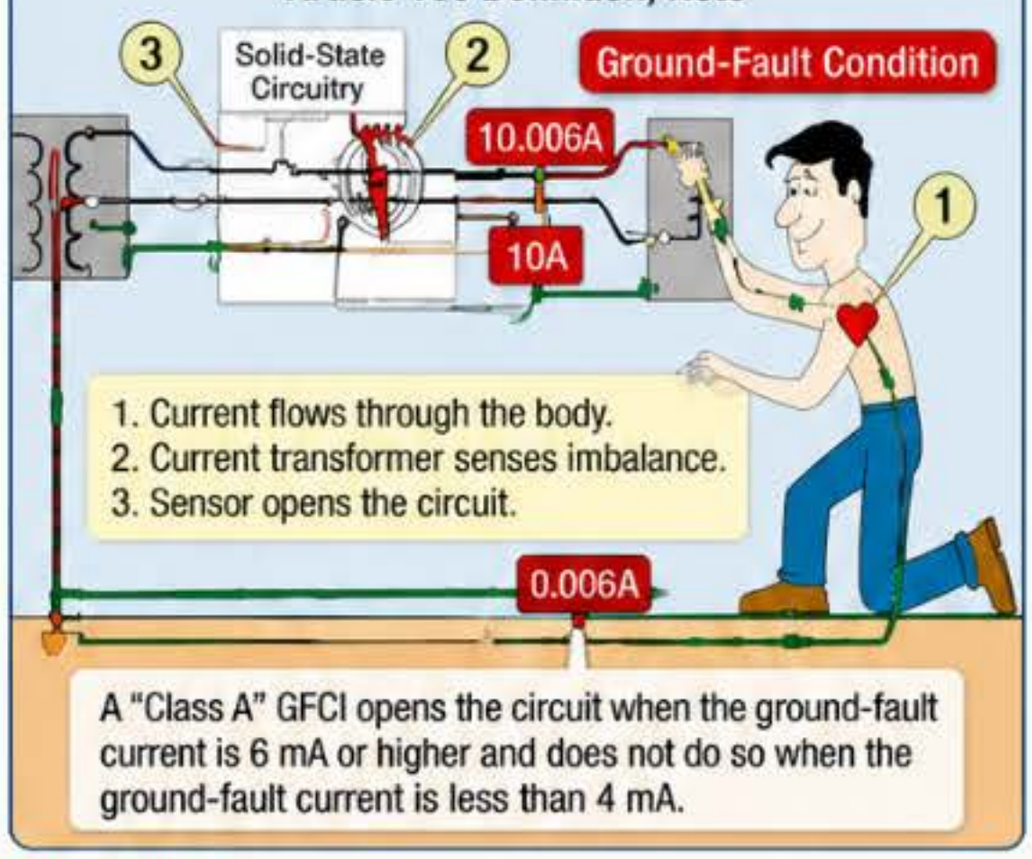


▸ Figure 100–75

Ground-Fault Circuit Interrupter (GFCI). A device designed to protect individuals by automatically removing power from a circuit when the ground-fault current exceeds the threshold set for a "Class A" device.

Note: A Class A ground-fault circuit interrupter opens the circuit when the ground-fault current is 6 mA or greater, and it does not trip when the ground-fault current is less than 4 mA. ▸ Figure 100–76

Ground-Fault Circuit Interrupter (GFCI)
Article 100 Definition, Note



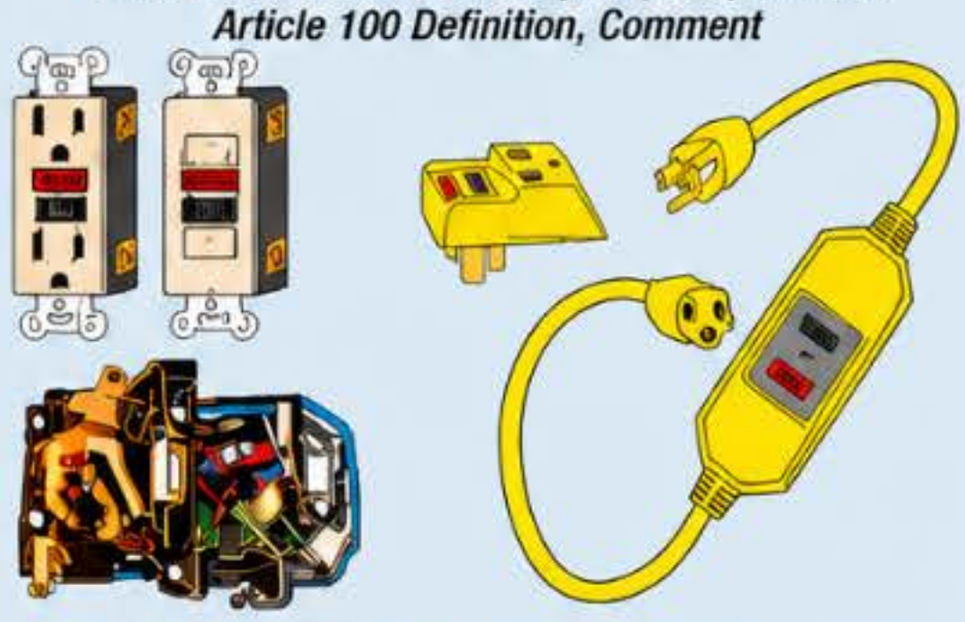
▸ Figure 100–76

Author's Commentary:

GFCI-protected equipment operates on the principle of continuously measuring the current in the ungrounded ("hot") conductor. In a 120-volt circuit, the GFCI monitors any difference between the ungrounded conductor and the neutral conductor. On 240-volt circuits it compares the current on all current-carrying conductors. Receptacles, circuit breakers, cord sets, and other GFCI devices for different applications are available.

— Michael Hamilton

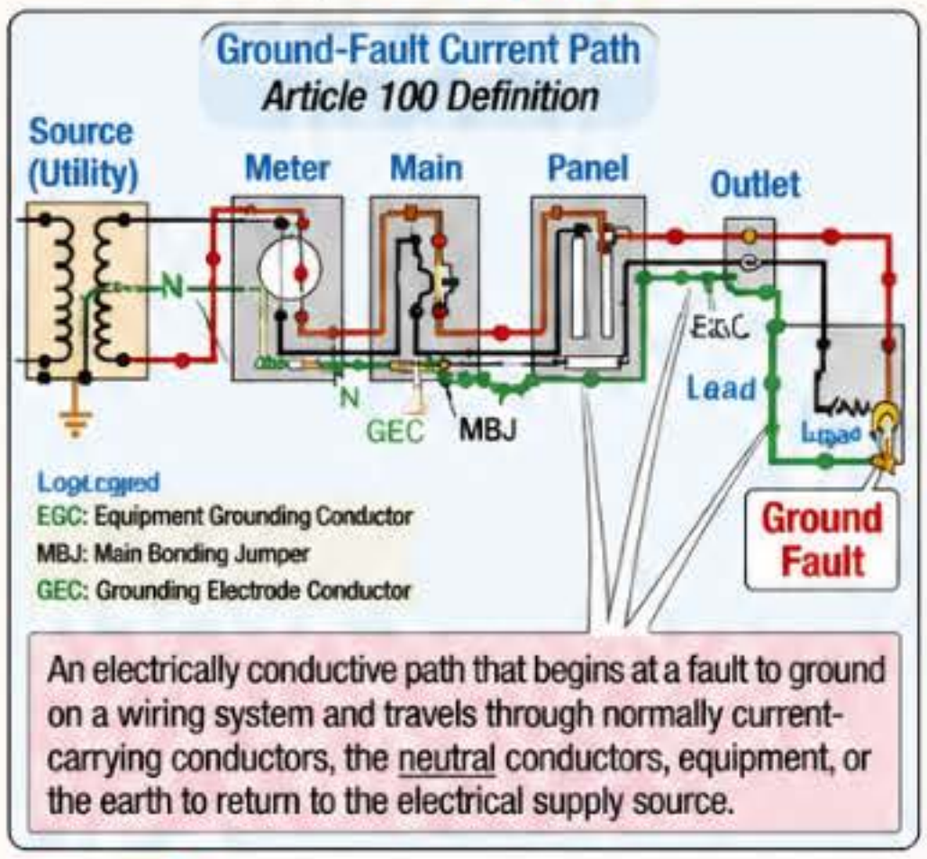
Ground-Fault Circuit Interrupter (GFCI) Devices
Article 100 Definition, Comment



A GFCI protects people from electric shock by monitoring any imbalance in current between the ungrounded and neutral conductors.

▸ Figure 100–77

Ground-Fault Current Path. A current path that is electrically conductive and forms a connection from the location of a ground fault on a wiring system through conductors that normally carry current, the neutral conductors, equipment grounding conductors, equipment, or the earth itself back to the electrical supply source. ▸ Figure 100–78



▸ Figure 100–78

Note 1: Examples of ground-fault current paths include any mix of equipment grounding conductors, metallic raceways, metal cable sheaths, electrical equipment, and other conductive materials such as metal tubing, water piping, gas piping, steel framing members, stucco mesh, metal ducting, reinforcing steel, communication shields cables, neutral conductors, and the earth.

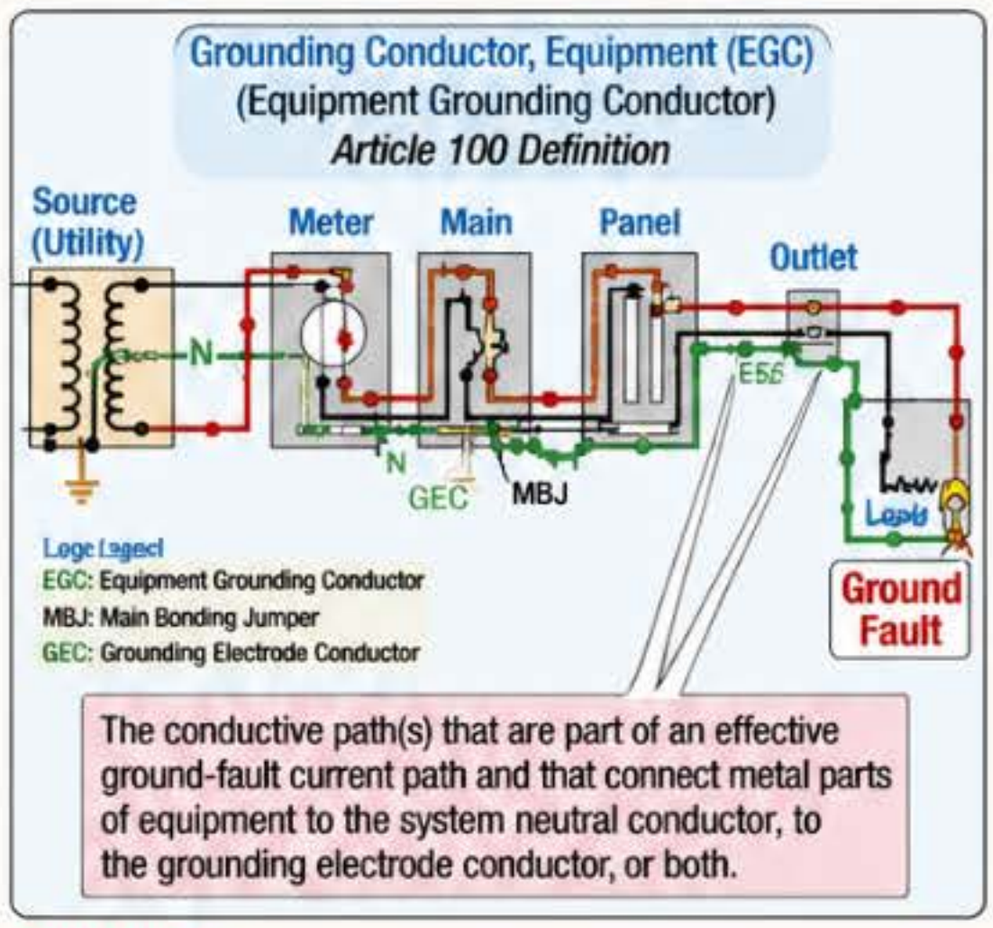
Ground-Fault Protection of Equipment. A system designed to protect equipment from damage caused by ground-fault currents by opening all phase conductors of the faulty circuit. This protection is provided at current levels far below those needed to prevent conductor overheating during normal circuit currents [250.4(A)(3), 215.10, 230.95, and 240.13].

Author's Commentary:

- This type of protective device is not intended to safeguard people. It trips (opens the circuit) at a higher current level than that of a "Class A" GFCI-protective device. It is typically referred to as ground-fault protection for equipment, or GFPE; never call it a GFCI.

— Michael Hamilton

Grounding Conductor, Equipment (Equipment Grounding Conductor). The conductive path(s) that are part of an effective ground-fault current path and connect metal parts of equipment to the system neutral conductor or to a grounded-phase conductor [250.110 through 250.126]. ▸ Figure 100–79



▸ Figure 100–79

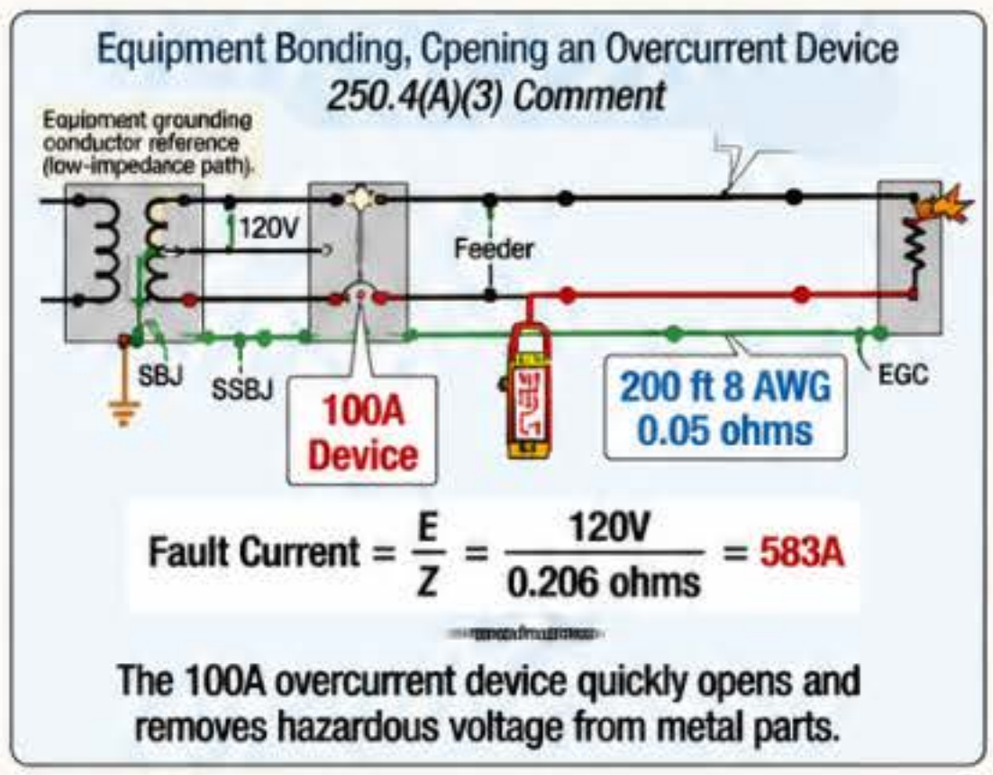
Note 1: The circuit equipment grounding conductor also performs bonding.

Author's Commentary:

- To quickly remove hazardous touch voltage from metal parts that become energized during a ground fault, the equipment grounding conductor (EGC) must be connected to the system neutral conductor at the source. Without a low-impedance connection to the source, the fault current may remain too small to trip the overcurrent protective device [250.4(A)(3].

▸ Figure 100–80

— Michael Hamilton



▸ Figure 100–80

Note 2: Equipment grounding conductors may be any one of, or a combination of, the conductor types listed in 250.118.

▸ Figure 100–81

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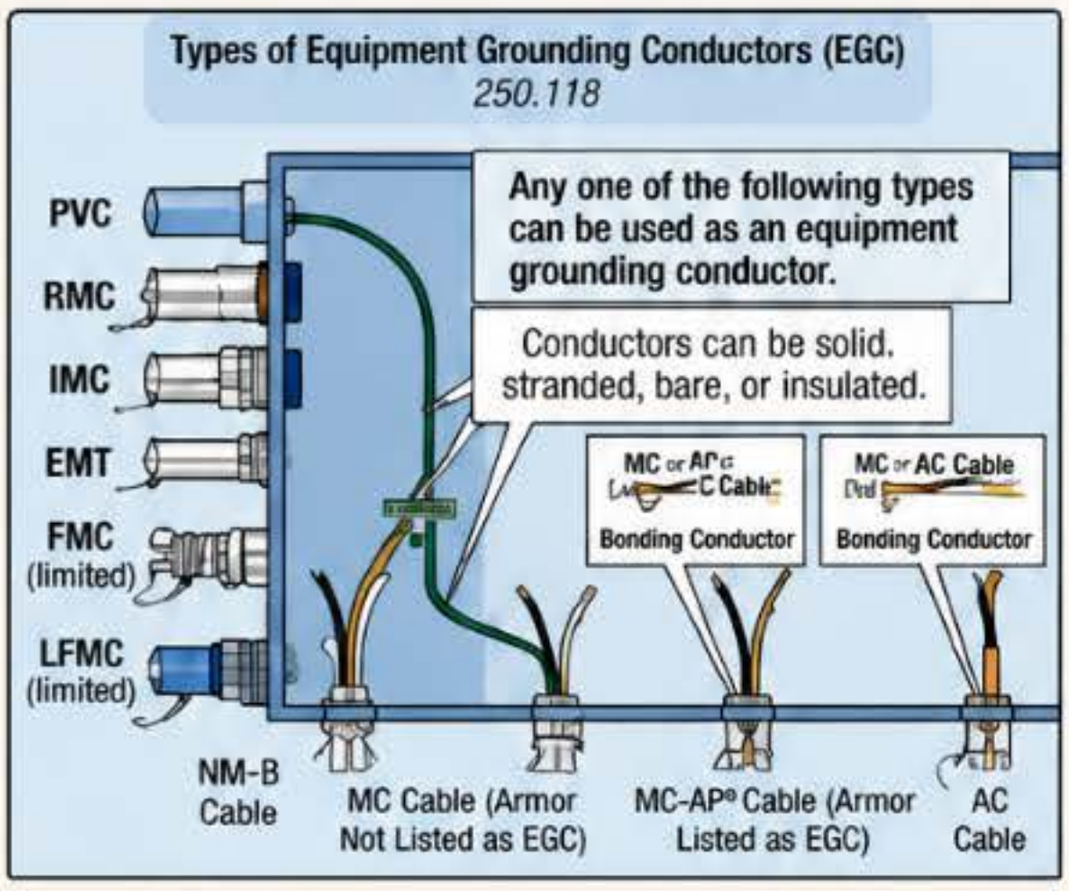


Figure 100-81

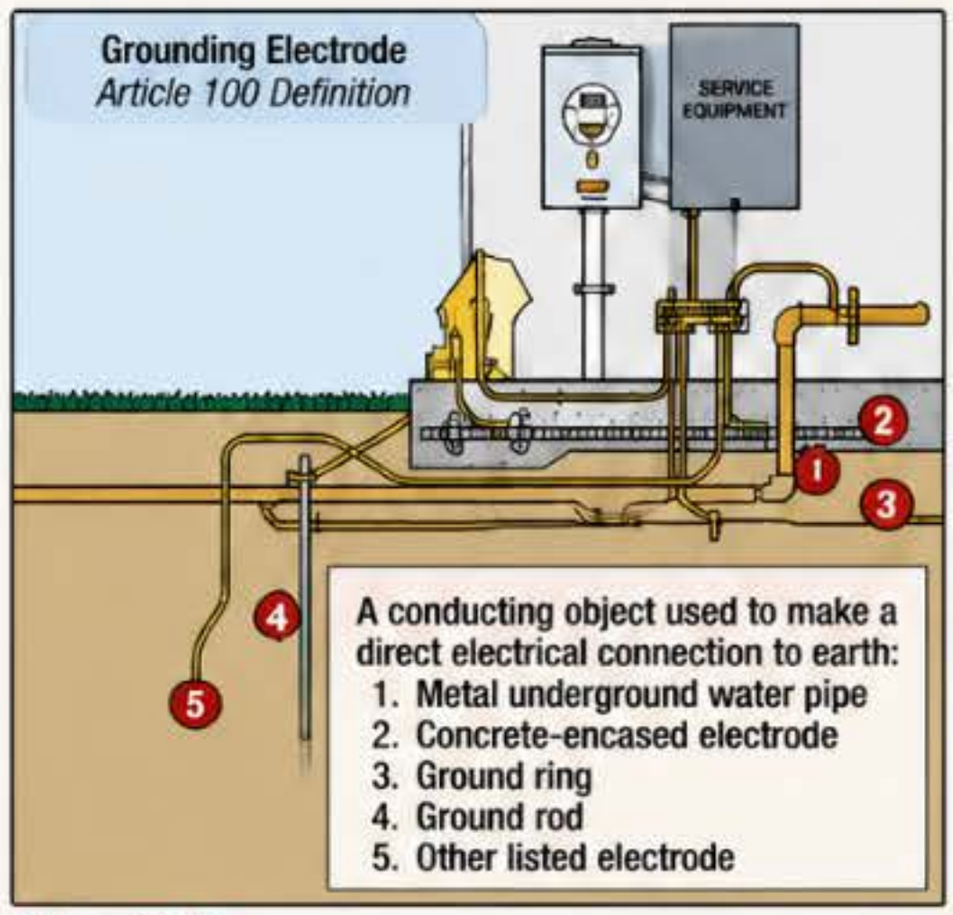


Figure 100-82

Author's Commentary:

Equipment grounding conductors include:

- A bare or insulated conductor
- Rigid metal conduit
- Intermediate metal conduit
- Electrical metallic tubing
- Listed flexible metal conduit as limited by 250.118(5)
- Listed liquidtight flexible metal conduit as limited by 250.118(6)
- Armored cable
- The copper metal sheath of mineral-insulated cable
- Metal-clad cable as limited by 250.118(10)
- Metal cable trays as limited by 250.118(11) and 392.60
- Electrically continuous metal raceways listed for grounding
- Surface metal raceways listed for grounding
- Metal enclosures

— Michael Hamilton

Grounding Electrode. A conducting object used to make a direct electrical connection to the Earth [250.50through250.70]. Figure 100-82

Grounding Electrode Conductor. The conductor used to connect the system neutral conductor or grounded-phase conductor, or the equipment to the grounding electrode system. Figure 100-83

Guest Room. An accommodation combining living, sleeping, sanitr-ty, and storage facilities. Figure 100-84

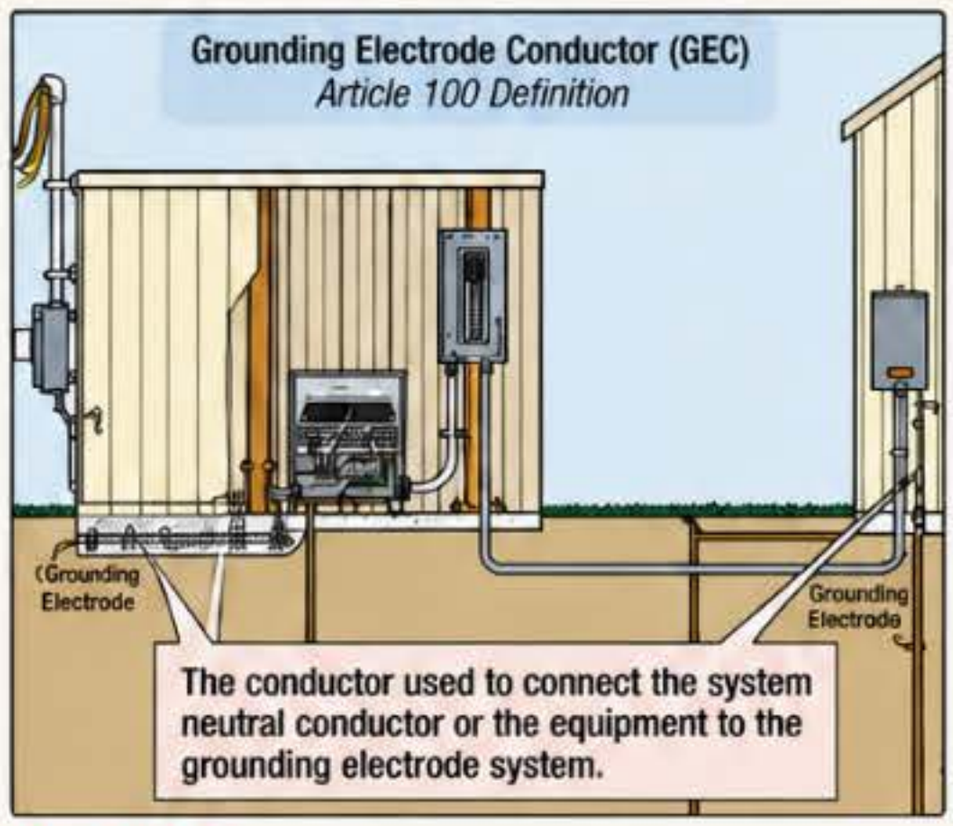
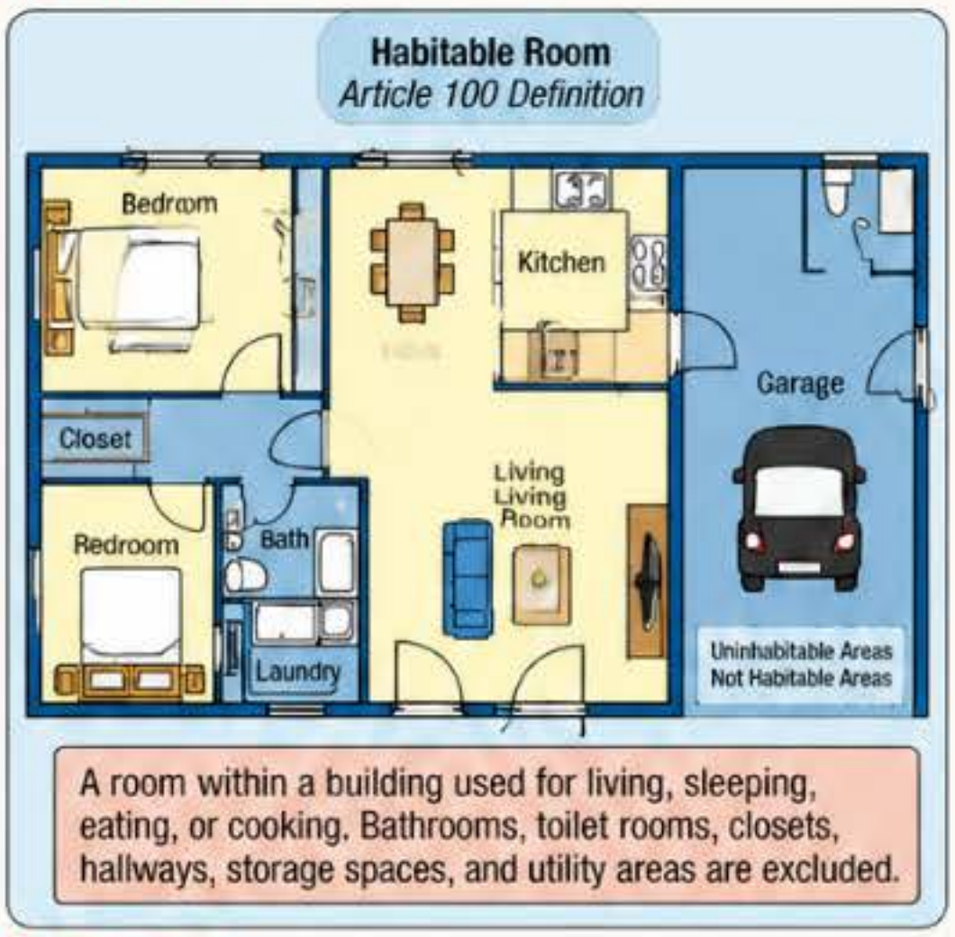


Figure 100-83

Figure 100-84

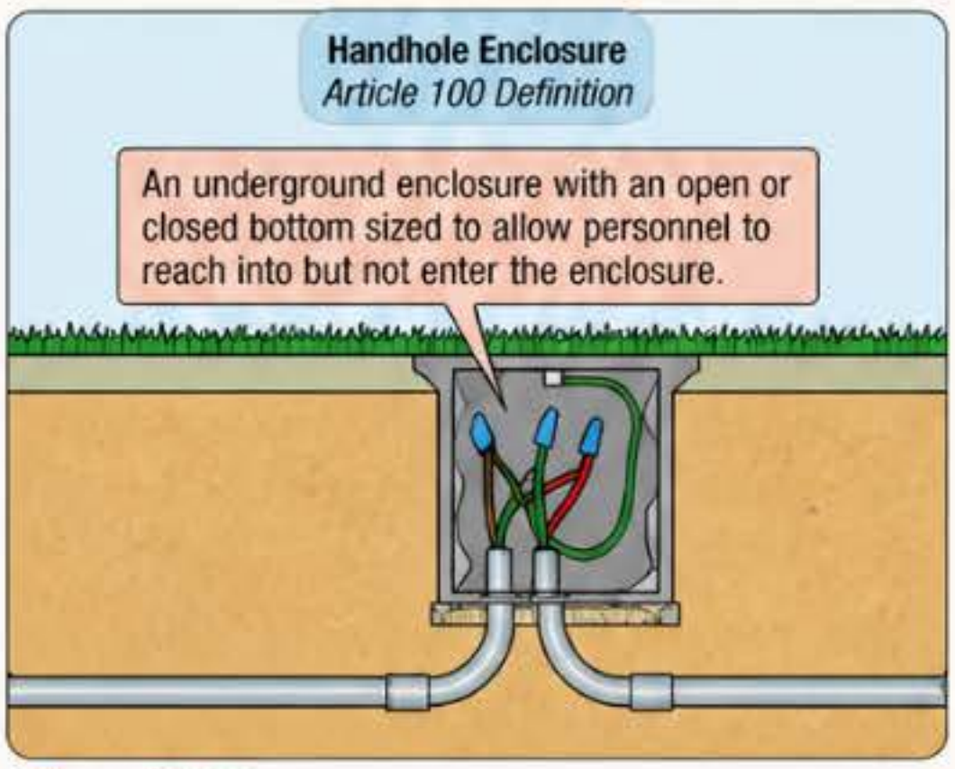
Guest Suite. An area set up with two or more adjoining rooms that may or may not have doors between them. The suite provides living, sleeping, sanitary, and storage functions.

Habitable Room. A room intended for living, sleeping, eating, or cooking. This excludes bathrooms, toilet rooms, closets, corridors, storage spaces, utility rooms, and similar spaces. **Figure 100–85**



▸ Figure 100–85

Handhole Enclosure. An underground enclosure with an open or closed bottom that allows personnel access but does not provide an entry point. **Figure 100–86**



▸ Figure 100–86

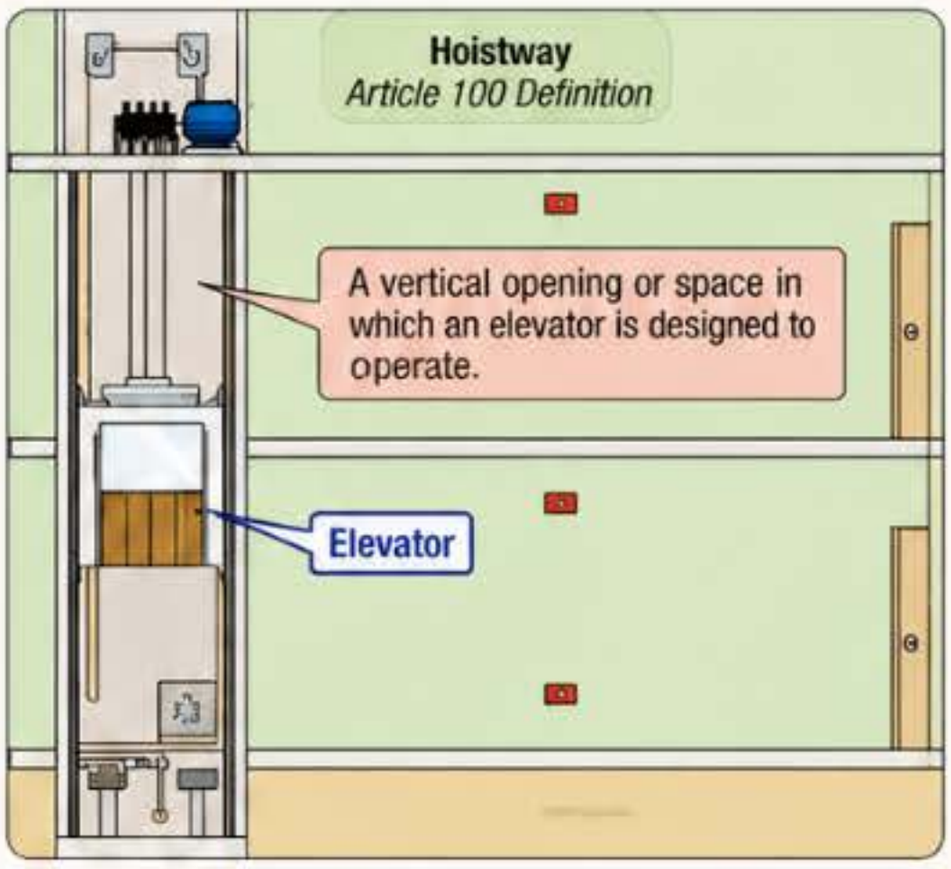
Author's Commentary:

- See 314.30 for the requirements governing the installation of handhole enclosures.

— Michael Hamilton

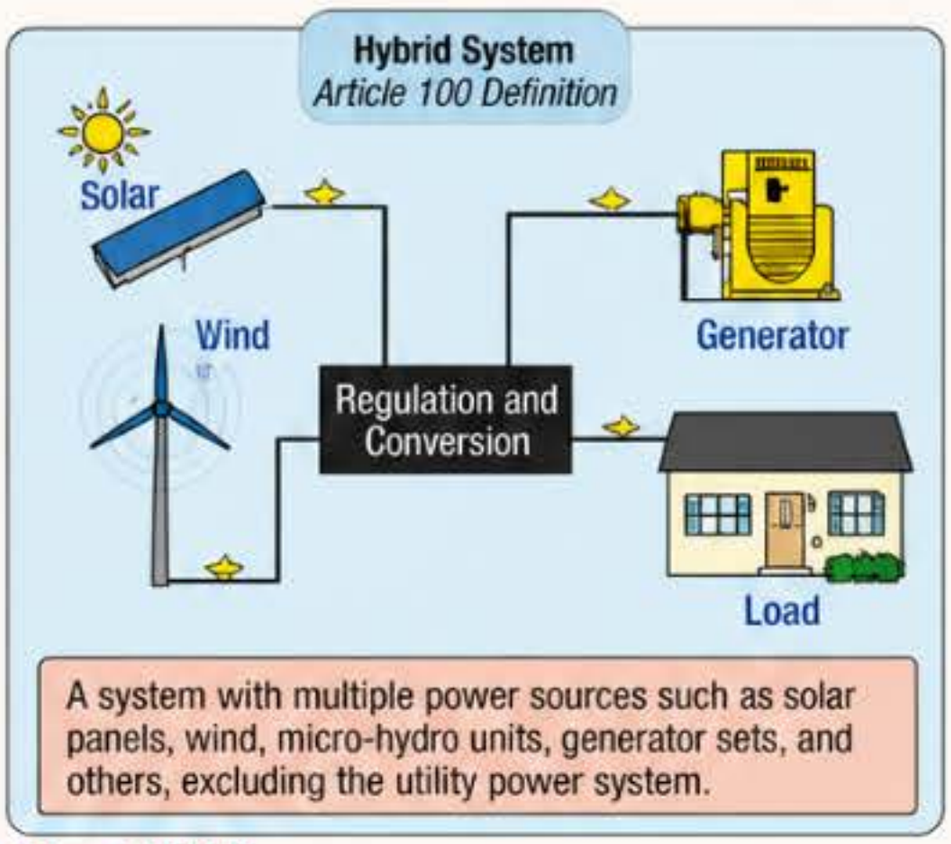
Hermetic Refrigerant Motor-Compressor. A compressor and motor sealed within a common housing and designed to operate with refrigerant.

Hoistway. A vertical shaft or space in which an elevator or dumbwaiter is intended to function. **Figure 100–87**



▸ Figure 100–87

Hybrid System. A combination of several electric power sources such as photovotatic, wind, micro-hydro units, generator sets, and other sources, but excluding the utility power system. **Figure 100–88**



▸ Figure 100–88

Identified (as applied to equipment). Recognized as suitable for a particular use, function, environment, or application for which it is described in a *Code* requirement. **Figure 100–89**

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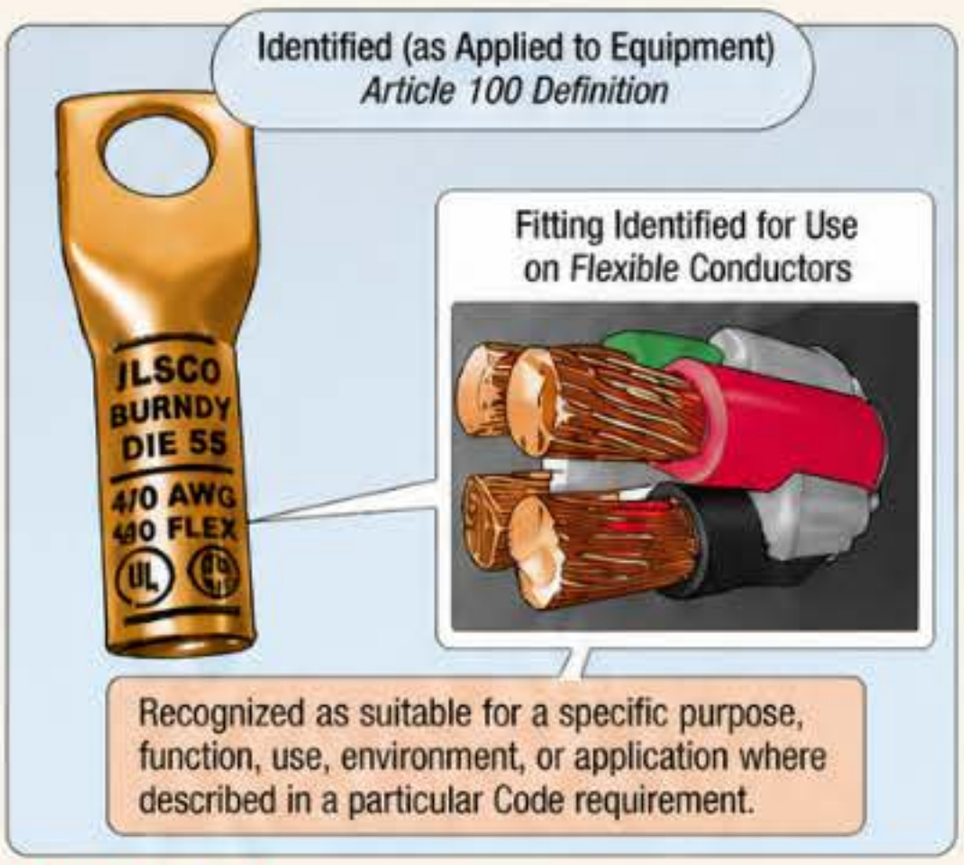
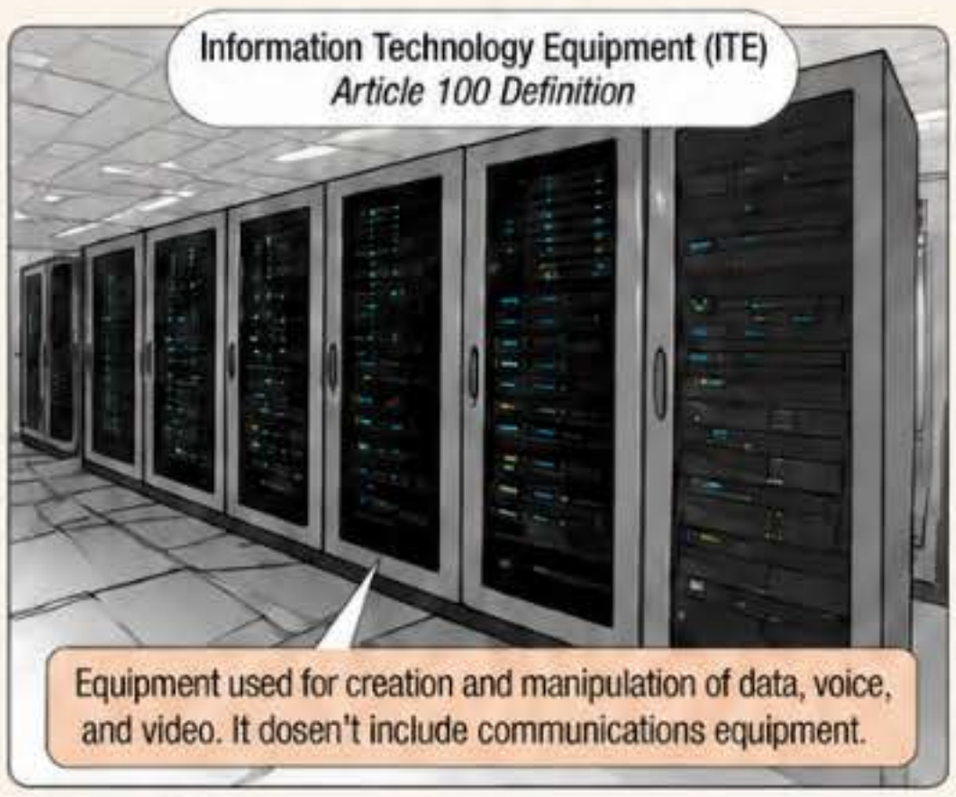


▶ Figure 100–89

Author's Commentary:
See 90.4, 90.7, and 110.3(A(1) along with the definitions for "Approved," "Labeled," and "Listed" in this article.
— *Michael Hamilton*

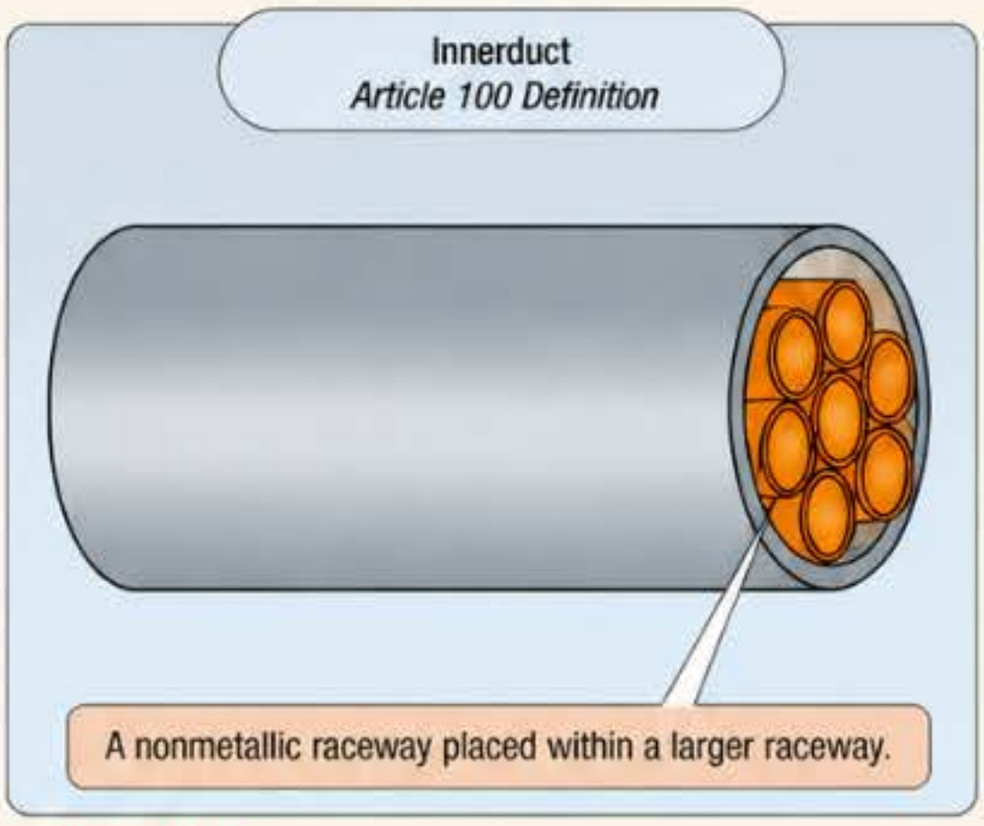
Information Technology Equipment (ITE). Equipment used for generating, handling, or managing data, voice, and video. It does not include communications equipment. ▶ Figure 100–90



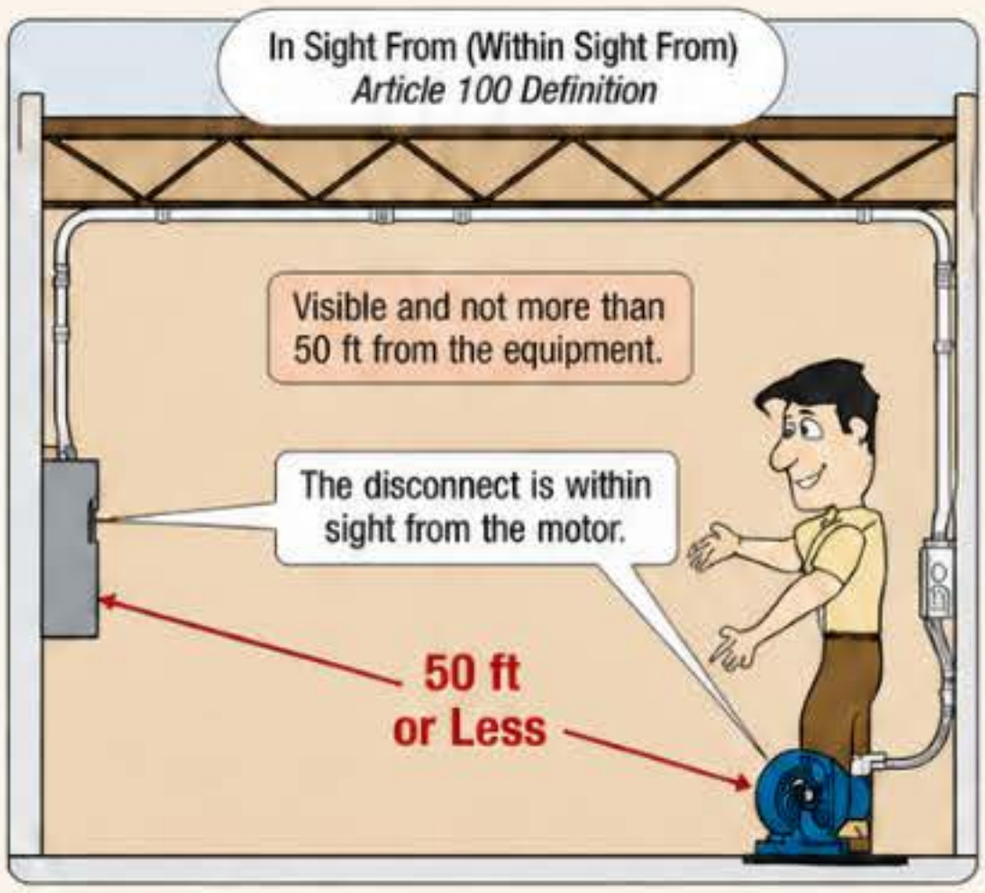
▶ Figure 100–90

Innerduct. A nonmetallic raceway placed within a larger raceway. ▶ Figure 100–91

In Sight From (Within Sight From). Visible and not more than 50 ft away from the equipment. ▶ Figure 100–92



▶ Figure 100–91



▶ Figure 100–92

Interactive Inverter. An inverter intended to be used in parallel with a power source(s), such as the serving electric utility, to supply common loads and is capable of delivering power to the serving electric utility. ▶ Figure 100–93

Author's Commentary:
A listed interactive inverter automatically stops exporting power upon loss of utility voltage and cannot be reconnected until the voltage has been restored. Interactive inverters can automatically or manually resume exporting power to the utility once the utility source is restored.
— *Michael Hamilton*

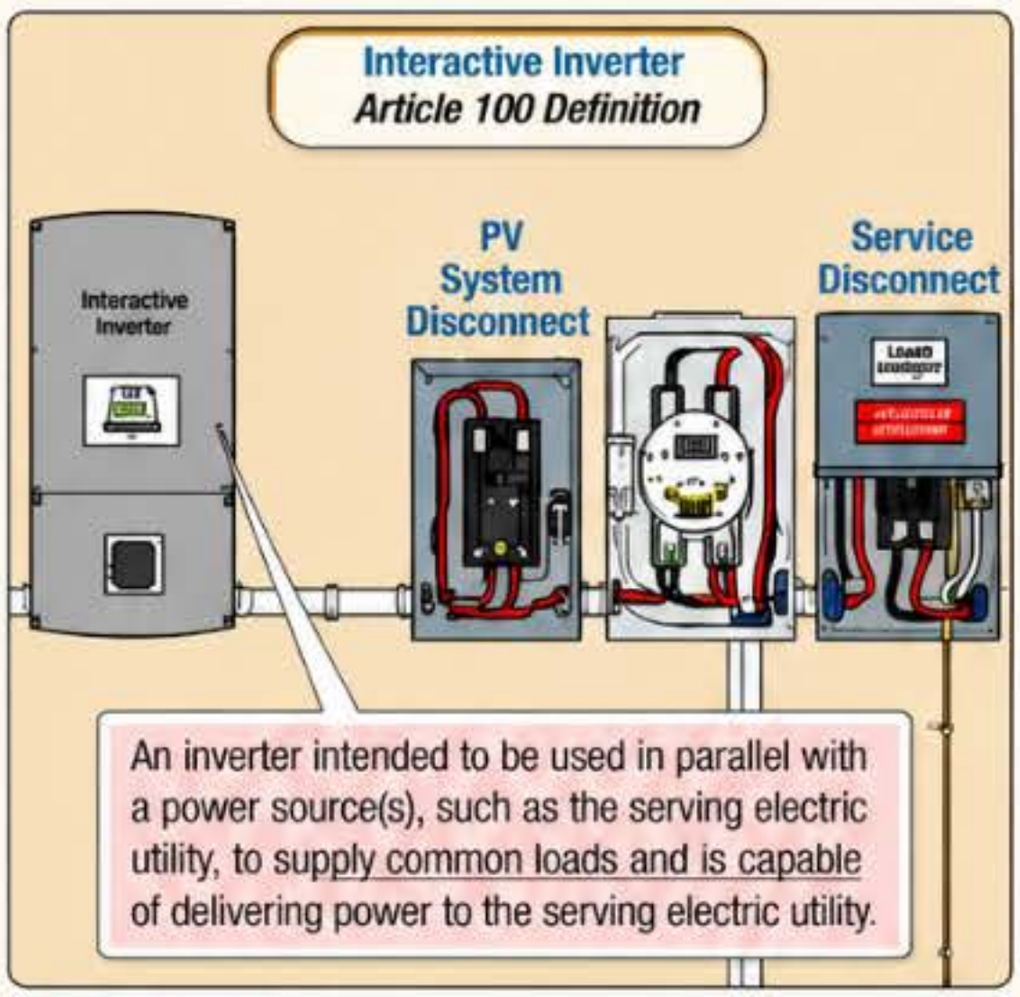


Figure 100–93

Interactive System. An electric power production system that operates in parallel with, and may deliver power to, the serving electric utility. **Figure 100–94**

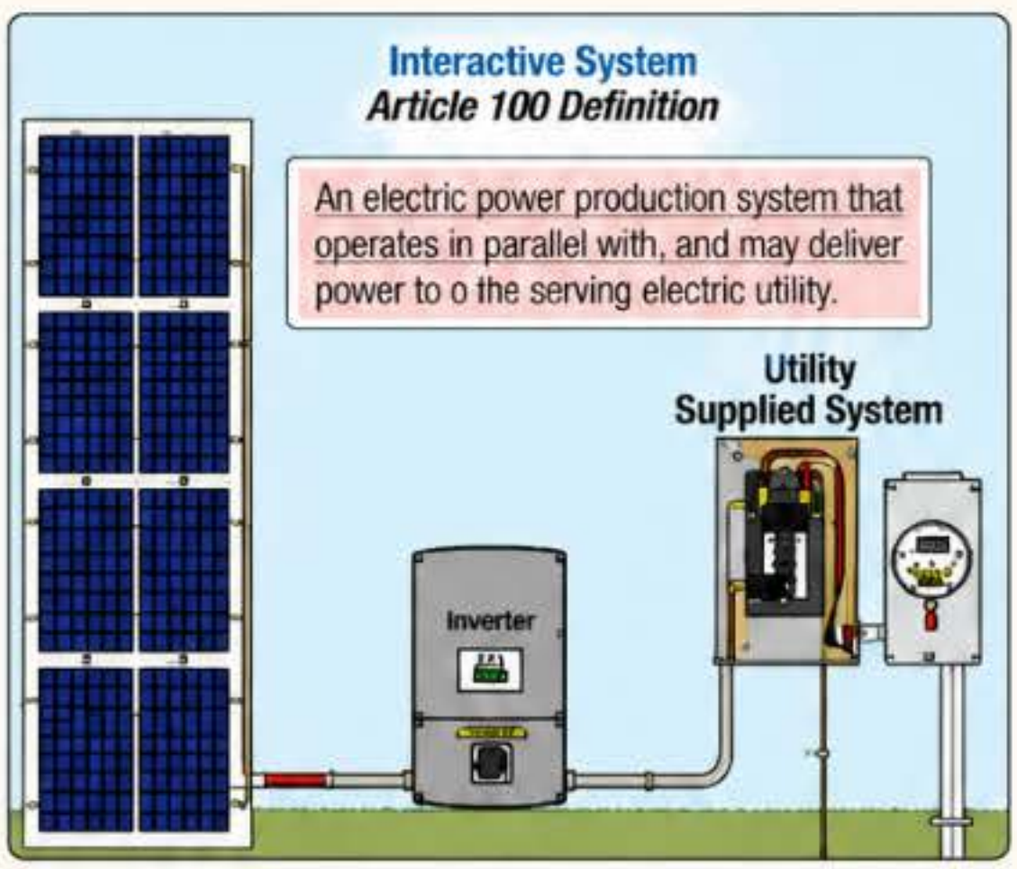


Figure 100–94

Interrupting Rating. The highest short-circuit current at rated voltage the device is identified to safely interrupt under standard test conditions.

Intersystem Bonding Termination. A device that provides a means to connect intersystem bonding conductors for communications systems (twisted wire, antennas, and coaxial cable) to the grounding electrode system, in accordance with 250.94. **Figure 100–95**

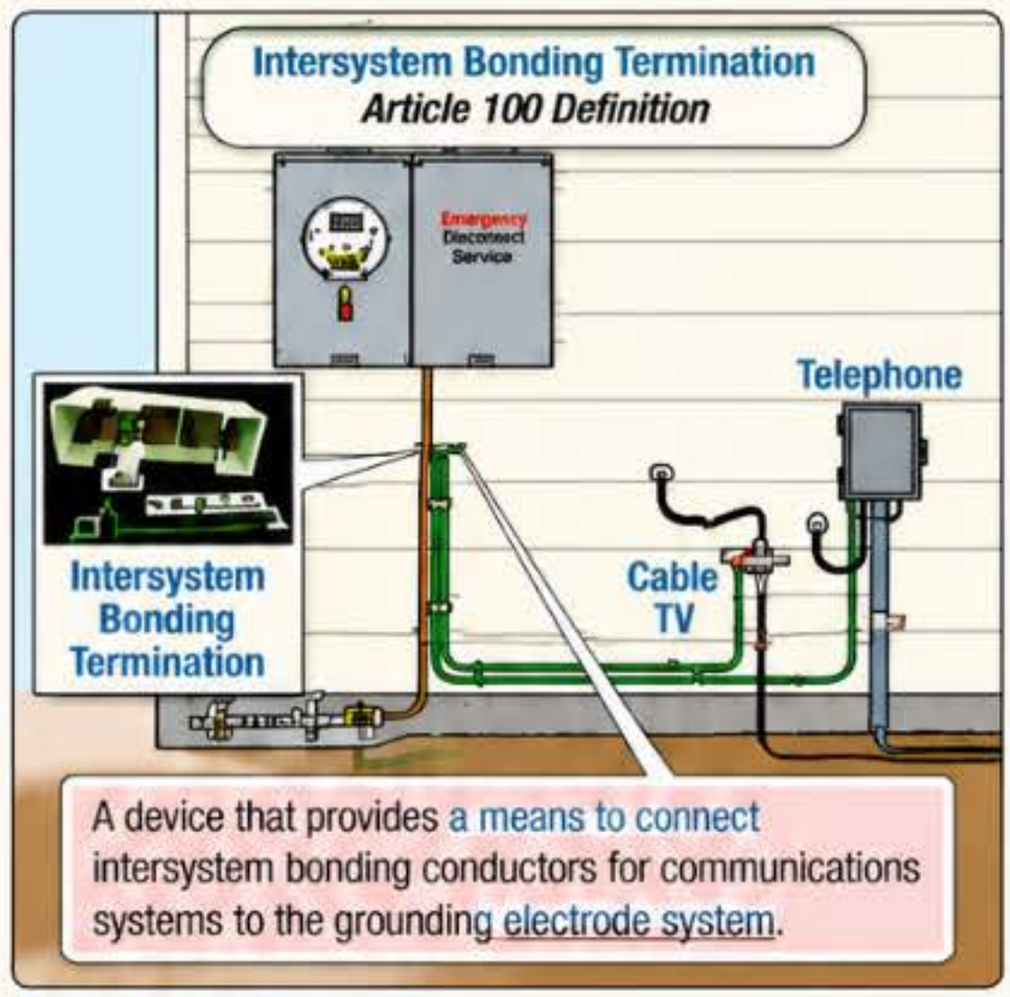


Figure 100–95

Author's Commentary:

- Overcurrent protective devices have two current ratings, "rated current" and "fault current." Rated current protects circuits under normal conditions and the rating is labeled on the handle of the circuit breaker. The fault current rating or "ampere interrupting capacity" (AIC) is the amount of current the device can safely handle during a ground fault or short circuit. Fault current ratings range up to the tens, or even hundreds, of thousands of amperes!
- For more information, see 110.9 in this textbook.

— Michael Hamilton

Inverter. Equipment that changes direct current to alternating current. **Figure 100–96**

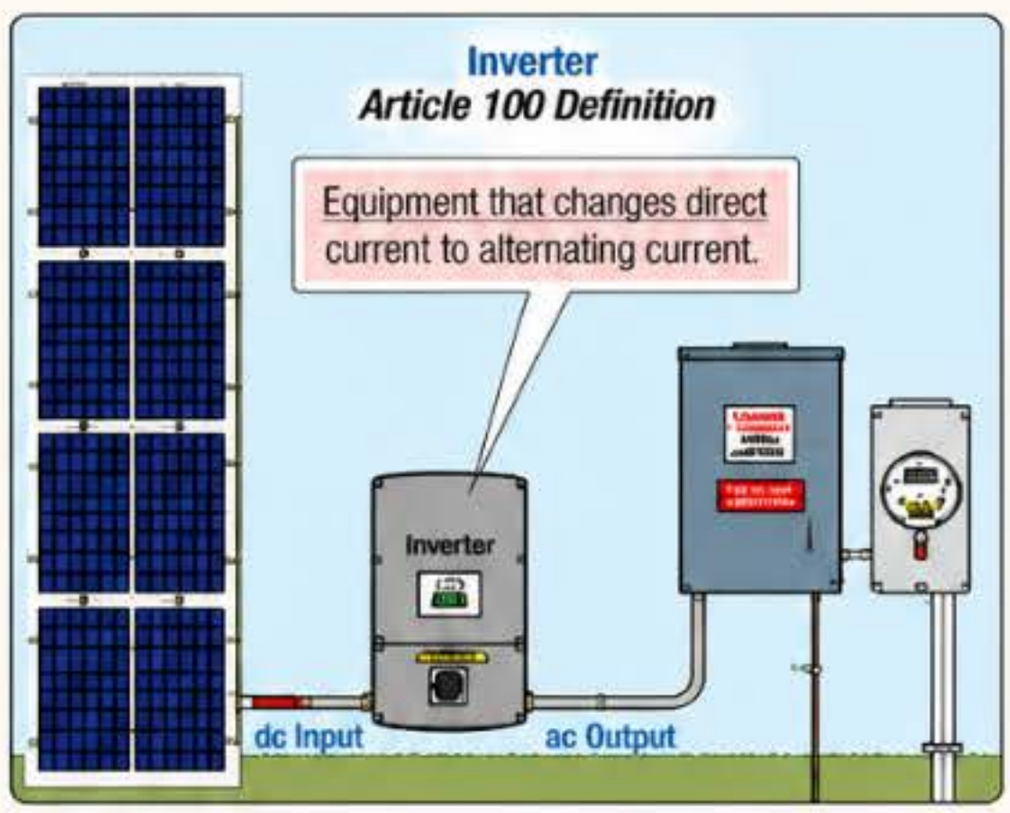
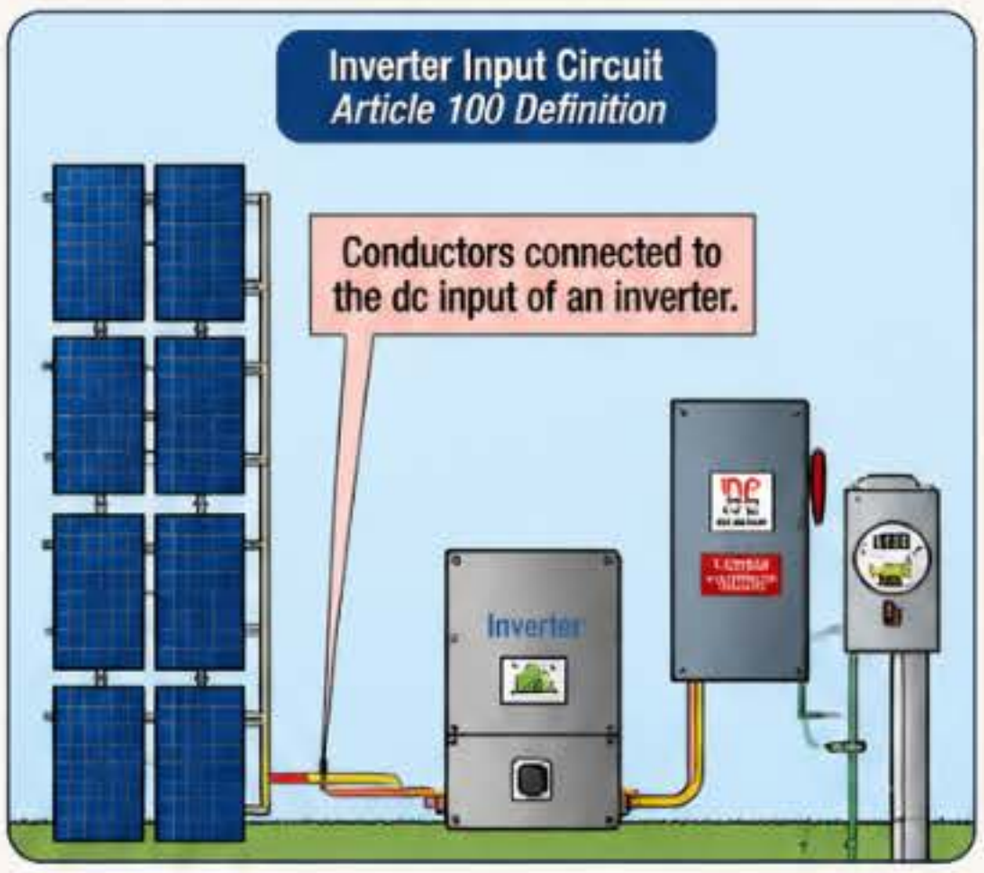


Figure 100–96

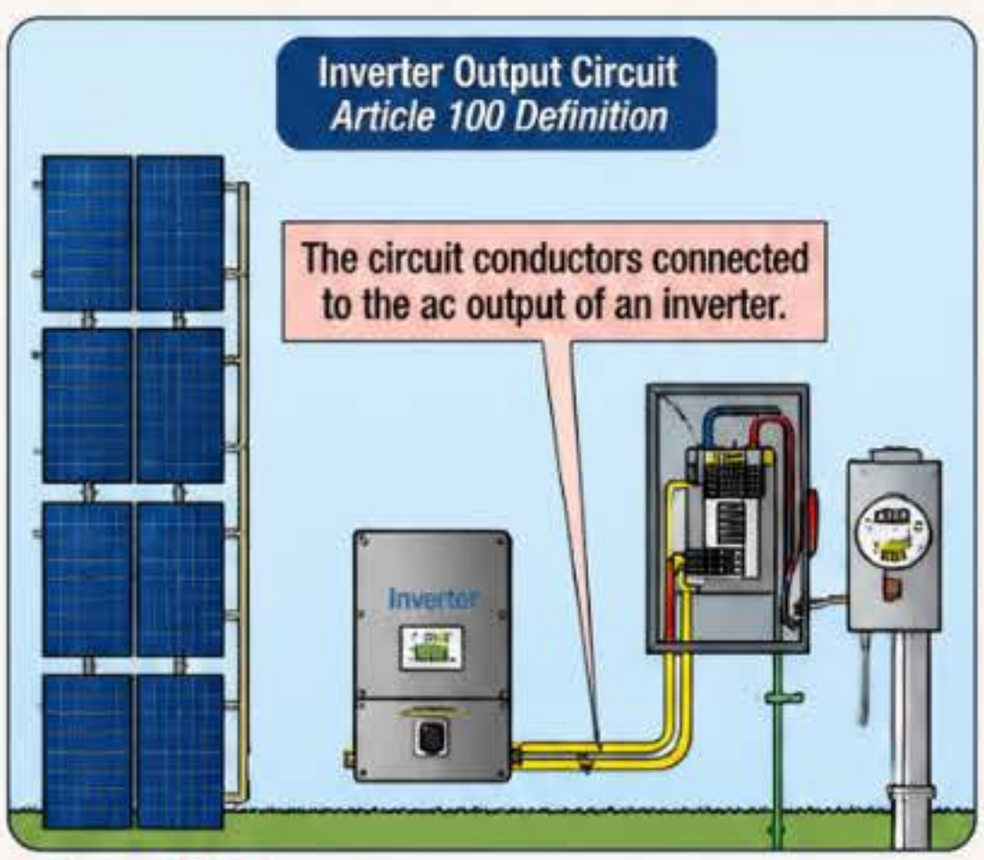
DEFINITIONS | From Michael Hamilton Publications

Inverter Input Circuit. Conductors sonnected to the direct-current input of an inverter. ▸Figure 100-97



▸Figure 100-97

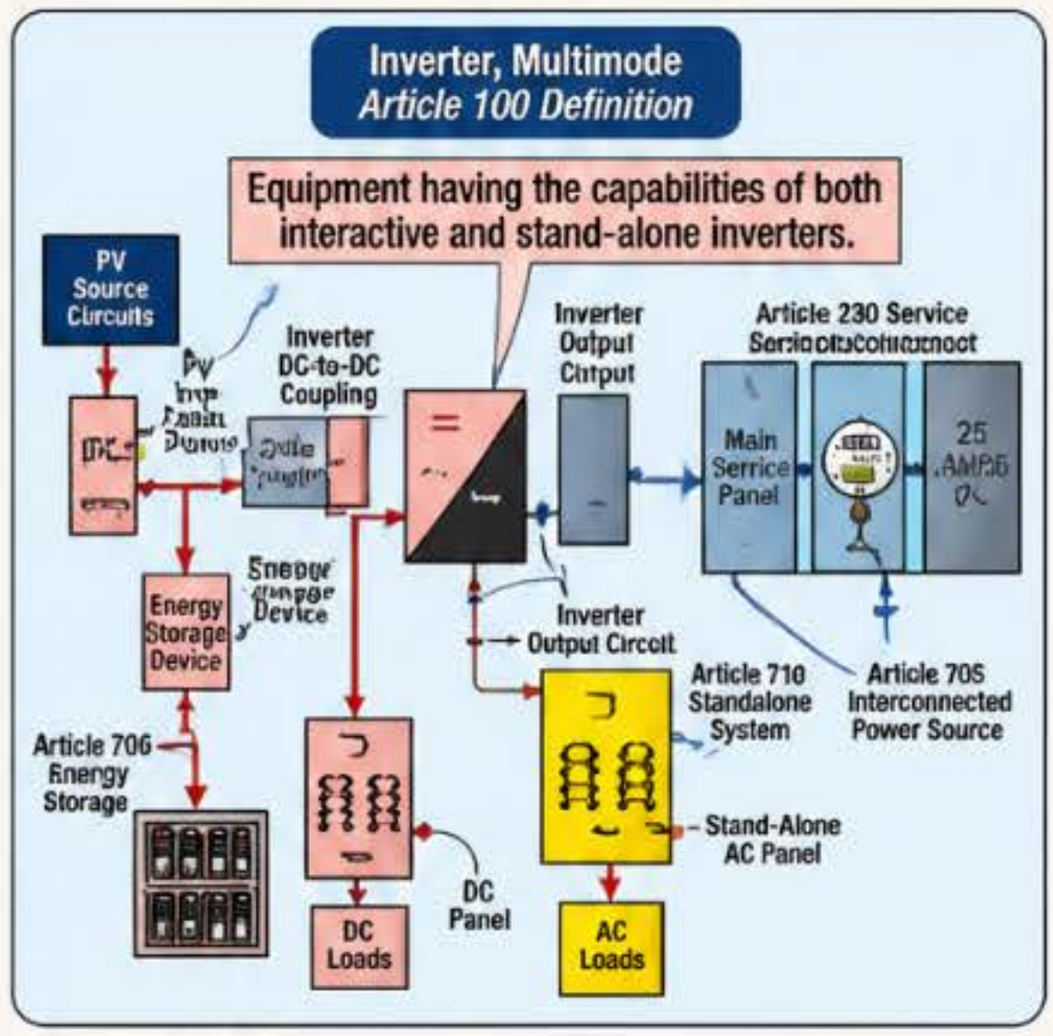
Inverter Output Circuit. The circuit conductors connected to the alternating-current output of an inverter. ▸Figure 100-98



▸Figure 100-98

Inverter, Multimode. Equipment having the capabilities of both interactive and stand-alone inverters. ▸Figure 100-99

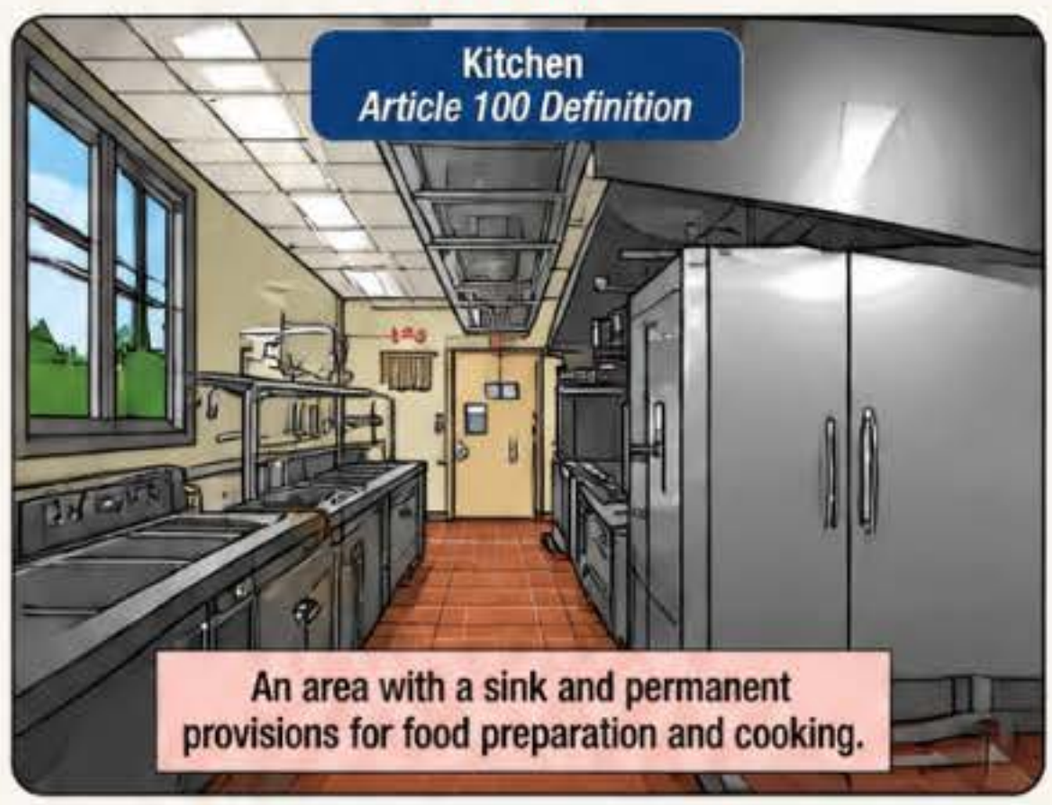
Island Mode. The operational mode for stand-alone power production equipment or an isolated microgrid (or for a multimode inverter or an interconnected microgrid) that is disconnected from an electric power production and distribution network or other primary power source.



▸Figure 100-99

Isolated. Not readily accessible to persons unless special means for access are used.

Kitchen. An area with a sink and permanent provisions for food pearation and cooking. ▸Figure 100-100



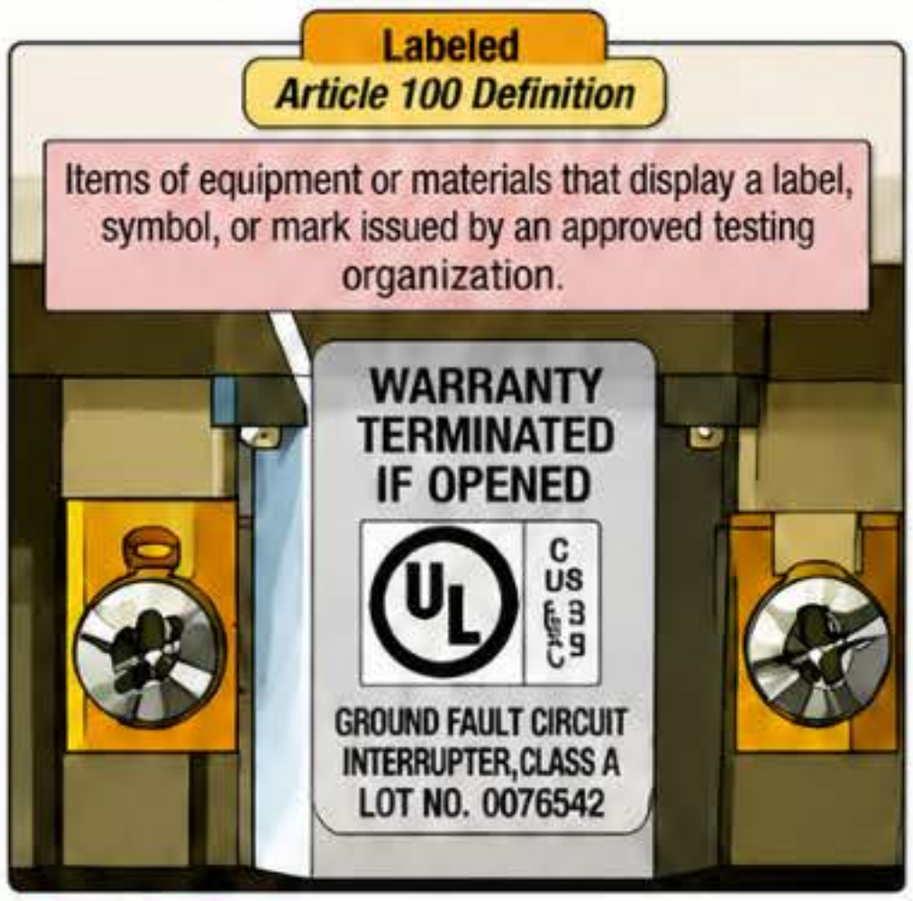
▸Figure 100-100

Author's Commentary:

- An area like an employee break room with a sink and cord-and-plug-connected cooking appliance such as a microwave oven is not considered a kitchen.

— Michael Hamilton

Labeled. Items of equipment or materials that display a label, symbol, or other identifying mark. This may include a sticker, decal, printed tag, or an identifying mark that is molded or stamped into the product by a recognized testing laboratory acceptable to the authority having jurisdiction. ▶ Figure 100–101



▶ Figure 100–101

Author's Commentary: Listing and labeling equipment helps authorities determine that requirements for approval in their area were met.

— Michael Hamilton

Note: When the size, shape, material, or surface texture of a product makes it impossible to apply the entire label in a readable way, the label may be shown on the smallest unit package that actually contains the product.

Laundry Area. A space that includes a laundry tray, clothes washer, and/or clothes dryer. ▶ Figure 100–102

Author's Commentary: A "laundry tray" is a fixed laundry or utility sink with the plumbing connections that are normally found next to a washer and dryer. A "laundry area" refers to the design surrounding it, whether the equipment is in place or not.

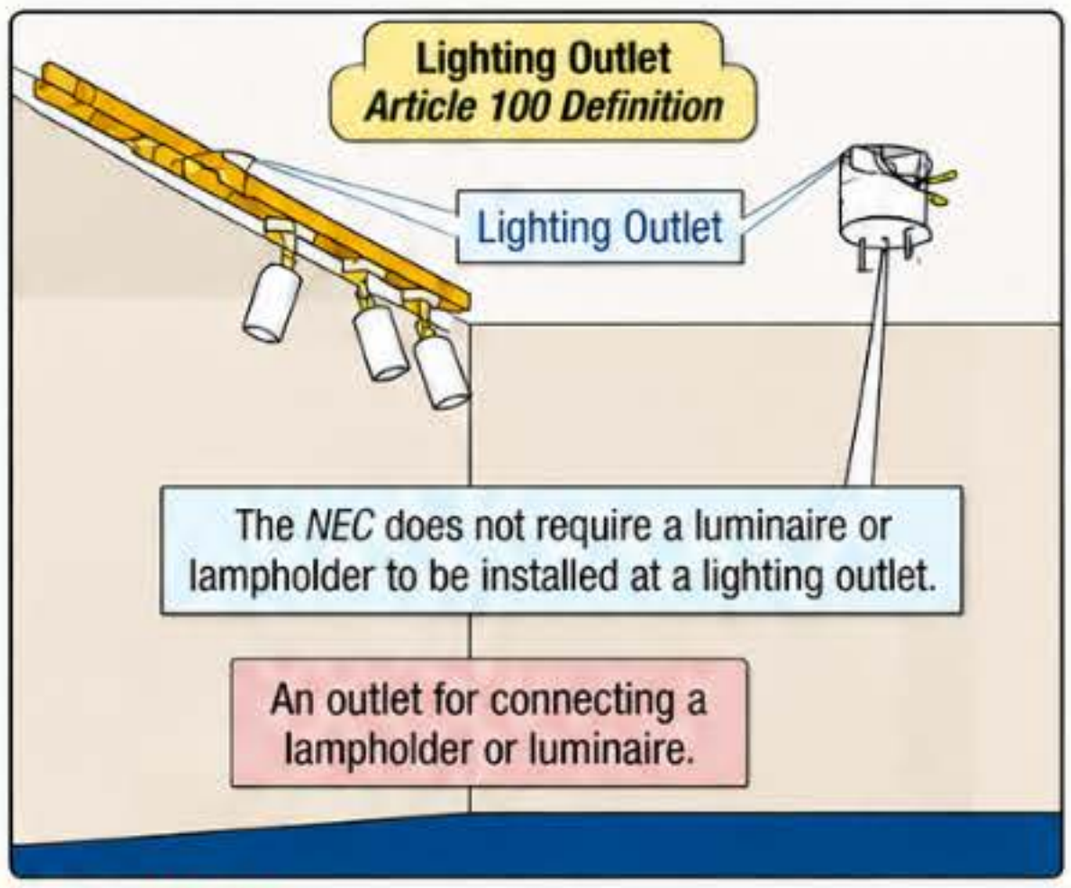
— Michael Hamilton

Lighting Outlet. An outlet intended for connecting a luminaire. ▶ Figure 100–103

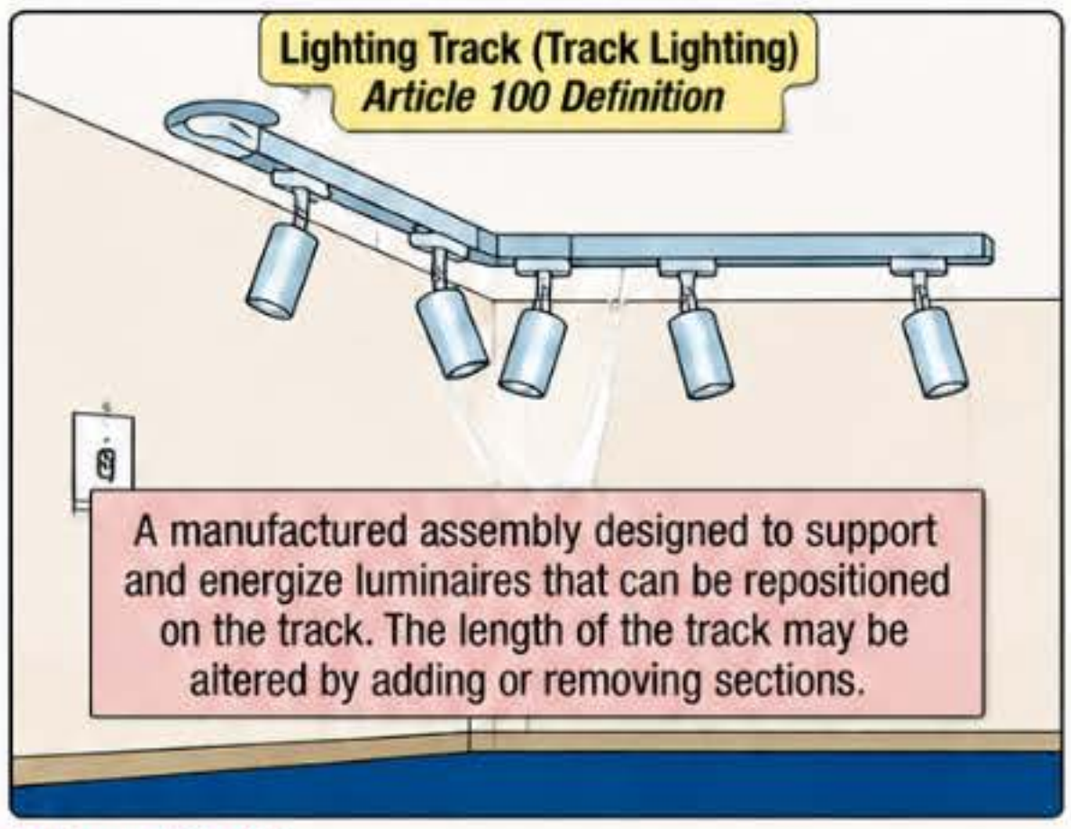
Lighting Track (Track Lighting). A manufactured assembly made to support and supply power to luminaires that can be easily moved along the track. The length of the track may change by adding or removing track sections.

▶ Figure 100–104

▶ Figure 100–102



▶ Figure 100–103



▶ Figure 100–104

Listed. Products, equipment, and materials appear on a roster from a nationally recognized testing organization that authorities having jurisdiction accept for use. These organizations routinely evaluate manufacturing facilities, listed equipment, and materials to verify they conform to suitable design standards for the intended application.

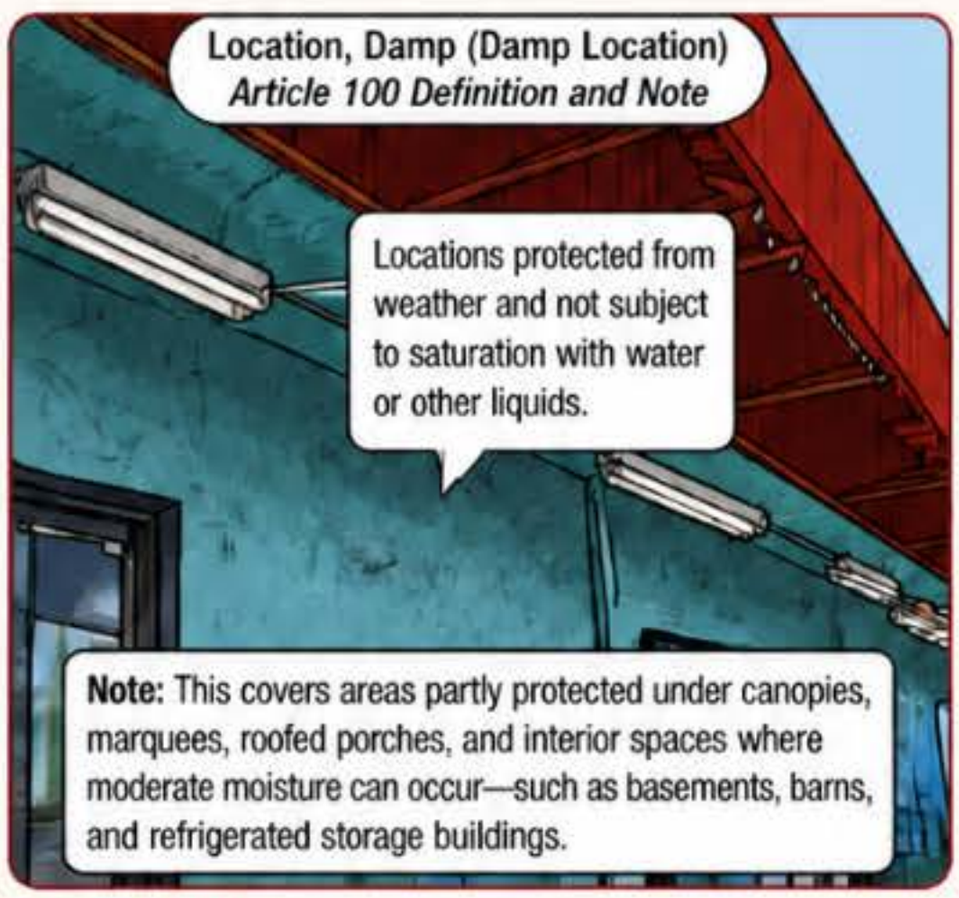
Note: Well-known recognized testing bodies (NRTLs) include Underwriters Laboratories (UL) and the Canadian Standards Association (CSA). Acceptance is in the United States or Canada and most electrical products bear a label by these agencies. Always check for that label and refuse counterfeit or imtiation items.

Author's Commentary:

- The *NEC* does not mandate that all electrical products be "listed," but some Code rules do require or call for certain equipment. Organizations such as OSHA are increasingly requiring listed devices when that equipment is used. (See 90.7, 110.2, and 110.3.)

— *Michael Hamilton*

Location, Damp (Damp Location). Places shielded from weather conditions and not exposed to saturation by water or other liquids. ▸ Figure 100–105

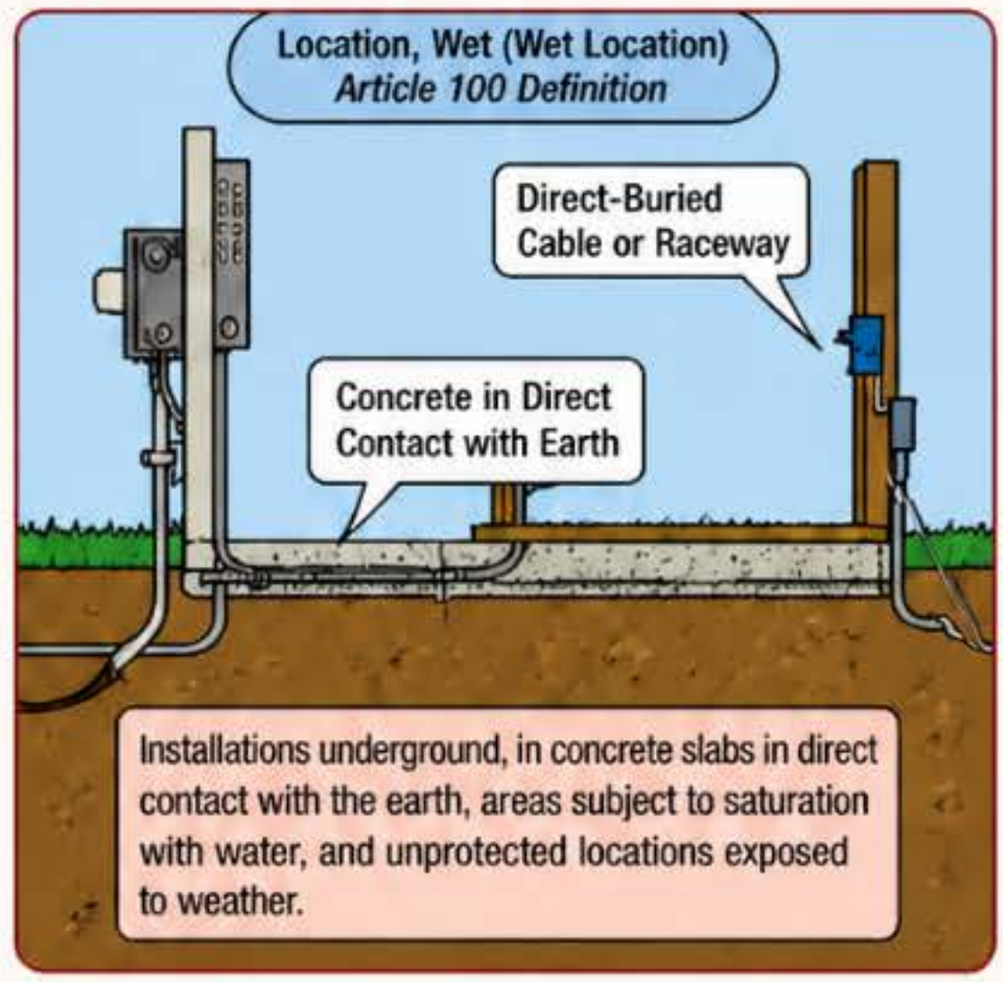


▸ Figure 100–105

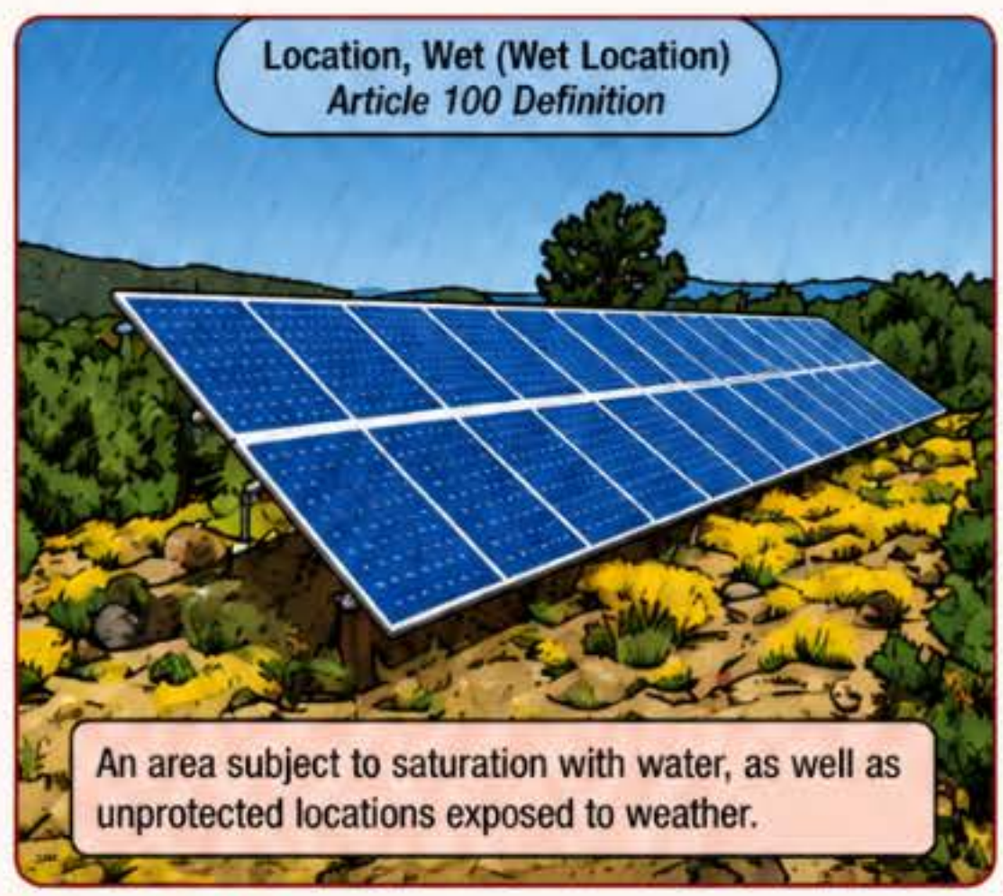
Note: This includes places partly protected by canopies, marquees, roofed porches, and interior areas that can experience moderate moisture—such as basements, barns, and cold-storage structures.

Location, Dry (Dry Location). Spaces normally free from moisture or dampness, but that may see temporary moisture during construction, such as inside a building while it is being built.

Location, Wet (Wet Location). Underground installations in concrete slabs directly touching the ground, areas subject to soaking with water, and unprotected places where weather can reach them.
▸ Figure 100–107 ▸ Figure 100–107



▸ Figure 100–106

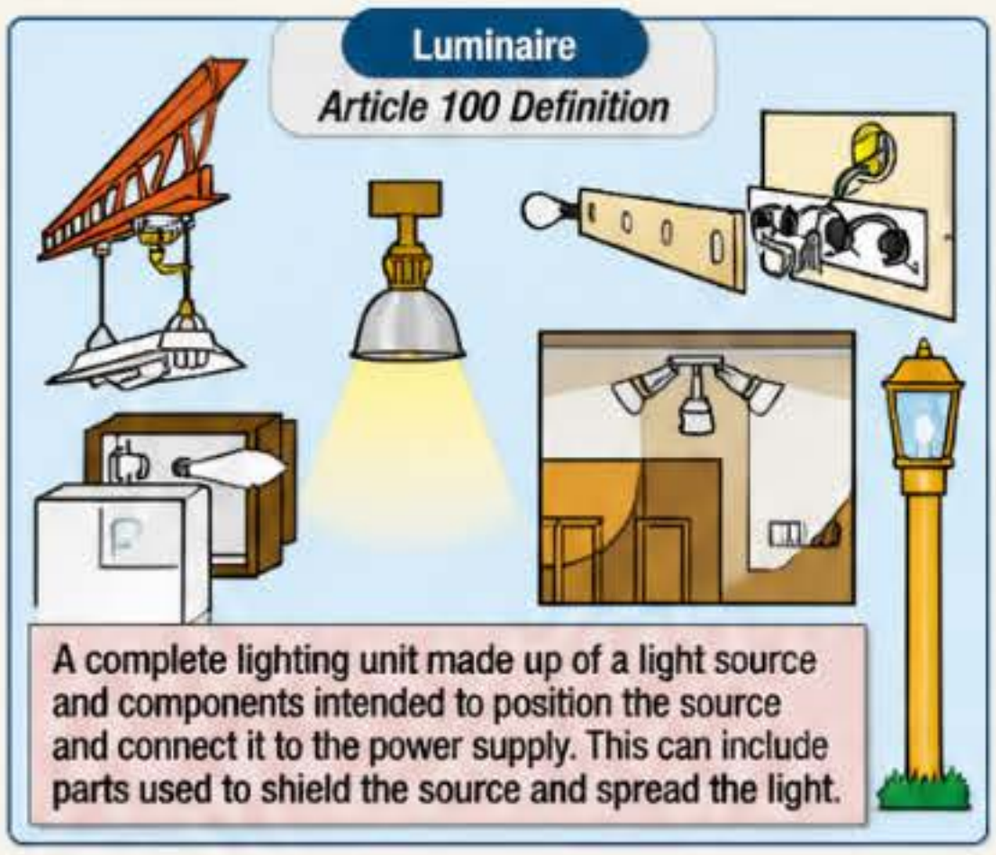


▸ Figure 100–107

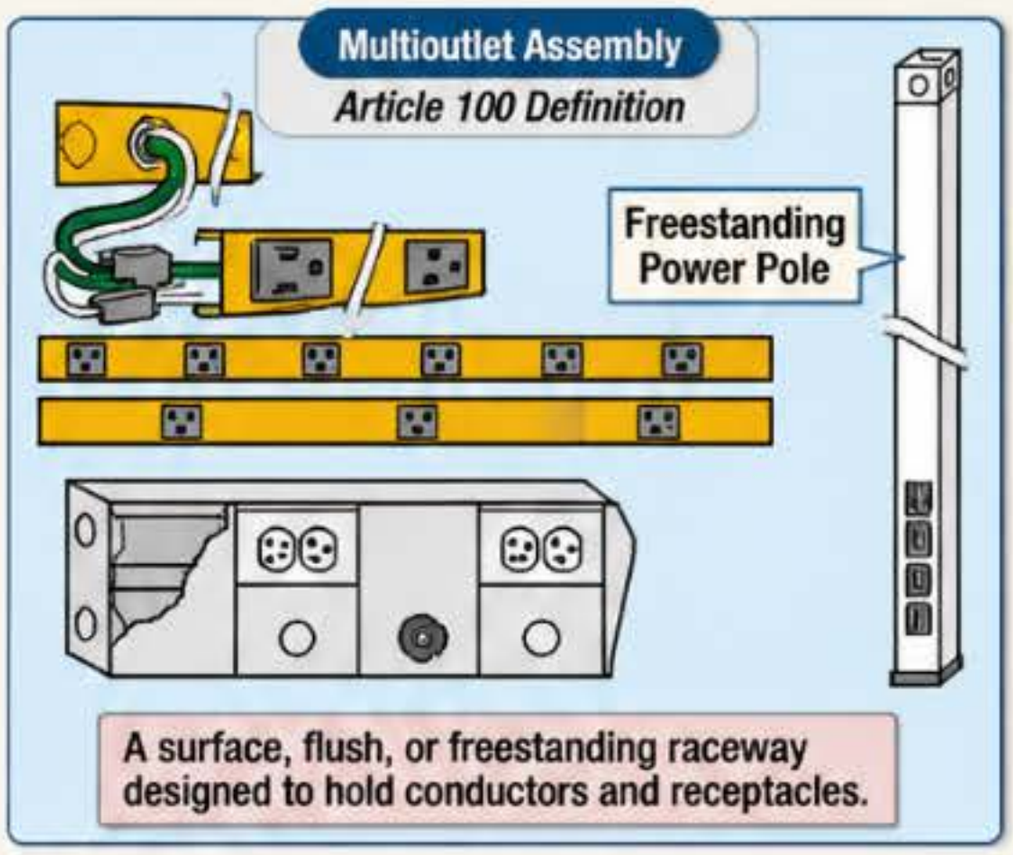
Luminaire. A complete lighting unit consisting of a light source with the parts designed to correctly position the source and to connect it to the power supply. May also include parts that safeguard and distribute the light. ▸ Figure 100–108

Messenger or Messenger Wire. A wire run alongside, or built into, a cable or conductor to give mechanical support to that cable or conductor. ▸ Figure 100–109

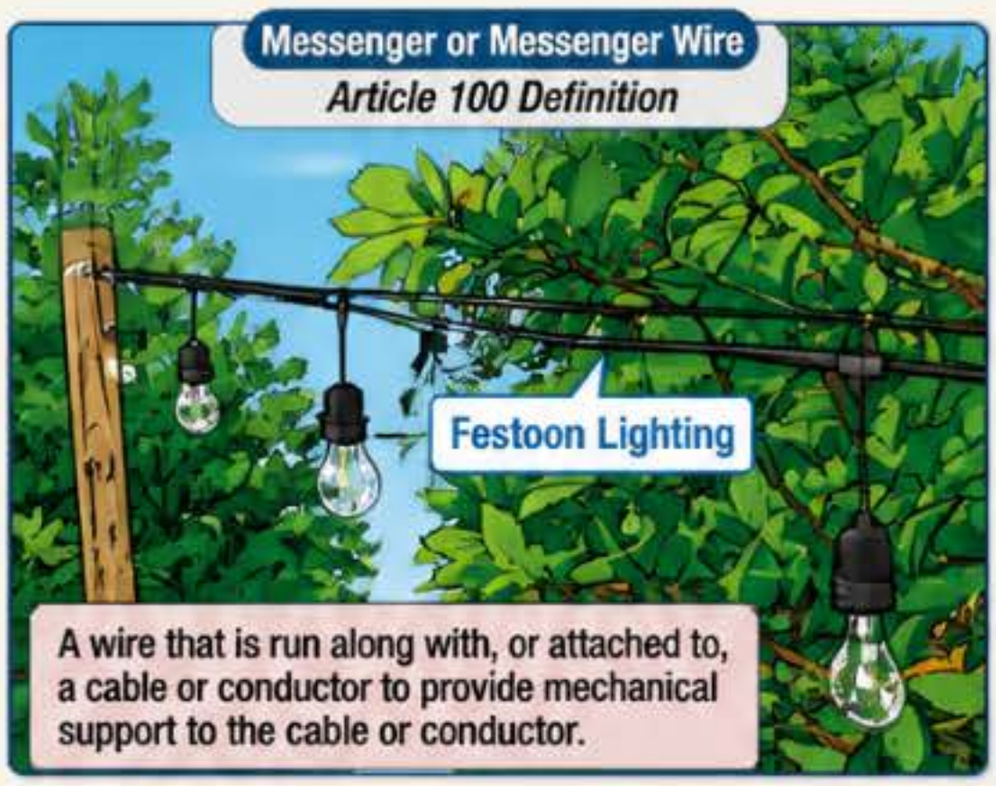
100 | Definitions



▸ Figure 100–108



▸ Figure 100–110



▸ Figure 100–109

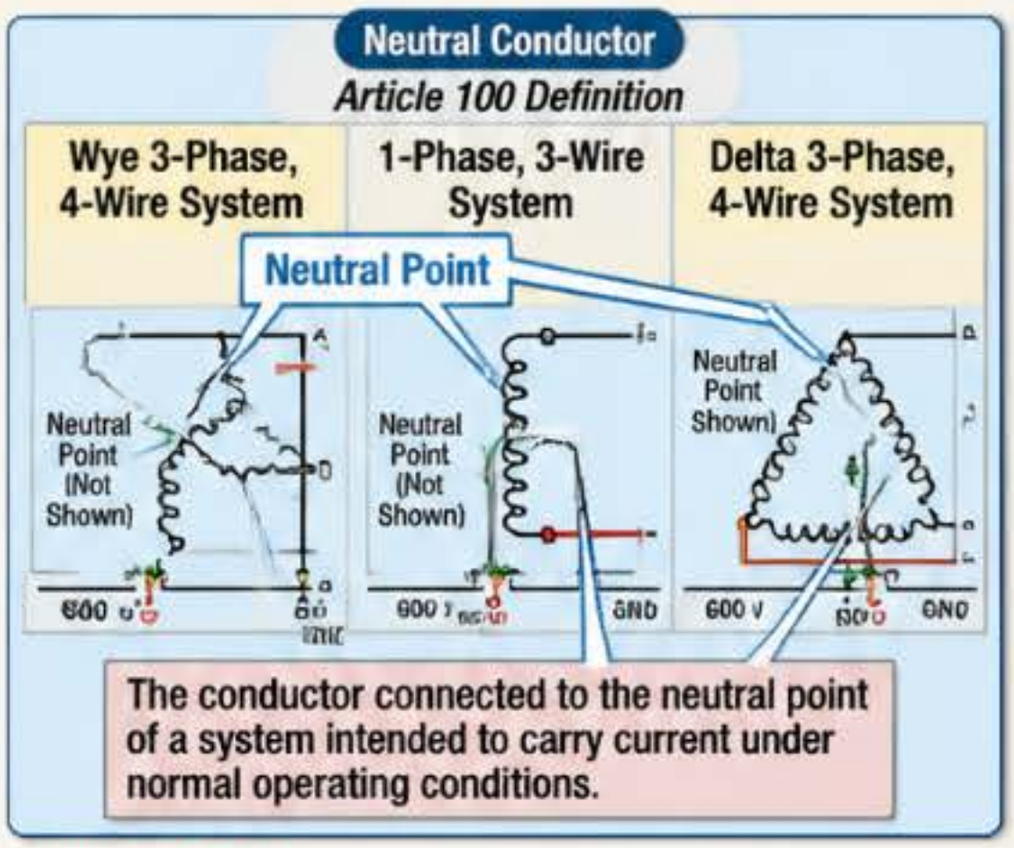
▸ Figure 100–111

Multioutlet Assembly. A surface, flush, or freestanding raceway designed to hold conductors and receptacles. ▸Figure 100–110

> ***Author's Commentary:***
> Portable assemblies such as power strips are relocatable power taps, not multioutlet assemblies.
> ***— Michael Hamilton***

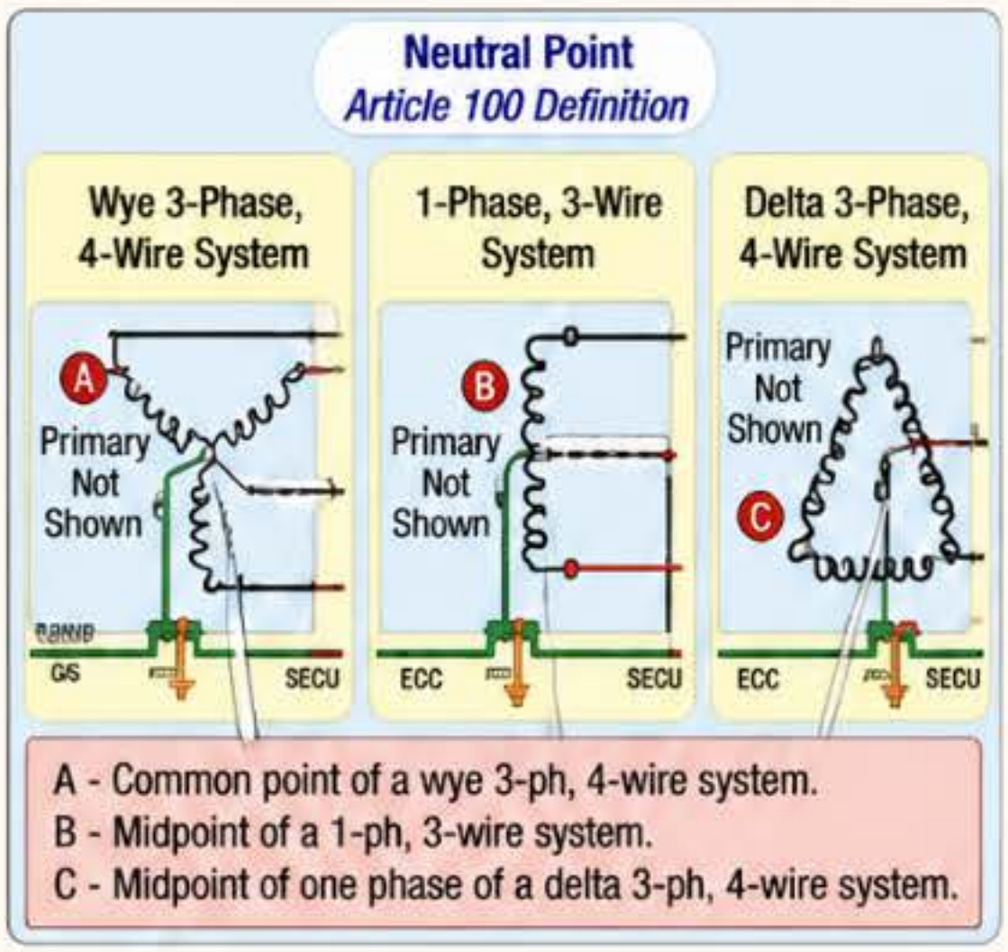
Neutral Conductor. The conductor connected to the neutral point of a system that is intended to carry current under normal conditions. ▸Figure 100–112

Neutral Point. The common point of a 4-wire, three-phase, wye-connected system; the midpoint of a 3-wire, single-phase system; or the midpoint of the single-phase portion of a three-phase, delta-connected system. ▸Figure 100–113



▸ Figure 100–112

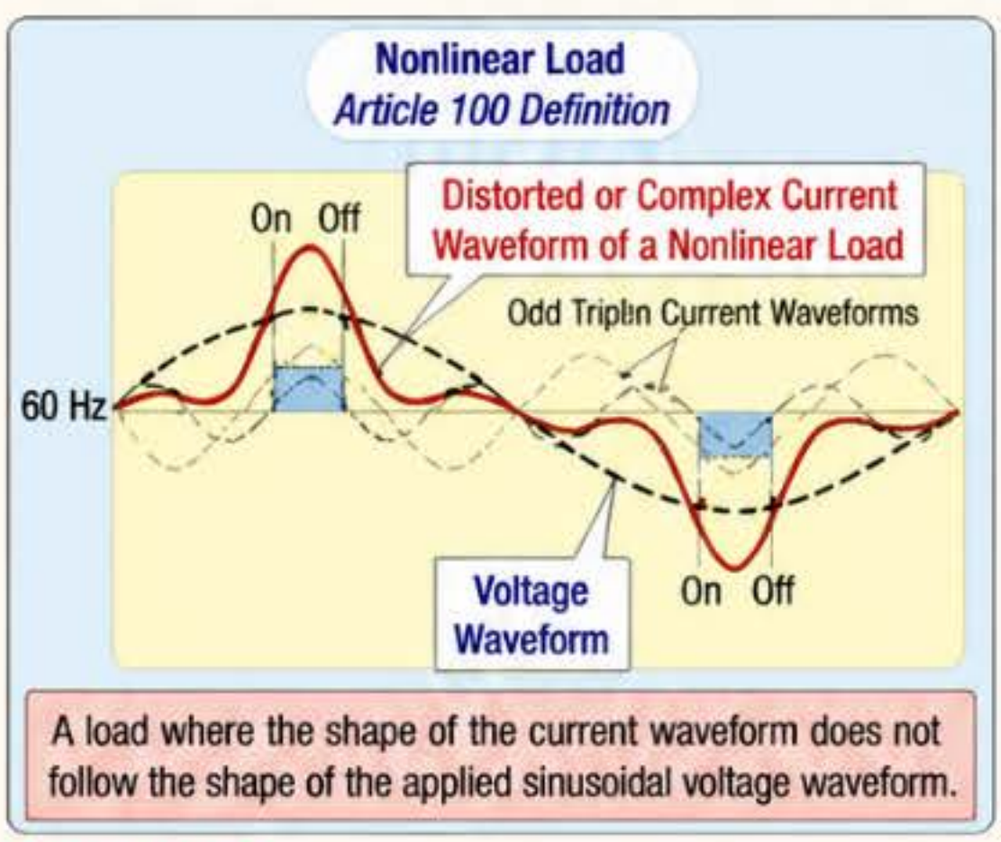
DEFINITIONS | From Michael Hamilton Publications



▸Figure 100–113

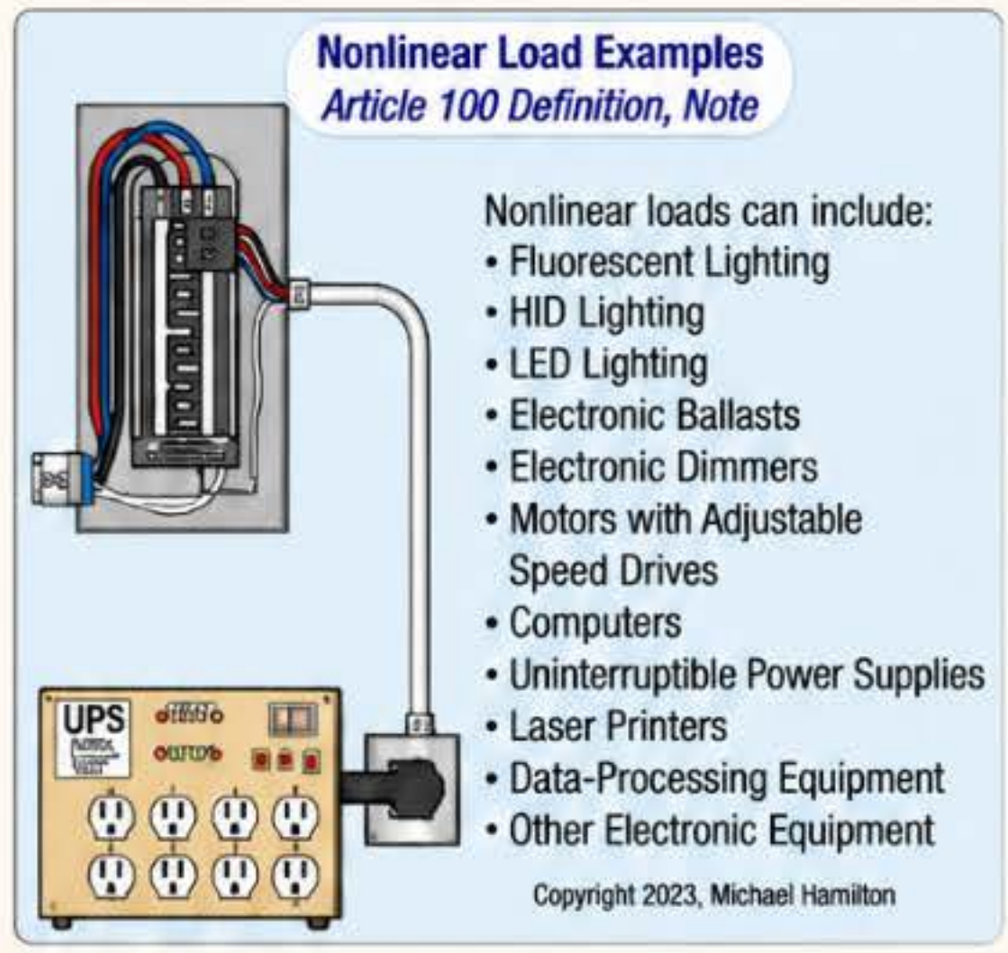
Nonautomatic. Refers to a function that requires a person to take action and operate it.

Nonlinear Load. A load whose current waveform shape does not match the form of the applied sinusoidal voltage. ▸Figure 100–114



▸Figure 100–114

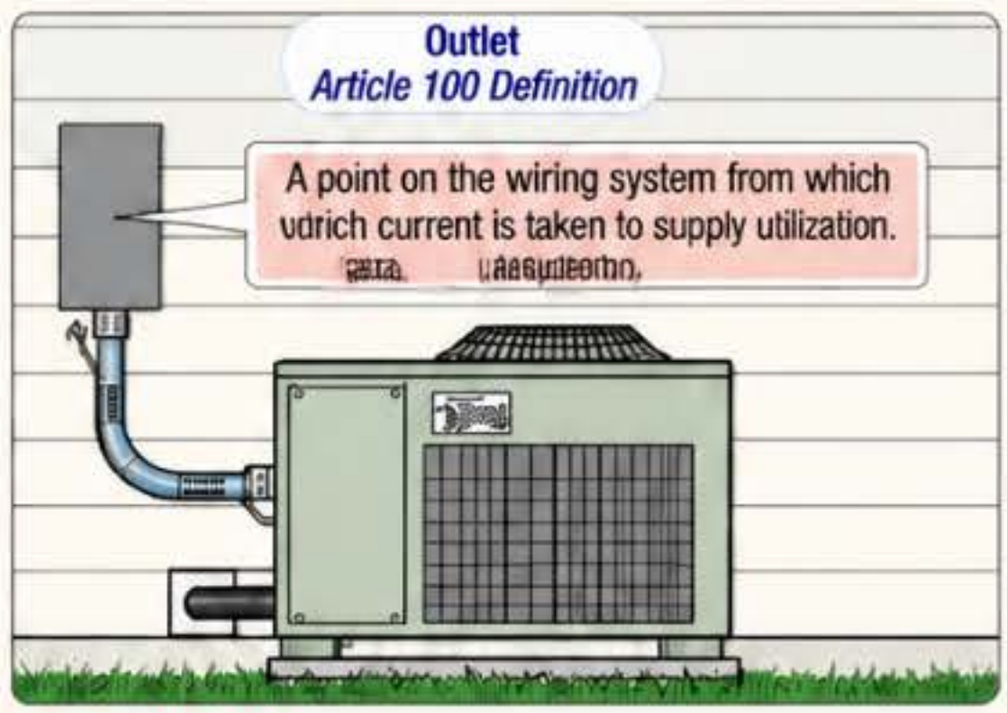
Note: Single-phase nonlinear loads include electronic equipment such as copy machines, laser printers, and electric-discharge lighting. Three-phase nonlinear loads include uninterruptible power supplies, induction motors, and electronic switching devices such as adjustable-speed drive systems. ▸Figure 100–115



▸Figure 100–115

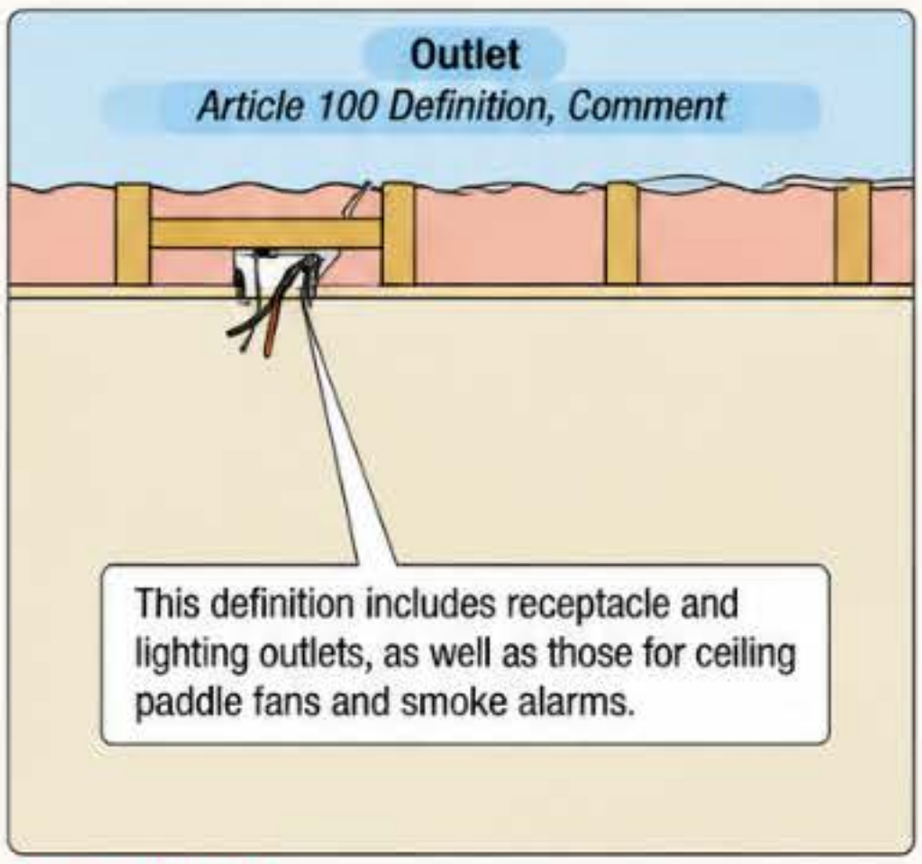
Author's Commentary:
Loads that are nonlinear fall outside the usual scope of this textbook. If you want to dig deeper into this subject, go to www.MichaelHamiltonPublications.com and open the "Technical" section, then select the "Power Quality" resource.
— Michael Hamilton

Outlet. An accessible connection point in a wiring system intended to provide electricity for utilization equipment. ▸Figure 100–116



▸Figure 100–116

Author's Commentary:
This category includes receptacle outlets and illumination outlets, along with the connections for ceiling fans and smoke detection alarms.
— Michael Hamilton



▸Figure 100–117

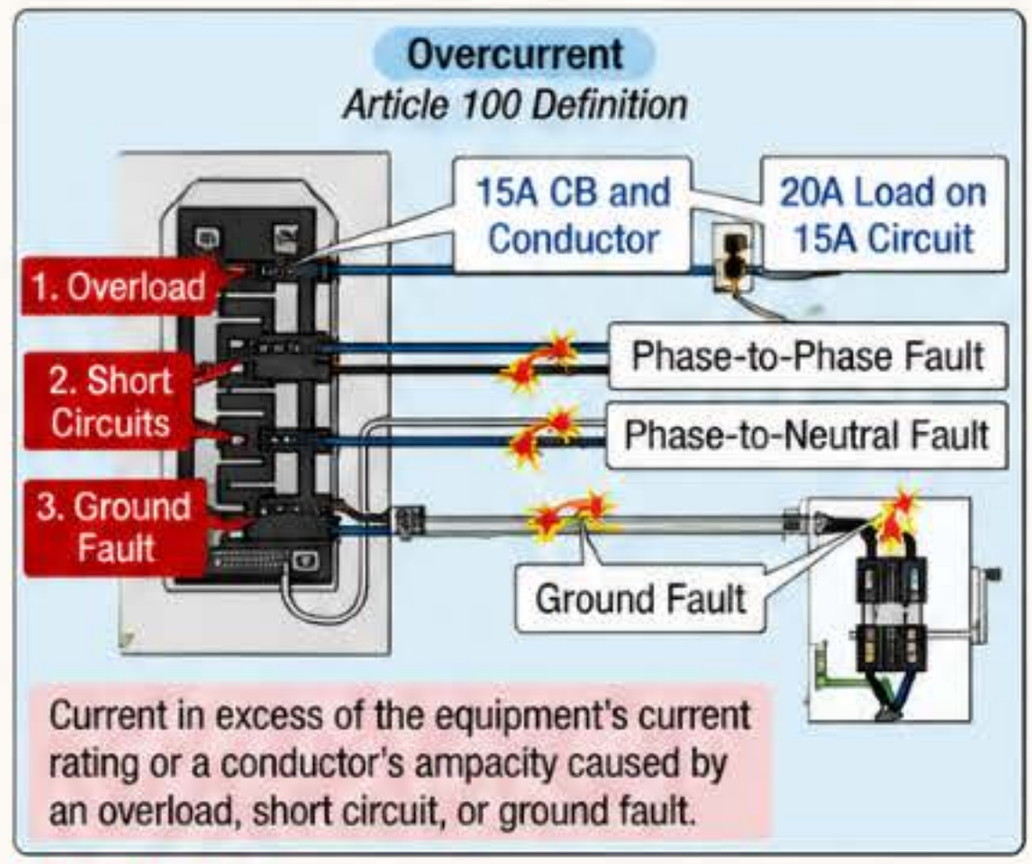
Outline Lighting. An arrangement of an electrically powered light source used to outline or call attention to building features such as the shape of a building or the decoration of a window. ▸Figure 100–118

▸Figure 100–118

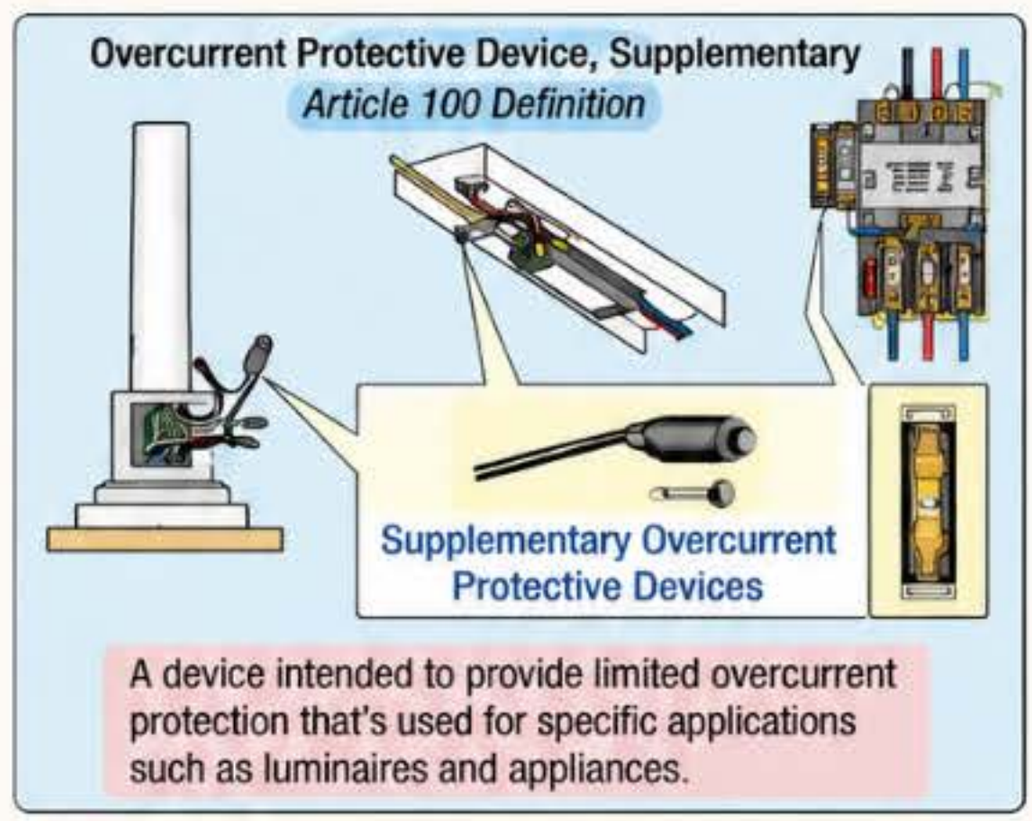
Overcurrent. Current in excess of the equipment's current rating or a conductor's ampacity caused by an overload, short circuit, or ground fault. ▸Figure 100–119

Overcurrent Protective Device, Branch Circuit. A device capable of providing protection from an overload, short circuit, or ground fault for service, feeder, and branch circuits.

Overcurrent Protective Device, Supplementary. A device intended to provide limited overcurrent protection for specific applications and utilization equipment, such as luminaires and appliances. This limited protection is in addition to the protection required and provided by the branch-circuit overcurrent protective device. ▸Figure 100–120



▸Figure 100–119



▸Figure 100–120

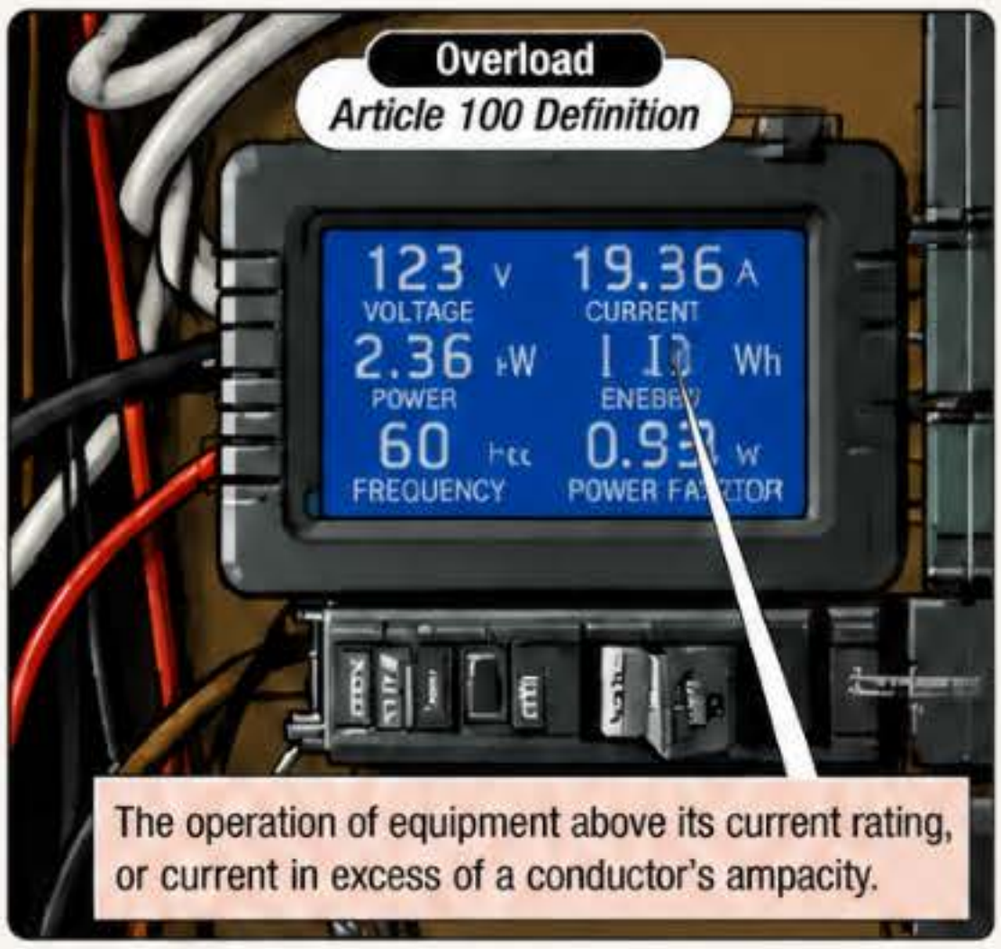
Overload. The operation of equipment above its current rating, or current in excess of a conductor's ampacity. If an overload condition persists long enough, the result can be equipment failure or a fire from damaging or dangerous overheating, A fault, such as a short circuit or ground fault, is not an overload. ▸Figure 100–121

Panelboard. An assembly designed for the distribution of light, heat, or power circuits with overcurrent devices and typically placed in a cabinet. ▸Figure 100–122

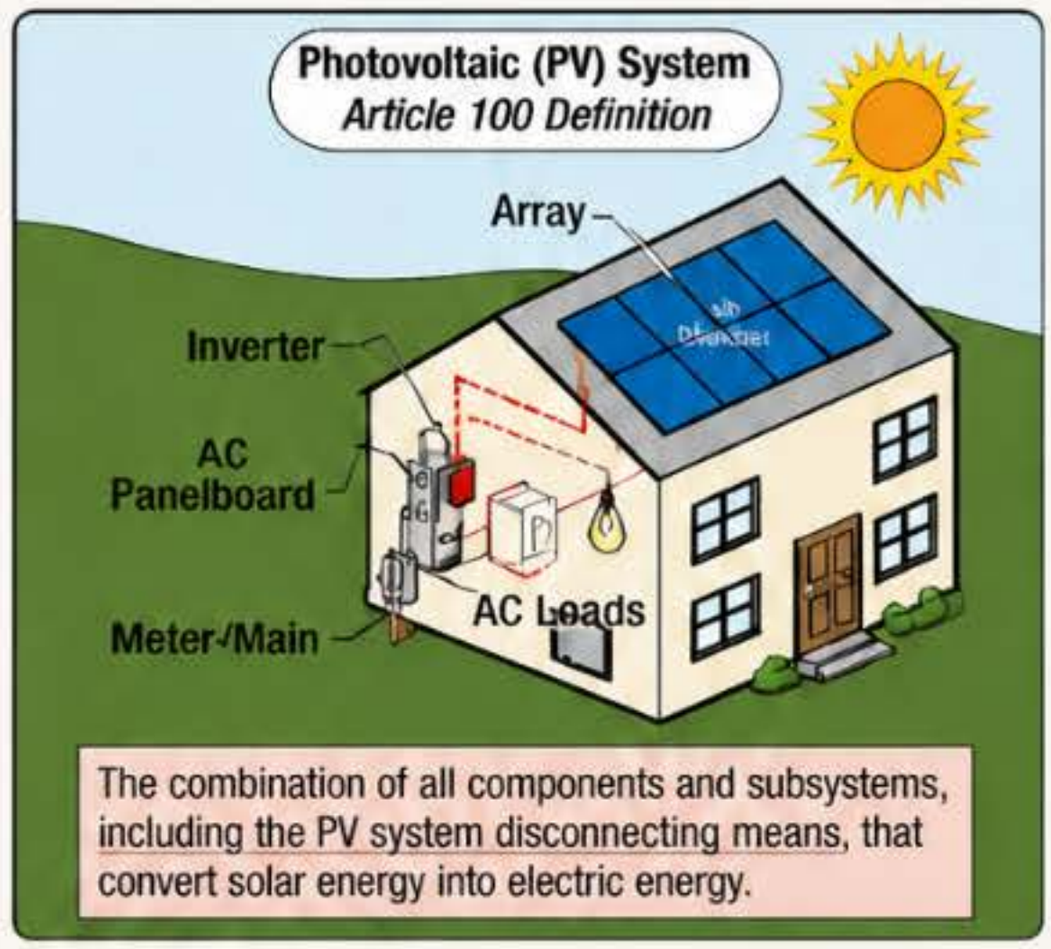
Author's Commentary:

- See the definition of "Cabinet" in this article.
- The slang term in the electrical field for a panelboard is "the guts." This is the interior of the panelboard assembly and is covered by Article 408, while the cabinet is covered by Article 312.

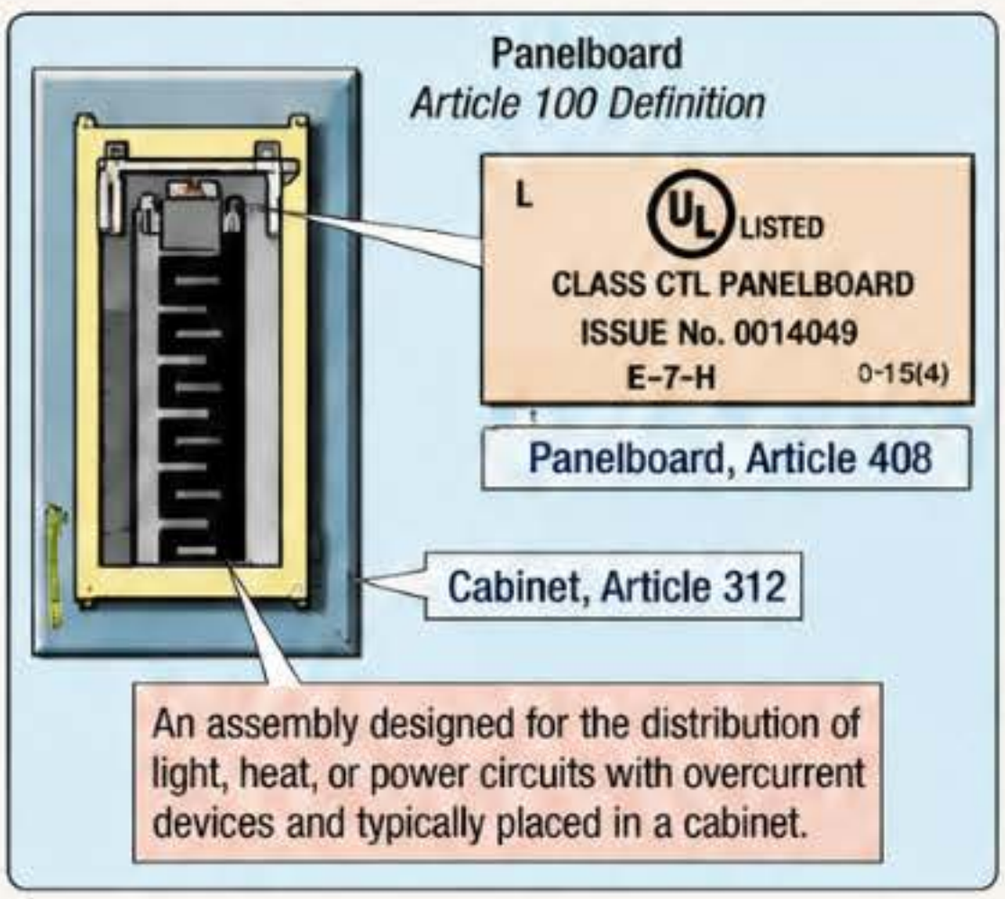
— Michael Hamilton



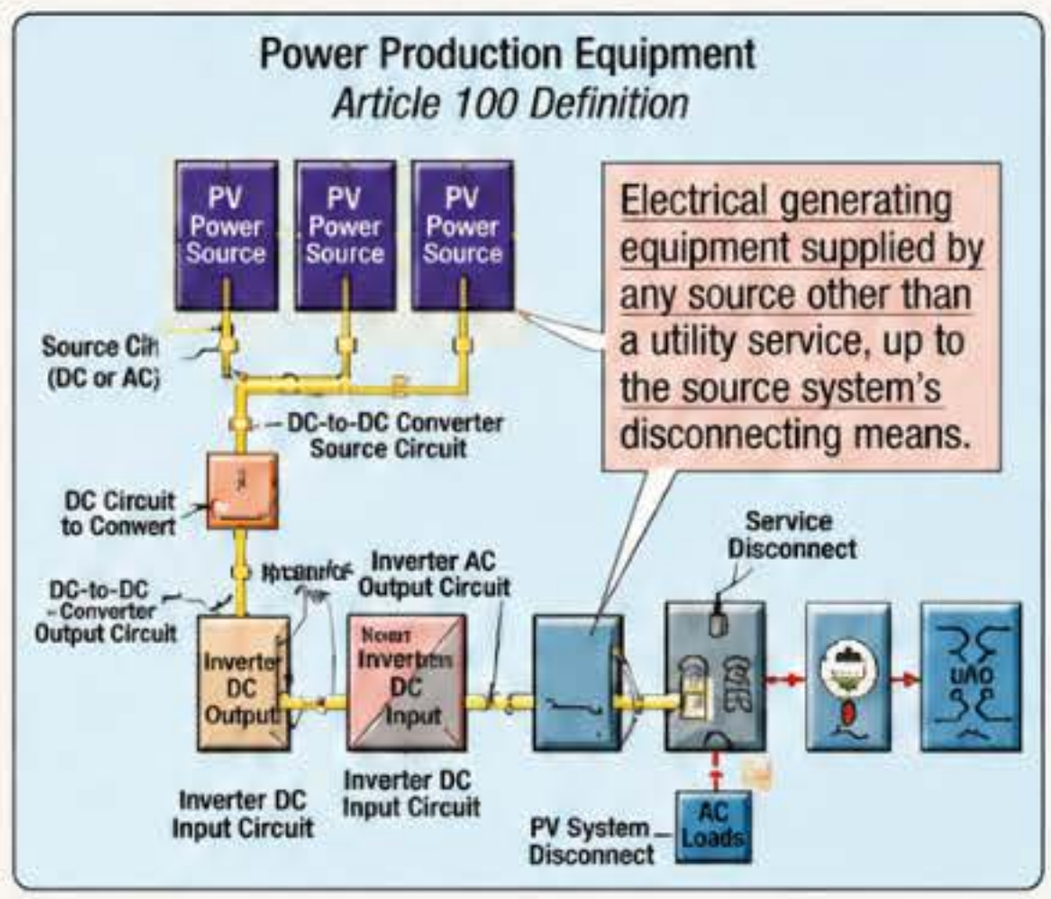
▸Figure 100–121



▸Figure 100–123



▸Figure 100–122



▸Figure 100–124

Photovoltaic (PV) System. All essential components and subsystems—such as the PV system disconnecting means—that transform sunlight into usable electrical energy for consumption by building loads. ▸Figure 100–123

Power Production Equipment. Electrical generating equipment that draws energy from any source other than a utility service and extends up to the source system's disconnecting means. ▸Figure 100–124

Note: Examples of power production equipment include devices such as generators, solar photovoltaic systems, and fuel cell systems.

Premises Wiring. The internal and external wiring, including power, lighting, control, and signaling circuits, along with associated hardware, fittings, and wiring devices. This encompasses both permanently installed wiring and temporary installations from the service point to outlets. When a service point is not present, premises wiring extends from the incoming electrical source (such as a generator, transformer, or PV system) to the outlets. ▸Figure 100–125

Premises wiring excludes internal wiring of equipment and appliances like luminaires, dishwashers, water heaters, motors, controllers, motor control centers, and air-conditioning equipment, among others. ▸Figure 100–126

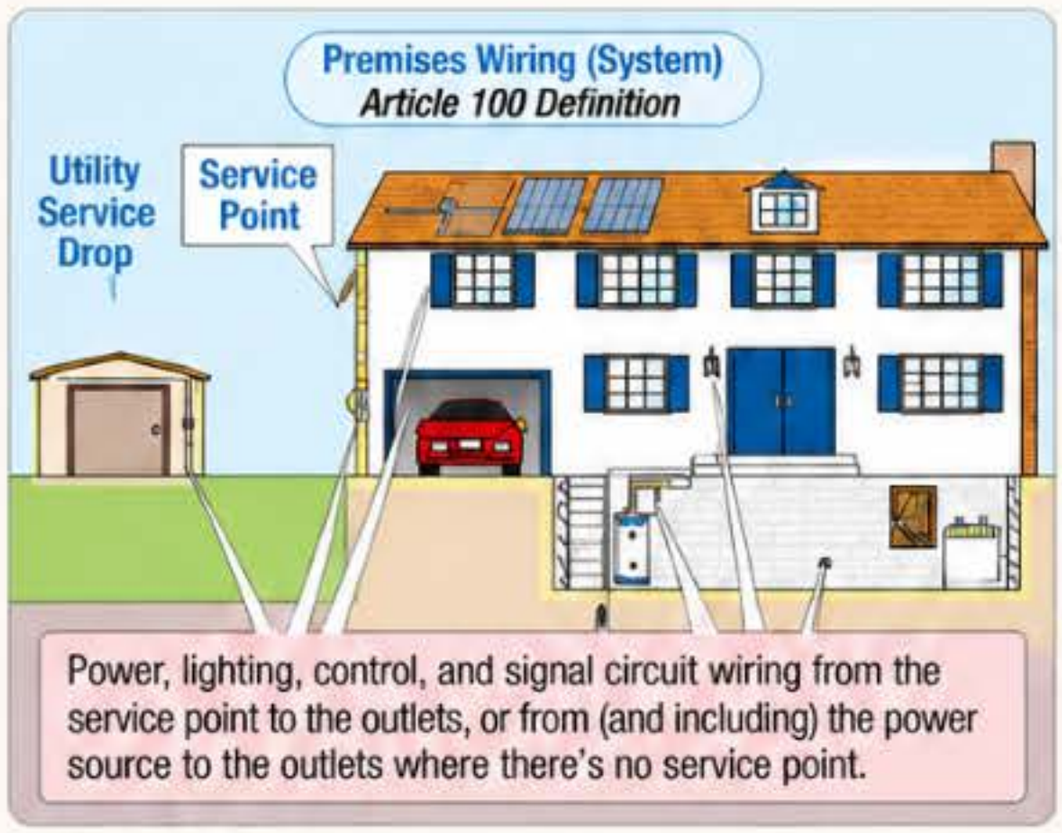


Figure 100–125

Figure 100–127

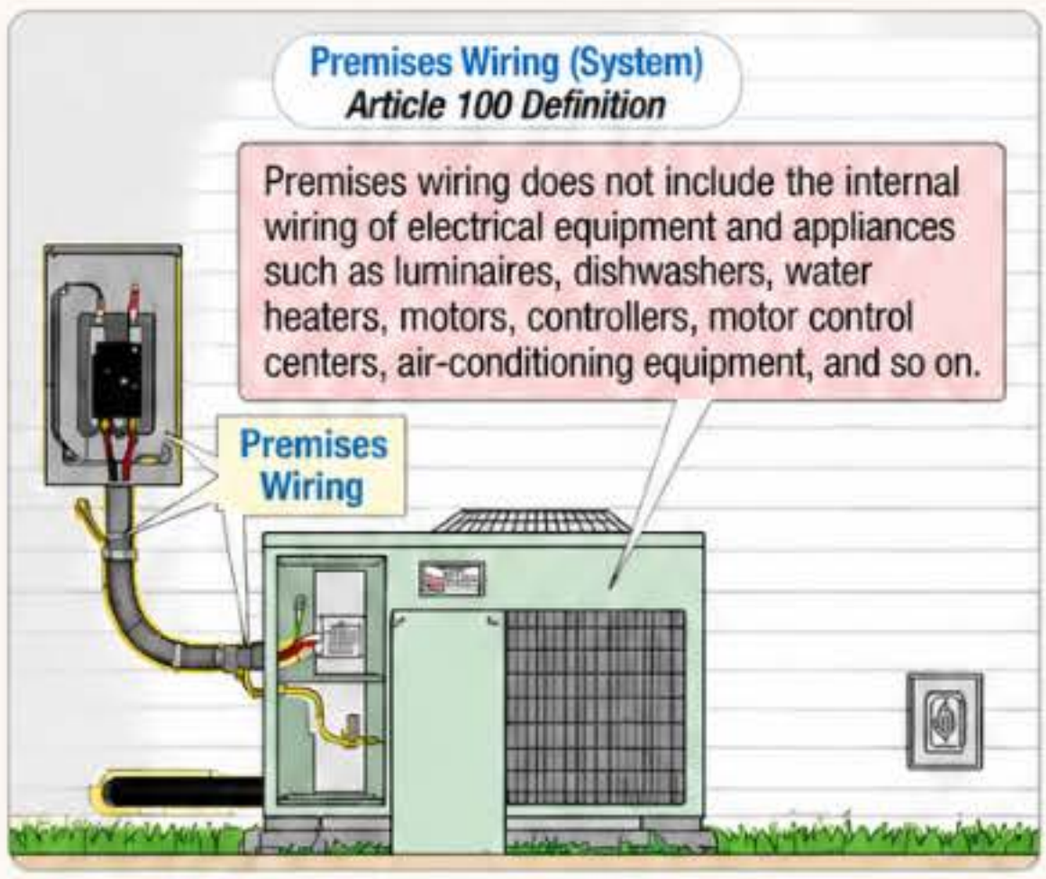


Figure 100–126

Note: Electric power sources include (but not limited to) interconnected or stand-alone batteries, PV systems, other distributed generation systems, and generators.

Prime Mover. The machine that supplies mechanical horsepower to a generator.

Qualified Person. A person who has the skill and knowledge related to the construction and operation of electrical equipment and its installation. This person must have received safety training to recognize and avoid the hazards involved with electrical systems. **Figure 100–127**

Note: NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides information on the safety training requirements expected of a "qualified person."

Author's Commentary:

- Examples of this safety training include, but are not limited to, training in the use of special precautionary techniques, personal protective equipment (PPE), insulating and shielding materials, and the use of insulated tools and test equipment when working on or near exposed conductors or circuit parts that can become energized.
- In many parts of the United States, electricians, electrical contractors, electrical inspectors, and electrical engineers must complete from 6 to 24 hours of *NEC* review each year as a requirement to maintain licensing. This, in and of itself, does not make one qualified to deal with the specific hazards involved with electrical systems.

Raceway. A channel designed for the installation of conductors, cables, or busbars.

Author's Commentary:

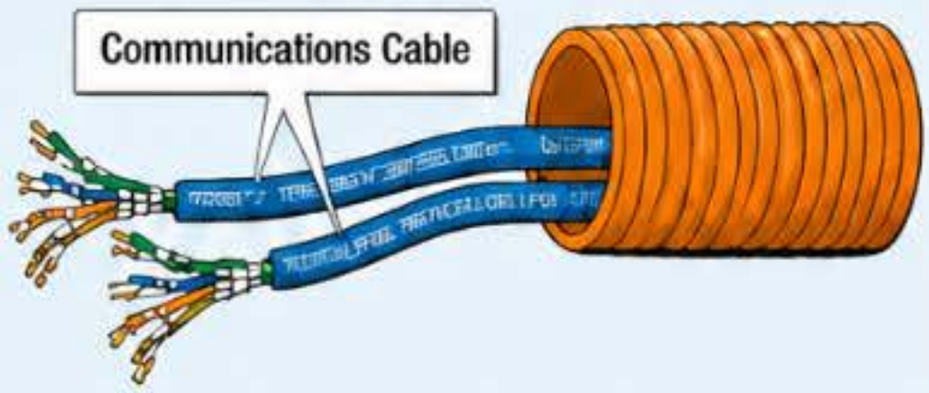
- A cable tray system is not a raceway; it is a support system for cables and raceways [392.2].

Raceway, Communications. An enclosed nonmetallic channel designed for holding communications wires and cables; optical fiber cables; data cables associated with information technology and communications equipment; Class 2, Type PLTC, and power-limited fire alarm cables in plenum spaces, risers, and general-purpose applications. **Figure 100–128**

Rainproof. Constructed, protected, or treated to prevent rain from interfering with the successful operation of the apparatus under specified test conditions.

Raceway, Communications

Article 100 Definition



An enclosed nonmetallic channel designed for holding communications wires and cables, optical fiber cables, data cables, Class 2, and Type PLTC cables, and power-limited fire alarm cables in plenum spaces, risers, and general-purpose applications.

▸ Figure 100–128

Raintight. Built or protected so that exposure to heavy rain does not allow water to enter under the stated test conditions.

Receptacle. A contact device installed at an outlet for the connection of an attachment plug, or for the direct connection of equipment designed to mate with the contact device (SGL receptacle). ▸ Figure 100–129

Receptacle

Article 100 Definition

A contact device installed at an outlet for the connection of an attachment plug, or for the direct connection of equipment designed to mate with the contact device.

Author's Commentary:

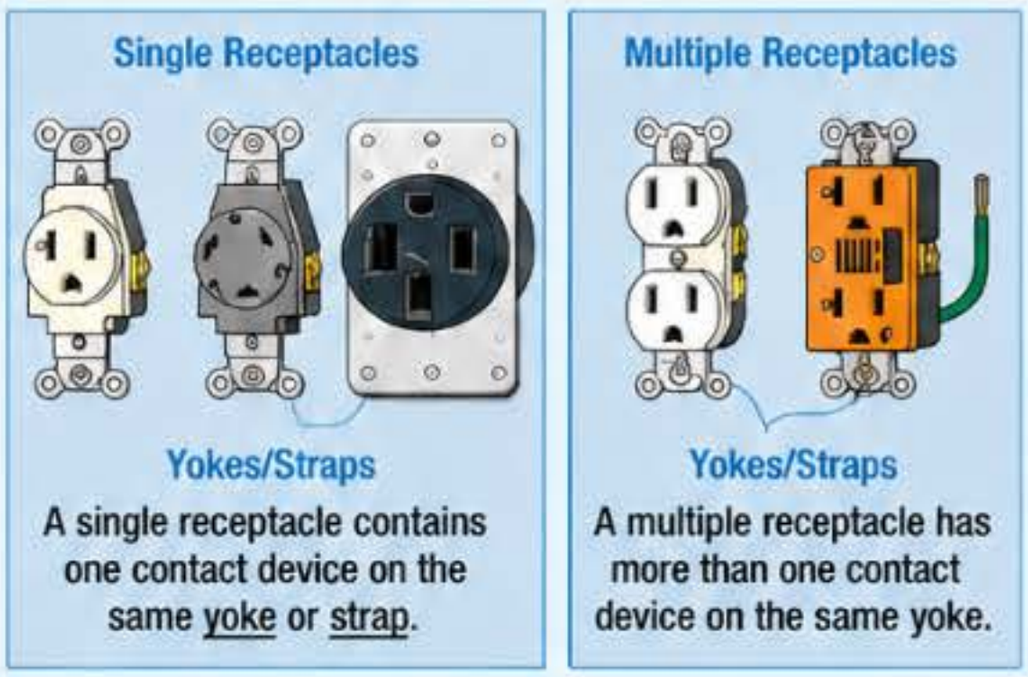
- For additional information about listed locking support and mounting receptacles, visit www.safetyquicklight.com.

— *Michael Hamilton*

A single receptacle contains one contact device on a yoke or strap; a multiple receptacle has more than one contact device on the same yoke or strap. ▸ Figure 100–130

Receptacle

Article 100 Definition

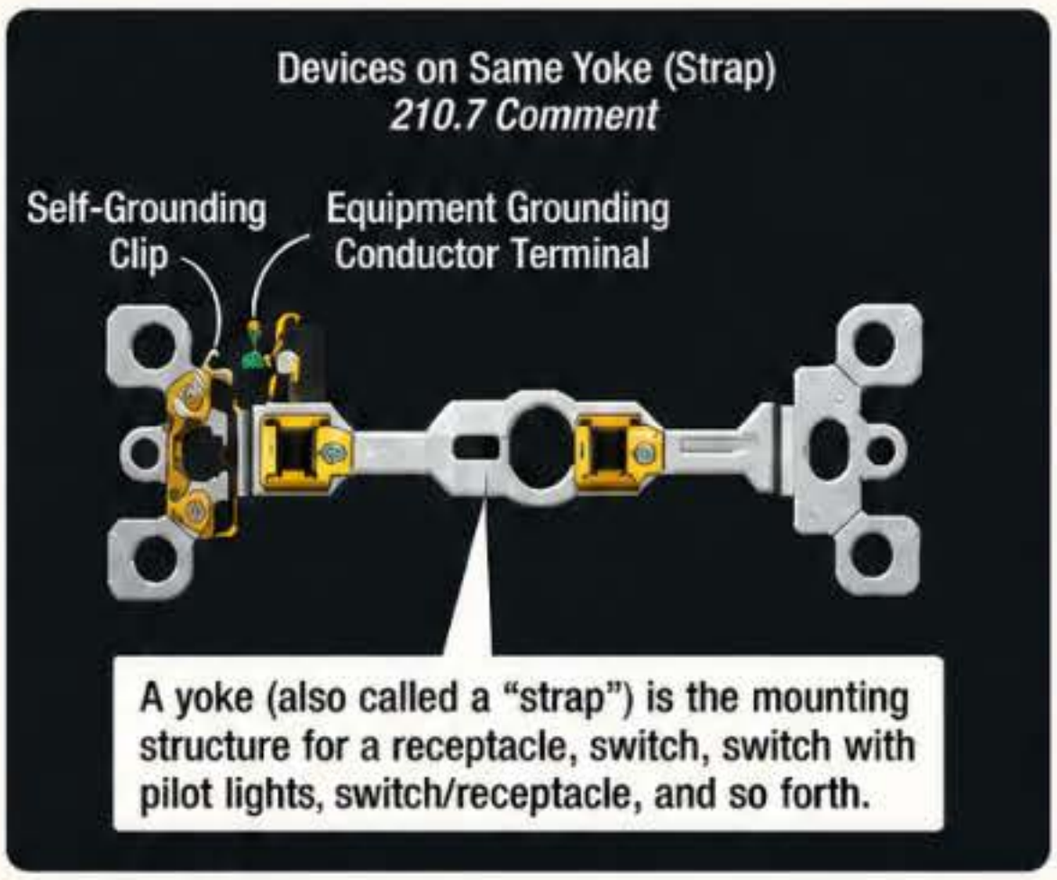


▸ Figure 100–130

Author's Commentary:

- A yoke (also called a "strap") is the metal mounting structure for items such as receptacles, switches, switches with pilot lights, and switch/receptacles to name a few. ▸ Figure 100–131 and Figure 100–132

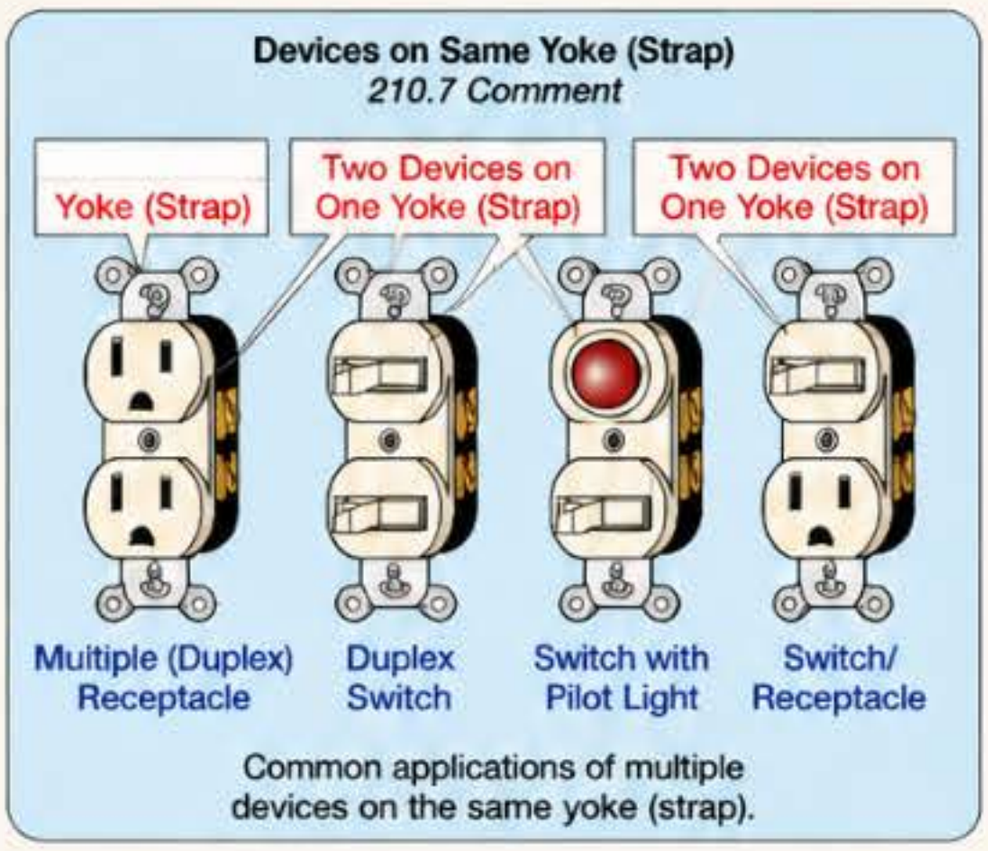
— *Michael Hamilton*



▸ Figure 100–131

Note: A duplex receptacle is an example of a multiple receptacle with two receptacles on the same yoke or strap.

Receptacle Outlet. An opening in an outlet box where receptacles have been installed.

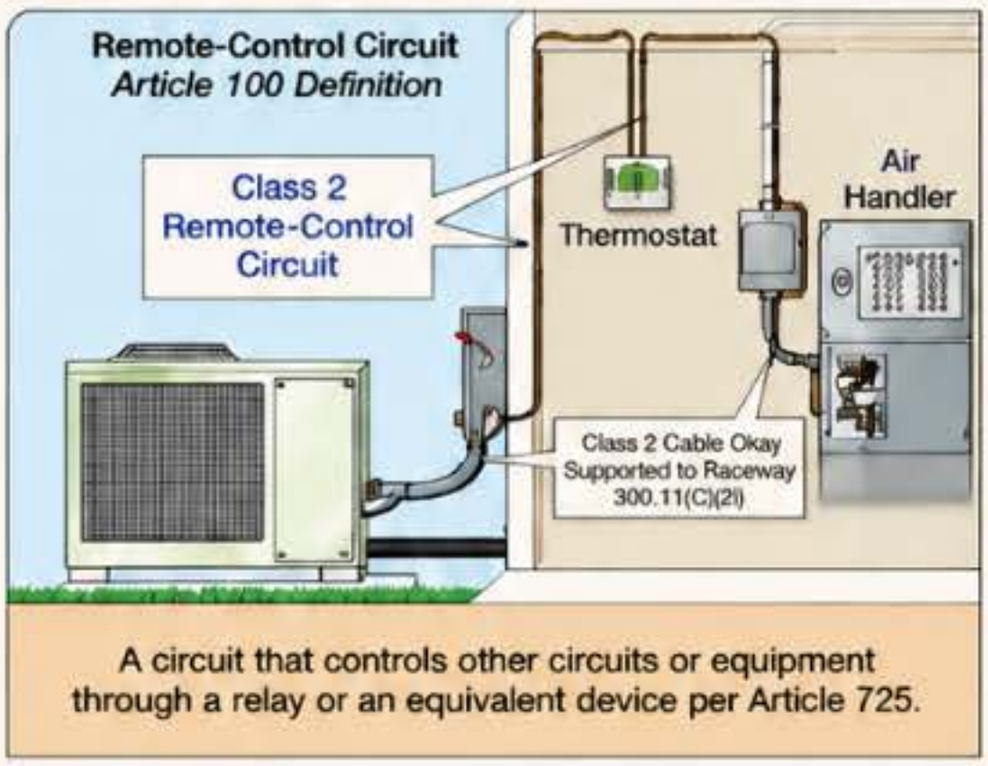


▸ Figure 100–132

Reconditioned. Electromechanical systems, equipment, apparatus, or parts that have been returned to a functional condition. This process is different from standard maintenance or repair since the item stays in an existing location, or a listed device is restored on a one-time basis.

Note: Reconditioning is commonly called eebuilding, overhauling, refurbishing, or remanufacturing.

Remote-Control Circuit. An electrical circuit that operates another circuit by means of a relay or equivalent device installed in accordance with Article 725. ▸ Figure 100–133



▸ Figure 100–133

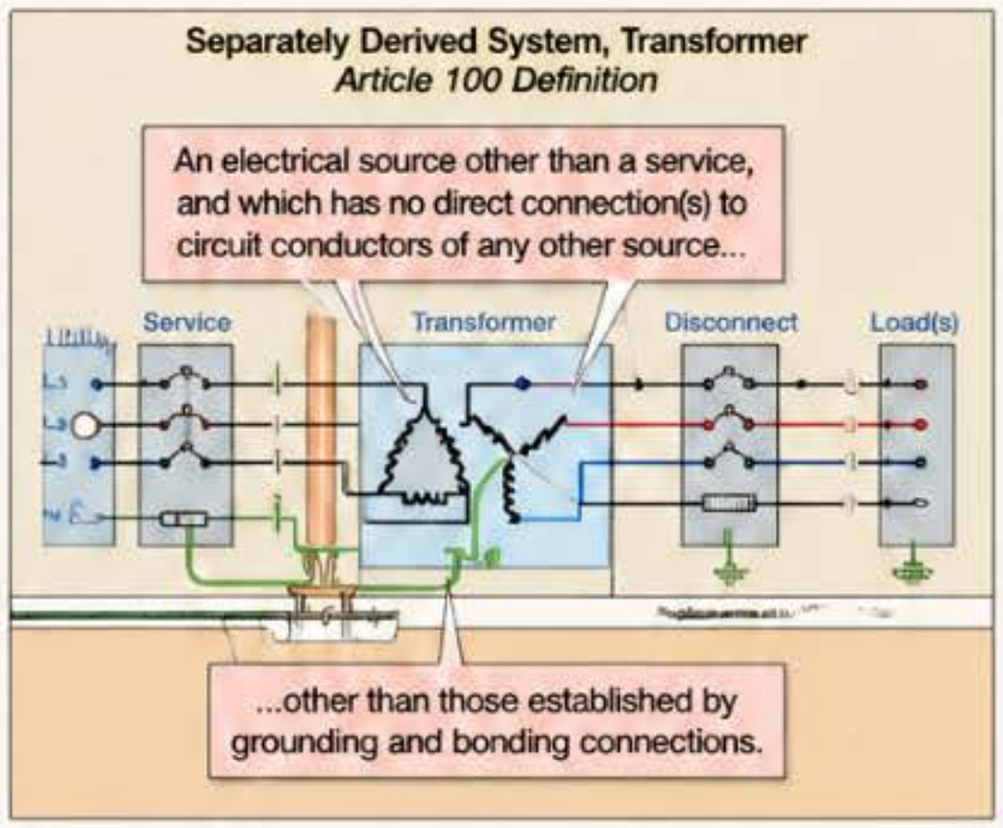
Retrofit Kit. An assembly of parts that allows the field conversion of utilization equipment.

Sealable Equipment. Equipment enclosed with a means of sealing or locking so internal parts cannot be accessed without opening the enclosure.

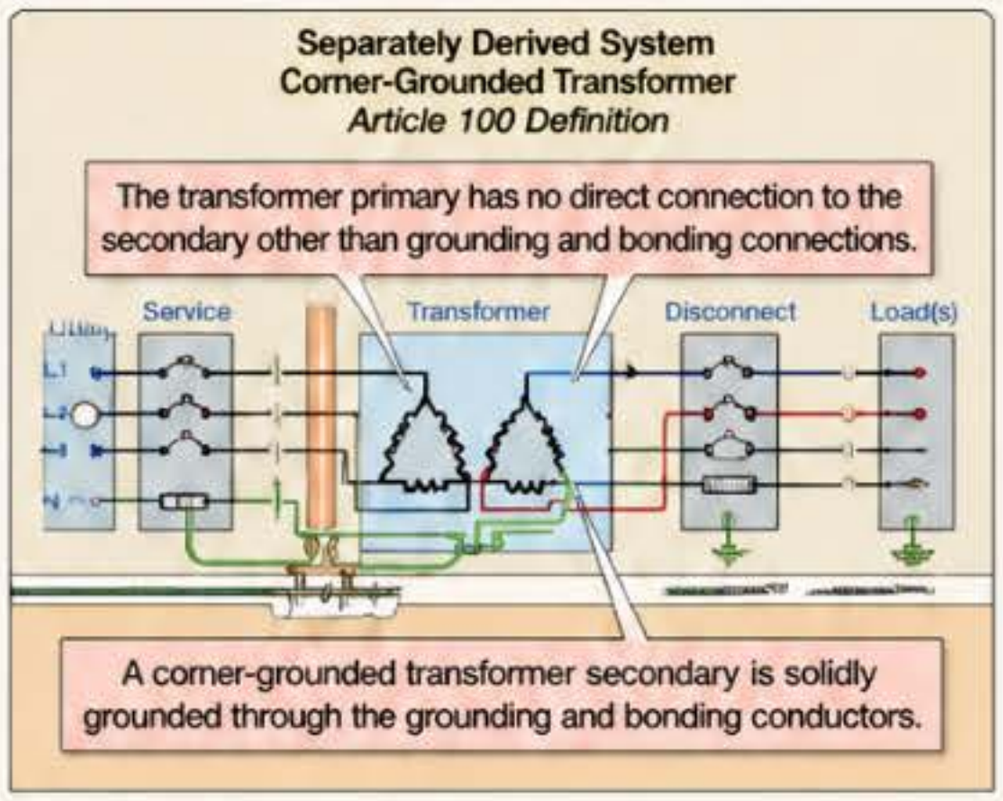
Note: Equipment may or may not be operable without opening the enclosure.

Separately Derived System. A system supplied by an electrical source other than a service, and which has no direct connection(s) to the circuit conductors of any other source other than those formed by grounding and bonding connections.

▸ Figure 100–134, ▸ Figure 100–135, and ▸ Figure 100–136



▸ Figure 100–134



▸ Figure 100–135

Author's Commentary:

▸ A generator is not a separately derived system if its neutral conductor is firmly connected to a service neutral conductor. An example is a generator equipped with a transfer switch that includes a neutral conductor that is not switched.

— Michael Hamilton

▸ Figure 100–136

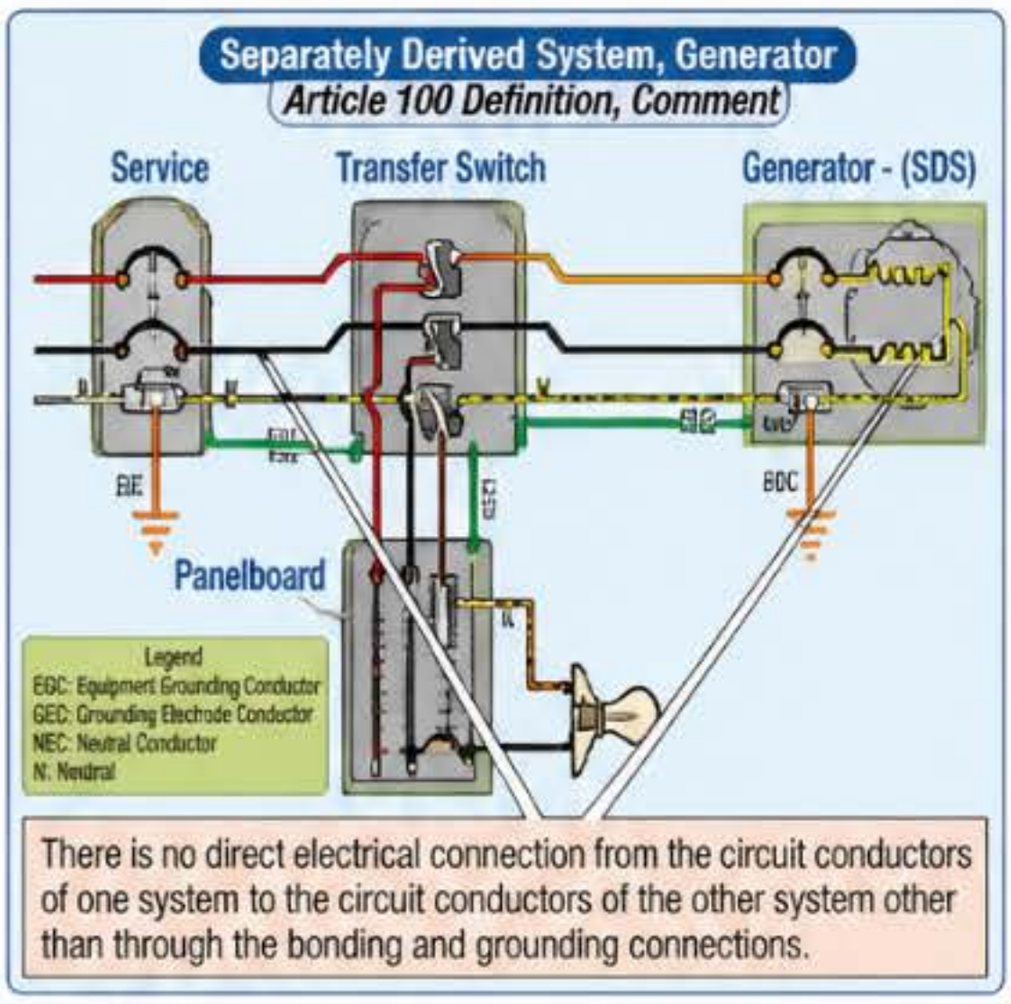


Figure 100–136

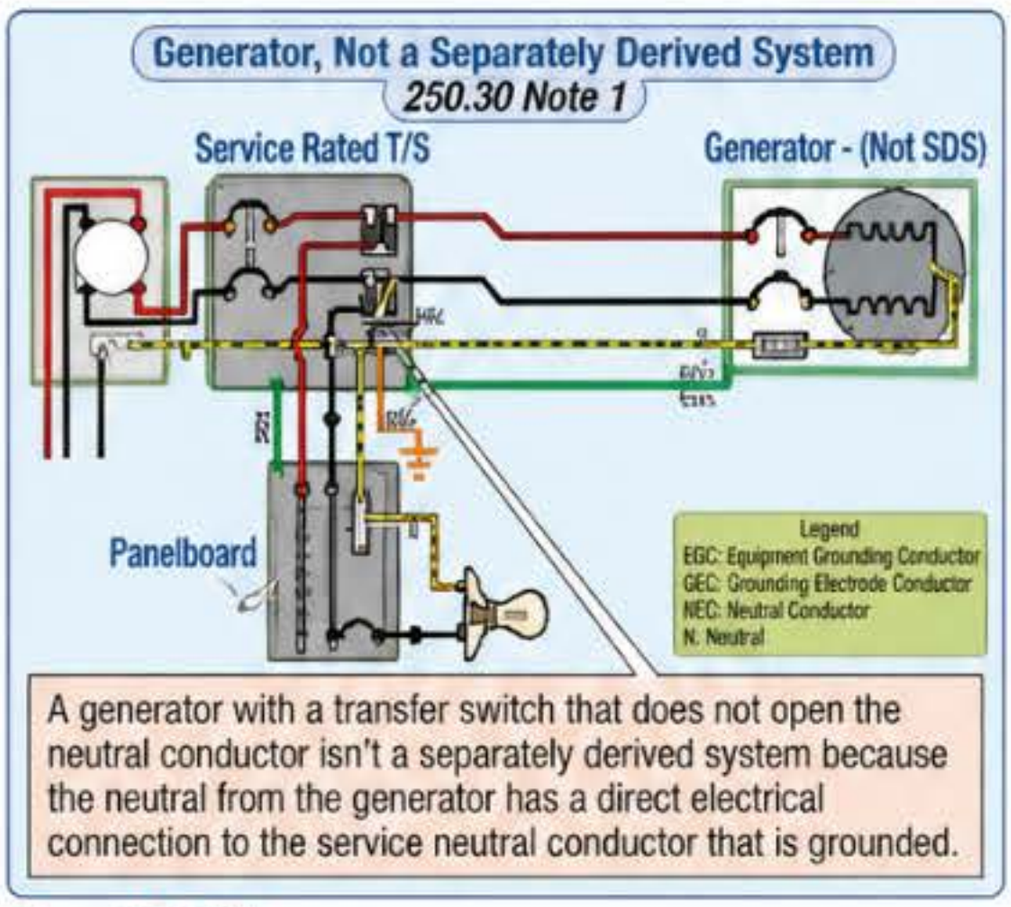


Figure 100–137

Author's Commentary:
Separately derived systems are much more complicated than the Code's definition suggests and understanding them requires additional study. For more information, see 250.30.
— Michael Hamilton

Service [Article 230]. The conductors and equipment connecting the serving electric utility to the wiring system of the premises served. **Figure 100–138**

Author's Commentary:
A service can only be supplied by the serving electric utility and is not covered by the *NEC*. If power is supplied by other than the serving electric utility, the conductors and equipment are part of a feeder and covered by the Code.
— Michael Hamilton

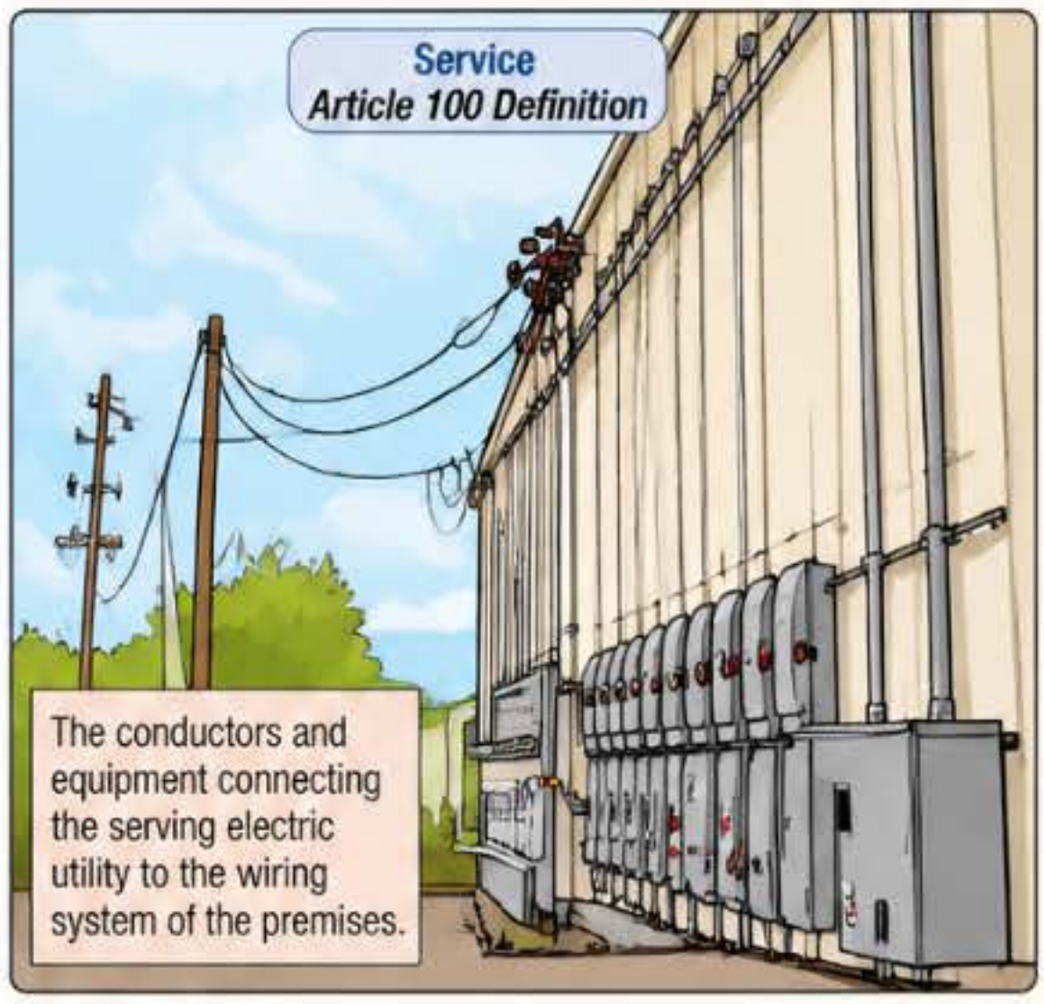


Figure 100–138

- Conductors from UPS systems, solar PV systems, generators, or transformers are not service conductors. See the definitions of "Feeder" and "Service Conductors" in this article.

Service Conductors. The conductors from the serving electric utility service point to the service disconnect. **Figure 100–139**

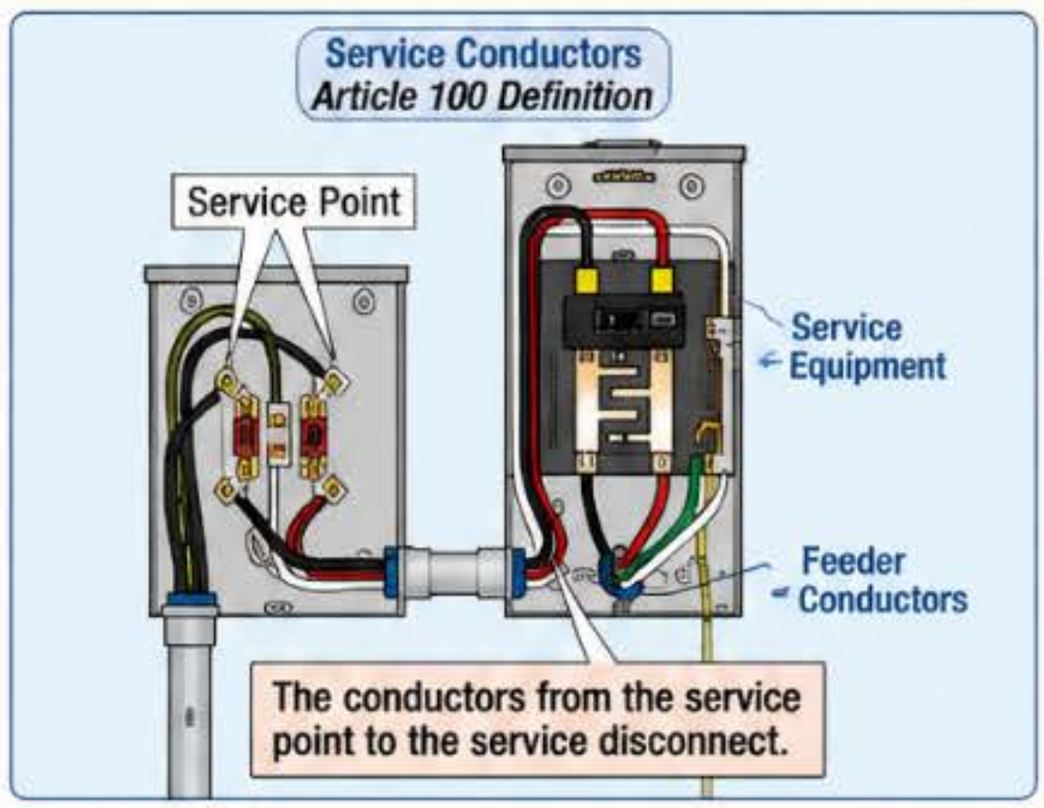


Figure 100–139

Author's Commentary:
Service conductors can include overhead service conductors, overhead service-entrance conductors, and underground service conductors. These conductors are not under the exclusive control of the serving electric utility, which means they are owned by the customer and are covered by the requirements in Article 230.
— Michael Hamilton

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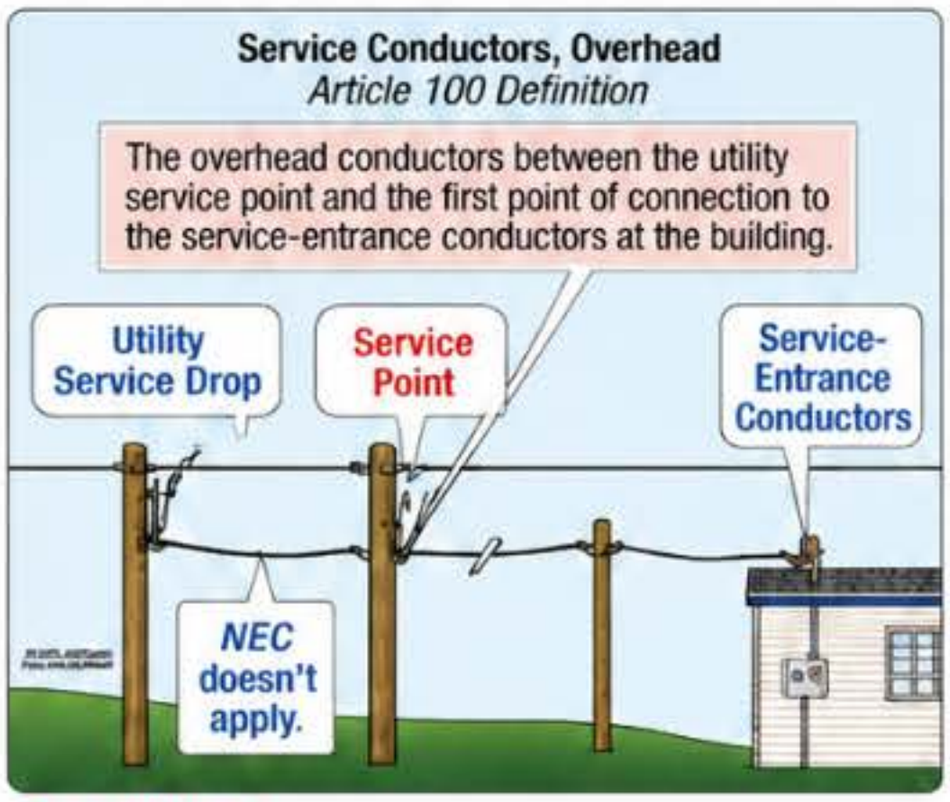
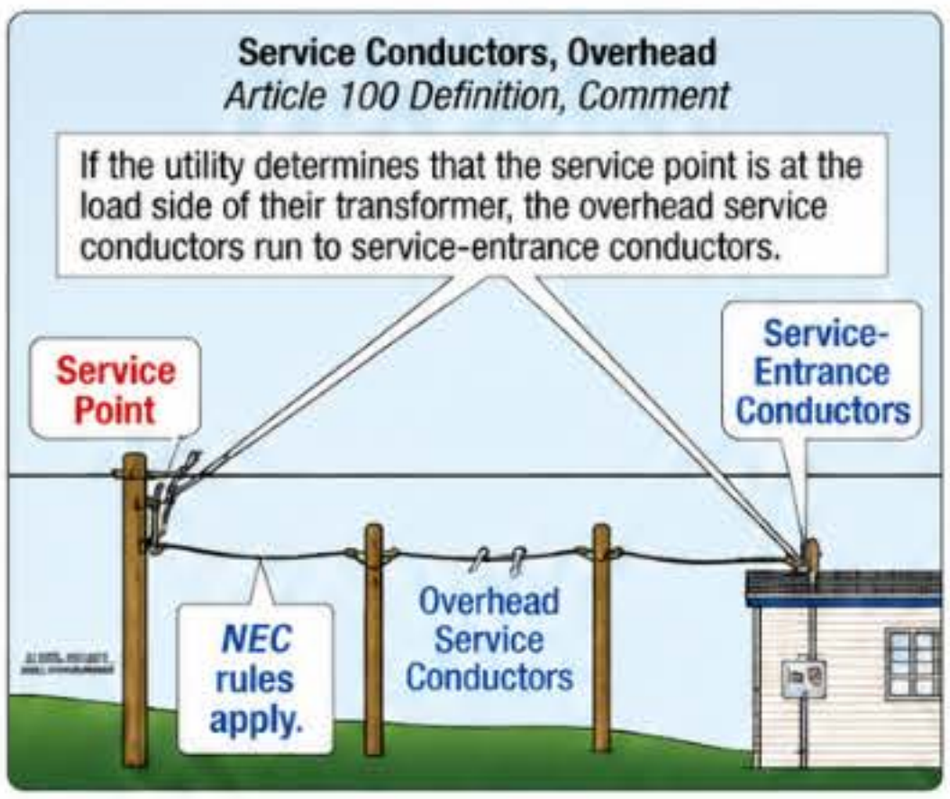
Service Conductors, Overhead (Overhead Service Conductors). Overhead conductors that run between the electric utility's serving point and the first location where the service-entrance conductors connect to the service-entrance conductors at the building. ▸ Figure 100–140



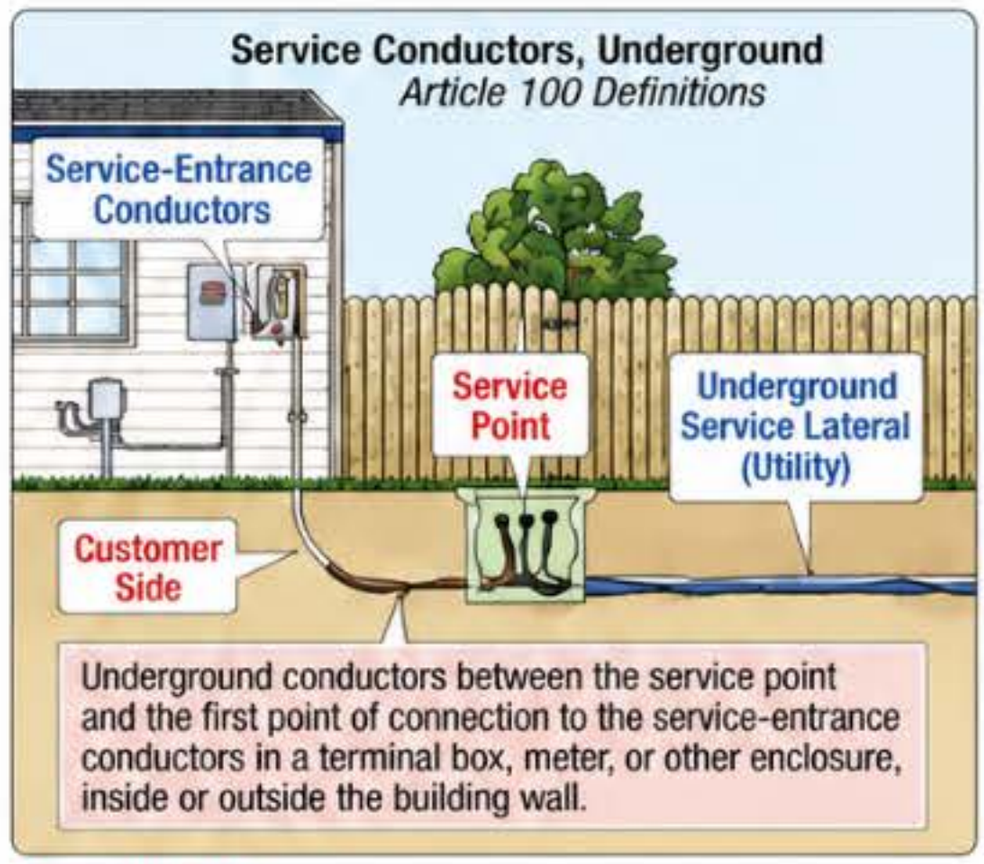
▸ Figure 100–140

Author's Commentary:
The service point is normally determined by the serving utility. If the utility assigns the service point at the load side of their transformer, the overhead service conductors run to the service-entrance conductors.
— Michael Hamilton



▸ Figure 100–141

Service Conductors, Underground (Underground Service Conductors). Underground conductors between the service point and the first point of connection to the service-entrance conductors in a terminal box, meter, or other enclosure; inside or outside the building wall. ▸ Figure 100–142

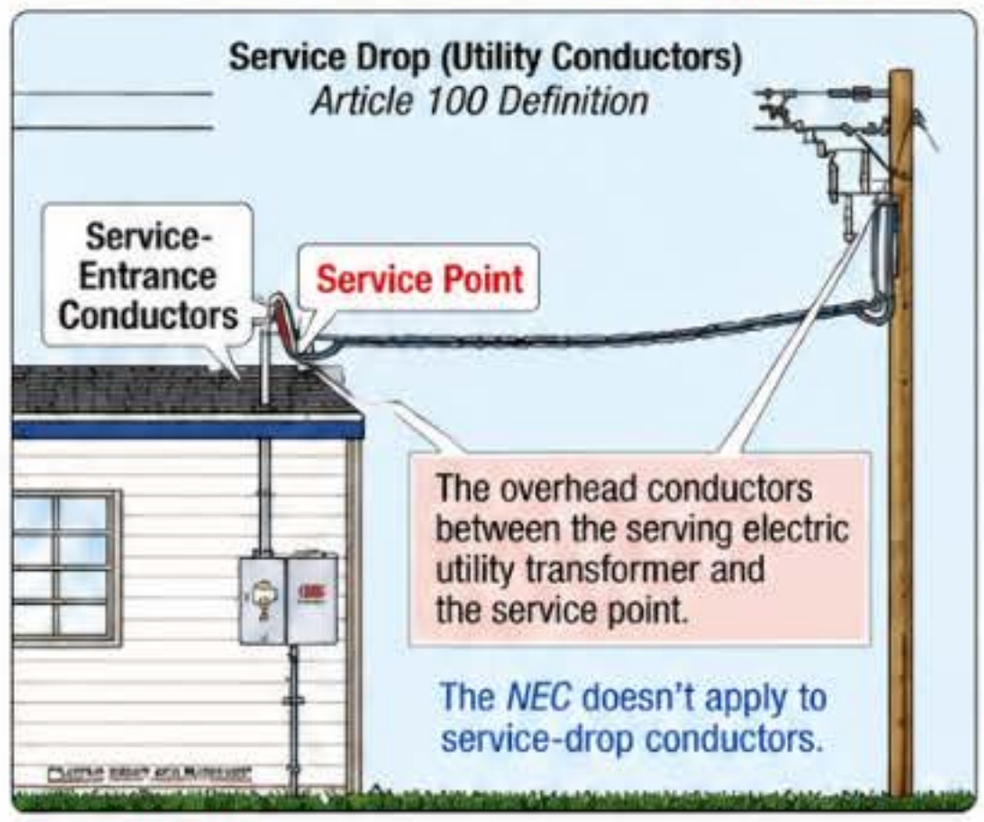


▸ Figure 100–142

Author's Commentary:
Service conductors must comply with Article 230 because they are not under the exclusive control of the serving electric utility.
— Michael Hamilton

Note: Where there is no terminal box, meter, or other enclosure, the point of connection is considered to be the location where the service conductors enter the building.

Service Drop. Utility-owned overhead conductors between the serving electric utility and the service point. ▸ Figure 100–143

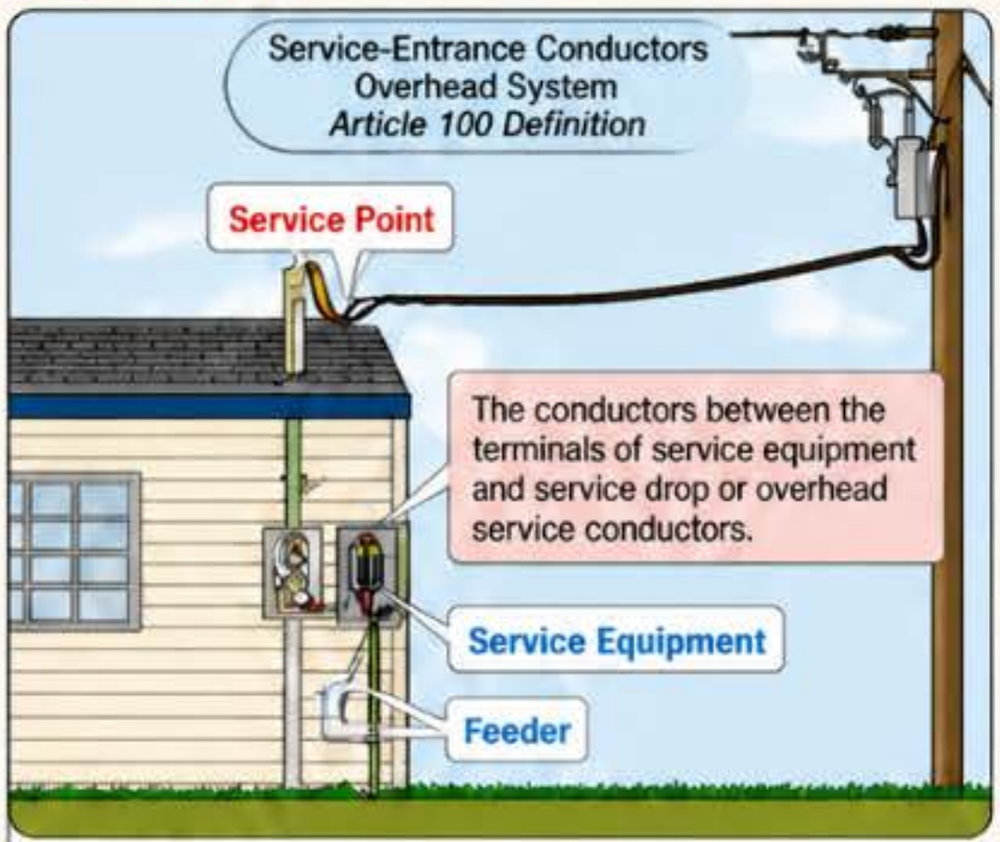


▸ Figure 100–143

Author's Commentary:
The *NEC* does not apply to service drops.
— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

Service-Entrance Conductors, Overhead (Overhead Service-Entrance Conductors). The conductors that run between the utility's terminals at the service disconnect and the service drop or overhead service conductors. ▸ Figure 100–144

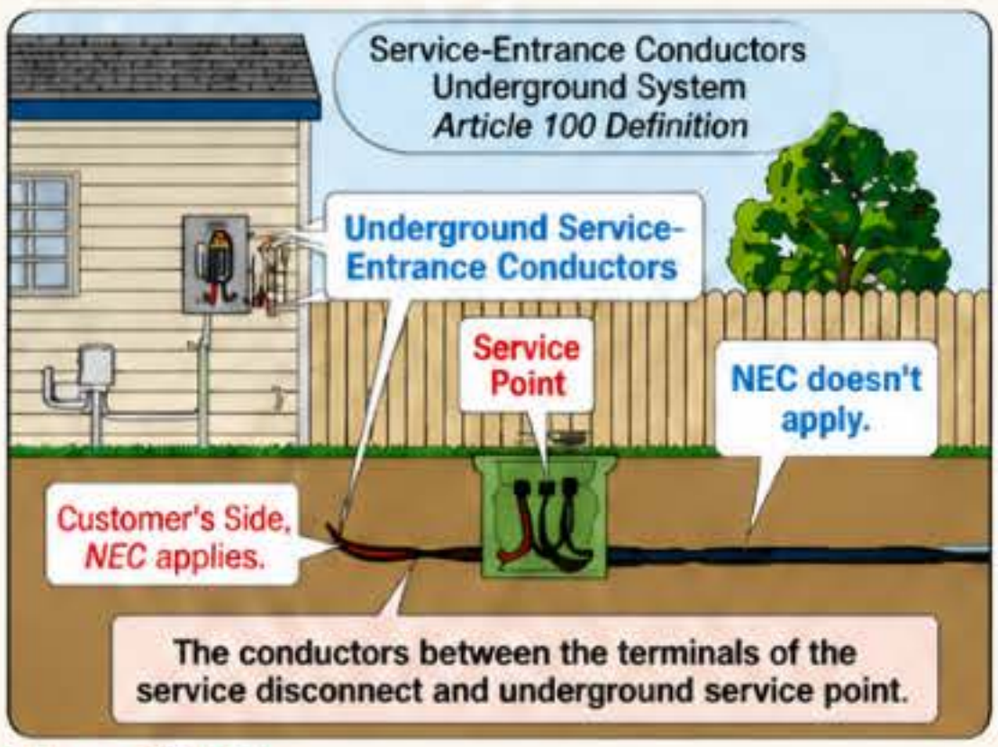


▸ Figure 100–144

Author's Commentary:
Entrance conductors. Because these are overhead service-entrance conductors, they are not under the exclusive control of the serving electric utility.

— *Michael Hamilton*

Service-Entrance Conductors, Underground (Underground Service-Entrance Conductors). These are the conductors that run between the service disconnect and the underground service point. ▸ Figure 100–145



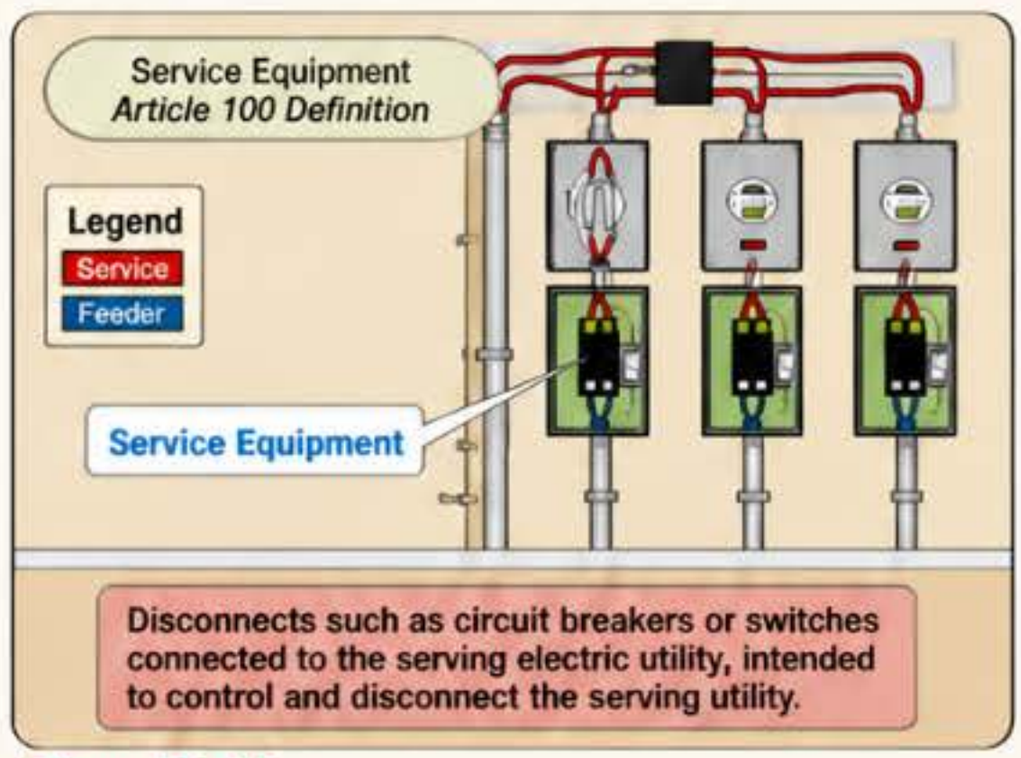
▸ Figure 100–145

Author's Commentary:
Entrance conductors. Because these are overhead service-entrance conductors, they are not under the exclusive control of the serving electric utility.

Author's Commentary:
Underground service-entrance conductors are subject to Article 230 because they remain outside the exclusive control of the serving electric utility.

— *Michael Hamilton*

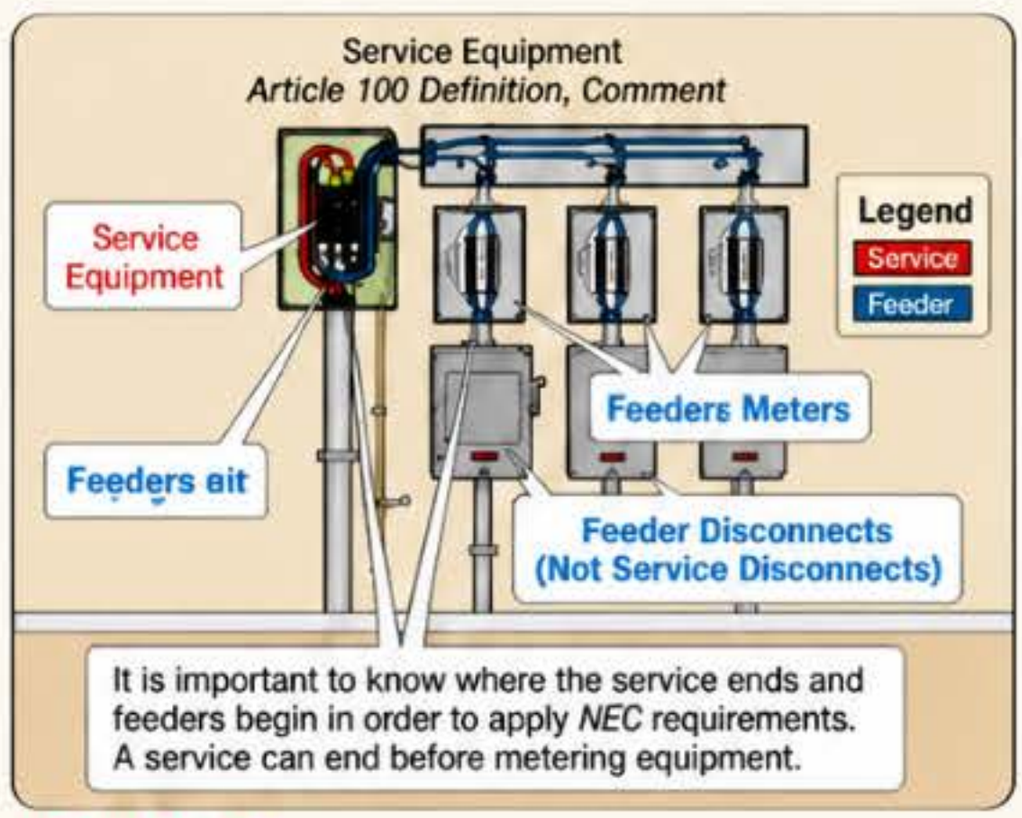
Service Equipment (Service Disconnect). Devices such as circuit breakers or switches that are attached to the serving electric utility system and are intended to control and disconnect the power from the serving electric utility. ▸ Figure 100–146



▸ Figure 100–146

Author's Commentary:
It's important to know where a service begins and where it ends to properly apply the *Code* rules. Sometimes the service ends before the metering equipment.

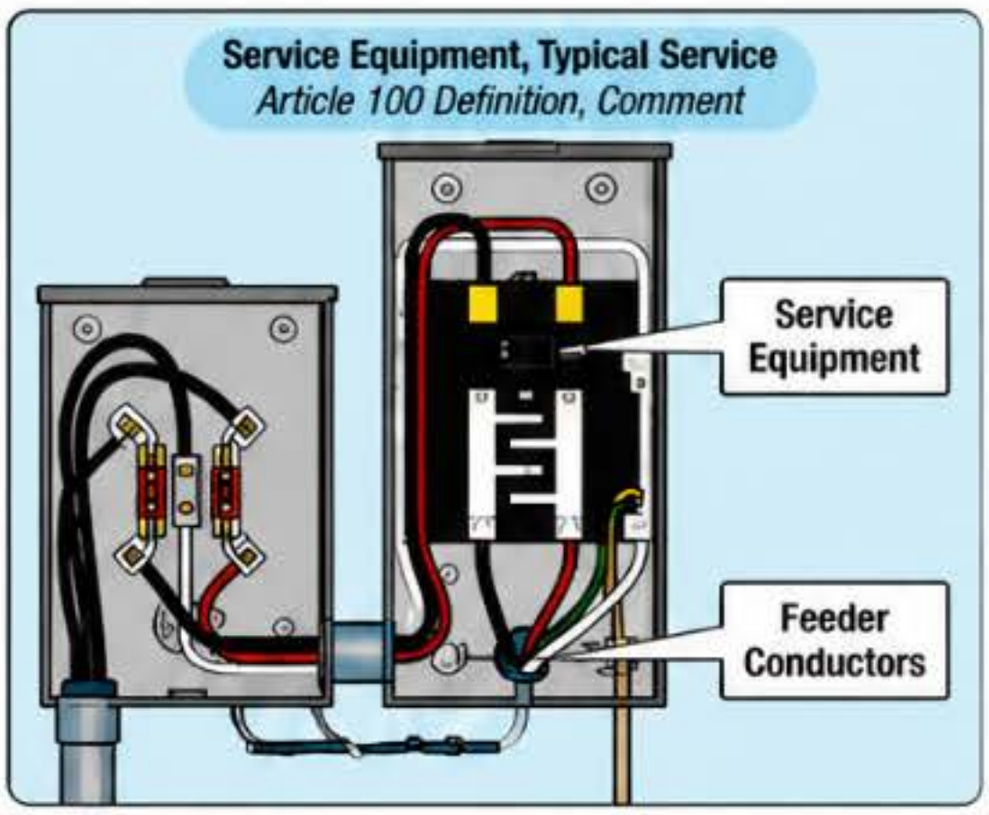
— *Michael Hamilton*



▸ Figure 100–147

Author's Commentary:
Identifying the start and end points of a service is essential for applying the correct *Code* requirements.

— *Michael Hamilton*



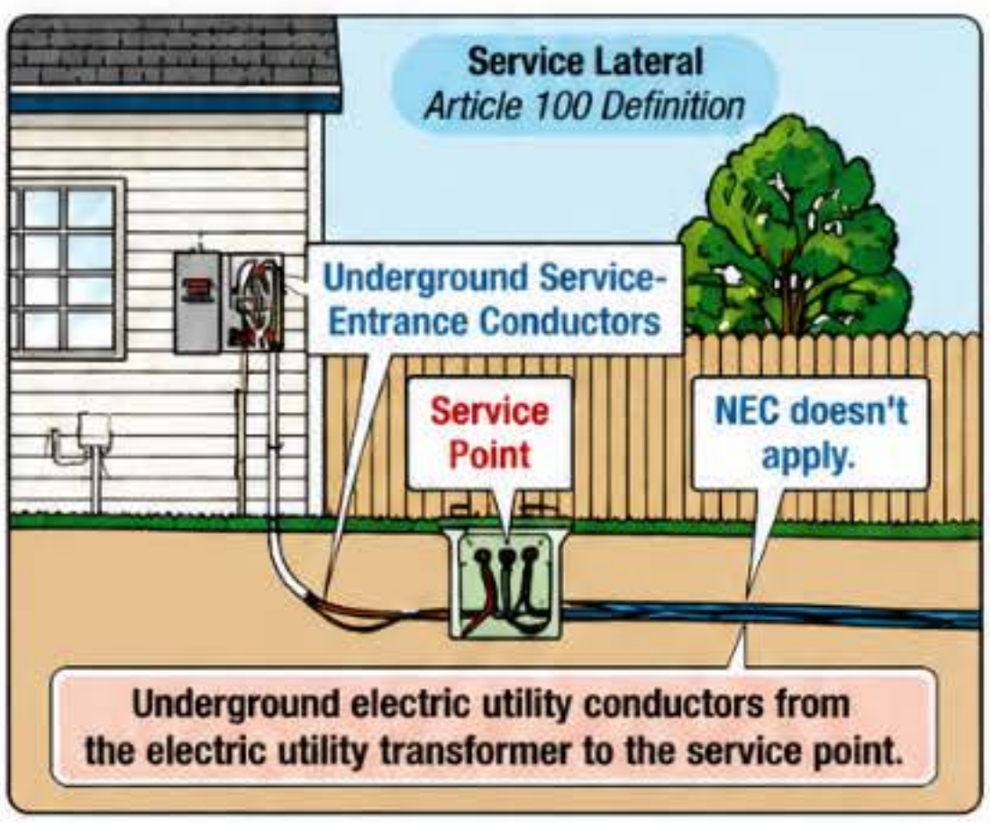
▸ Figure 100–148

Author's Commentary:

- Service equipment is generally described as the "service disconnect" or "service main."
- Meter socket enclosures are not regarded as service equipment [230.66].

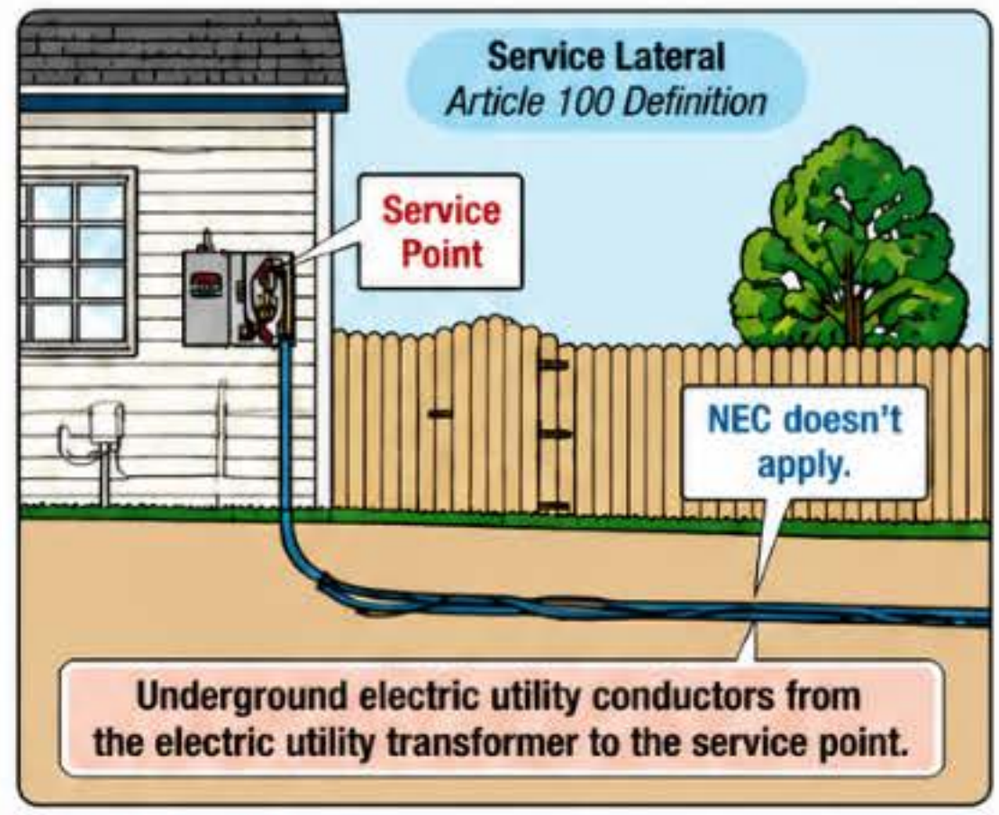
— *Michael Hamilton*

Service Lateral. Utility-owned underground conductors between the serving electric utility transformer and the service point. **Figure 100–149** and **Figure 100–150**

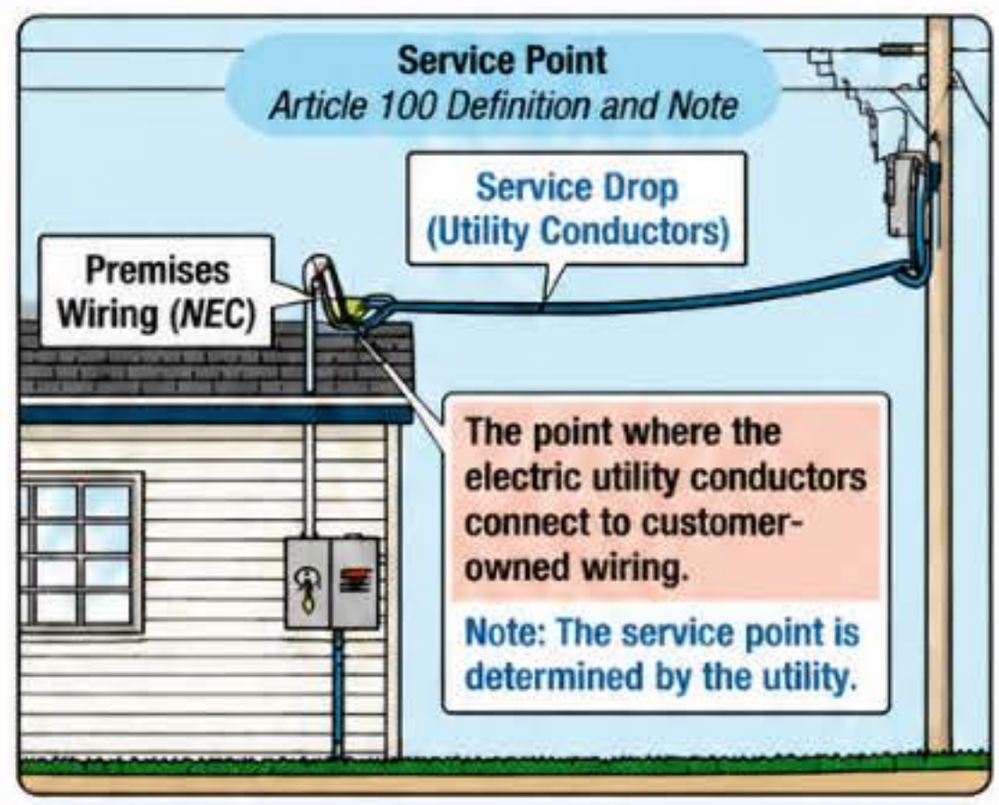


▸ Figure 100–149

Service Point. The point where the serving electric utility conductors connect to customer-owned wiring. **Figure 100–151**



▸ Figure 100–150



▸ Figure 100–151

Author's Commentary:

- The service point is usually chosen by the serving utility and can differ across utilities and occupancy types.
- For utility-owned transformers, this point occurs at the serving utility's transformer secondary terminals, at the service drop, or at the meter socket enclosure—based on where their conductors terminate. **Figure 100–152**
- For customer-owned transformers, the service point is at the termination of the serving utility conductors, which is typically at the utility's pole. **Figure 100–153**

— *Michael Hamilton*

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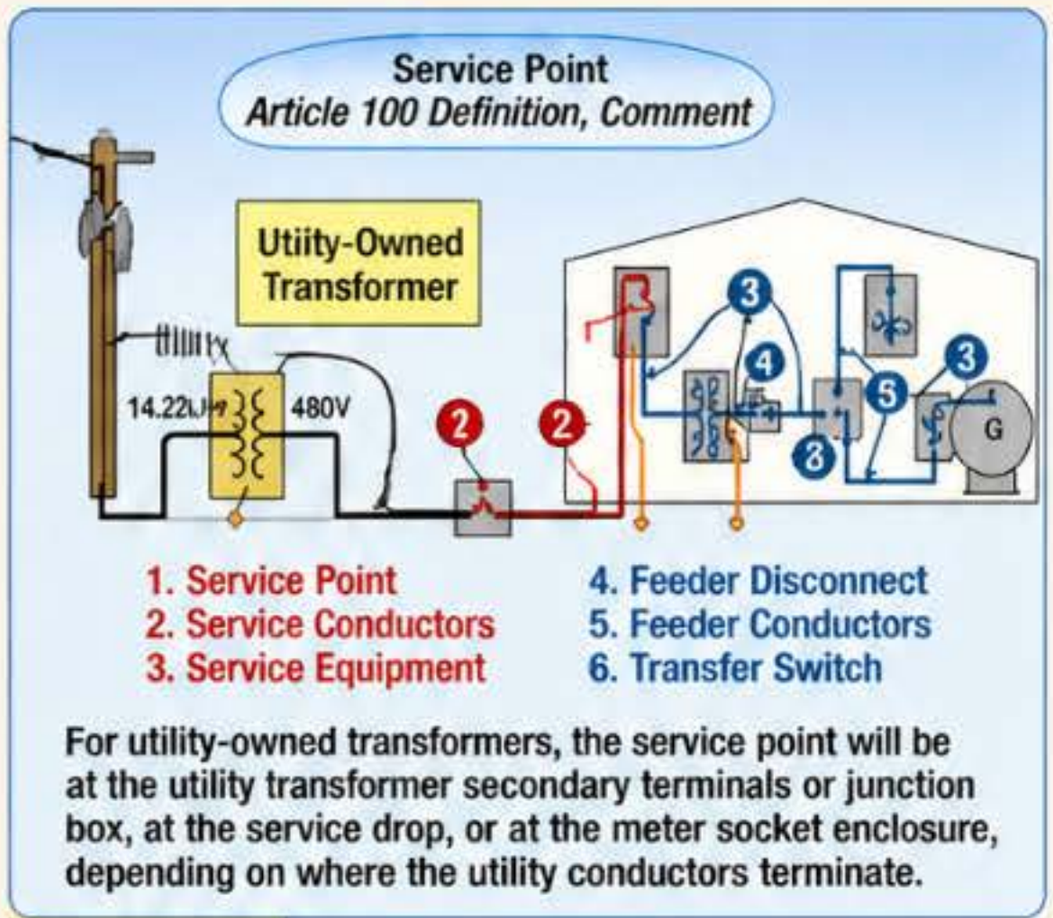

Figure 100–152

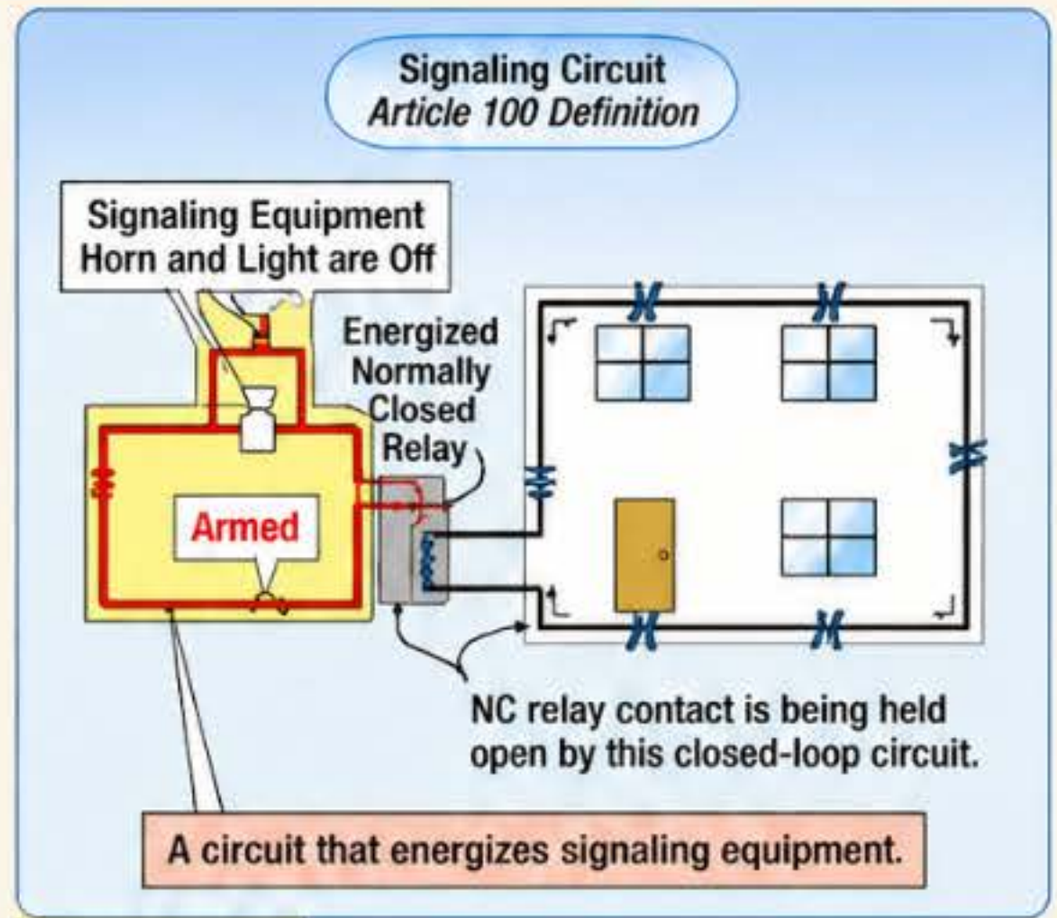

Figure 100–154

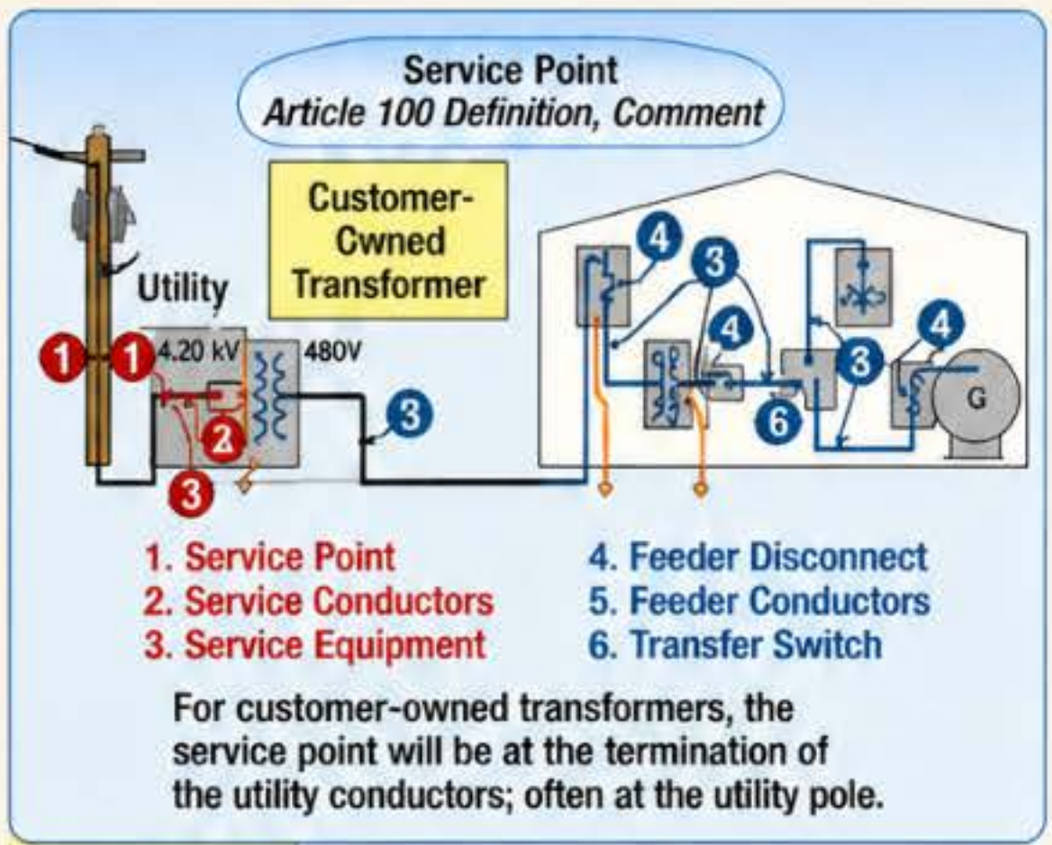

Figure 100–153

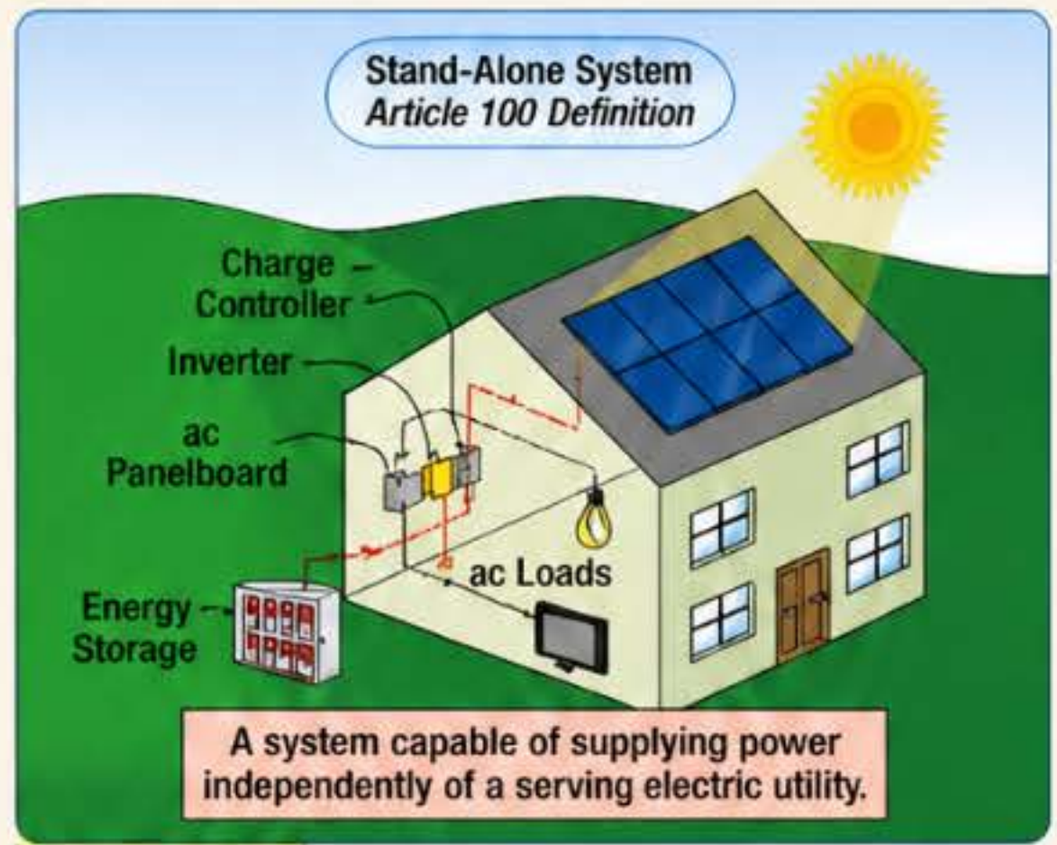

Figure 100–155

Short-Circuit Current Rating. The prospective symmetrical fault current at a nominal voltage to which electrical equipment can be connected without sustaining damage exceeding defined acceptance criteria.

Signaling Circuit [Article 725]. A circuit that energizes signaling equipment. ▸**Figure 100–154**

Special Permission. Written consent from the authority having jurisdiction.

Author's Commentary:

See the definition of "Authority Having Jurisdiction."

— Michael Hamilton

Stand-Alone System. A system capable of supplying power independently of a serving electric utility. ▸**Figure 100–155**

Author's Commentary:

Although stand-alone systems can operate independently of the serving electric utility, they may include a connection to the serving electric utility for use when not operating in stand-alone mode ("island mode").

— Michael Hamilton

Structure. That which is built or constructed, other than equipment. ▸**Figure 100–156**

Surge-Protective Device. A protective device intended to limit transient voltages by diverting or limiting surge current and preventing its continued flow while remaining capable of repeating these functions. ▸**Figure 100–157** and ▸**Figure 100–158**

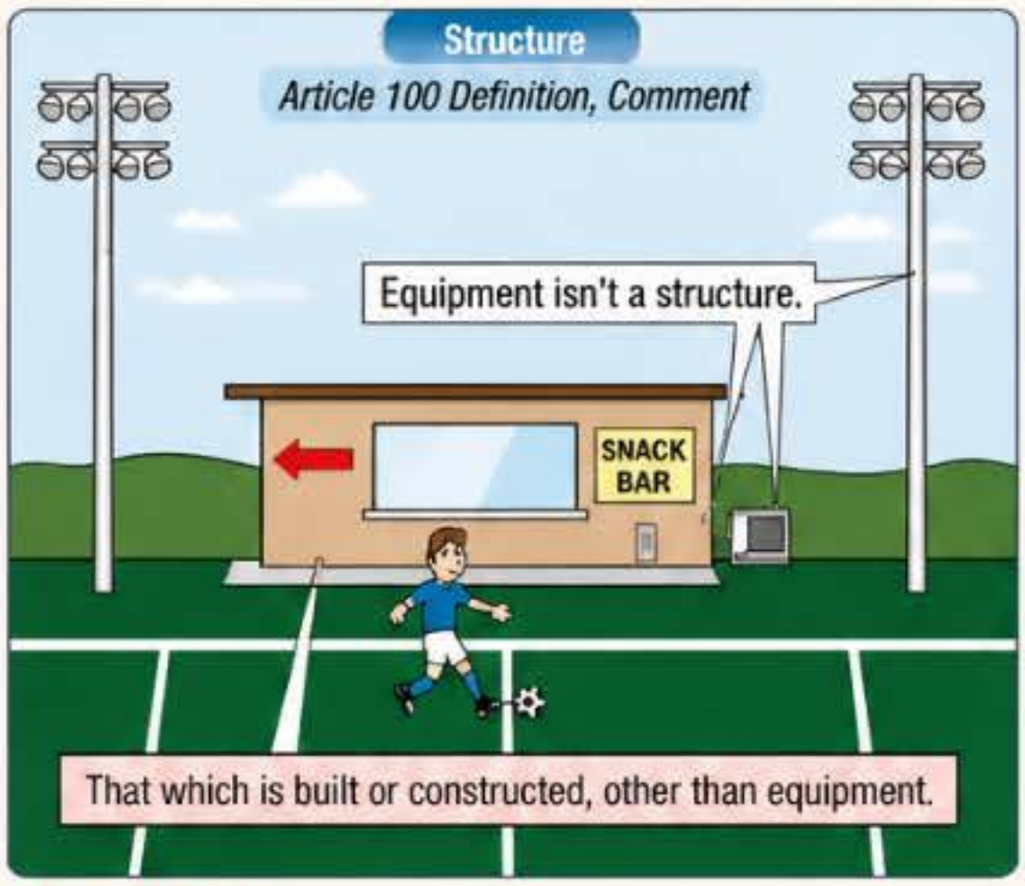

Figure 100–156

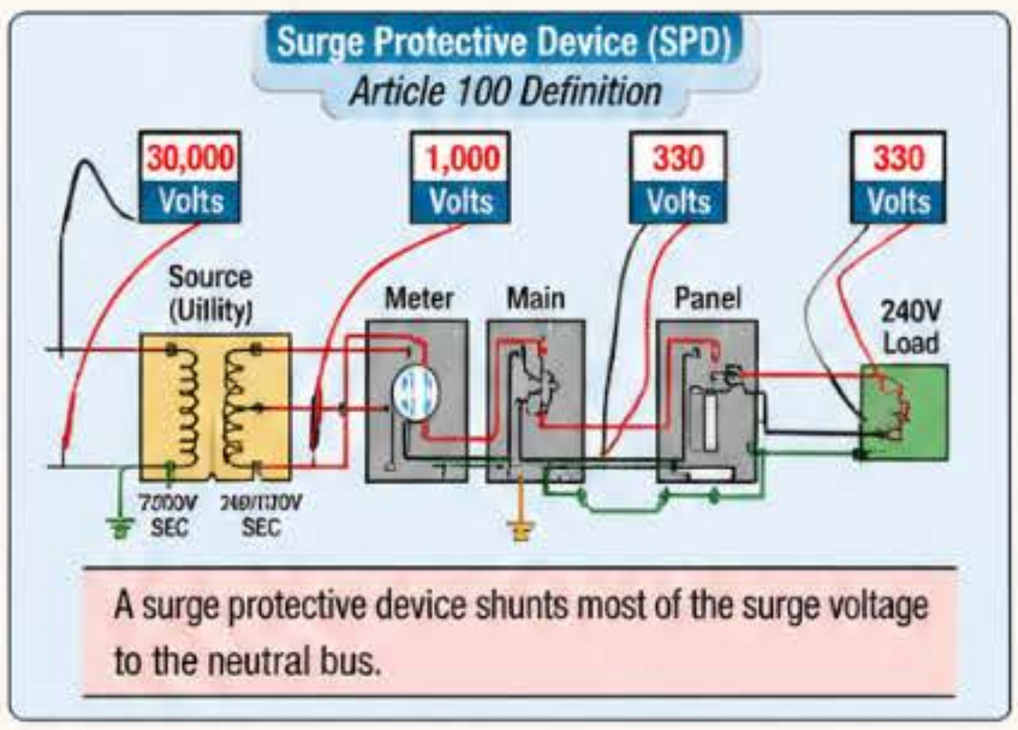

Figure 100–157

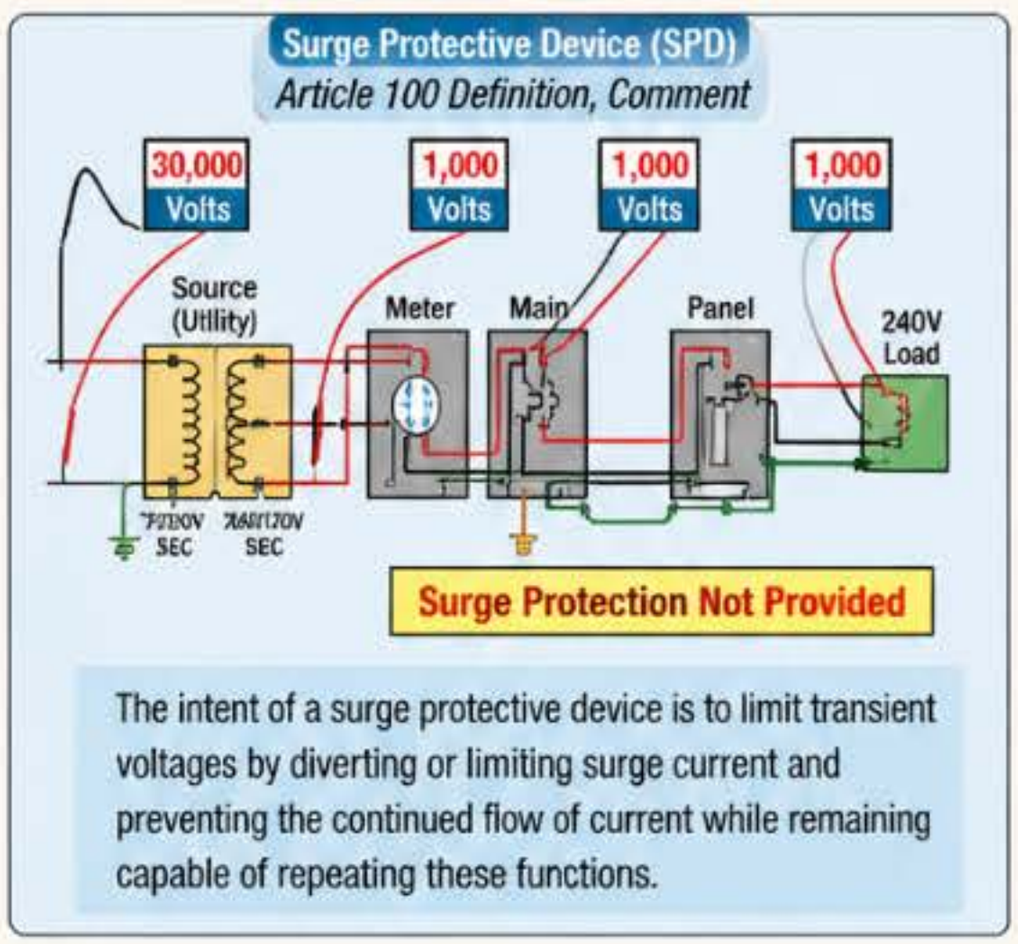

Figure 100–158

Type 1. A permanently connected surge protective device listed for installation at or ahead of the service disconnect. Figure 100–159

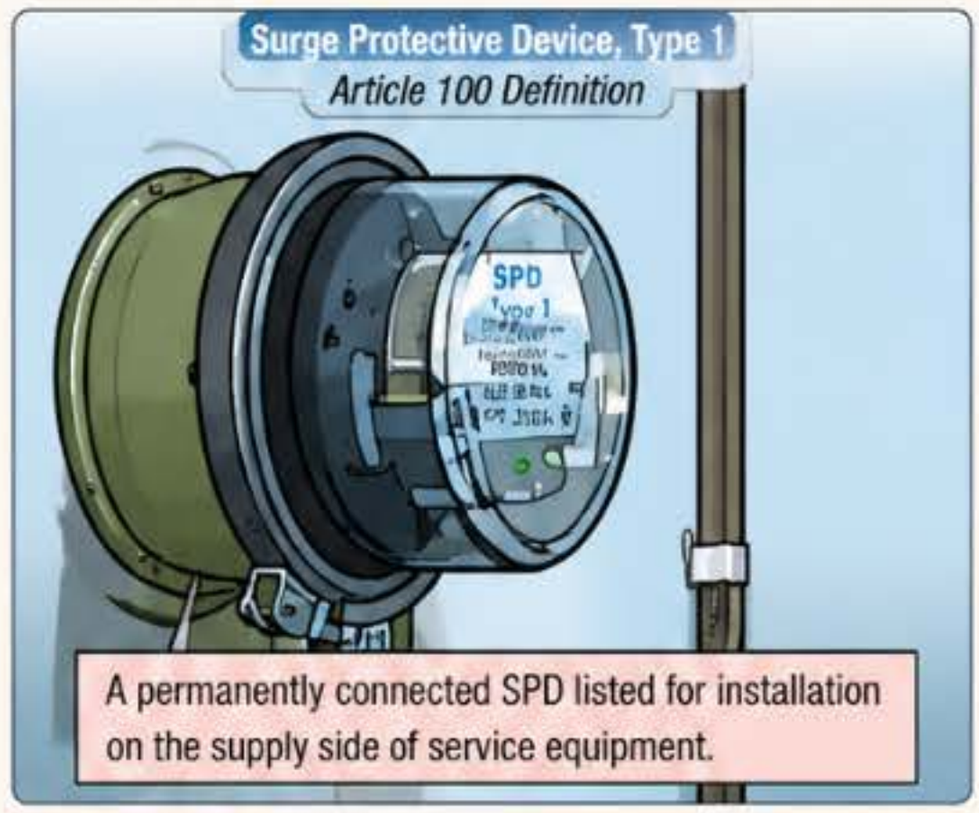

Figure 100–159

Type 2. A permanently connected surge protective device listed for installation on the load side of the service disconnect. Figure 100–160

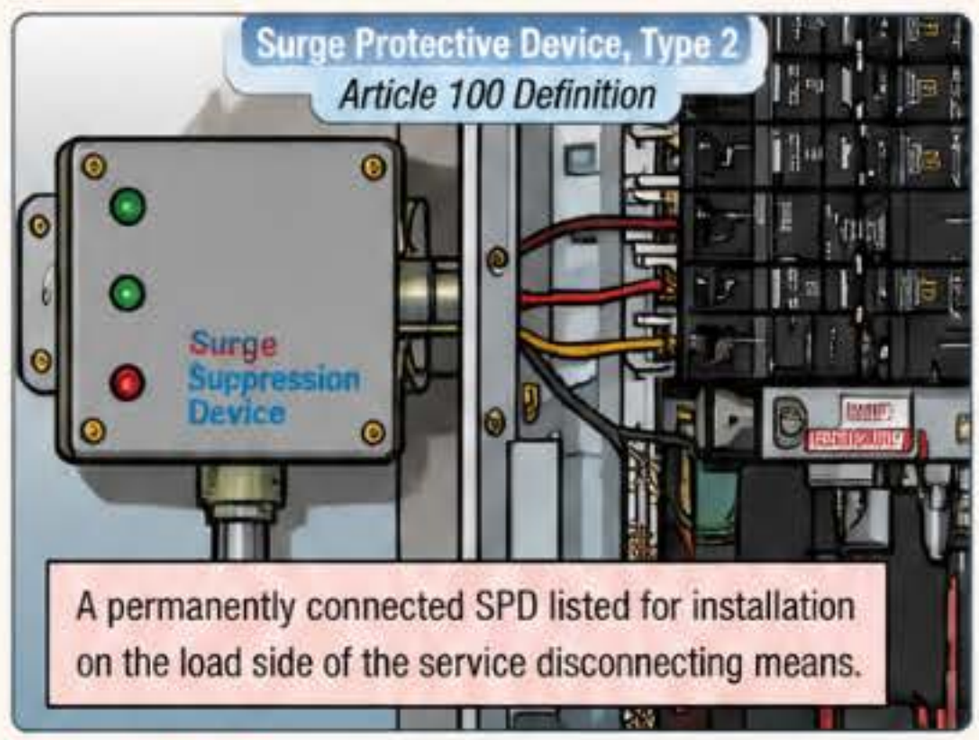

Figure 100–160

Type 3. A surge protective device listed for installation on branch circuits. Figure 100–161

Author's Commentary:

- Type 3 surge protective devices can be placed anywhee on the load side of branch-circuit overcurrent protection up to the equipment served, provided there is a conductor at least 30 inches in length between the connection and the service or transformer.

— Michael Hamilton

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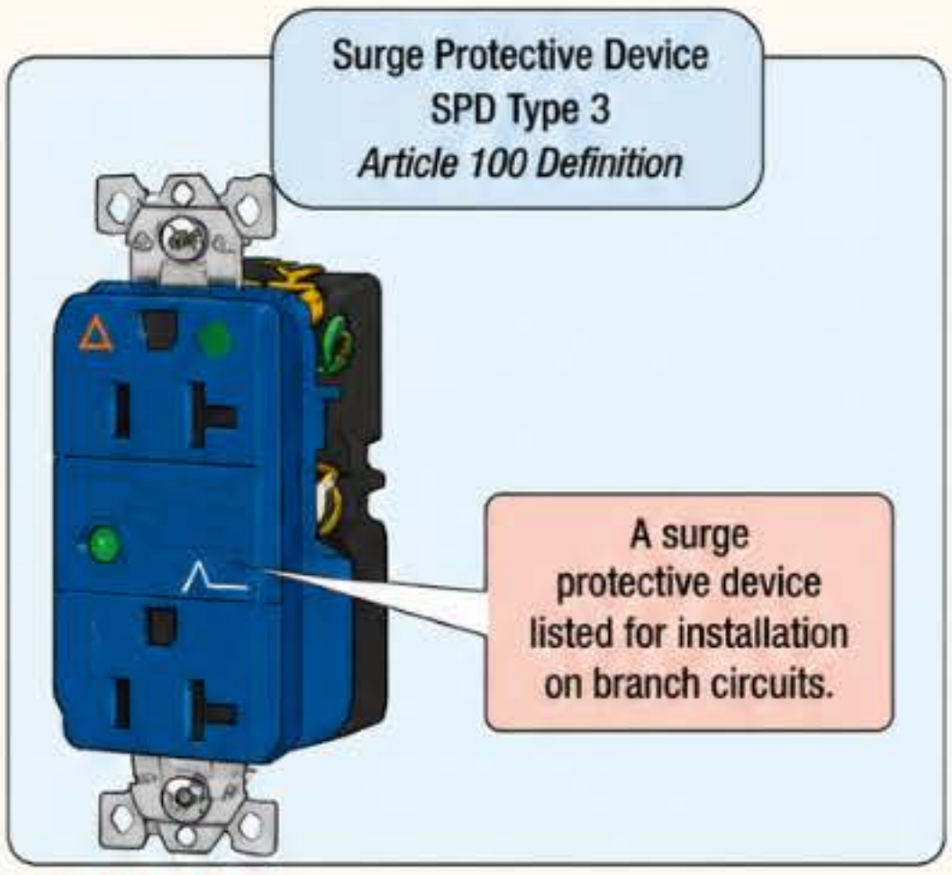


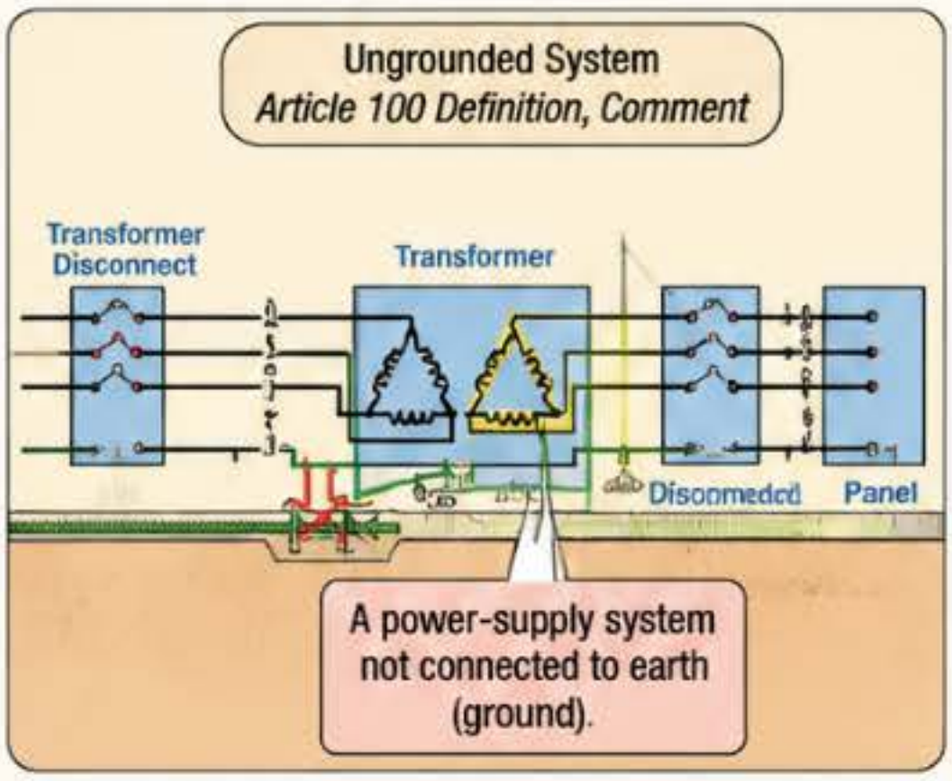
▶ Figure 100–161

Type 4. A component surge protective device which includes those installed in receptacles and relocatable power taps (power strips).

Note: For further information, see UL 1449, *Standard for Surge Protective Devices.*

Switch, General-Use Snap (General-Use Snap Switch). A switch constructed to be installed in a device box or a box cover.

Ungrounded System. A power-supply system not connected to earth (ground). **Figure 100–162**



▶ Figure 100–162

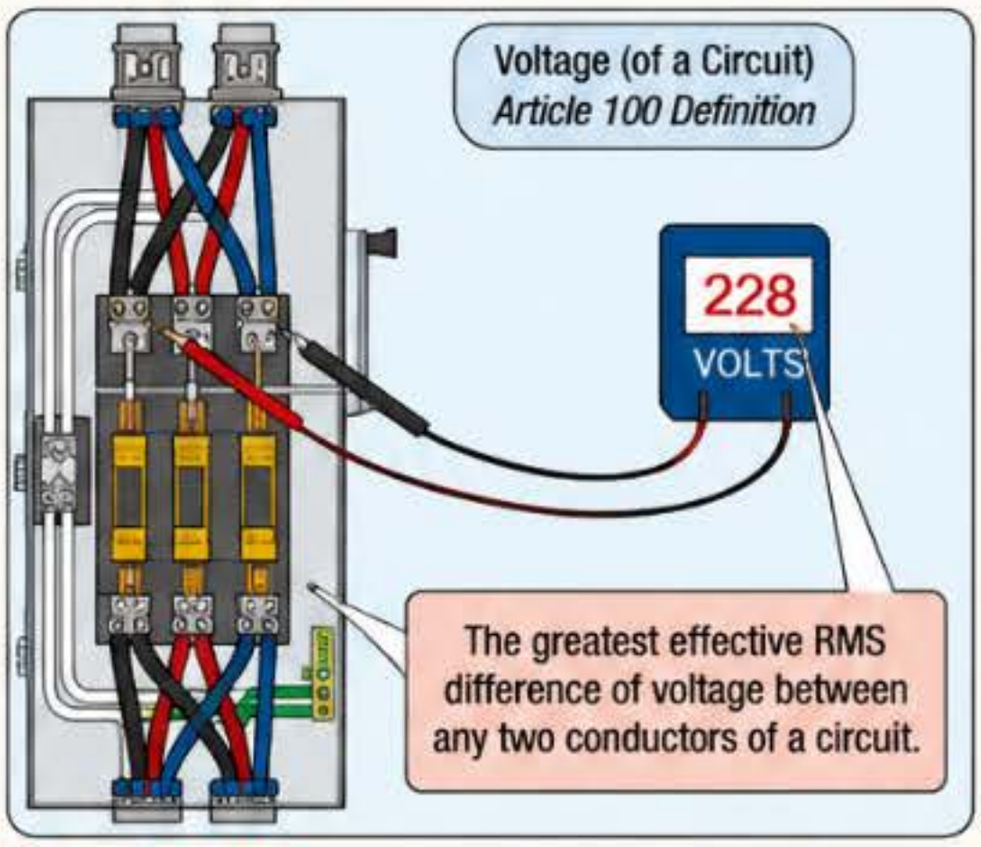
Author's Commentary:

- An electrical system may be ungrounded, however the enclosure must still be connected to Earth [250.4(B)].

— Michael Hamilton

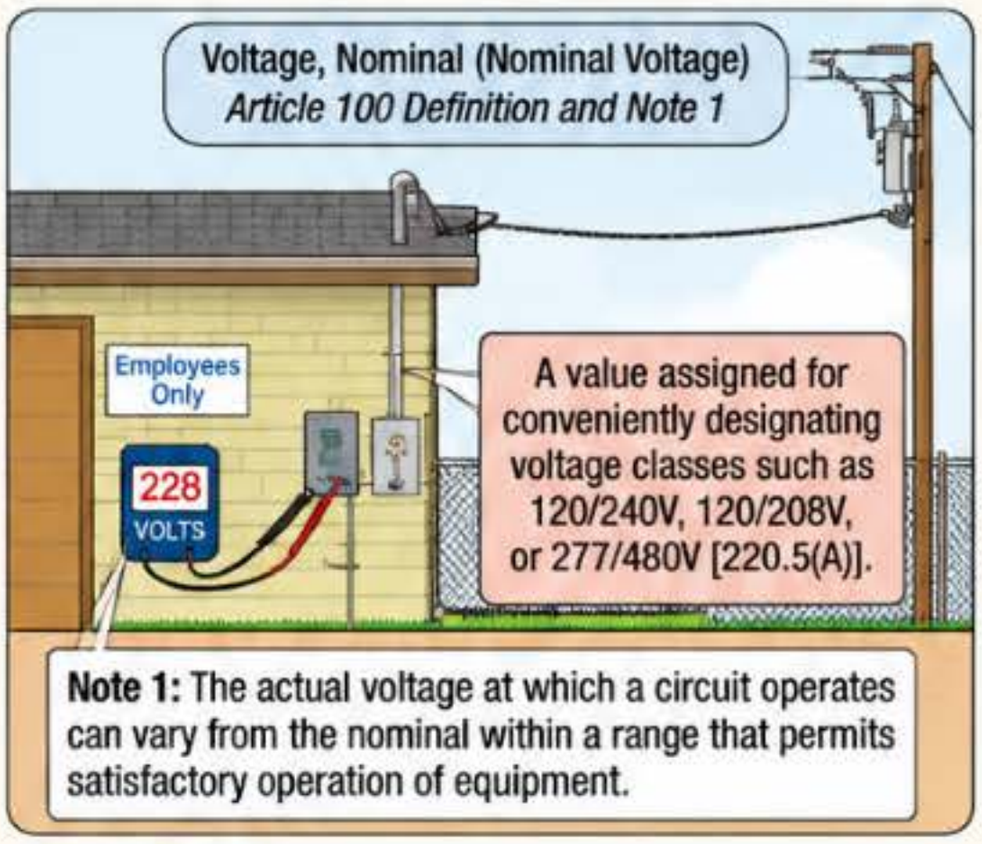
Utilization Equipment. Equipment that utilizes electricity for electronic, electromechanical, chemical, heating, lighting, or similar purposes.

Voltage of a Circuit. The greatest effective root-mean-square (RMS) difference of voltage between any two conductors of the circuit. **Figure 100–163**



▶ Figure 100–163

Voltage, Nominal (Nominal Voltage). A value assigned for conveniently designating voltage classes. Examples are 120/240V, 120/208V, or 277/480V [220.5(A)]. **Figure 100–164**



▶ Figure 100–164

Note 1: The actual voltage at which a circuit operates may vary from the nominal within a range that permits satisfactory operation of equipment.

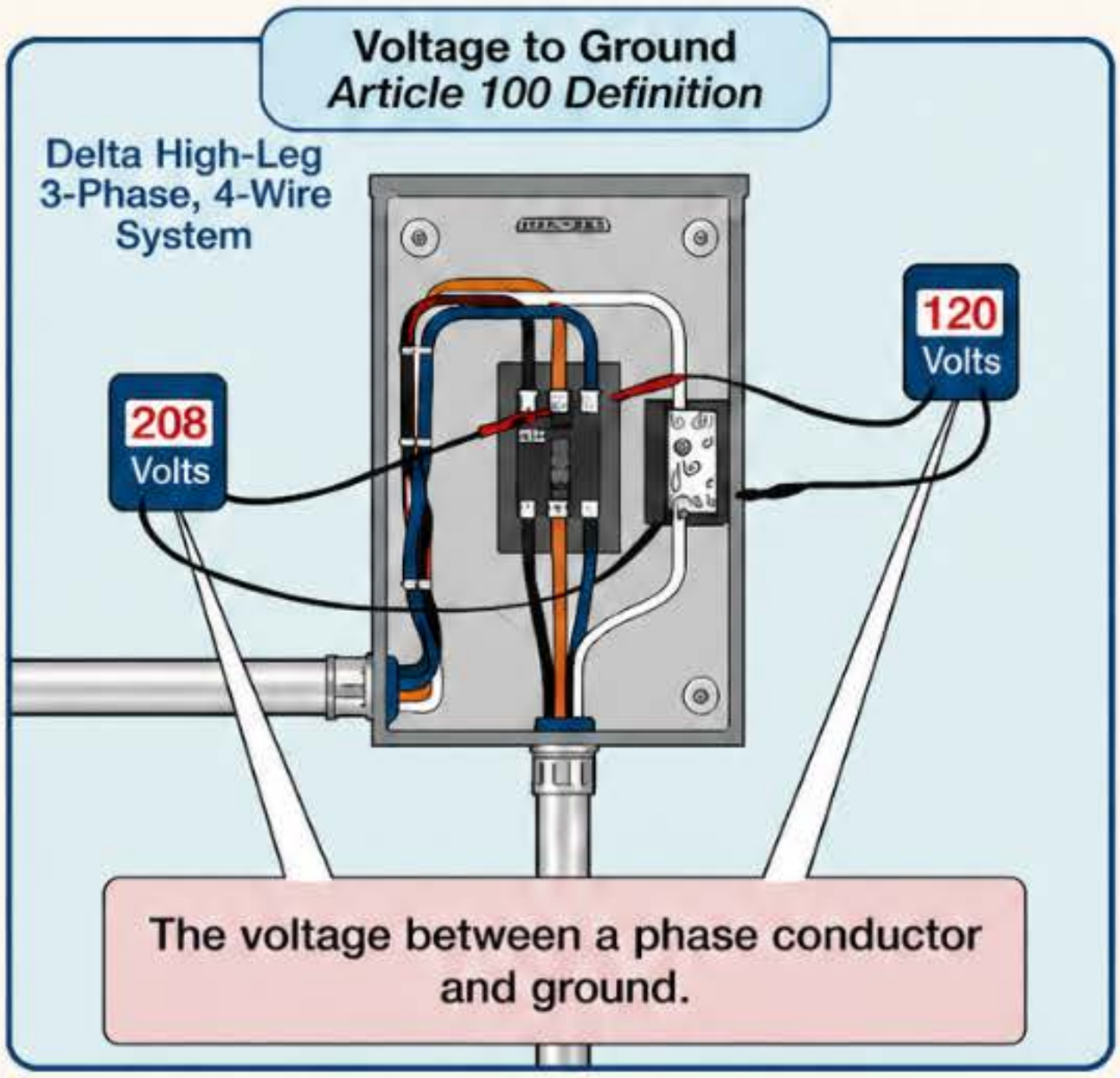
Author's Commentary:

- Typical nameplate voltages for electrical gear include 115V, 200V, 208V, 230V, and 460V. The supply available might be stated at 240V for single-phase, 3-wire systems, yet some equipment carries a lower rating. Equipment must be considered a rated appliance when its nameplate voltage is less than the system voltage.

— *Michael Hamilton*

Note 3: Some battery systems are identified as 48V dc, even when their charging source uses a voltage up to 58V dc.

Voltage to Ground. For grounded systems, this term describes the potential difference between any phase conductor and the grounded (neutral) conductor; in most cases, the neutral serves as the ground reference.



▶ **Figure 100–165**

For ungrounded systems, the maximum electrical potential to earth is the highest root-mean-square (RMS) voltage from any phase conductor.

Watertight. Built to prevent moisture from entering the enclosure under specified testing conditions.

Weatherproof. Built to withstand outdoor exposure without interference to reliable operation.

Author's Commentary:

- Article 100 now begins a "Part III" section titled Hazardous (Classified) Locations. Several definitions were moved from Chapter 5 to this new section.

— *Michael Hamilton*

ARTICLE 110 REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

Introduction to Article 110—Requirements for Electrical Installations

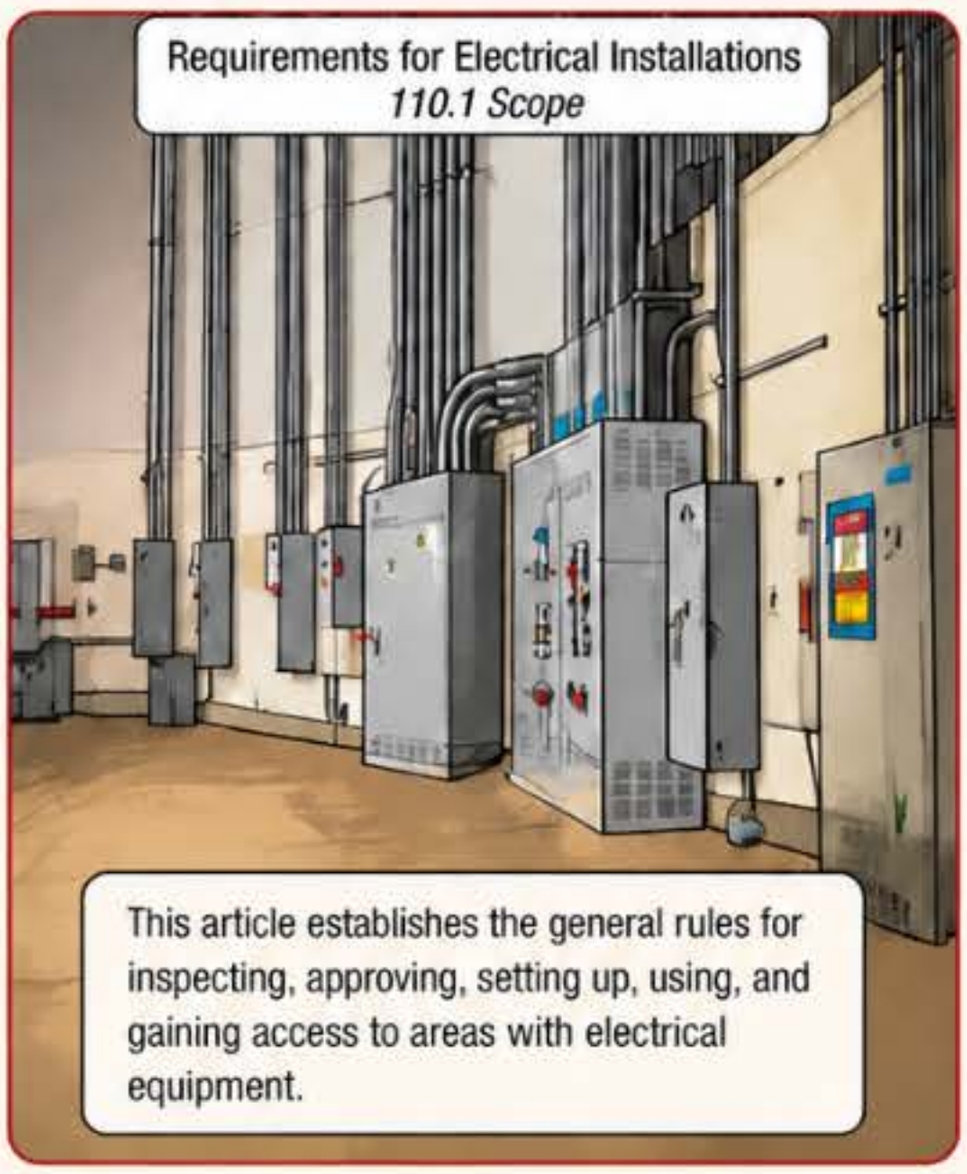
Article 110 explains how the rest of the *NEC* is applied. It lays the groundwork that everything else in the *Code* depends on. To apply the *NEC* correctly, you must first grasp all parts of this article. Its purpose is to safeguard installations, emphasize a bit more on the electrician and how worthwhile and important it is to ensure that installations are both secure for the user and easy to maintain.

Part I General Requirements

110.1 Scope

This article addresses the overall rules for inspecting, approving, installing, using, and gaining access to spaces where electrical equipment is located.

▶ Figure 110–1



▶ Figure 110–1

Note: See Annex J for information regarding ADA accessibility design.

Author's Commentary:

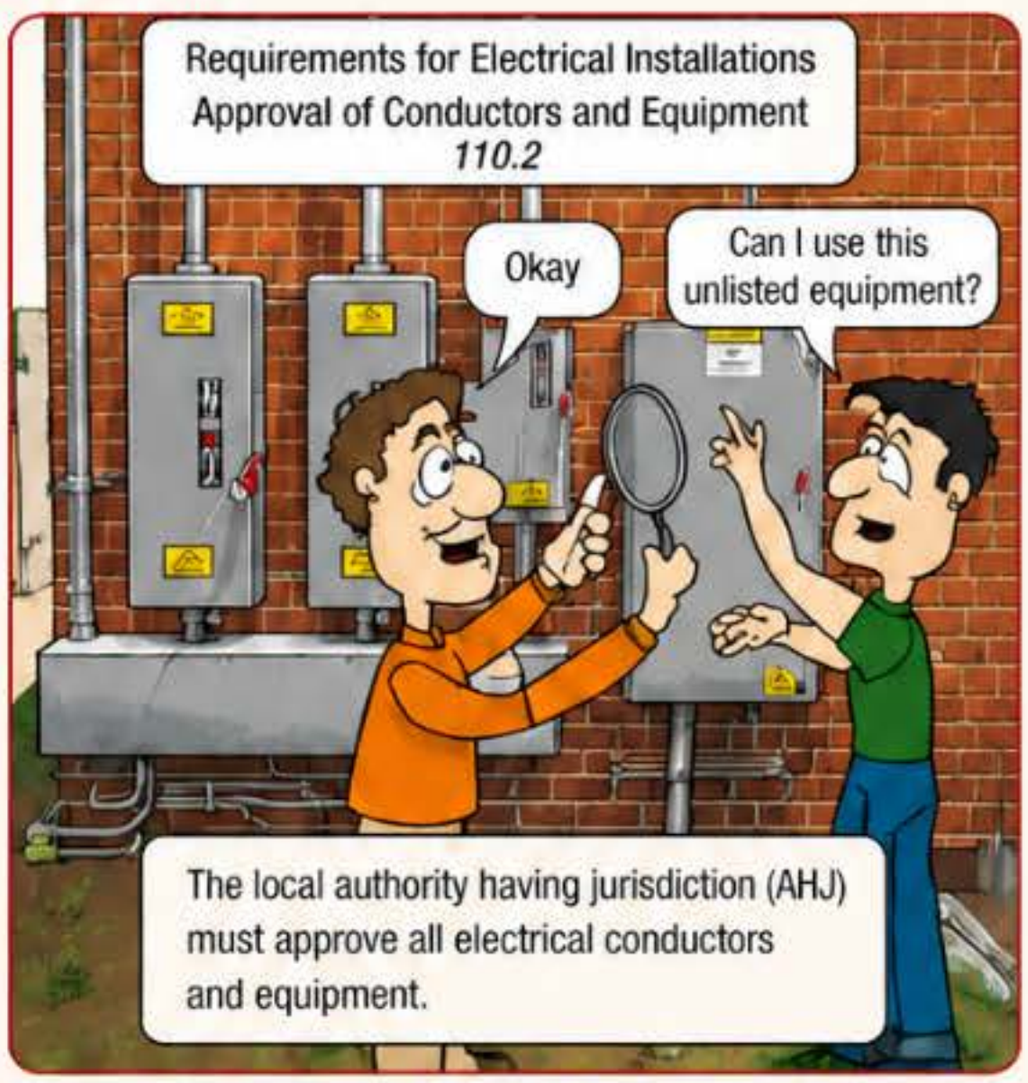
- People with disabilities may need items such as mounting heights for switches and receptacles or specific clearances to objects (like walls) that could protrude from a surface.

— *Michael Hamilton*

110.2 Approval of Conductors and Equipment

The local authority having jurisdiction (AHJ) must approve all electrical conductors and equipment.

▶ Figure 110–2



▶ Figure 110–2

110.3 | Requirements for Electrical Installations

Author's Commentary:

To build a solid understanding of this topic, study 90.4, 90.7, and 110.3, along with the definitions for "Approved," "Identified," "Labeled," and "Listed" in Article 100.

— Michael Hamilton

110.3 Use and Product Listing (Certification) of Equipment

(A) Guidelines for Approval. The authority having jurisdiction must approve equipment. In doing so, consider the following:

(1) Suitability for installation and intended use in accordance with the *NEC*

Note 1: Equipment might be new, reconditioned, refurbished, or remanufactured.

Note 2: Suitability may be shown by a description marked on the item or by a product that indicates its fitness for the application, environment, or use. Special conditions of use or other limitations can be identified on the equipment, in the product instructions, or in private listing and labeling information. Suitability may also be demonstrated by listing or labeling.

(2) Mechanical strength and durability

(3) Wire-bending and connection space

(4) Electrical insulation

(5) Heating effects under all conditions of use

(6) Arcing effects

(7) Classification by type, size, voltage, current capacity, and specific use

(8) Other factors contributing to the practical safegurarding of people and property in contact with the equipment

(B) Installation and Use. Equipment that is listed, labeled, or both must be installed and used according to all instructions included in the listing or labeling. ▶ **Figure 110-3**

(C) Product Listing. Product testing, evaluation, and listing must be performed by a recognized, qualified testing laboratory in accordance with standards that ensure effective safety compliance with the *NEC*.

Note: OSHA recognizes qualified electrical testing laboratories that provide product certification that meets their electrical standards.

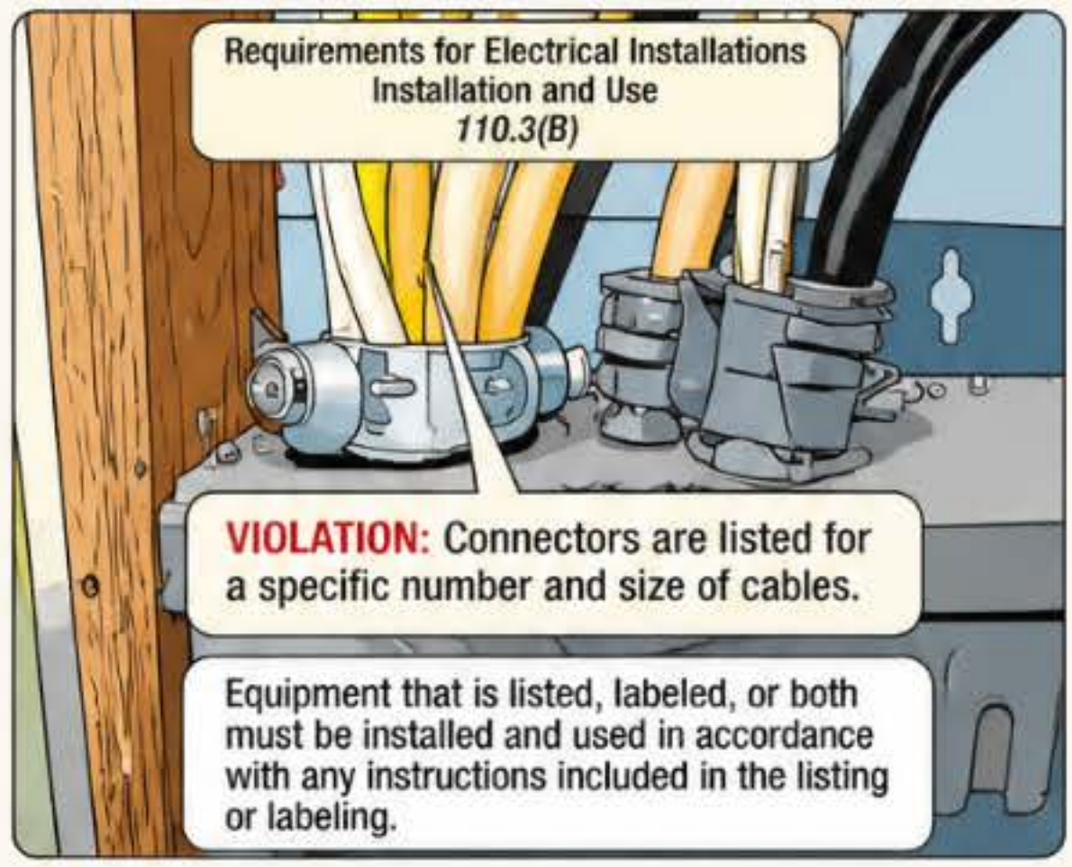


Figure 110-3

110.4 Voltage Rating of Electrical Equipment

The circuit nominal system voltage is not permitted to be greater than the rating of the equipment. ▶ **Figure 110-4**

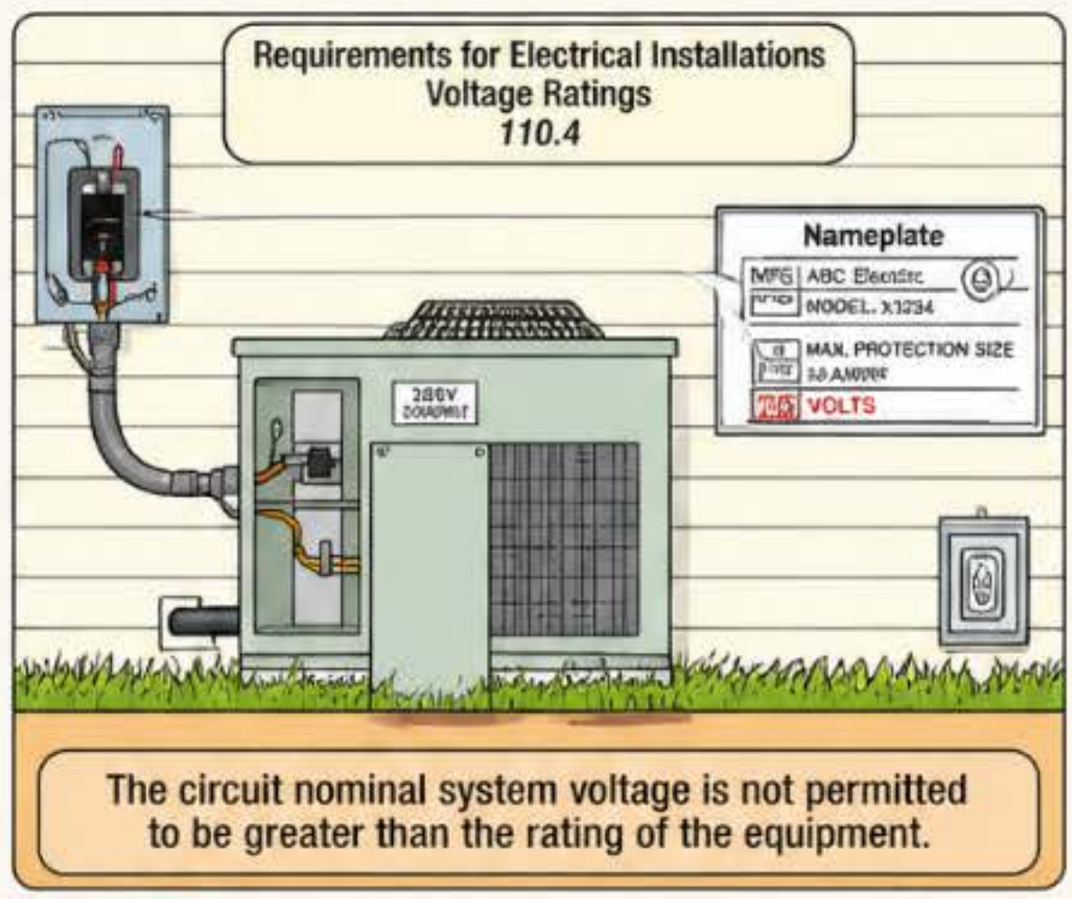


Figure 110-4

110.5 Conductor Material

Conductors must be copper, aluminum, or copper-clad aluminum unless otherwise provided in this *Code*, and when the conductor material is not specified in a rule, the sizes given in the *NEC* are based on a copper conductor. ▶ **Figure 110-5**

REQUIREMENTS FOR ELECTRICAL INSTALLATIONS 110.8

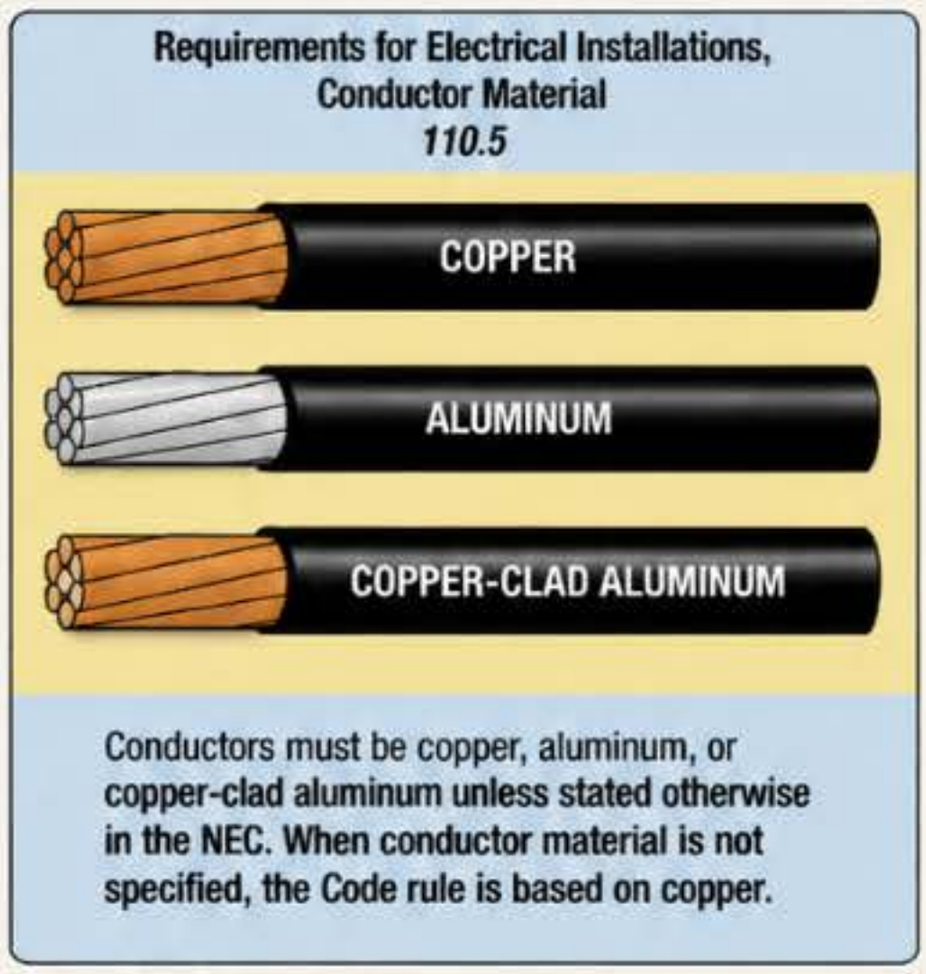


Figure 110-5

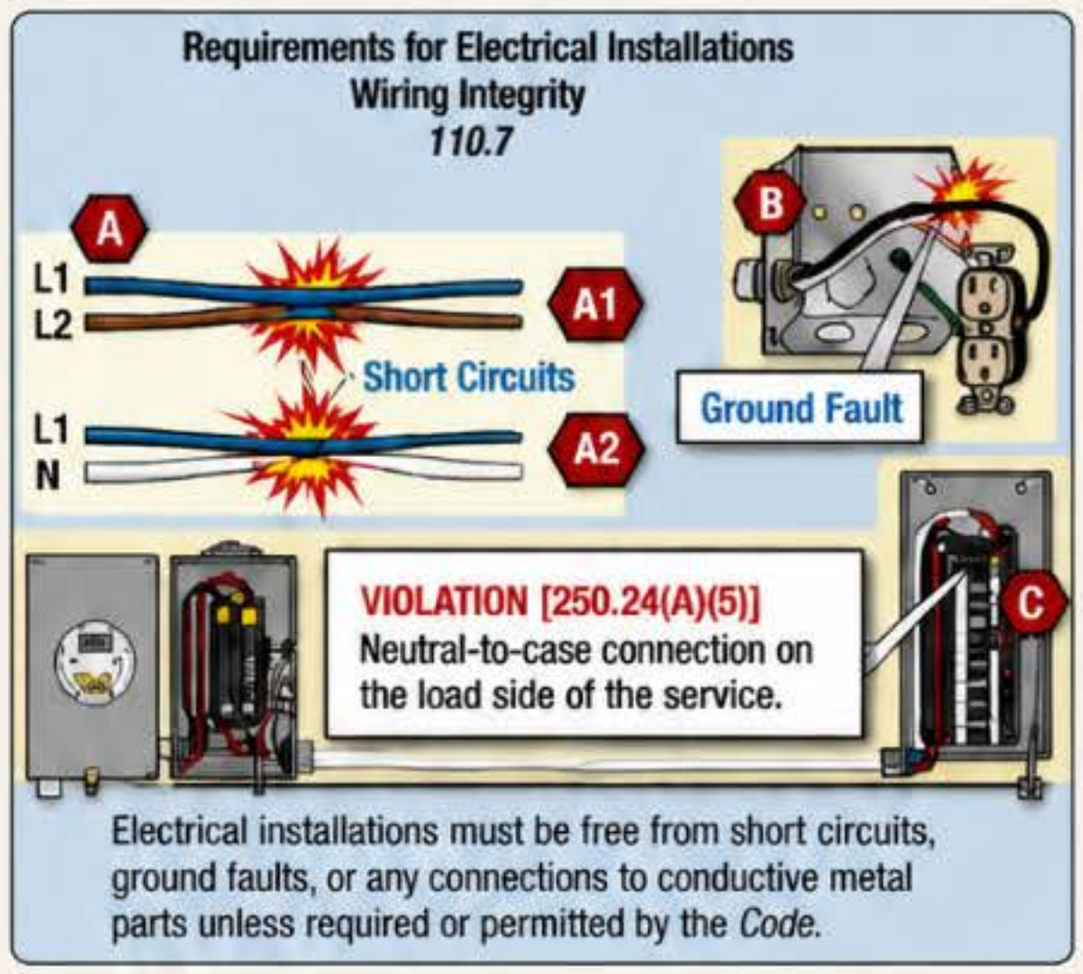


Figure 110-7

110.6 Conductor Sizes

Conductor sizes are expressed in American Wire Gage (AWG) or circular mils (cmil). **Figure 110-6**

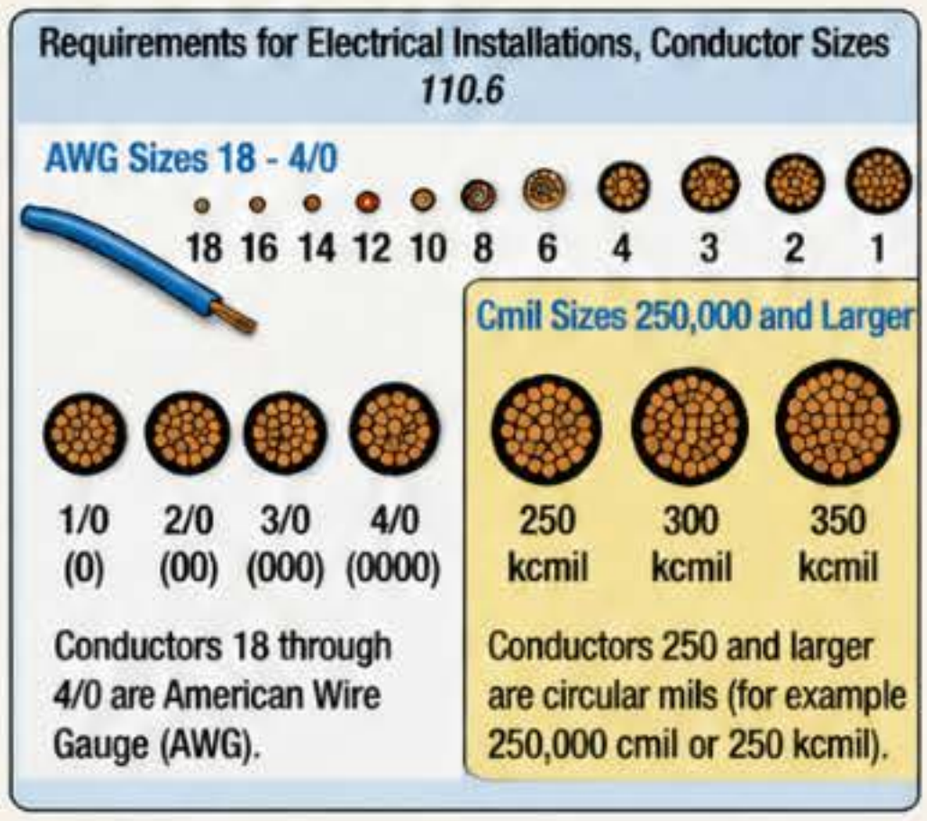


Figure 110-6

110.7 Wiring Integrity

Electrical systems must be installed so they are protected from short circuits, ground faults, or any attachment to conductive metal parts—except where the *Code* specifically allows or requires it. **Figure 110-7**

110.8 Suitable Wiring Methods

The only wiring methods permitted by the *NEC* are those included in the *Code*. **Figure 110-8**

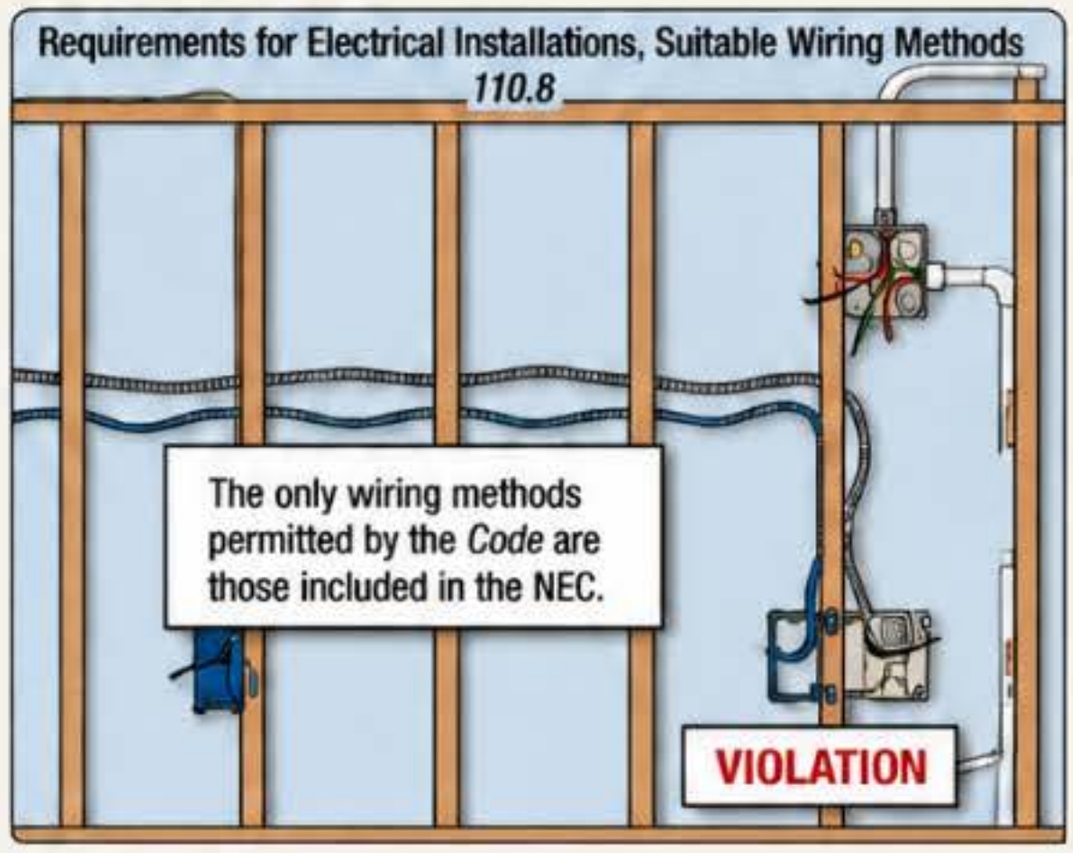


Figure 110-8

Author's Commentary:

- See Chapter 3 for power and lighting wiring methods; Chapter 7 for signaling, remote-control, and power-limited circuit wiring methods; and Chapter 8 for communications circuits wiring methods.

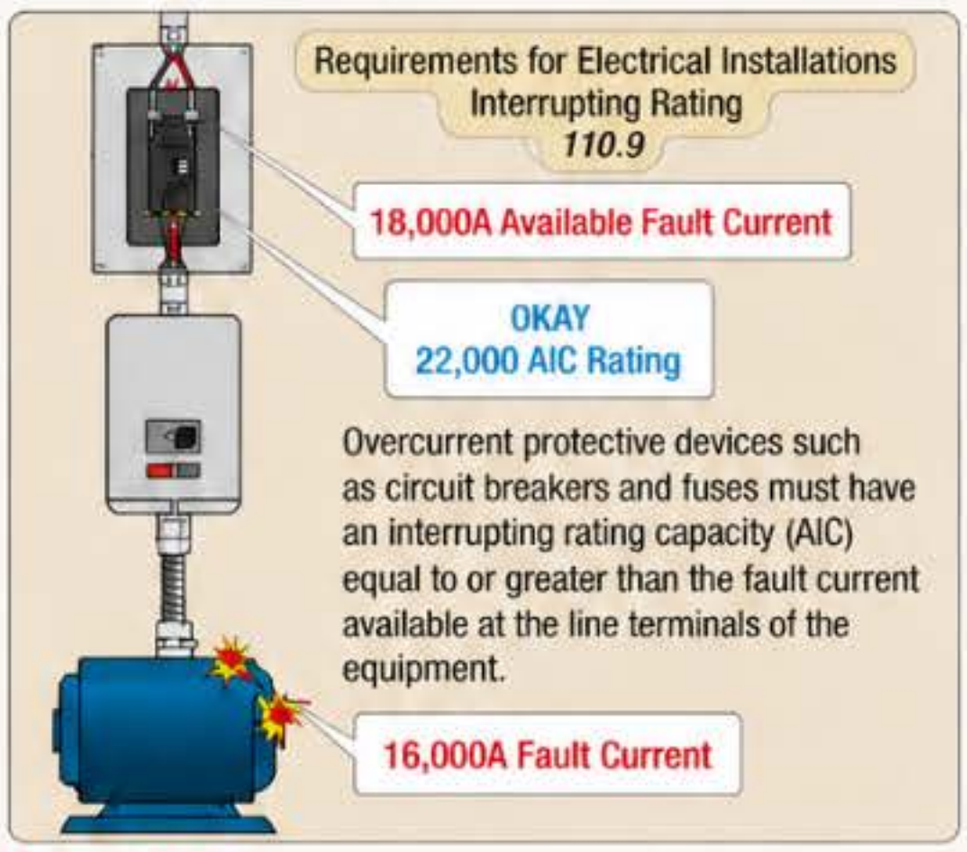
— Michael Hamilton

110.9 Requirements for Electrical Installations

110.9 Interrupting Rating (Overcurrent Protective Devices)

Overcurrent protective devices—such as circuit breakers and fuses—must have an interrupting capacity (AIC) that is equal to or greater than the maximum fault current available at the line terminals of the equipment.

▸ Figure 110-9



▸ Figure 110-9

Author's Commentary:

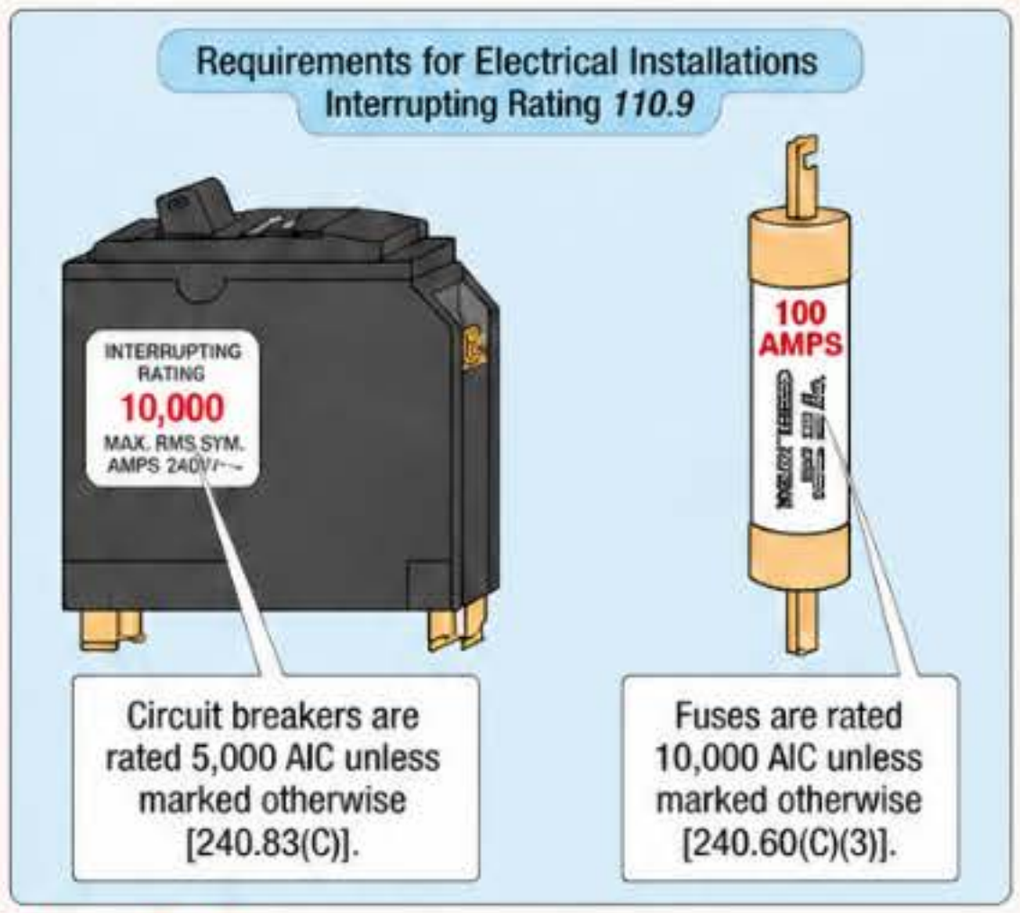
- Within Article 100, "Interrupting Rating" refers to the highest short-circuit current that a device at a given voltage can safely interrupt during a test under standard conditions.
- Interrupting ratings are frequently called "Ampere Interrupting Rating" (AIR) or "Ampere Interrupting Capacity" (AIC).
- Unless marked otherwise, for example "Interrupting rating for circuit breakers is 5,000A [240.83(C)], and for fuses it is 10,000A [240.60(C)(3)]."

— Michael Hamilton

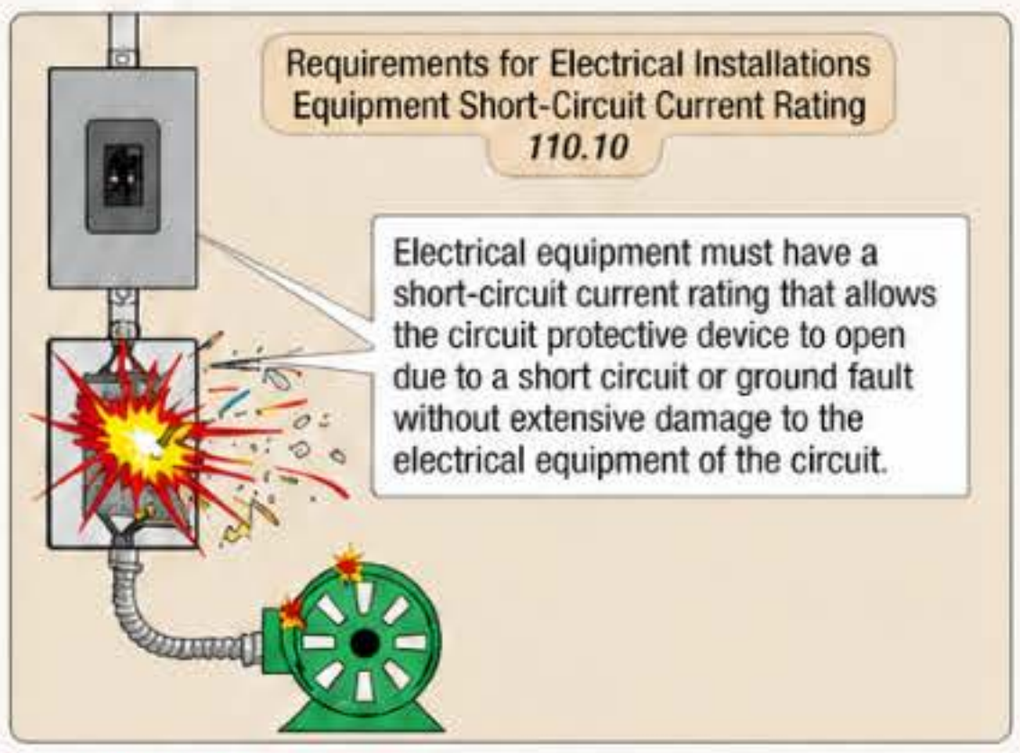
110.10 Equipment Short-Circuit Current Rating

Electrical equipment must be listed with a short-circuit current rating that allows the circuit protective device to open safely when a short circuit or ground fault occurs, all without causing excessive damage to the equipment. Listed equipment used in accordance with its listing is considered to have met this requirement.

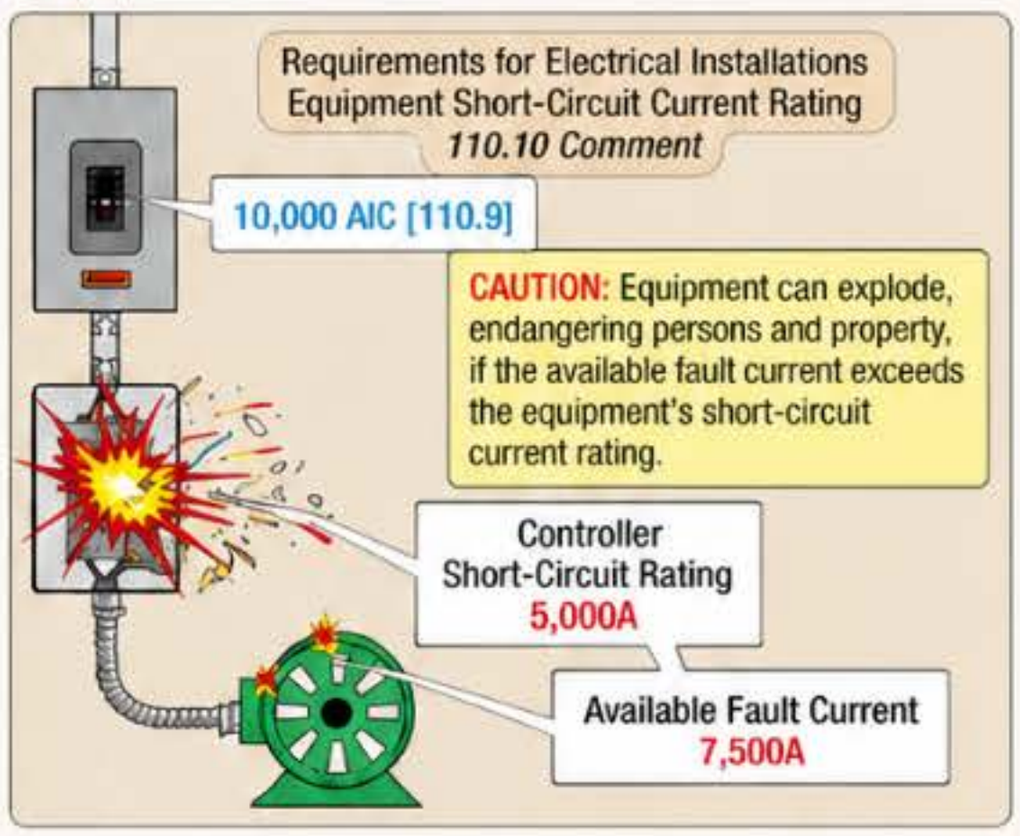
▸ Figure 110-11 and ▸ Figure 110-12



▸ Figure 110-10



▸ Figure 110-11



▸ Figure 110-12

DEFINITIONS | From Michael Hamilton Publications

AVAILABLE SHORT-CIRCUIT CURRENT

Sections 110.9 and 110.10 use similar wording, which can make the distinctions confusing. The key is knowing what "interrupting rating" means in the context of short-circuit current.

Available short-circuit current is the current, in amperes, present at a specific point in an electrical system. It's the highest current that the source, such as the utility transformer, can deliver to that location. After this value is determined at the service disconnect terminals, panelboards, and other equipment on the load side of the service, the permissible connections are reduced from that point forward. As we move farther from the utility transformer, the available short-circuit current drops at each downstream connection in the electrical system.

The level of available short-circuit current at any location depends on the impedance of the circuit. Higher impedance means lower available short-circuit current. **Figure 110–13**

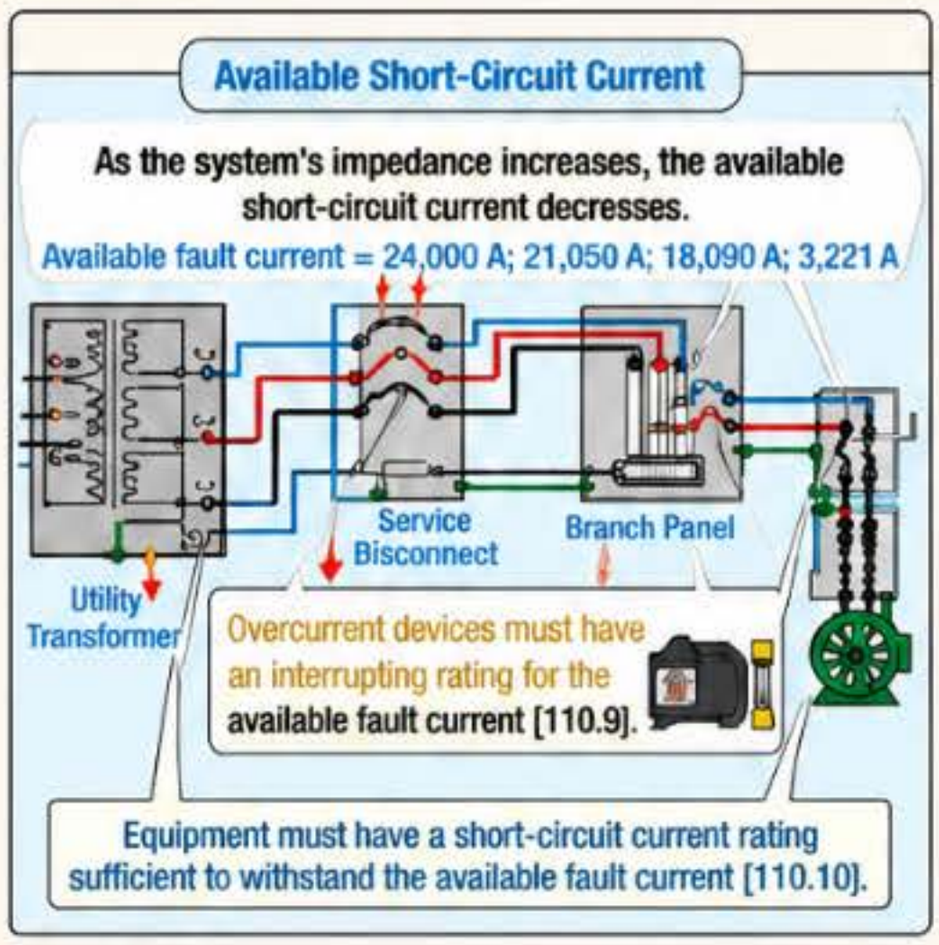


Figure 110–13

Factors that influence the available short-circuit current at the utility transformer include system voltage, transformer kVA rating, and impedance. Elements that affect circuit impedance include the conductor material (copper vs. aluminum), conductor size, conductor length, raceway type (metallic vs. nonmetallic), ambient temperature, and motor load contributions.

CAUTION

Extremely high values of current from short circuits or ground faults can cause severe thermal and magnetic damage. If an overcurent protective device cannot quickly interrupt the current at the available fault level, it can explode and hurl metal parts, posing serious injury or death risks. It can also damage electrical equipment and the system over time. **Figure 110–14**

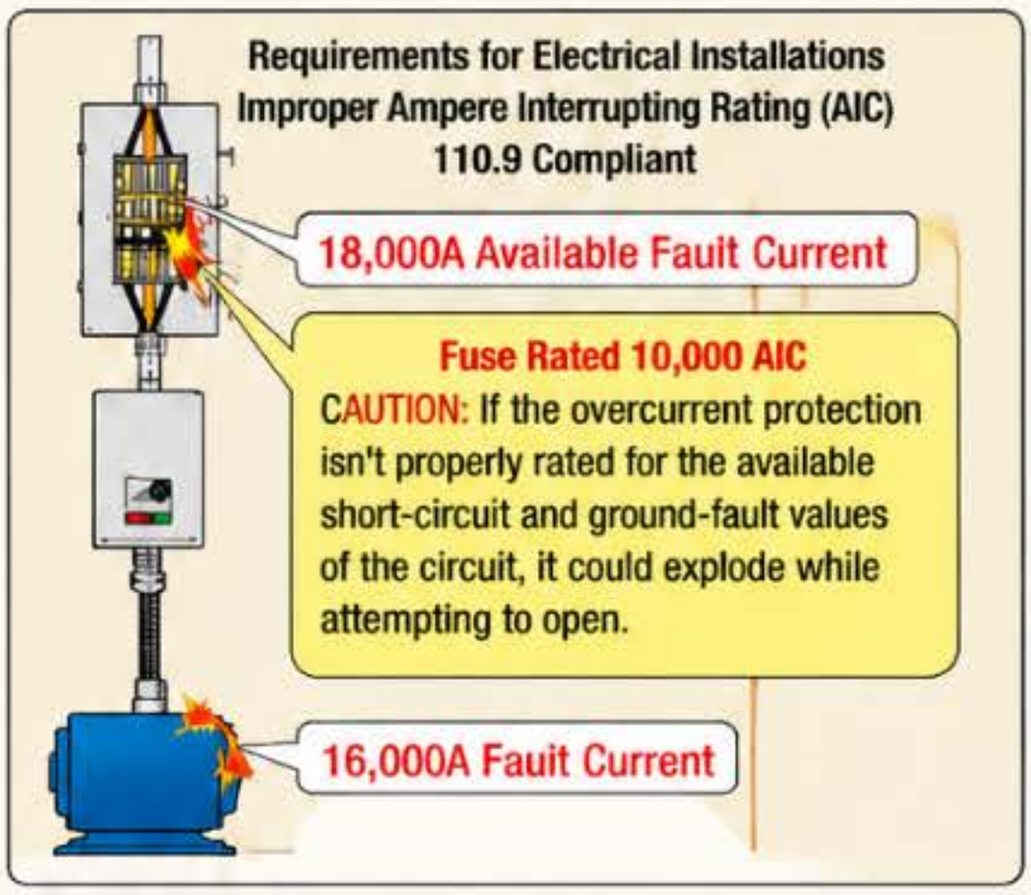


Figure 110–14

110.11 DETERIORATING AGENTS

Electrical equipment and conductors must be suitable for the environment in which they are used. Consider the presence of corrosive gases, fumes, vapors, liquids, or other materials that can damage conductors and equipment. **Figure 110–15**

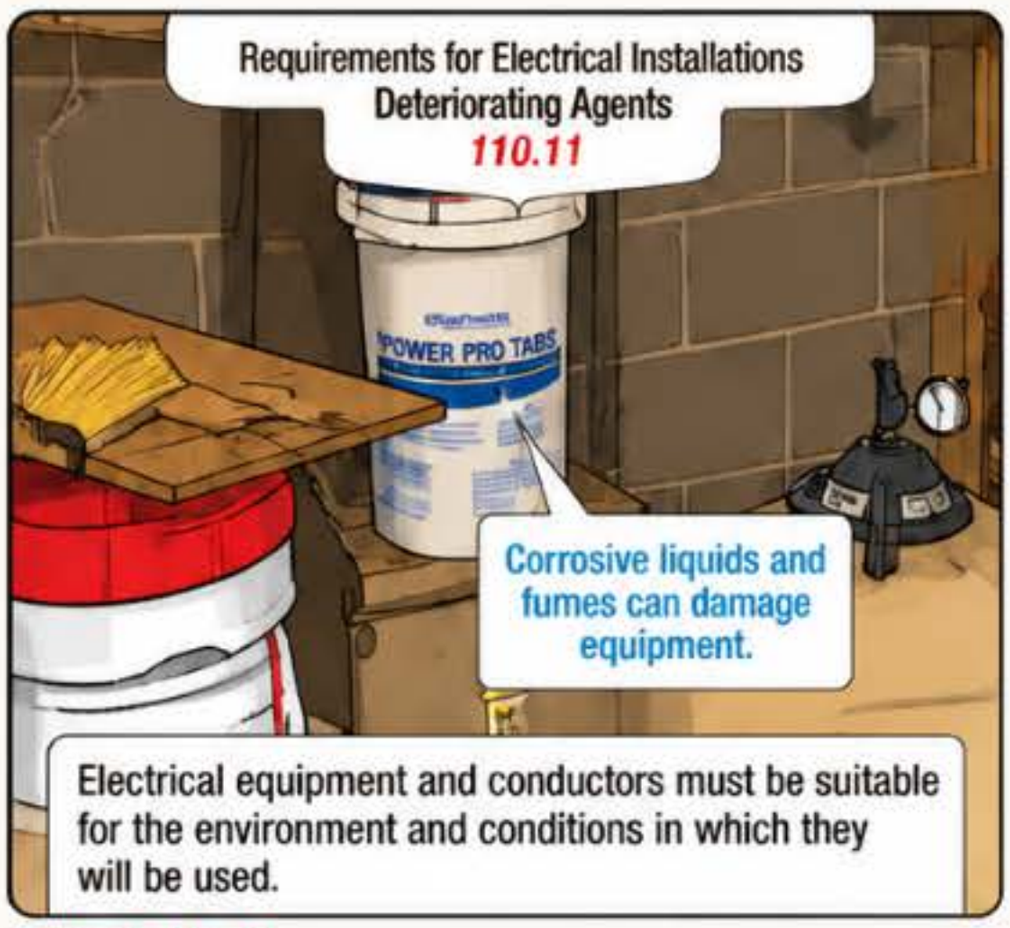
Note 1: Raceway systems, cable support hardware, cabinets, boxes, cable jackets, fittings, couplings, brackets, supports, and related hardware must be appropriate for the environment; see 300.6. **Figure 110–16**

Note 2: Some cleaning and lubrication products contain chemicals that may attack and degrade plastics.

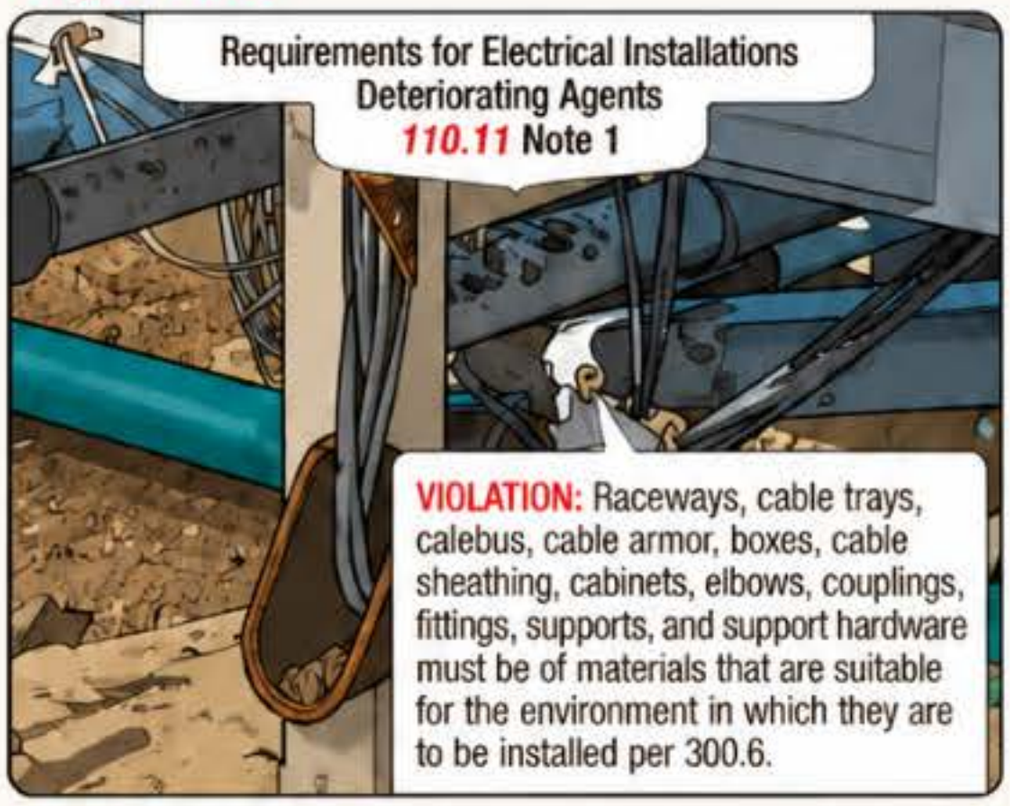
Note 3: See Table 110.28 for enclosure type designations per NEMA.

Note 4: For minimum flood protection requirements, consult the *International Building Code (IBC)* and the *International Electrical Code (IRC)* for 2023.

110.12 | Requirements for Electrical Installations



▶ Figure 110–15



▶ Figure 110–16

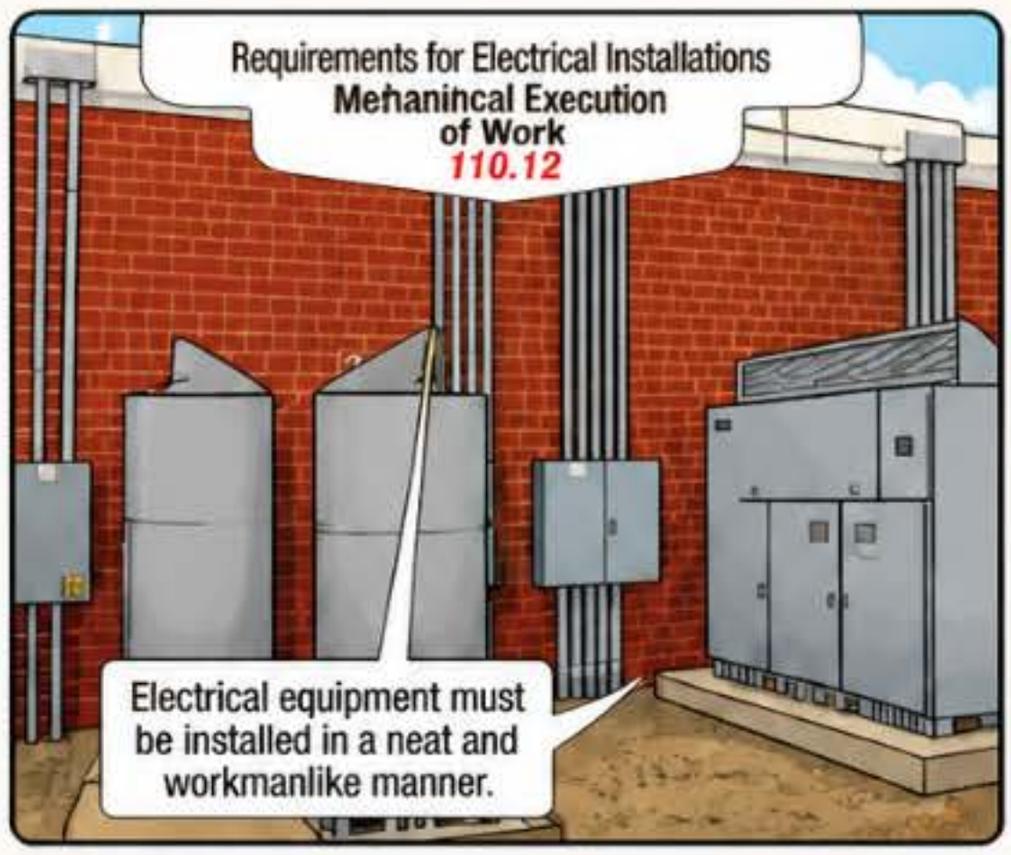
110.12 Mechanical Execution of Work

Electrical equipment must be installed in a neat and workmanlike manner. ▶ Figure 110–17

Author's Commentary:

This rule is perhaps one of the most subjective of the entire *Code* and its application is still ultimately a judgment call made by the authority having jurisdiction.

— Michael Hamilton



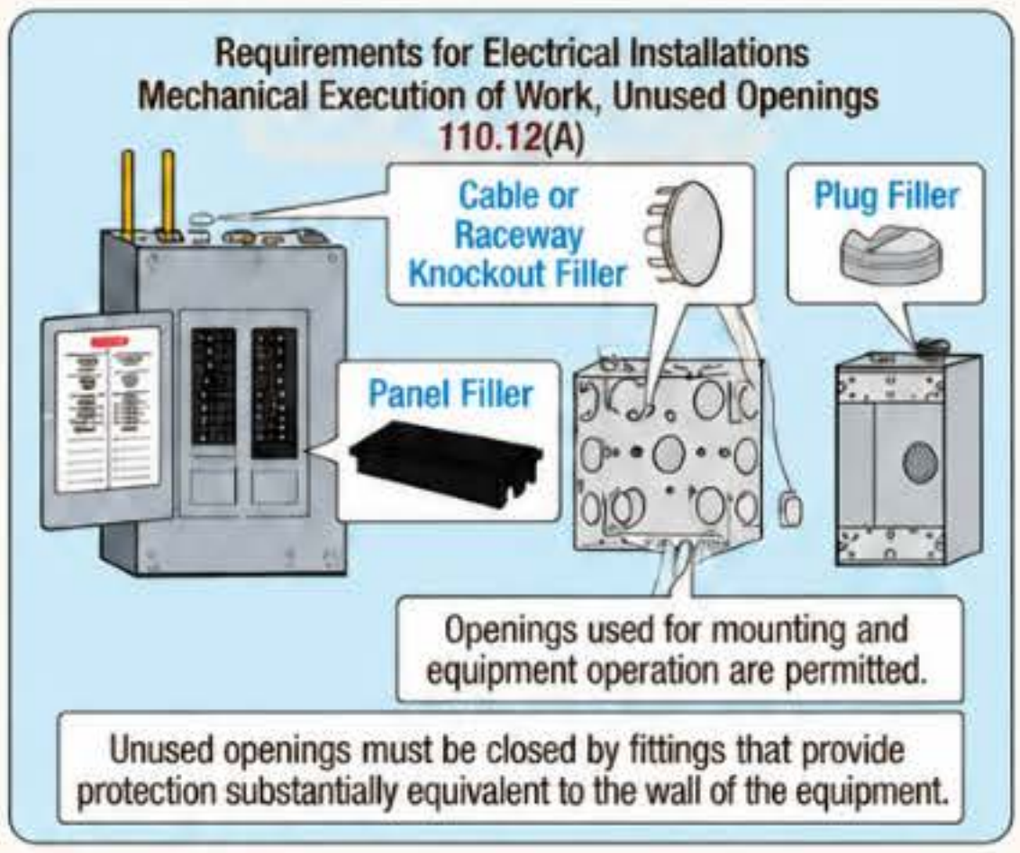
▶ Figure 110–17

Author's Commentary:

The National Electrical Contractors Association (NECA) developed a series of *National Electrical Installation Standards (NEIS)*® that produced the industry's first quality guidelines for electrical installations. These standards present a benchmark (baseline) of quality and *workmanship* for installing electrical products and systems. They describe what installing electrical products and systems in a "neat and workmanlike manner" means.

For more information about these standards, visit NECA-NEIS.org.

(A) Unused Openings. Unused openings must be closed by fittings that provide protection substantially equivalent to the wall of the equipment. ▶ Figure 110–18



▶ Figure 110–18

Requirements for Electrical Installations 110.12

(B) Integrity of Electrical Equipment. The internal components of electrical equipment must remain unharmed and free from contamination by foreign substances such as paint, plaster, cleaning agents, and similar materials. See Figure 110-19.

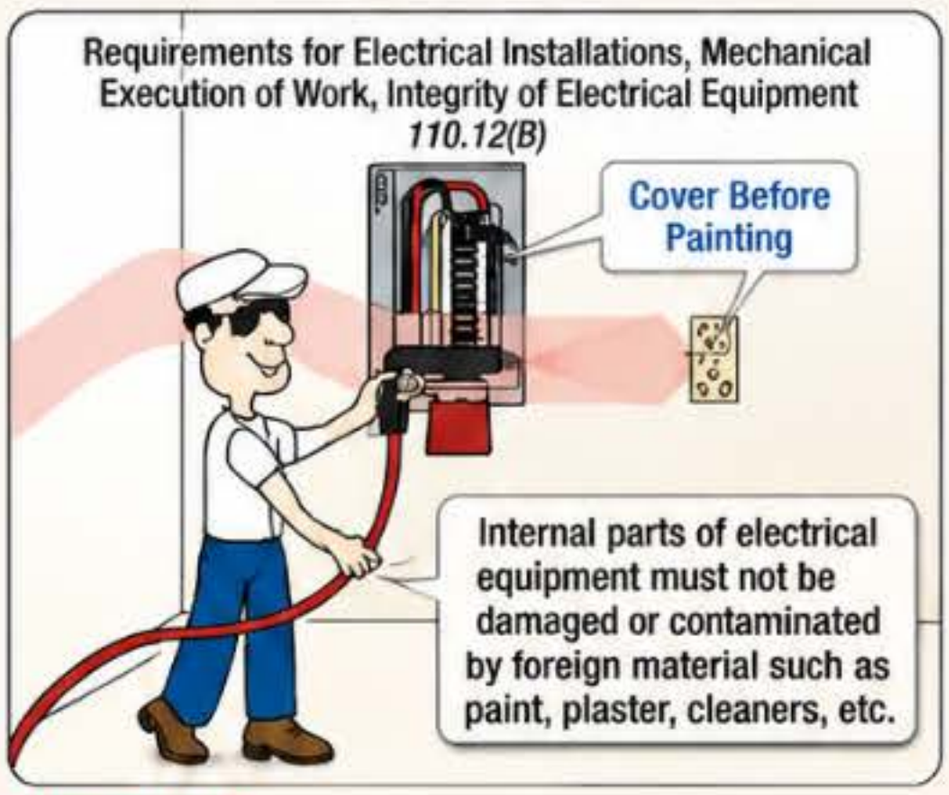


Figure 110-19

Author's Commentary:

Preventive steps must be taken to shield the interior components of panelboards and receptacle outlets from contamination during construction. Ensure equipment is properly masked and protected before painting, sheetrock work, or any other operation that could introduce materials capable of causing harm.

— Michael Hamilton

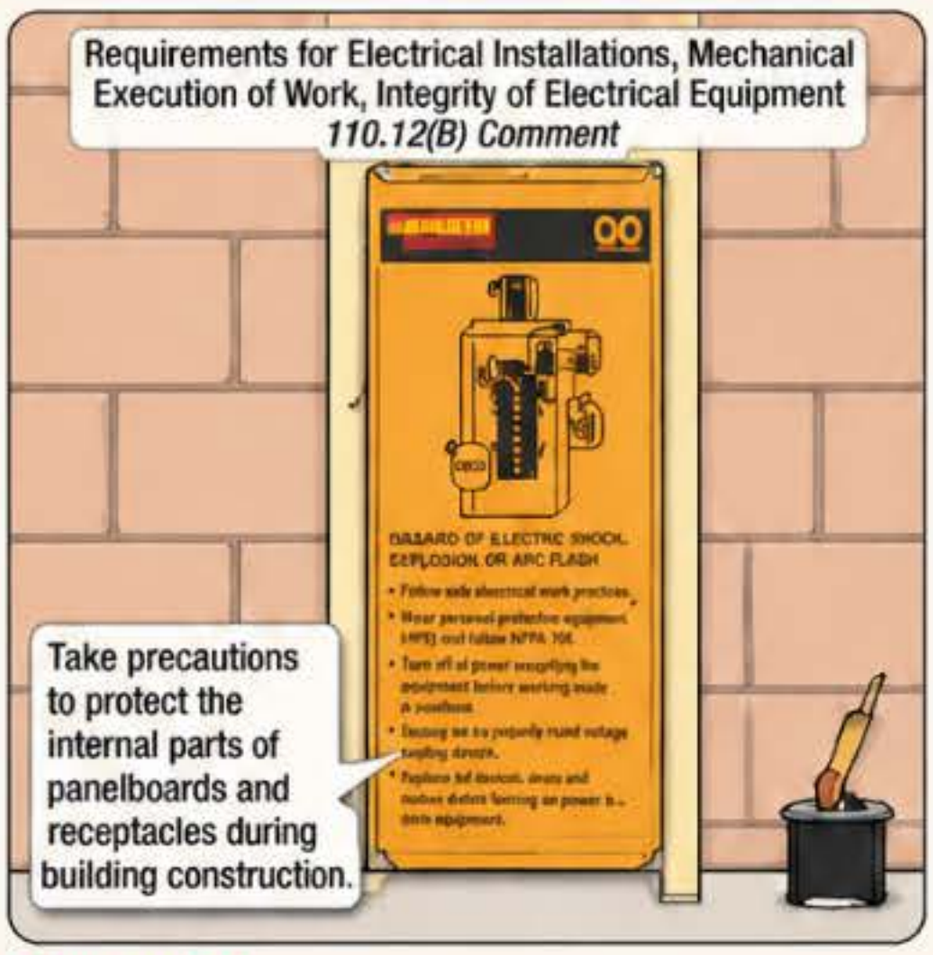


Figure 110-20

Electrical equipment that contains damaged items (examples: broken, bent, or cut parts) or parts that have deteriorated due to corrosion, chemical attack, or overheating must not be installed. See Figure 110-21.

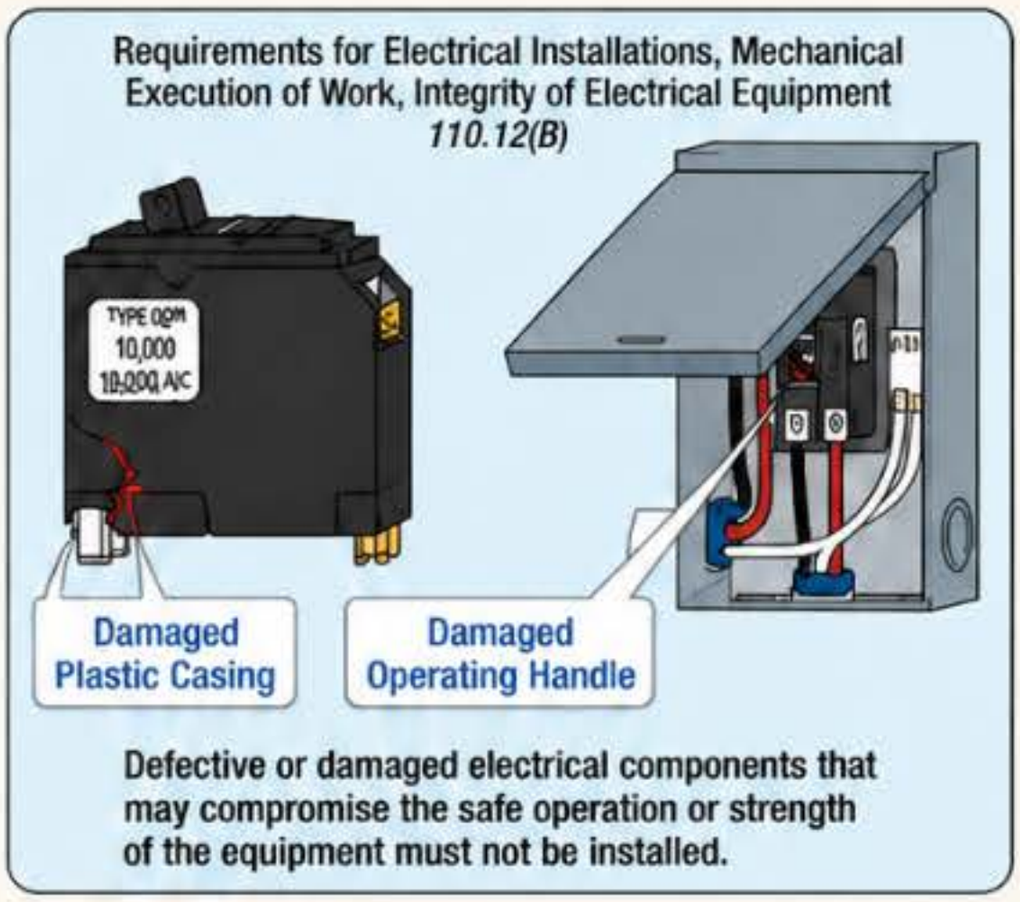


Figure 110-21

Author's Commentary:

Damaged parts can include cracked insulators, arc shields that are incorrectly positioned, overheated fuse clips, and broken or missing switch handles or circuit-breaker operating handles.

— Michael Hamilton

(C) Cables and Conductors. Cables and conductors must be installed using neat and workmanlike practices. See Figure 110-22.

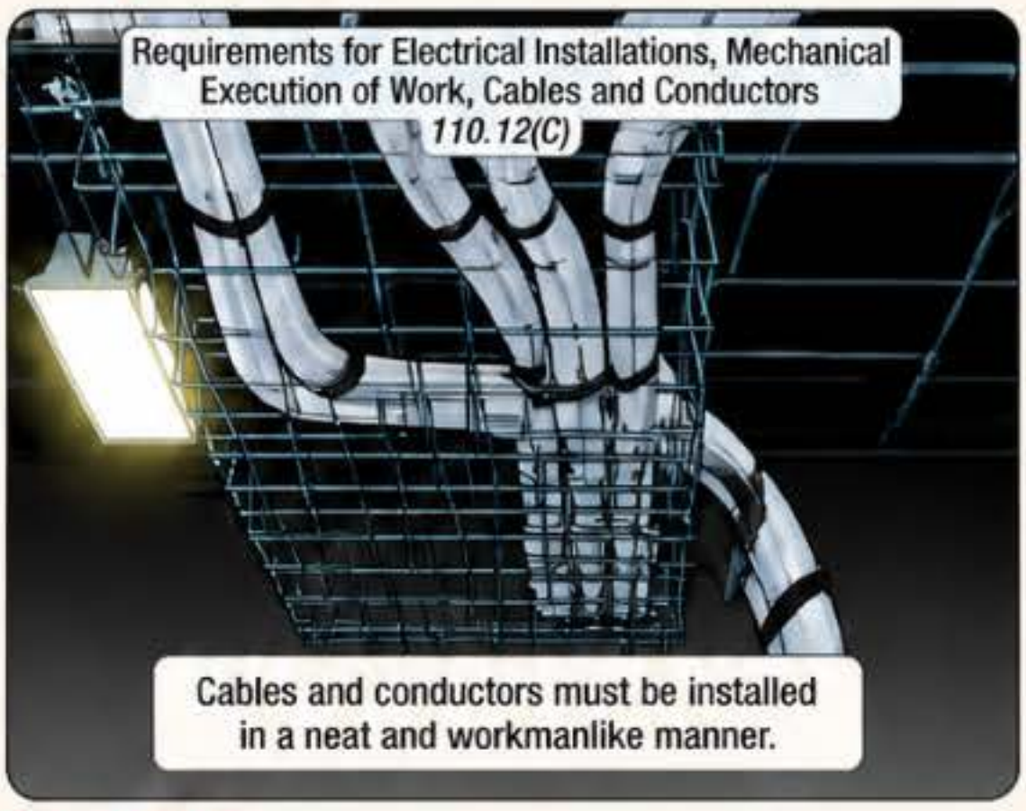
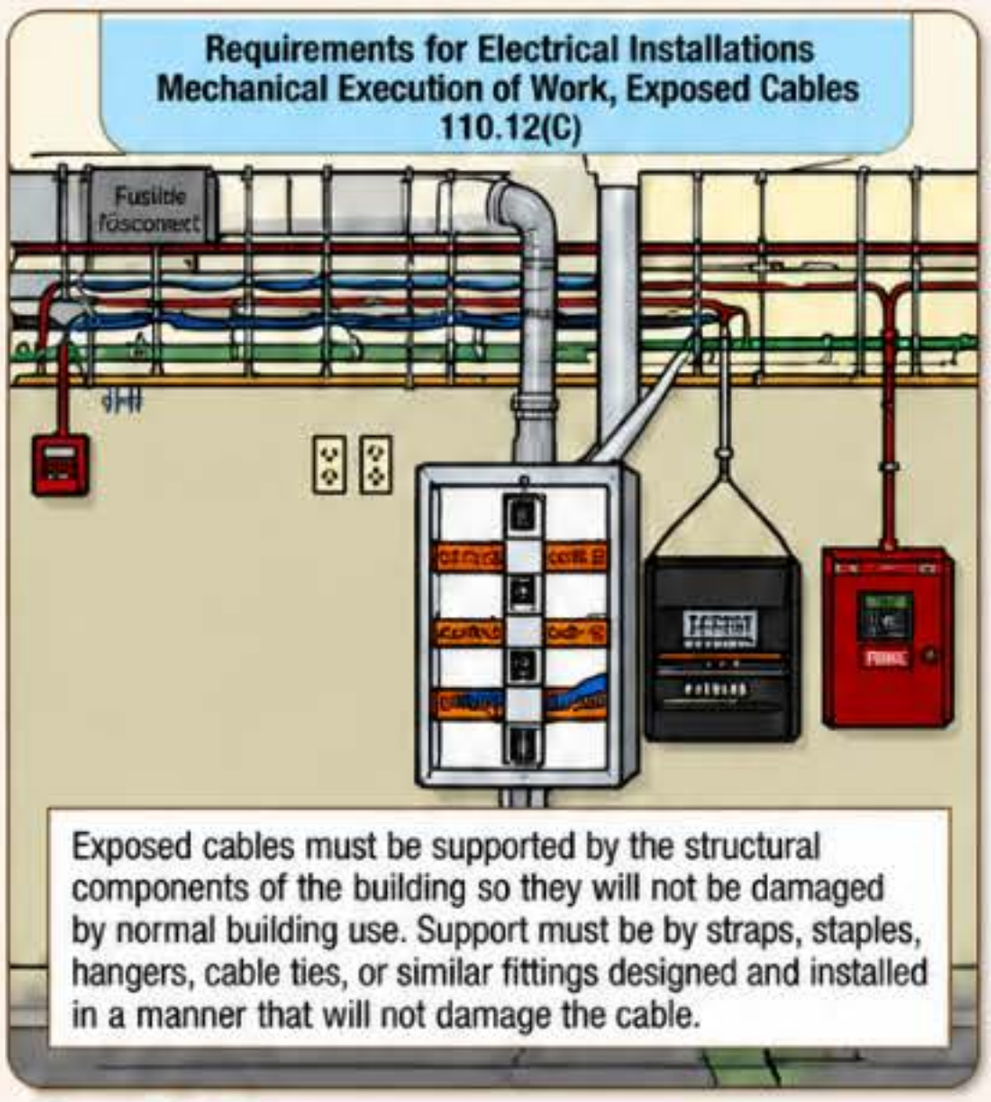


Figure 110-22

110.13 Requirements for Electrical Installations

Exposed cables need structural support from the building components so they remain protected from ordinary wear and damage. Use straps, staples, hangers, cable ties, or similar fittings that are designed and installed so they won't harm the cable. ▸ Figure 110-23



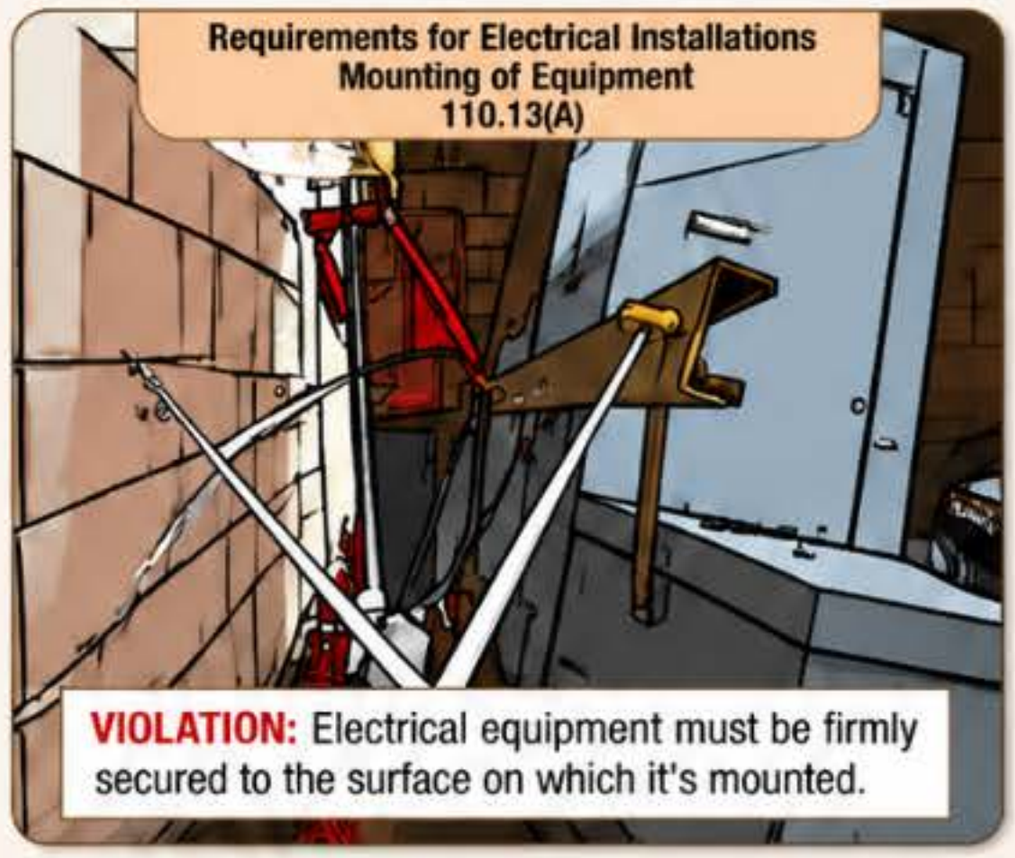
▸ Figure 110-23

Note 1: Industry practices are described in ANSI/*NECA*/FOA 301, *Standard for Installing and Testing Fiber Optic Cables*, and other ANSI-approved installation standards.

Note 3: Paint, plaster, cleaners, abrasives, corrosive residues, or other contaminants can result in an undetermined alteration of optical fiber cable properties.

110.13 Mounting and Cooling of Equipment

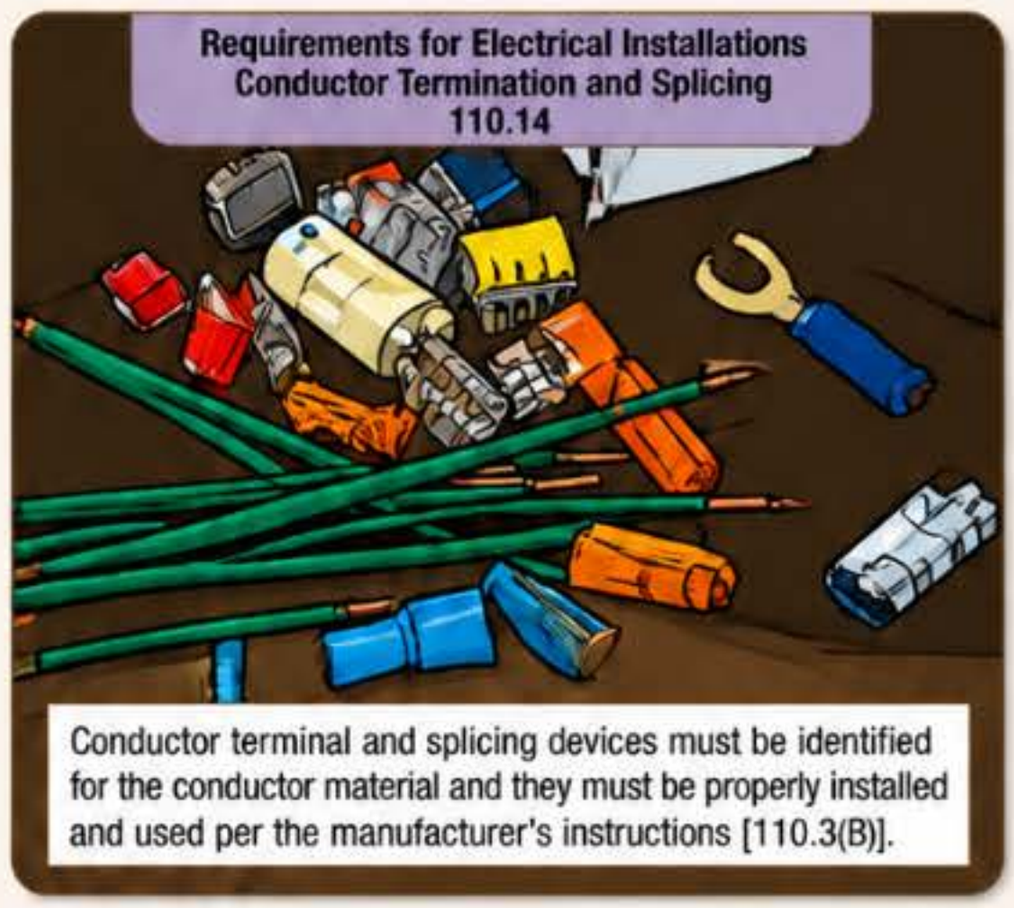
(A) Mounting. Electrical equipment must be securely attached to the surface on which it is mounted. ▸ Figure 110-24



▸ Figure 110-24

110.14 Conductor Termination and Splicing

Conductor termination and splicing devices must be identified for the conductor material and must be properly installed and used in accordance with the manufacturer's instructions [110.3(B)]. ▸ Figure 110-25



▸ Figure 110-25

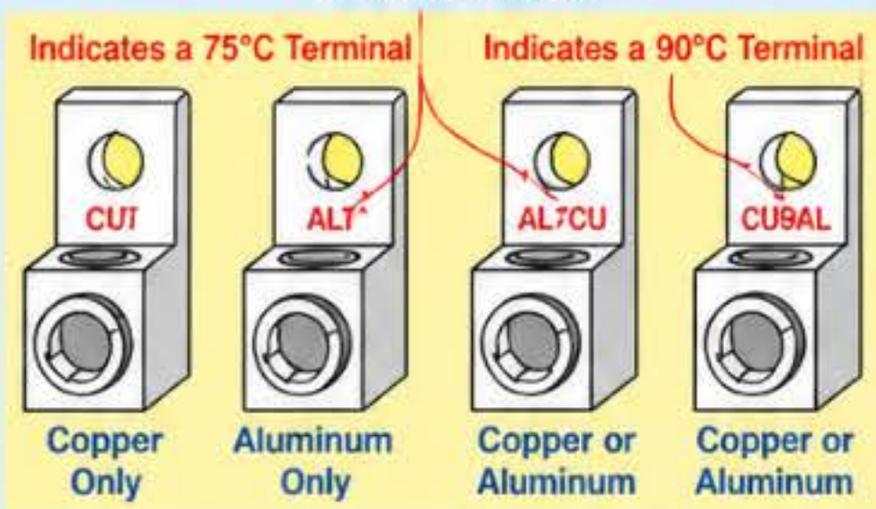
Author's Commentary:

- Conductor terminals suitable for aluminum wire only will be marked "AL." Those acceptable for copper wire only will be marked "CU." Terminals suitable for both copper and aluminum will be marked "CU-AL" or "AL-CU." For 6 AWG and smaller, the markings can be printed on the container or on an information sheet inside the container. A "7" or "75" indicates a 75°C rated terminal, and a "9" or "90" indicates a 90°C rated terminal. If a terminal bears no marking, it can be used only with copper conductors. ▸ Figure 110-26

Connectors and terminals for conductors more finely stranded than Class B and Class C must be identified for the use of finely stranded conductors. ▸ Figure 110-27

Requirements for Electrical Installations 110.14

Requirements for Electrical Installations
Conductor Terminal Marking
110.14 Comment



Terminals that are suitable only for aluminum must be marked AL. Terminals suitable for both copper and aluminum must be marked CU-AL or AL-CU.

Figure 110–26

Requirements for Electrical Installations
Finely Stranded Flexible Conductor Terminations
110.14

Connectors and terminations for conductors more finely stranded than Class B and Class C [Chapter 9, Table 10] stranding must be identified for the conductor class.

Figure 110–27

Author's Commentary:

- According to Article 100, "Identified" means an item is acceptable for a particular purpose, function, or environment based on listing, labeling, or other forms of approval from the authority having jurisdiction.
- Conductor terminations must comply with the manufacturer's instructions as required by 110.3(B). For example, if the instructions for the device say, "Suitable for 18-12 AWG Stranded," then only stranded conductors can be used with the terminating device. If they say, "Suitable for 18-12 AWG Solid," then only solid conductors are permitted, and if the instructions say, "Suitable for 18-12 AWG," then either solid or stranded conductors can be used with the terminating device.

— Michael Hamilton

Copper and Aluminum Mixed. Copper and aluminum conductors (dissimilar metals) are not allowed to touch each other in a device unless the device is listed and identified for this purpose.

Author's Commentary:

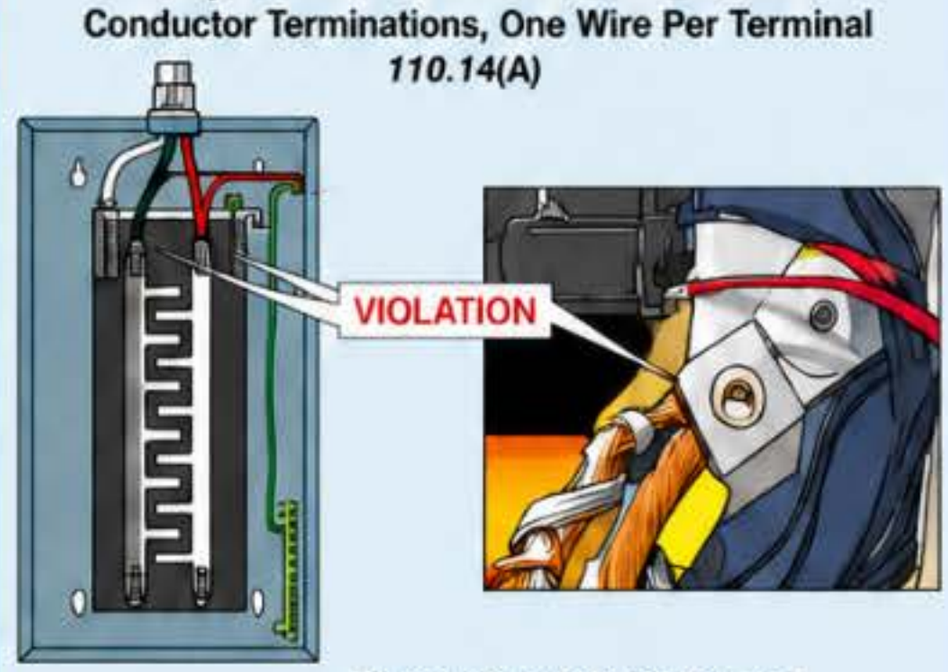
- Terminations are listed for mixing aluminum and copper conductors, but if they are, that will be marked on the product package or terminal device. The reason copper and aluminum should not be in contact with each other is because corrosion develops between the two different metals due to galvanic action, increasing contact resistance at the splicing device. This higher resistance can cause the splice to overheat and even start a fire.

— Michael Hamilton

(A) Conductor Terminations. Conductor terminals must ensure a good connection without damaging the conductors.

Terminals are listed for one conductor unless marked otherwise. Terminals for more than one conductor must be identified for this purpose, either within the equipment instructions or on the terminal itself. Figure 110–28

Requirements for Electrical Installations
Conductor Terminations, One Wire Per Terminal
110.14(A)



Terminals are listed for one conductor unless marked otherwise.

Figure 110–28

Author's Commentary:

- Split-bolt connectors are commonly listed for only two conductors, although some are listed for three. However, it is standard industry practice to terminate as many conductors as possible within a split-bolt connector, even though this violates the *NEC*. Figure 110–29

— Michael Hamilton

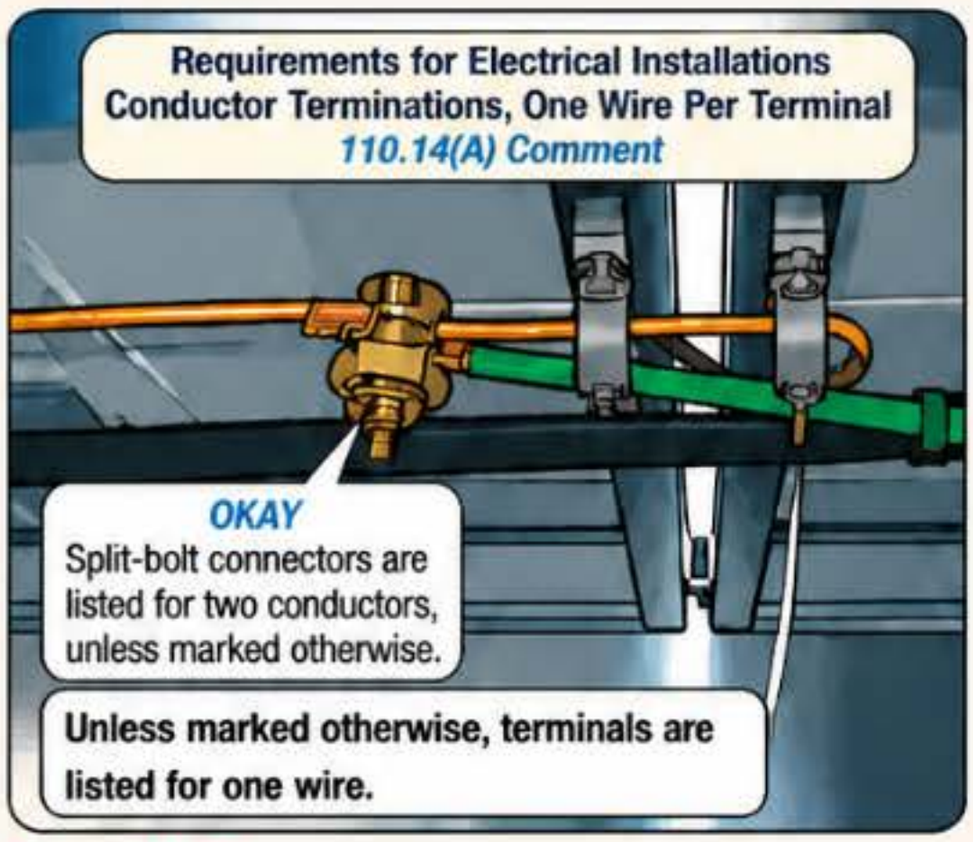


Figure 110–29

(B) Conductor Splices. Conductors must be spliced by a splicing device that is identified for the purpose. Figure 110–30

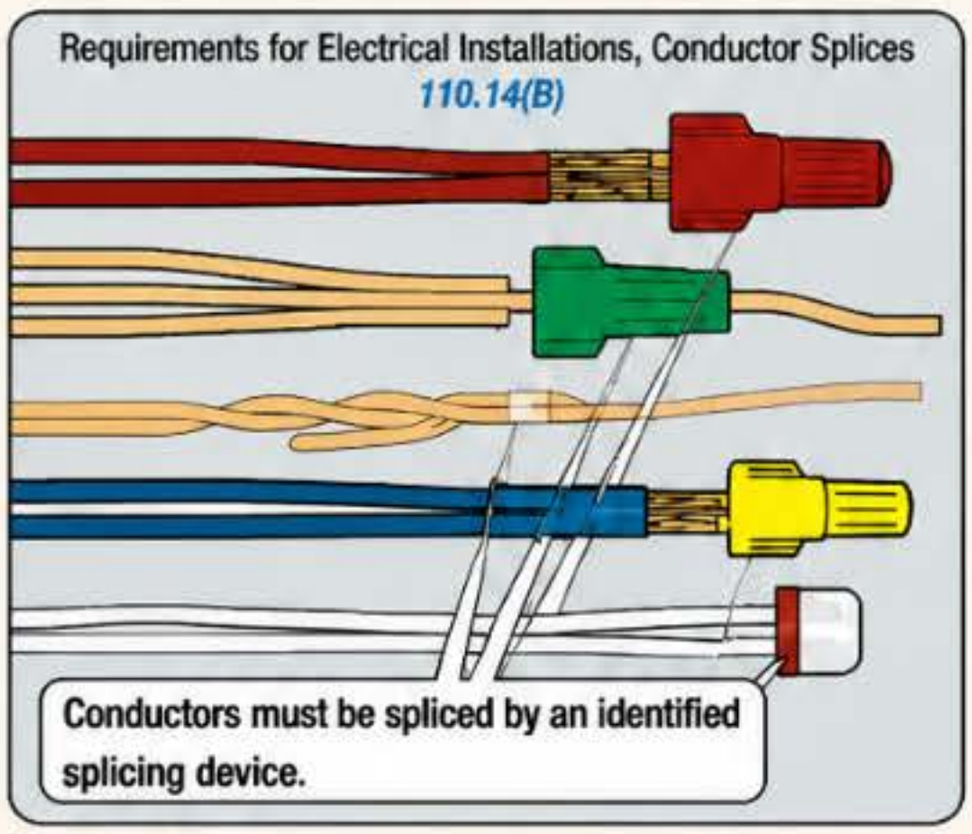


Figure 110–30

Unused circuit conductors are not required to be removed. However, to prevent an electrical hazard, the free ends of the conductors must be insulated to prevent the exposed end(s) from touching energized parts. This requirement can be met by using an insulated twist-on or push-on wire connector. Figure 110–31

Author's Commentary: Under Article 100, "Energized" means connected to a source of voltage.

— Michael Hamilton

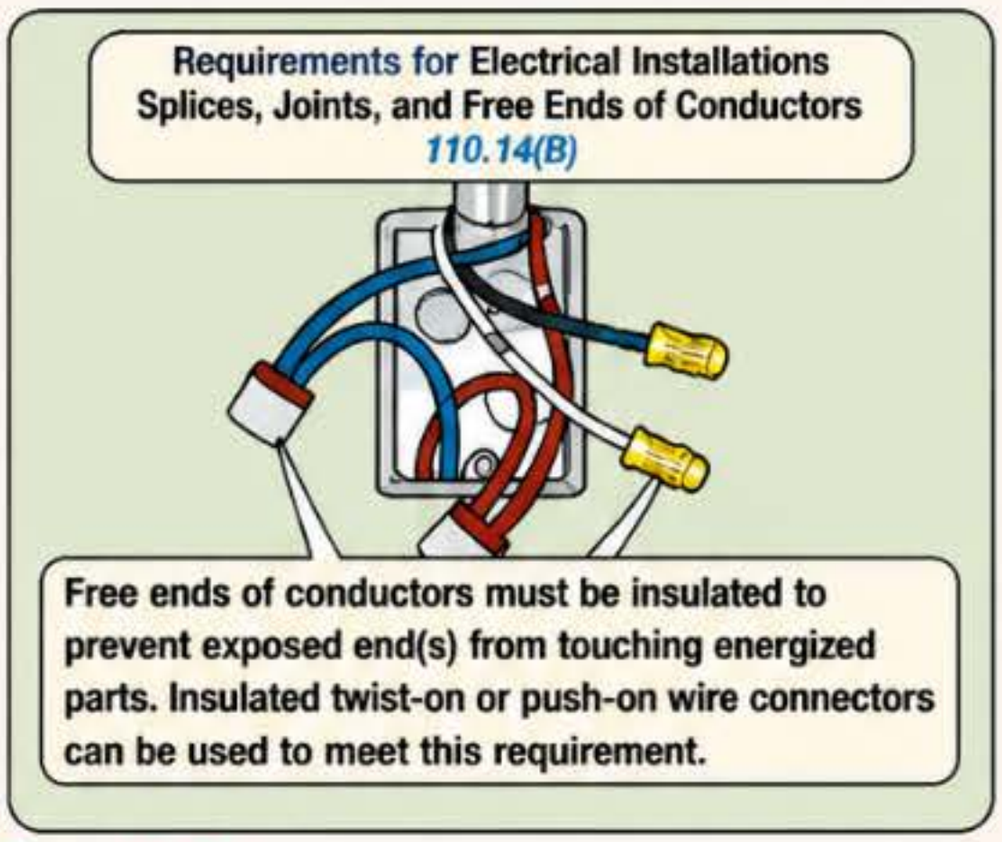


Figure 110–31

- Pre-twisting conductors before applying twist-on wire connectors has been a very common practice in the field for years. The question (and subsequent debate) has always been, "Is pre-twisting required?" The NEC does not require that practice and, in fact, Ideal® made a statement about their Wing-Nut® twist-on connectors which said, "Pre-twisting is acceptable, but not required. If required, follow the manufacturer's instructions and there will be no question [110.3(B)].
- Reusing twist-on connectors seems to be another point of contention in the field. Should they be reused? Some say that they just never seem quite the same once they have been used, while others say they reuse them all the time. Defer to the manufacturer's instructions; Ideal® noted in their information that it is perfectly fine to reuse their twist-on connectors.

Figure 110–32

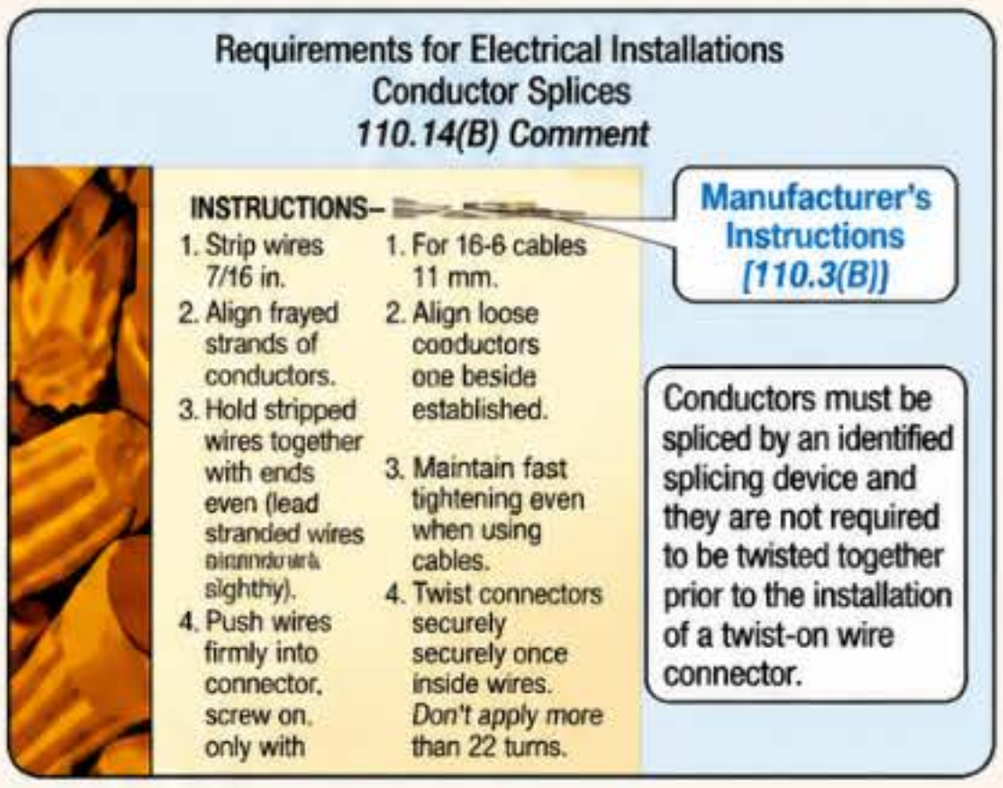
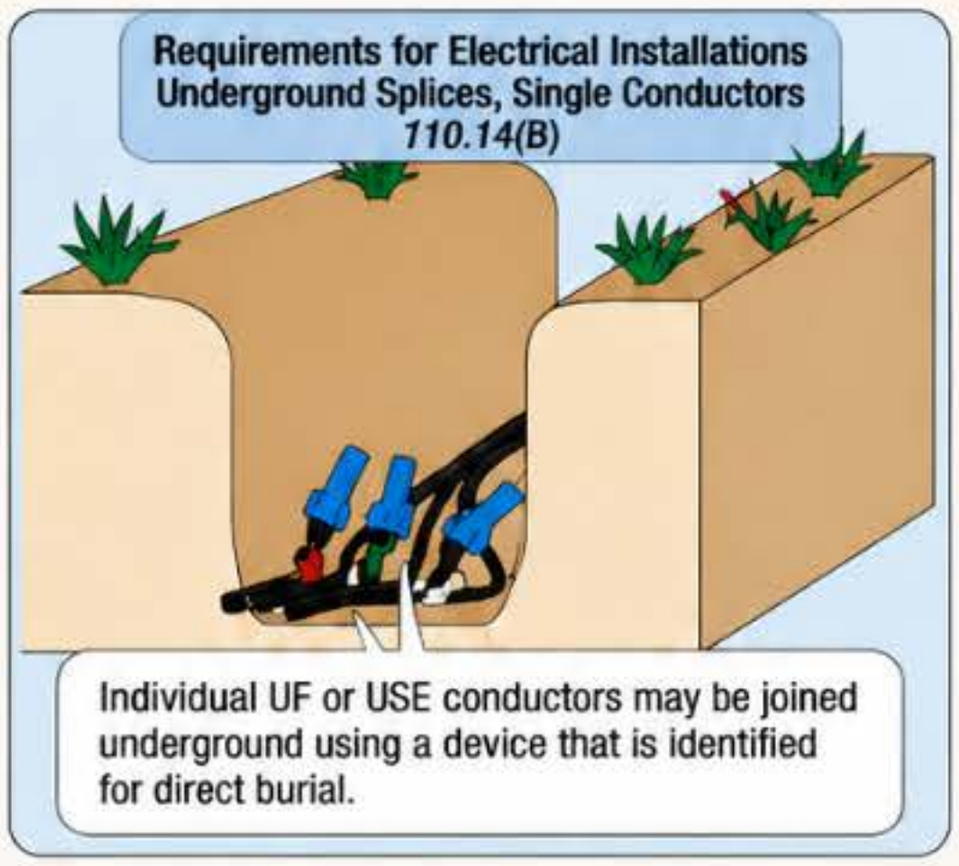


Figure 110–32

Requirements for Electrical Installations

Underground Splices, Single Conductors. Individual UF or USE conductors may be joined underground using a device that is identified for direct burial [300.5(E) and 300.15(G)]. ▶Figure 110–33



▶Figure 110–33

Underground Splices, Multiconductor Cable. The insulated conductors of multiconductor UF or USE cable may be spliced underground using an assembly that is identified for underground use and that encloses the splices and the cable jacket.

Author's Commentary:

Faulty terminations are a frequent source of equipment trouble and building fires. Loose connections, poor mechanical work, ignoring the manufacturer's directions, and using the wrong amount of torque can all create high resistance that leads to overheating. Damaged conductor insulation and poorly executed short circuits are also common culprits.

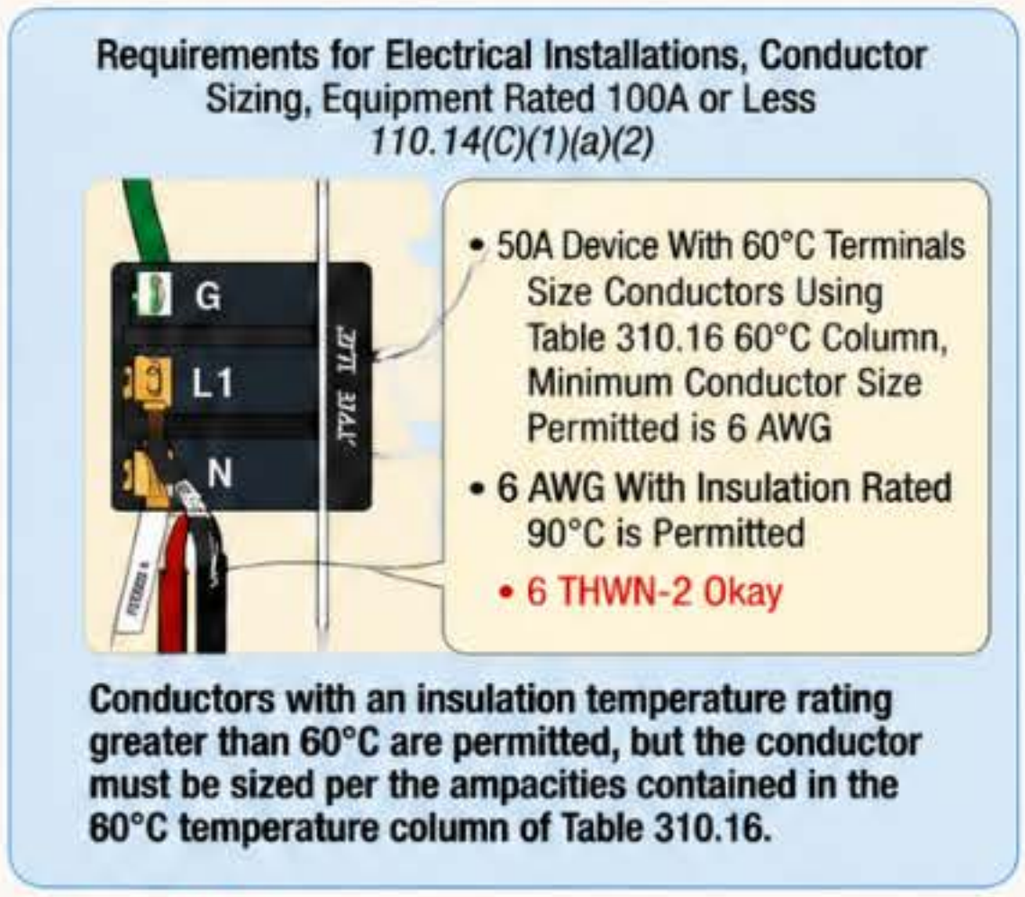
— Michael Hamilton

(C) Conductor Size to Terminal Temperature Rating. Conductor sizing must comply with 110.14(C)(1) and (2).

(1) Equipment Terminals. Electrical equipment must be marked to identify the conductor sizes it accepts, as follows:

(a) Equipment Rated 100A or Less.

(2) Conductors with insulation rated above 60°C are allowed, but the conductor size must be chosen in accordance with the ampacity values listed in the 60°C temperature column of Table 310.16. ▶Figure 110–34



▶Figure 110–34

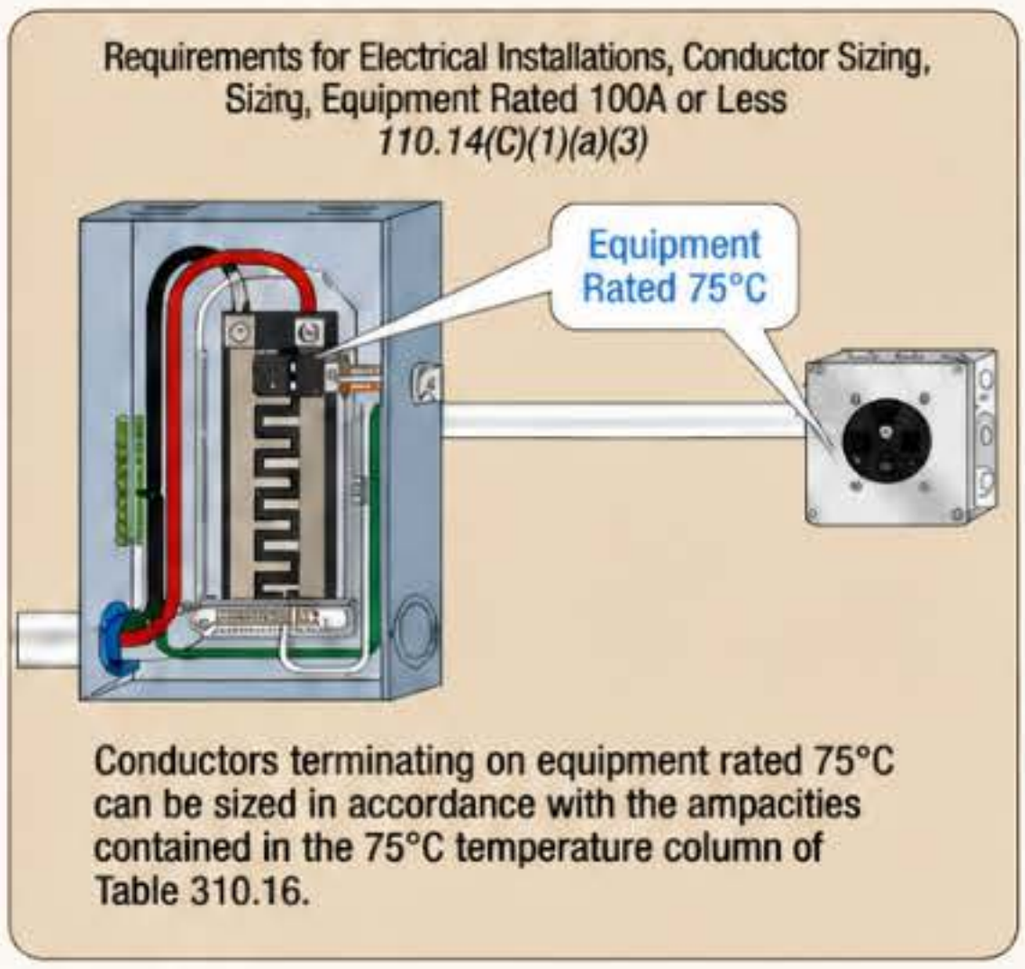
▶ Example

Question: *According to Table 310.16, what size THWN-2 conductor is required for a circuit rated 50A?*

(a) 10 AWG (b) 8 AWG (c) 6 AWG (d) 4 AWG

Answer: *(c) 6 AWG rated 55A at 60°C [110.14(C)(1)(a)(2) and Table 310.16]*

(3) Conductors terminating on terminals rated 75°C can be sized in accordance with the ampacities in the 75°C temperature column of Table 310.16. ▶Figure 110–35

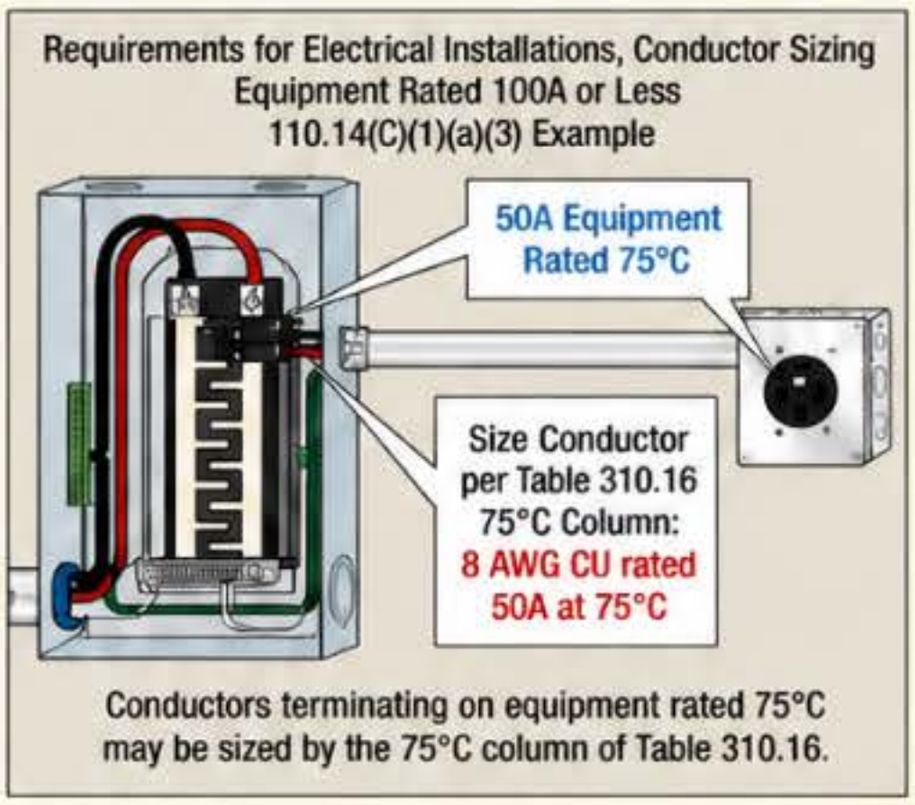


▶Figure 110–35

▶ Example

Question: *Based on Table 310.16, which conductor size is required for a 50A circuit where the equipment is permitted for use at 75°C?* ▸ **Figure 110–36**

(a) 1/0 AWG (b) 8 AWG (c) 6 AWG (d) 4 AWG



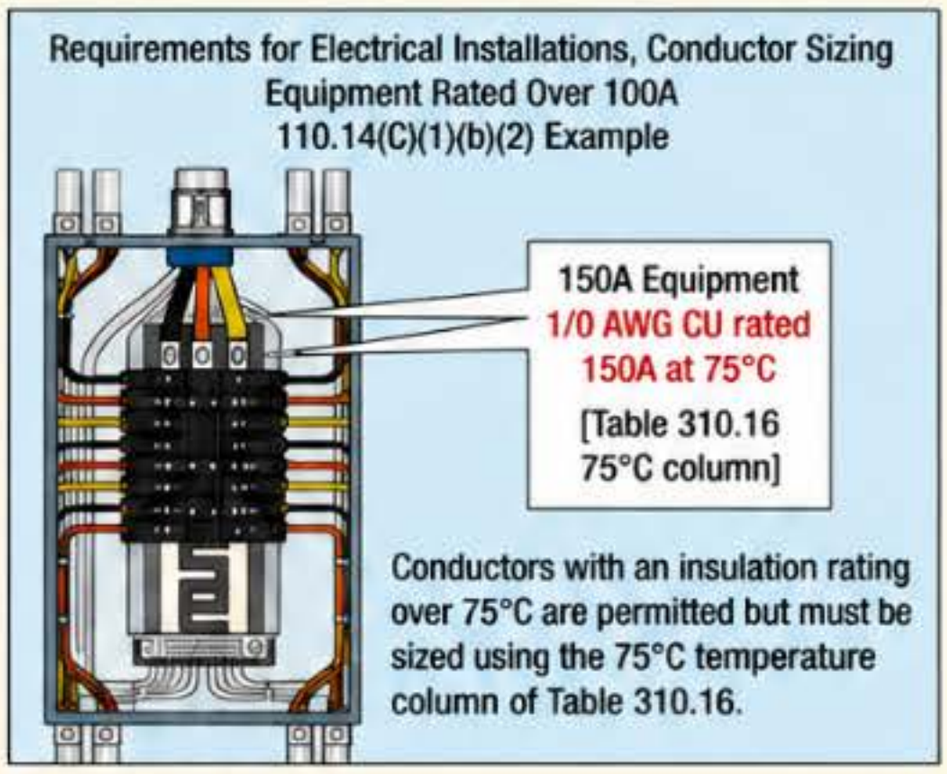
▸ **Figure 110–36**

Answer: *(b) 8 AWG rated 50A at 75°C [110.14(C)(1)(a)(3) and Table 310.16]*

▶ Example

Question: *Based on Table 310.16, which conductor size is needed to supply a 150A feeder?* ▸ **Figure 110–38**

(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

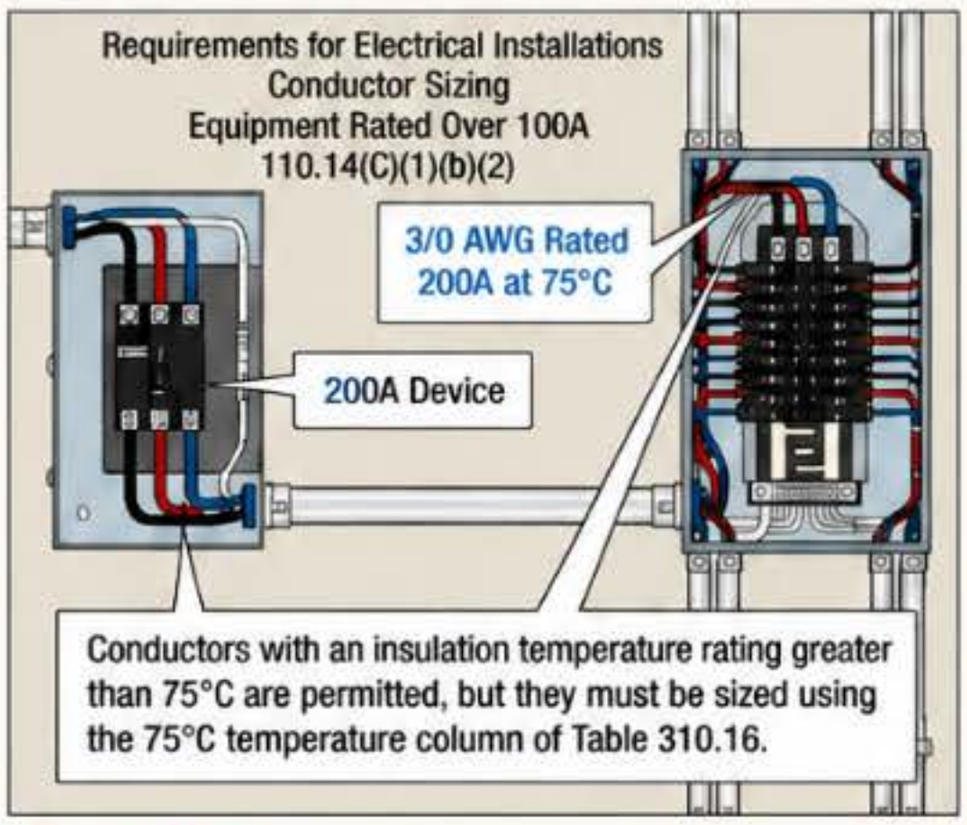


▸ **Figure 110–38**

Answer: *(a) 1/0 AWG rated 150A at 75°C [110.14(C)(1)(b)(2) and Table 310.16]*

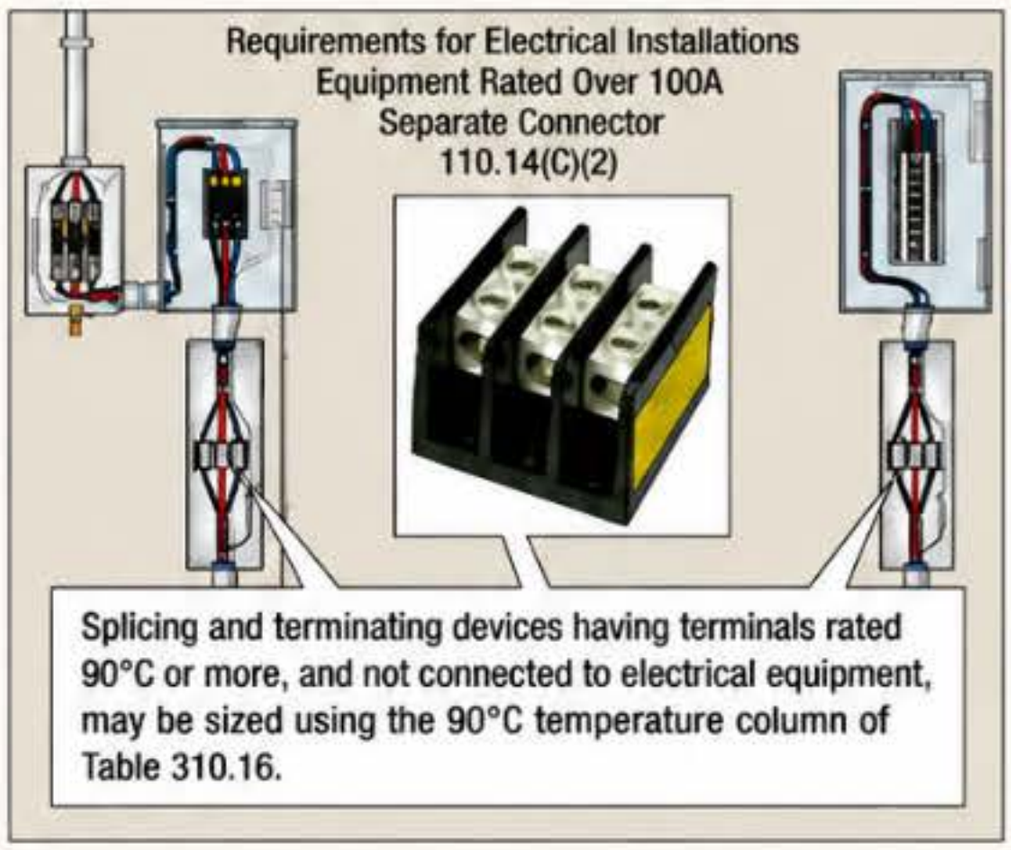
(b) Equipment Rated Over 100A

(2) Conductors with an insulation temperature rating greater than 75°C are allowed, but the conductor must be sized in accordance with the ampacities in the 75°C temperature column of Table 310.16. ▸ **Figure 110–37**



▸ **Figure 110–37**

(2) Separate Connector. Splicing and terminating devices with terminals rated 90°C or more, and not connected to electrical equipment, may be sized per the 90°C temperature column of Table 310.16 for conductor ampacities. ▸ **Figure 110–39**



▸ **Figure 110–39**

Requirements for Electrical Installations

110.14

▶ Example 1

Question: *Based on Table 310.16, what size aluminum conductor is allowable to interconnect busbars that are protected by a 200A overcurrent protective device if all equipment terminals are rated 90°C?*

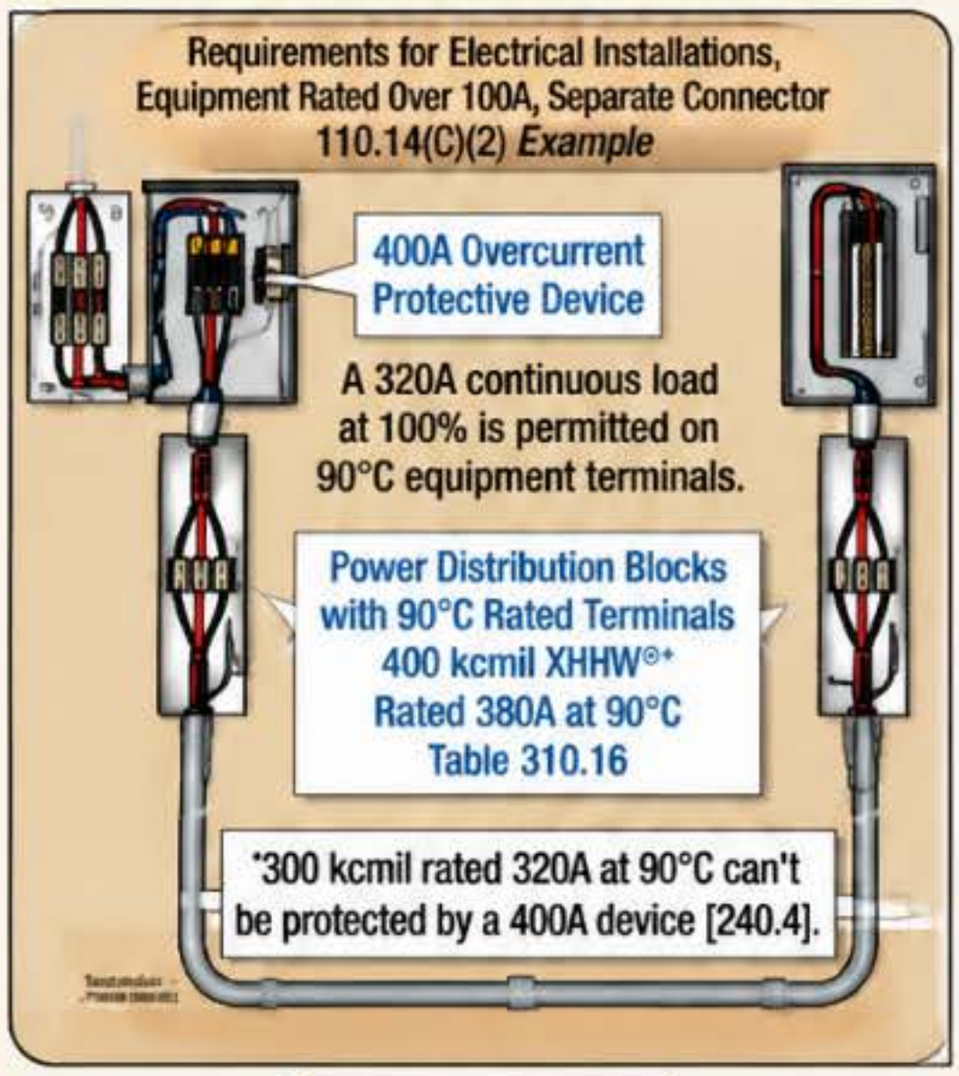
(a) 1/0 AWG (b) 2/0 AWG (c) 3/0 AWG (d) 4/0 AWG

Answer: *(d) 4/0 AWG aluminum rated 205A at 90°C [Table 310.16]*

▶ Example 2

Question: *Which size XHHW copper conductor is permitted to interconnect 90°C rated power distribution blocks that are protected by a 400A overcurrent protective device serving a 320A continuous load?*

(a) 250 kcmil (b) 300 kcmil (c) 350 kcmil (d) 400 kcmil



▶ Figure 110–40

Author's Commentary:

Although 350 kcmil is rated 350A at 90°C, it is not usable because it cannot be protected by a 400A overcurrent protective device [240.4].

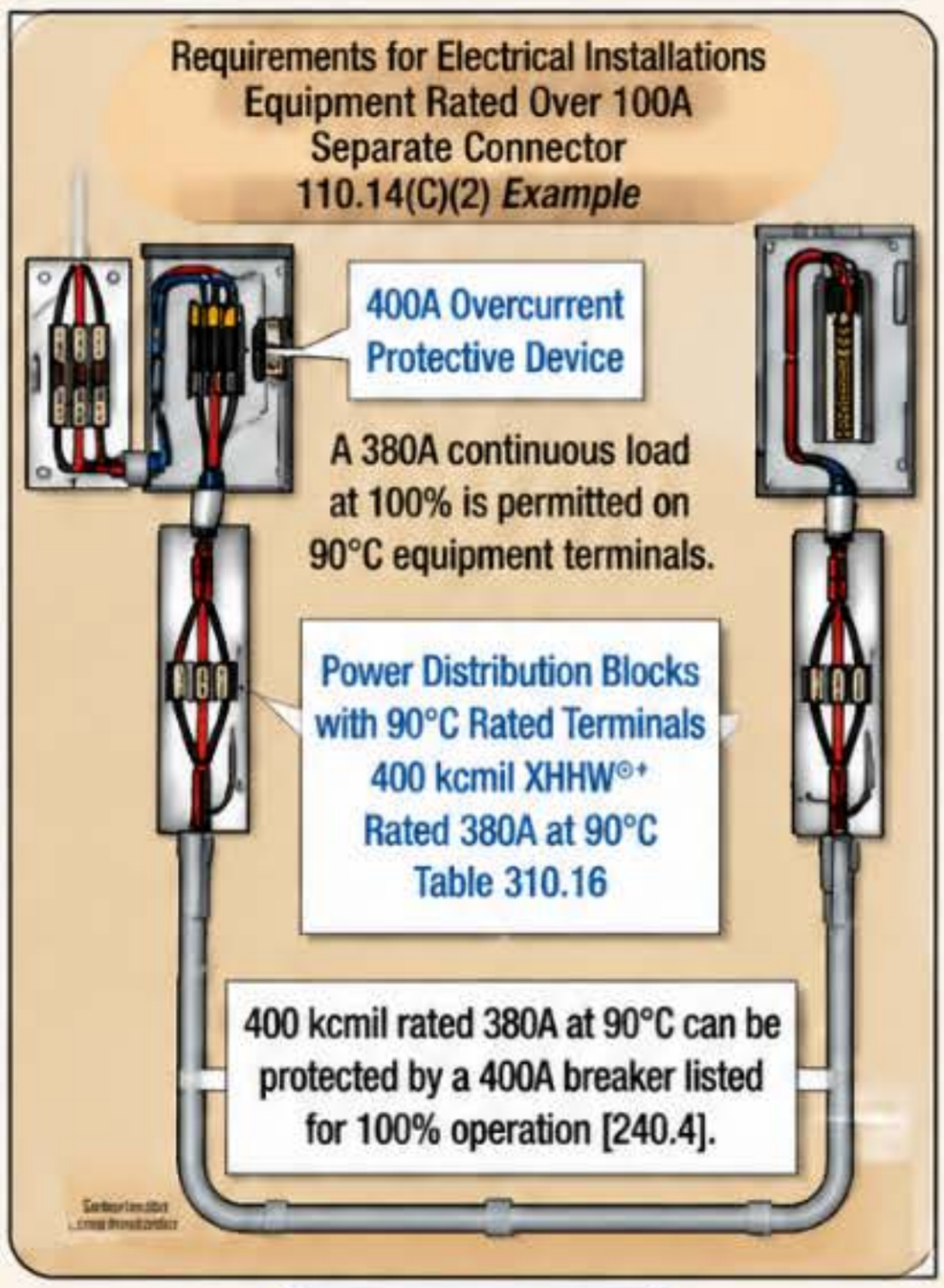
Answer: *(d) 400 kcmil rated 380A at 90°C [Table 310.16]*

— Michael Hamilton

▶ Example 3

Question: *Which size XHHW copper conductor can be used to interconnect 90°C rated power distribution blocks that are protected by a 400A overcurrent protective device serving a 375A continuous load?*

(a) 250 kcmil (b) 300 kcmil (c) 350 kcmil (d) 400 kcmil



▶ Figure 110–41

Author's Commentary:

A 400 kcmil conductor is rated 380A at 90°C and is permitted to be protected by a 400A overcurrent protective device that is listed for continuous operation at 100% [240.4].

Answer: *(d) 400 kcmil rated 380A at 90°C [Table 310.16]*

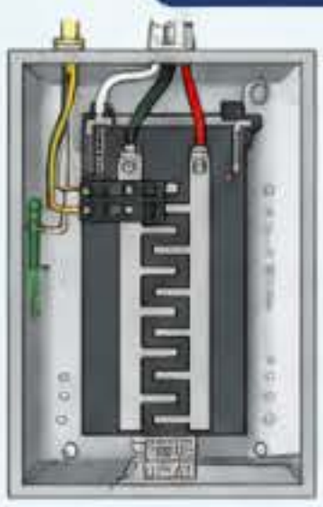
— Michael Hamilton

Table 310.16 Ampacities of Insulated Conductors Based on Not More Than Three Current-Carrying Conductors and Ambient Temperature of 30°C (86°F)

Size	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	Size
AWG kcmil	TW UF	RHW THHW THW THWN XHHW USE	RHH RHW-2 THHN THHW THW-2 THWN-2 USE-2 XHHW XHHW-2	TW UF	THW THWN XHHW	THHN THW-2 THWN-2 THHW XHHW XHHW-2	AWG kcmil
	Copper			Aluminum/Copper-Clad Aluminum			
14	15	20	25	15	20	25	14
12	20	25	30	20	20	25	12
10	30	35	40	25	30	35	10
8	40	50	55	35	40	45	8
6	55	65	75	40	50	55	6
4	70	85	95	55	65	75	4
3	85	100	115	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	145	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	195	230	260	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500

(D) Terminal Connection Torque. Installations must be torqued to the value specified for each termination on the equipment or in the installation instructions. An approved measurement of torque is required to verify that the listed torque has been achieved. ▸ Figure 110–42 and ▸ Figure 110–43

Requirements for Electrical Installations
Terminal Connection Torque
110.14(D)

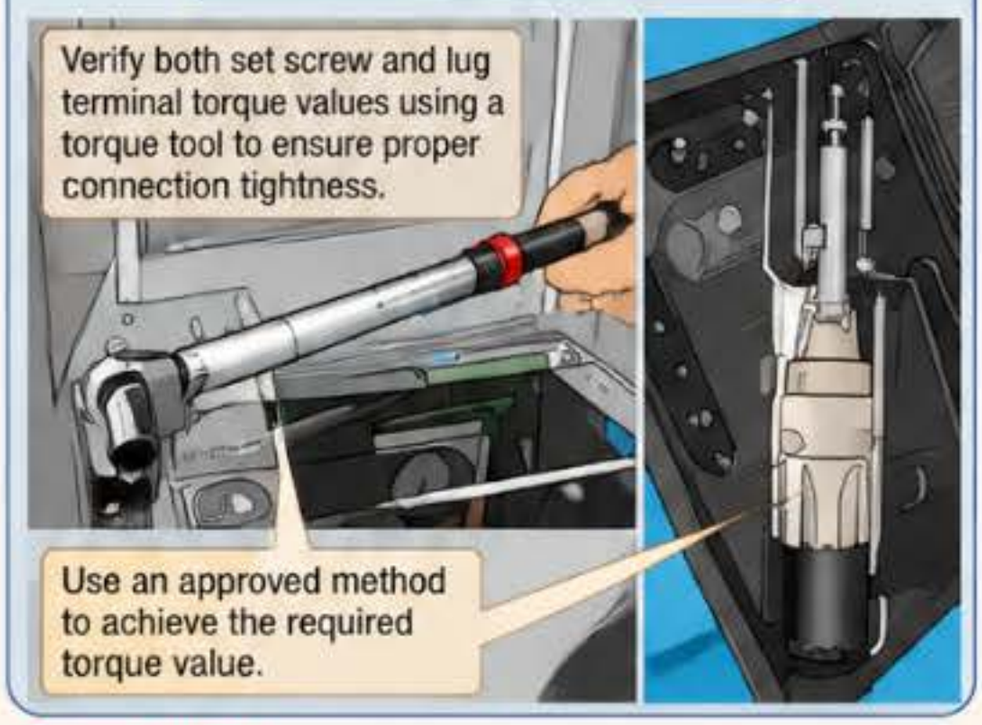


TORQUE WIRE PRESSURE SCREW(S) AS FOLLOWS.			
WIRE SIZE 60/75°C AL-CU AWG/ KCMIL	NEUTRAL & GROUND BAR LB-IN	GROUND LUG (GTL) NEUTRAL LUG (NL) LB-IN	PANEL LUGS (A & B) & MAIN NEUTRAL (M) LB-IN
#14–10	20	—	—
#8	25	—	—
#6–4	35	60	60
#3–2/0	—	80	60
#6–300	—	—	—

Torque on terminal connections must be verified using torque tools or equipment, or by following the installation instructions. An approved method is required to confirm that the specified torque has been reached.

▸ Figure 110–42

Requirements for Electrical Installations
Terminal Connection Torque
110.14(D)



▸ Figure 110–43

Author's Commentary:

All conductors must end in equipment that has been torqued in accordance with the manufacturer's torque specifications given in the instructions. Overheating can result if terminals are overly tight or too loose, or if devices are spliced instead of properly joined. Loose terminations can increase resistance, which may lead to excessive heat, arcing, or even a short circuit.

— Michael Hamilton

Ground faults may trigger fires, cause arc flashes, or lead to other serious hazards. Incorcect torqueing is also a violation of 110.3(B), which requires all equipment to be installed per the listing and labeling instructions.

Note 1: Some acceptable ways to reach the required torque include using torque wrenches, shear-head bolts, or breakaway-style devices with visible indicators that show correct torque has been achieved.

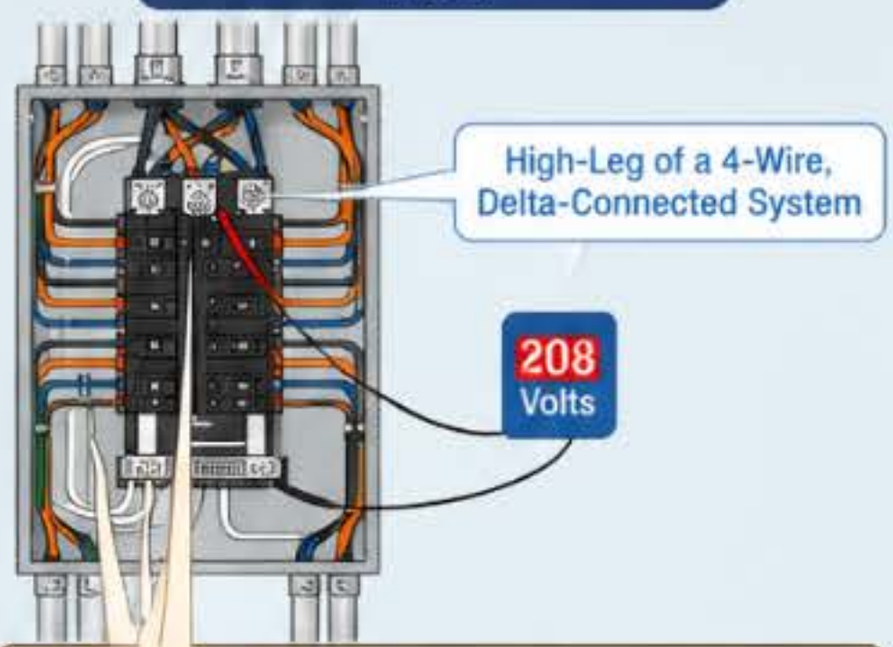
Note 2: If the equipment manufacturer does not provide a required torque or installation instructions, see Annex I of UL Standard 486A-486B, *Standard for Safety-Wire Connectors,* for torque values in the absence of the manufacturer's recommendations.

Note 3: More details on torquing threaded connections and terminations are found in Section 8.11 of NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance.*

110.15 High-Leg Conductor Identification

In a 4-wire, delta-connected, three-phase system (with the midpoint of one phase winding grounded), the conductor that measures 208V to ground (the "high leg") must be visibly and permanently identified along its entire length. Markings (insulation color or other effective means) must be applied at every point where a connection is made if the neutral conductor is present. ▸ Figure 110–44

Requirements for Electrical Installations
High-Leg Conductor Identification
110.15



The high-leg conductor must be marked in orange or by another effective method at every location in the system where a connection is made and the neutral conductor is present.

▸ Figure 110–44

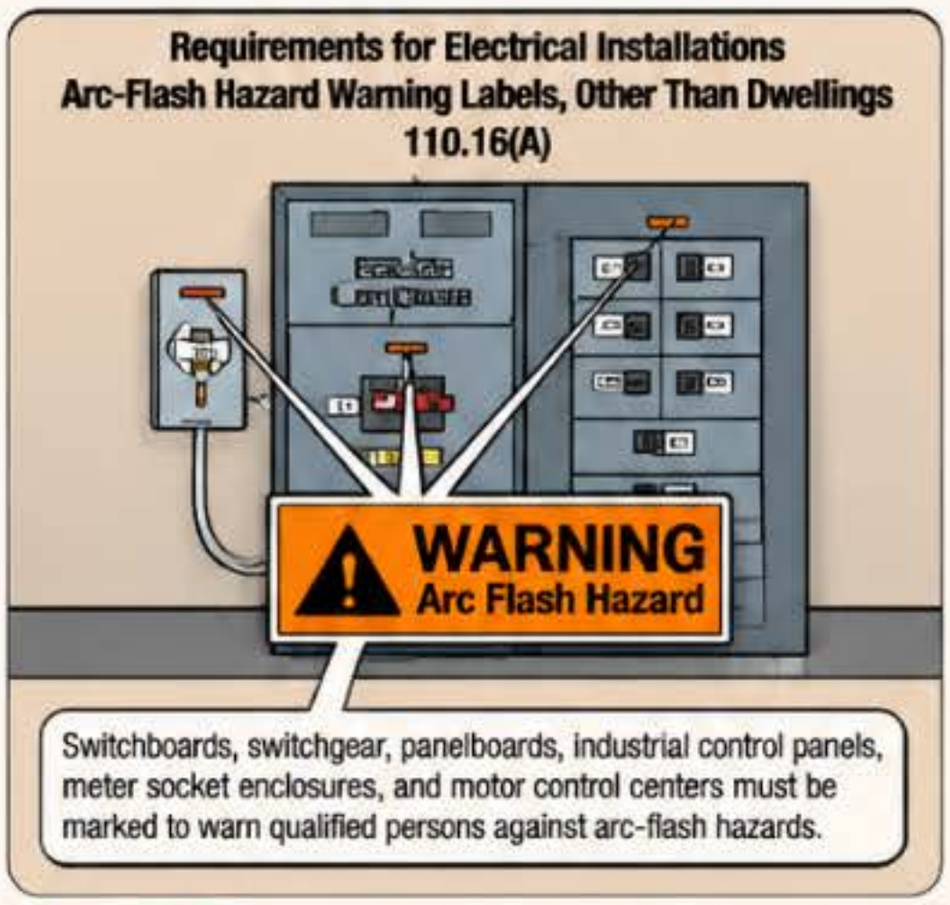
Author's Commentary:

The high-leg conductor is commonly known as the "wild leg" or "stinger leg."

— Michael Hamilton

110.16 Arc Flash Hazard Warning

(A) Arc Flash Hazard Warning Label. Beyond homes and dwelling units, service equipment, switchboards, switchgear, panelboards, industrial control panels, meter socket enclosures, and motor control centers are required to carry a permanent marker that notifies qualified persons of the risk of arc flash events caused by arcing faults. These labels must remain in place, resist wear over time, withstand the conditions involved [110.21(B)], and be easily visible to qualified individuals before they inspect, adjust, service, or maintain the equipment. ▸ Figure 110–45



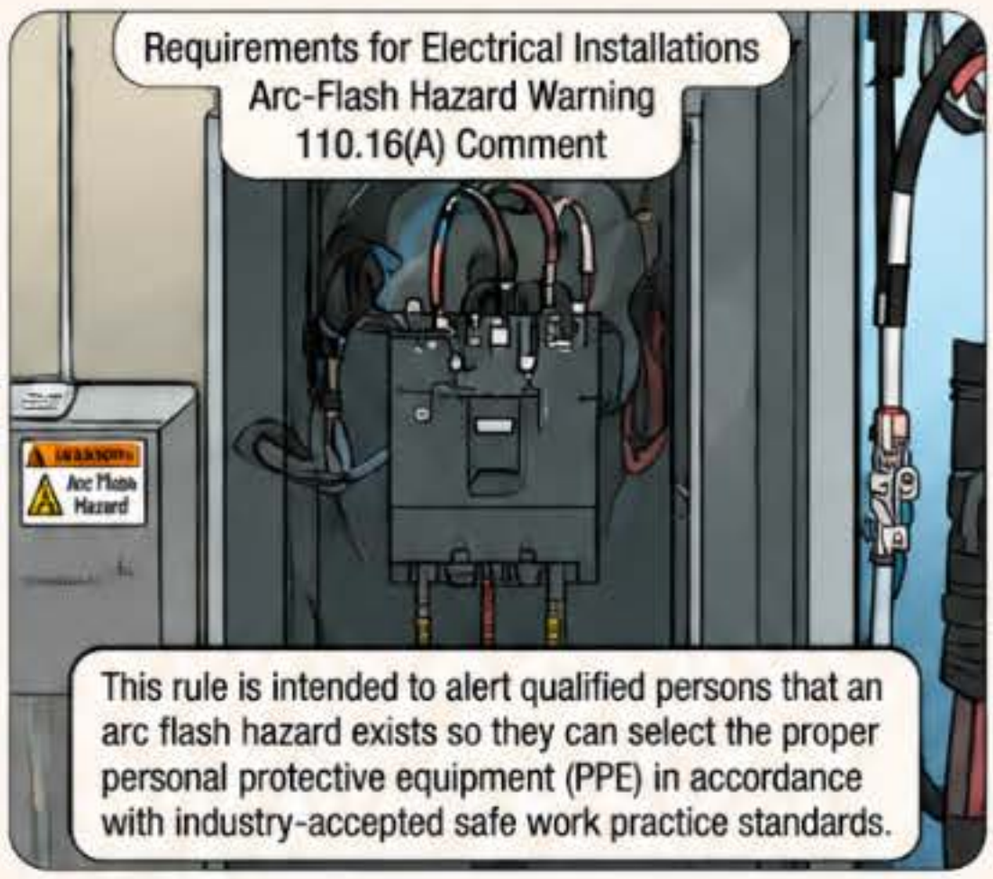
▸ Figure 110–45

Author's Commentary:

- Article 100 defines a "Qualified Person" as someone who has the knowledge and skills related to building and operating electrical equipment and its installation. This person must also receive safety training to identify and avoid electrical system hazards.
- NFPA 70E®, *Standard for Electrical Safety in the Workplace*, provides information about the qualifications for safety training required of a qualified person.

— Michael Hamilton

- Examples of this safety training include (but are not limited to) instruction on the use of special precautionary methods, personal protective equipment (PPE), insulating and shielding materials, and the use of insulated tools and test equipment when working on or near exposed conductors or circuit parts that can become energized.
- In many parts of the United States, electricians, electrical contractors, electrical inspectors, and electrical engineers must complete from 6 to 24 hours of *NEC* review each year as a requirement to maintain licensing. This does not necessarily make one qualified to handle the specific hazards involved with electrical systems.
- This rule is intended to warn qualified persons who work on energized electrical systems that an arc flash hazard exists and the severity of the potential danger. They will then be able to choose the necessary personal protective equipment (PPE) in accordance with industry-accepted safe work practice standards. ▸ Figure 110–46



▸ Figure 110–46

(B) Service Disconnect. In addition to the requirements in 110.16(A), a service disconnect rated 1,200 amperes or more must have a field or factory-installed label containing the following information and have sufficient durability to resist the environment: ▸ Figure 110–47

(1) Nominal system voltage

(2) Available fault current at the line side of the service overcurrent protective device

(3) Clearing time of the service overcurrent protective device

(4) Date the label was installed

REQUIREMENTS FOR ELECTRICAL INSTALLATIONS 110.21

Requirements for Electrical Installations
Arc-Flash Hazard Warning Label, Service Disconnect
110.16(B)

In addition to the requirements in 110.16(A), a service disconnect rated 1,200A or more must have a label that contains the nominal system voltage, available fault current, clearing time of the service overcurrent protection, and date the label was installed.

▶ Figure 110–47

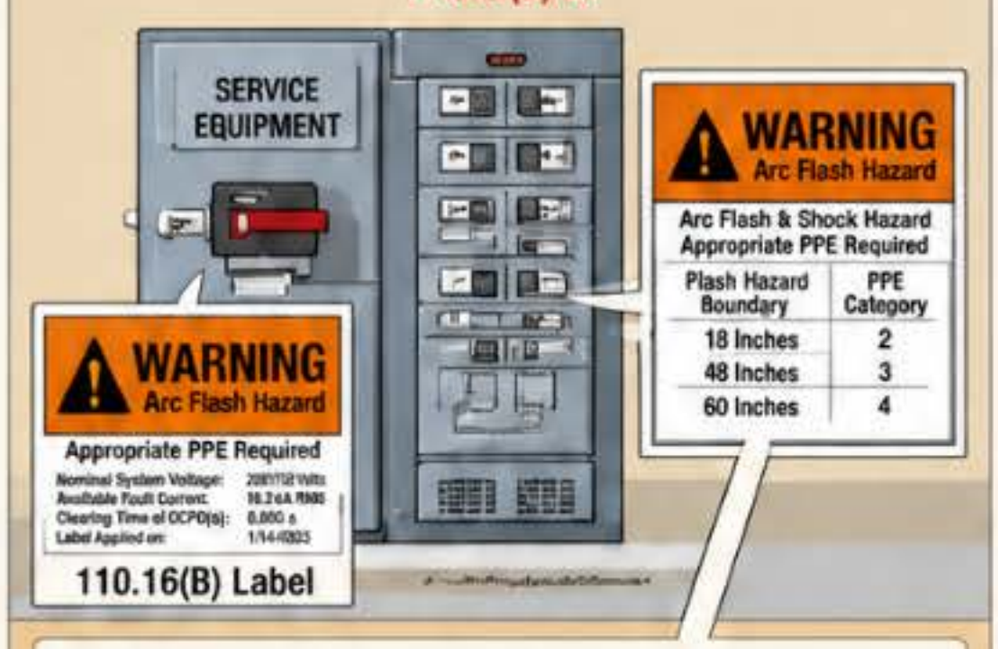
Author's Commentary:

To determine the available fault current on the line side of equipment terminals, you need to know the available fault current supplied by the electrical utility, the conductor material, the conductor length, and the wiring method used to install the conductors. With this information, you can run an app or use a computer software to calculate the available fault current at the line terminals.

— Michael Hamilton

Ex: *Service disconnect fault current labeling is not required if an arc flash label in accordance with NFPA 70E Standard for Electrical Safety in the Workplace, is applied. See Note 3.*

Requirements for Electrical Installations, Arc-Flash Hazard Warning Labels, Service Equipment 1,200A or More
110.16(B) Ex

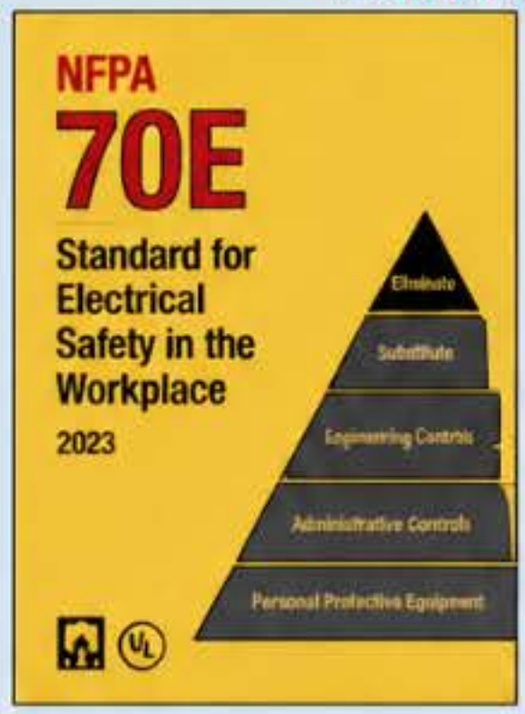


Service equipment labels required by 110.16(B) are not required if an arc flash label complying with NFPA 70E is applied.

▶ Figure 110–48

Note 1: NFPA 70E, *Standard for Electrical Safety in the Workplace,* provides guidance in determining the severity of potential exposure, planning safe work practices, arc flash labeling, and selecting personal protective equipment. ▶ Figure 110–49

Requirements for Electrical Installations
Arc-Flash Hazard Warning Labels, Service Equipment
110.16(B) Note 1



NFPA 70E, Standard for Electrical Safety in the Workplace, provides guidance in determining the severity of potential exposure, planning safe work practices, arc flash labeling, and selecting personal protection.

▶ Figure 110–49

Note 3: NFPA 70E, *Standard for Electrical Safety in the Workplace* provides specific criteria for developing arc flash labels such as nominal system voltage, incident energy levels, arc flash boundaries, and selecting personal protective equipment.

Author's Commentary:

The information required by 110.16(B)(1), (2), and (3) is necessary in order to determine the incident energy and arc flash boundary distance by using of an app or computer software to ensure the label complies with NFPA 70E to increase safety during future work on service equipment.

— Michael Hamilton

110.21 Markings

(A) Equipment Markings

(1) General. The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product can be identified must be placed on all electrical equipment. Other markings indicating voltage, current, wattage, or other ratings must be provided as specified elsewhere in this *Code*. The marking orf label must be of sufficient durability to withstand the environment involved.

(2) Reconditioned Equipment

Reconditioned equipment must carry a nameplate, trademark, or other descriptive marking from the organization that performed the reconditioning, along with the date the reconditioning was completed.

The equipment must be clearly identified as "reconditioned," and the original listing mark must be removed. Approval of reconditioned equipment cannot rely solely on the equipment's original listing.

Example: In industrial settings, when service or maintenance companies (along with supervisors) confirm that only qualified people will use the equipment, the markings referenced in 110.21(A)(2) are not required for equipment that is reconditioned by the owner or operator as part of a scheduled maintenance program.

Note 1: Industry standards provide guidance for the use of reconditioned and refurbished equipment.

Note 2: The term "reconditioned" can be used interchangeably with "rebuilt," "refurbished," or "remanufactured."

Note 3: The original listing mark may appear on the certifying body and not on the entire equipment label.

(B) Field-Applied Hazard Markings. When caution, warning, or danger labels are required, the labels must meet these requirements:

(1) The markings must alert to the hazards using one or more of the following: effective words, colors, symbols, or any combination of the three. ▶ Figure 110–50

Requirements for Electrical Installations
Field-Applied Hazard Markings
110.21(B)(1)

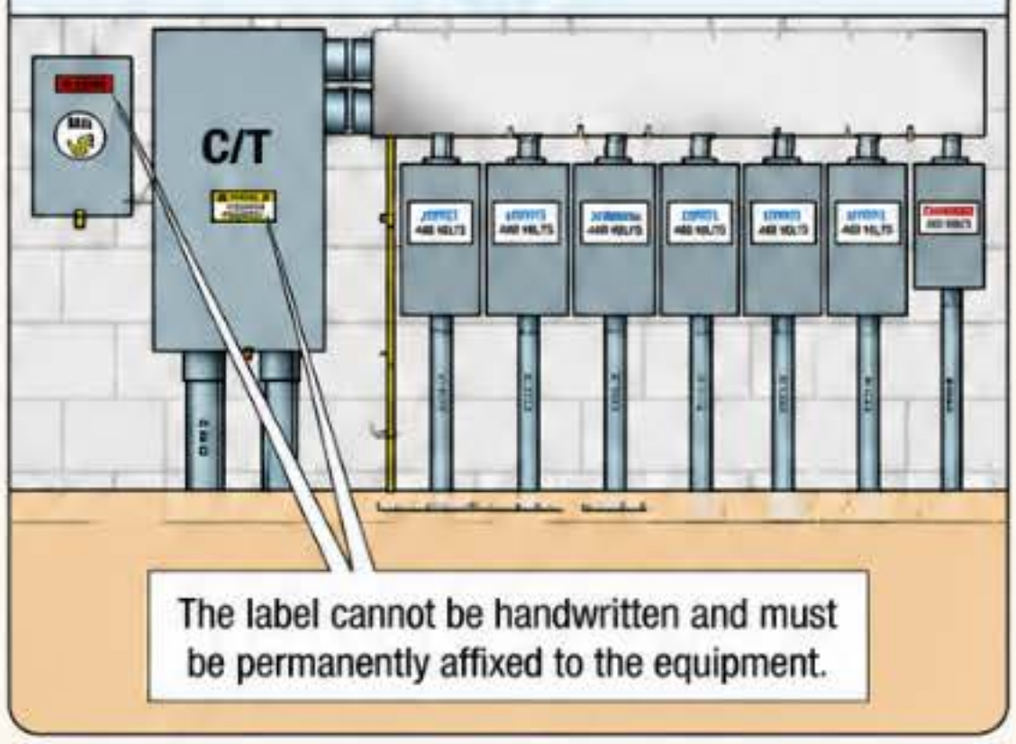
The markings must alert to the hazards using effective words, colors, symbols, or any combination of those elements.

▶ Figure 110–50

Note: ANSI Z535.4, *Product Safety Signs and Labels*, offers guidance on the design and durability of signs and labels.

(2) The label cannot be handwritten and must be permanently affixed to the equipment. ▶ Figure 110–51

Requirements for Electrical Installations
Field-Applied Hazard Markings, Label Requirements
110.21(B)(2)



▶ Figure 110–51

Example: Information that changes frequently may be printed, as long as the print remains easy to read.

(3) The marking must be durable enough to withstand the environment where it is installed.

110.22 Identification of Disconnecting Means

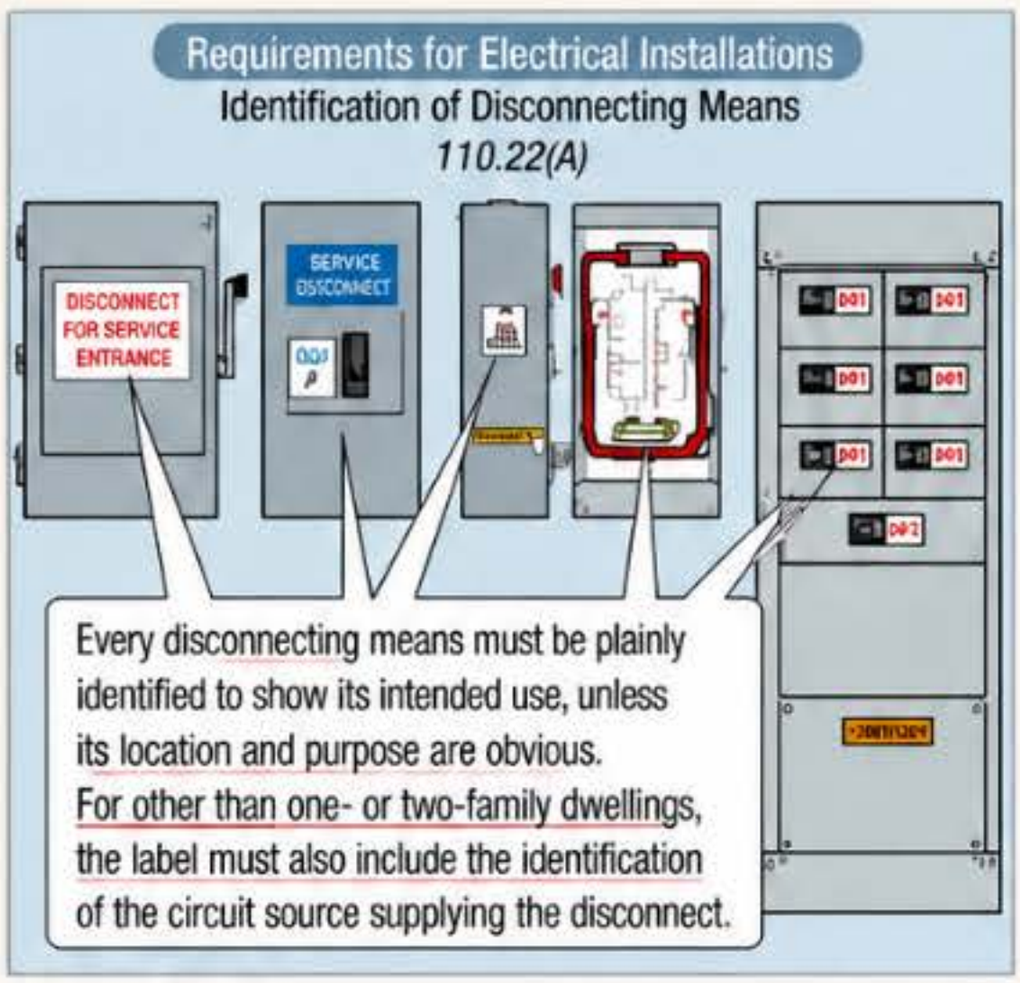
(A) General. Each disconnecting means must be clearly marked to show its intended purpose, unless its location and arrangement make its use obvious. In two- or multiple-family dwellings, the marking must include the identification of the circuit source that supplies the disconnecting means. The marking must also be durable enough to withstand the environmental conditions where it is installed. ▶ Figure 110–52

Author's Commentary:

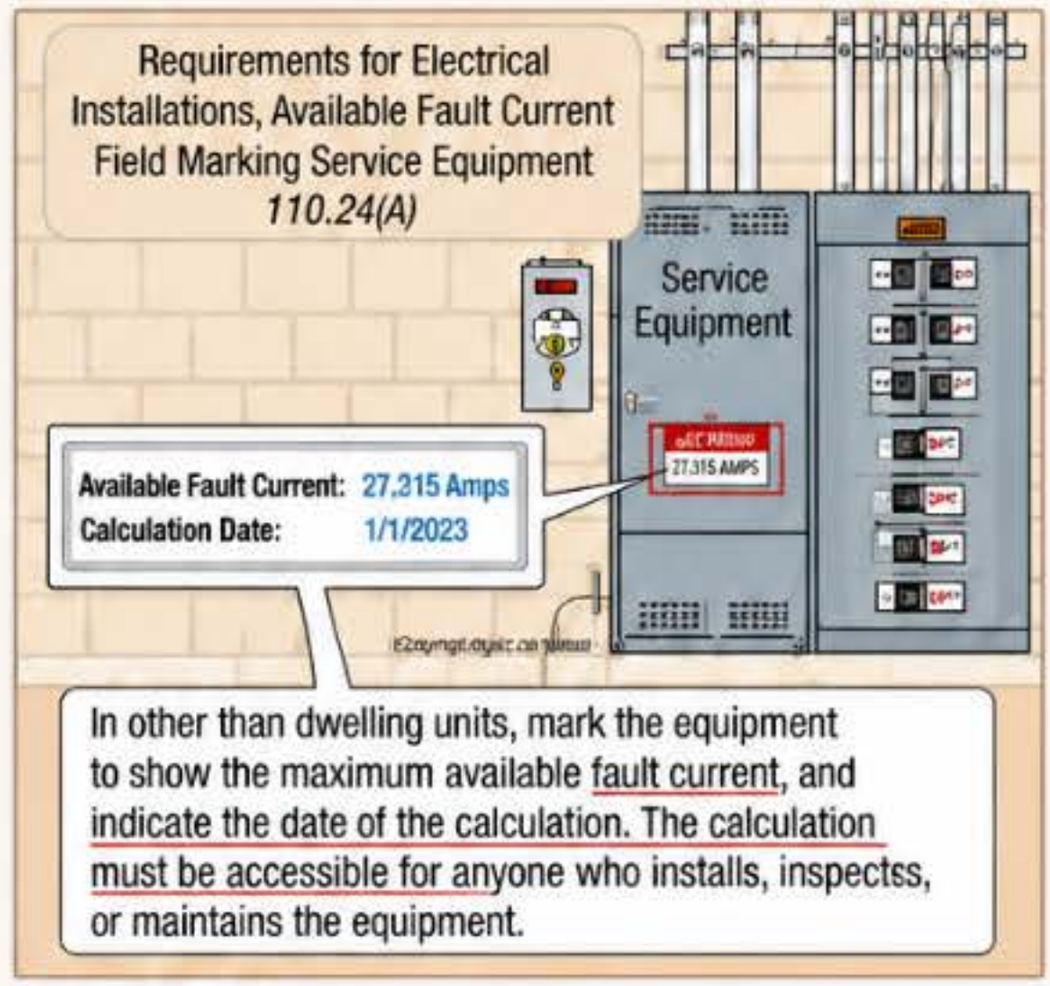
- See 408.4 for extra requirements related to identification markings on circuit directories for switchboards and panelboards.

— Michael Hamilton

(C) Tested Series Combination Systems. Tested series-rated installations must be clearly field-marked to show that the equipment has been applied using a series combination rating in accordance with 240.86(B). The marking must be permanently affixed and have enough durability to withstand the environment in accordance with 110.21(B) and must state:



▸ Figure 110-52



▸ Figure 110-53

CAUTION—SERIES COMBINATION SYSTEM RATED ___ AMPERES. IDENTIFIED REPLACEMENT COMPONENTS REQUIRED

110.24 Available Fault Current

(A) Field Marking. In other than dwelling units, service disconnects must be marked with the available fault current on the line side of the disconnect, along with the date the fault current calculation was performed. The marking must be durable enough to remain legible in the environment.

The available fault current calculation must be documented and accessible to those authorized to design, install, inspect, maintain, or operate the system. ▸ Figure 110-53

Note 1: The markings required by this section relate to the short-circuit and interrupting ratings of equipment specified in 110.9 and 110.10. They are not intended for use in arc flash analysis. Arc-flash hazard information is addressed in NFPA 70E, *Standard for Electrical Safety in the Workplace.*

Note 2: Values of available fault current for establishing short-circuit and interrupting ratings of equipment are provided by electric utilities in published or other forms.

(B) Modifications. If changes to an electrical installation affect the available fault current at the service disconnect, recalculate the available fault current to confirm that the new short-circuit current ratings at the service disconnect remain adequate for the available fault current. Any required field marking(s) required by 110.24(A) must be updated to reflect the new available fault current.

Author's Commentary:
It is typical for electrical systems to be modified to accommodate growth. When equipment is added to improve efficiency or to support alternative energy sources, these factors can raise the available fault current if the utility transformer is changed. This increase in available fault current may cause the short-circuit current ratings of equipment to be surpassed, potentially violating 110.9 and 110.10.
— Michael Hamilton

Ex: Field markings required in 110.24(A) and 110.24(B) are not required for industrial installations where ongoing maintenance and supervision are provided solely by qualified service personnel for the equipment.

110.25 Lockable Disconnecting Means

The *Code* requires that a disconnect be capable of being locked in the open position. The locking provisions must remain in place whether or not the locking mechanism is installed. ▸ Figure 110-54

Figure 110–54

When the Code calls for a disconnect to be lockable in the open position, the means for locking must stay in place whether the lock is on it or not.

Part II. 1,000V, Nominal, or Less

110.26 Spaces About Electrical Equipment

For the safety and proper upkeep of equipment, all electrical equipment must have free access and adequate working space. **Figure 110–55**

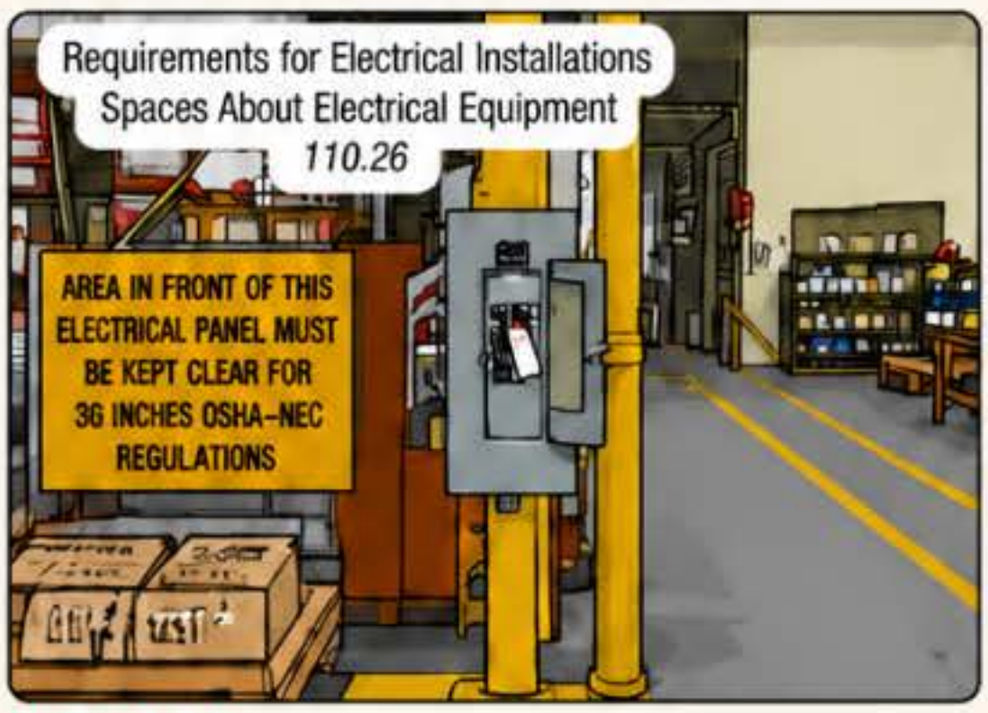


Figure 110–55

To allow safe operation and maintenance, there must be sufficient space around electrical equipment for access, inspection, and for worker protection [110.26(A)] and dedicated space for access and safeguarding the equipment [110.26(E)].

> ***Author's Commentary:*** Clearances around electrical equipment (its width, depth, and height) create a safe zone for workers [110.26(A)] and also provide room to reach and protect the equipment [110.26(E)].
>
> ***— Michael Hamilton***

(A) Working Space. Equipment that may require inspection, adjustment, servicing, or maintenance while energized must have sufficient working space provided as specified in 110.26(A)(1), (2), (3), and (4).

> ***Author's Commentary:*** The wording "*while energized*" is the starting point for many discussions. Always verify with the authority having jurisdiction to understand what equipment he or she requires to have adequate working space.
>
> ***— Michael Hamilton***

Note: NFPA 70E, *Standard for Electrical Safety in the Workplace*, offers guidance for evaluating the seriousness of possible arc flash exposure, planning safe work practices (including establishing an electrically safe work condition), applying arc flash labels, and choosing personal protective equipment.

(1) Depth of Working Space. The depth of working space, measured from the front of the enclosure, must be at least the distances listed in Table 110.26(A)(1), which vary depending on both voltage and the condition of the equipment. **Figure 10–56**

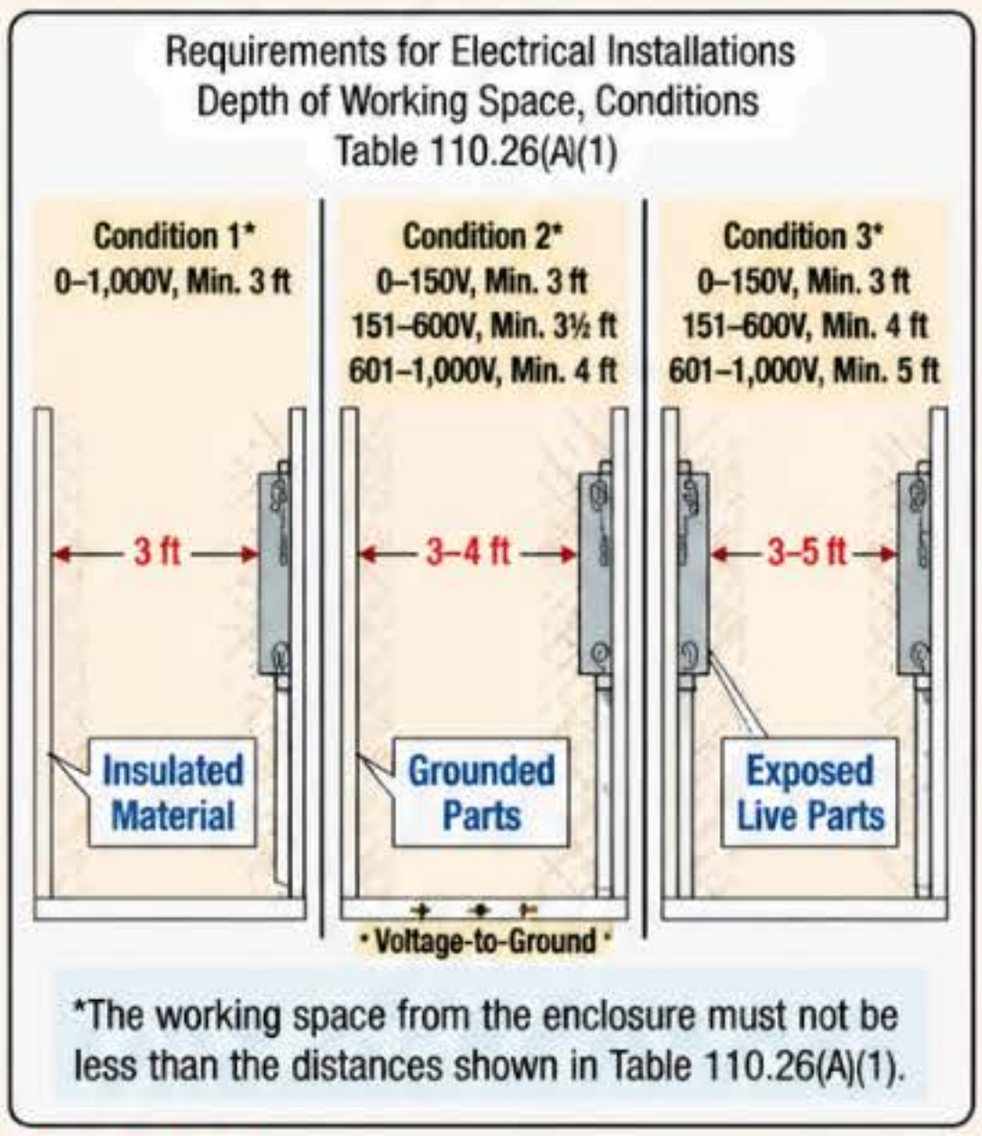


Figure 110–56

> ***Author's Commentary:*** Measure the depth of working space from the front face of the enclosure, not from the internal components.
>
> ***— Michael Hamilton***

Requirements for Electrical Installations | 110.26

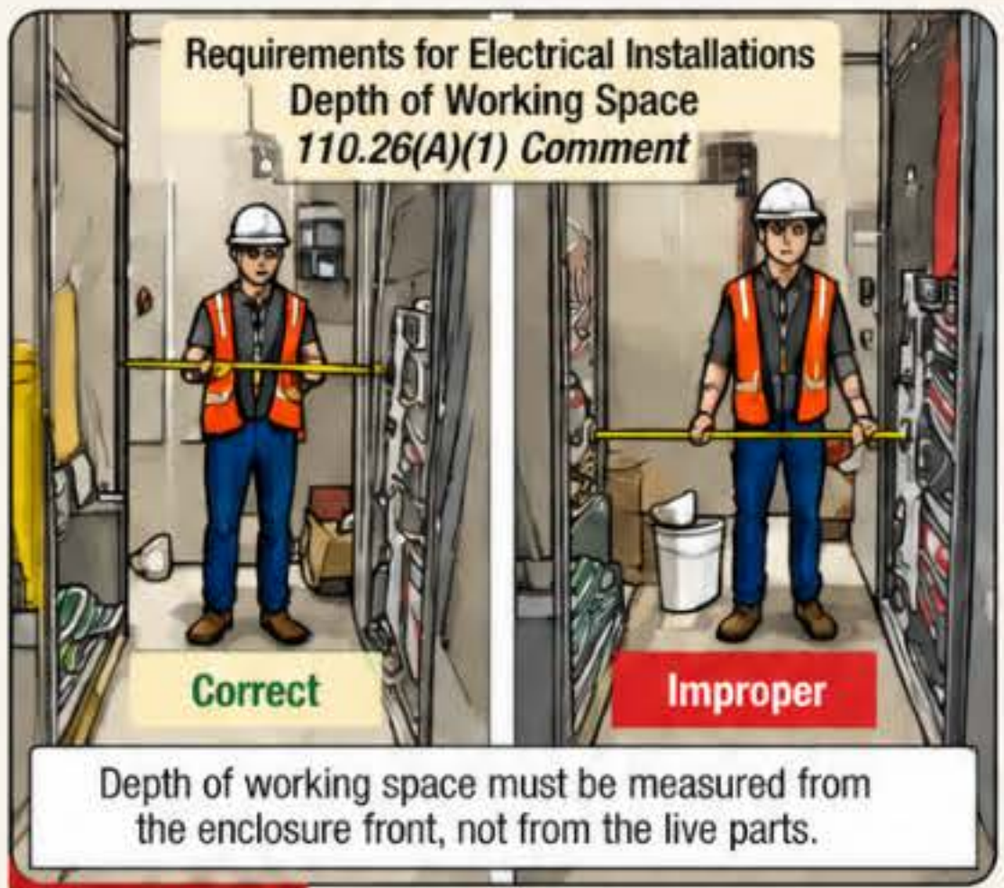


Figure 110-57

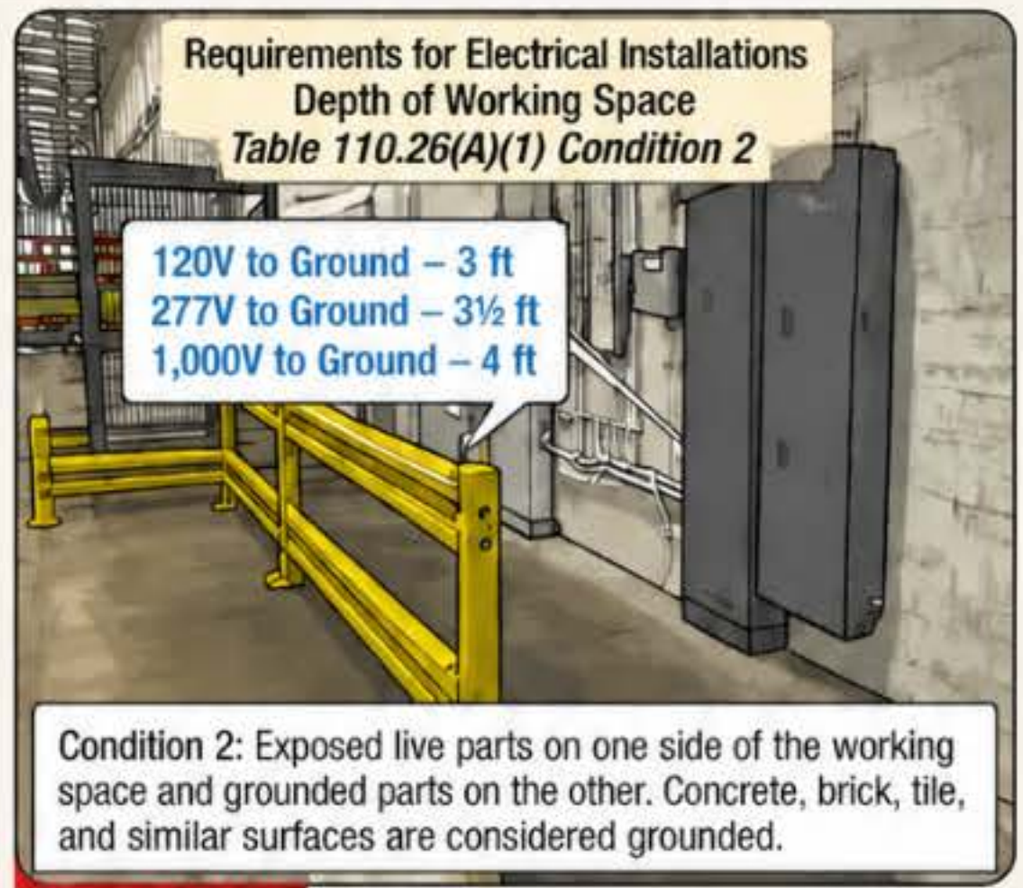


Figure 110-59

Table 110.26(A)(1) Working Space

Voltage-to-Ground	Condition 1	Condition 2	Condition 3
0–150V	3 ft	3 ft	3 ft
151–600V	3 ft	3½ ft	4 ft
601–1,000V	3 ft	4 ft	5 ft

▸**Figure 110-58**, **Figure 110-59**, *and* **Figure 110-60**

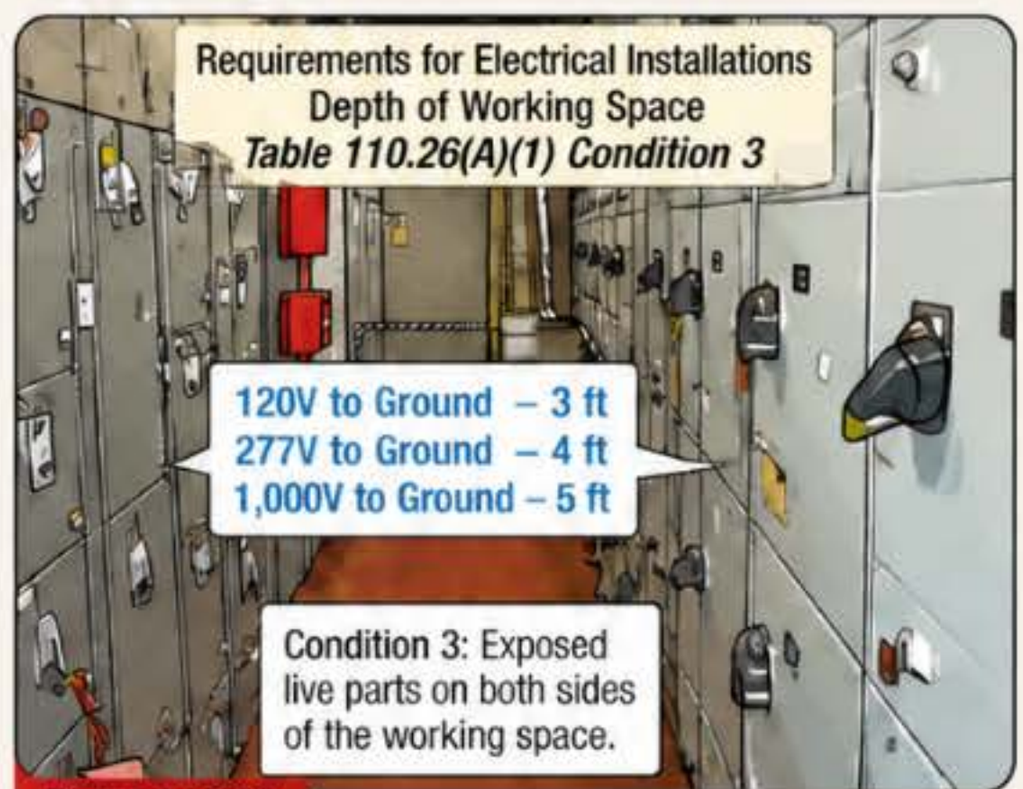


Figure 110-60

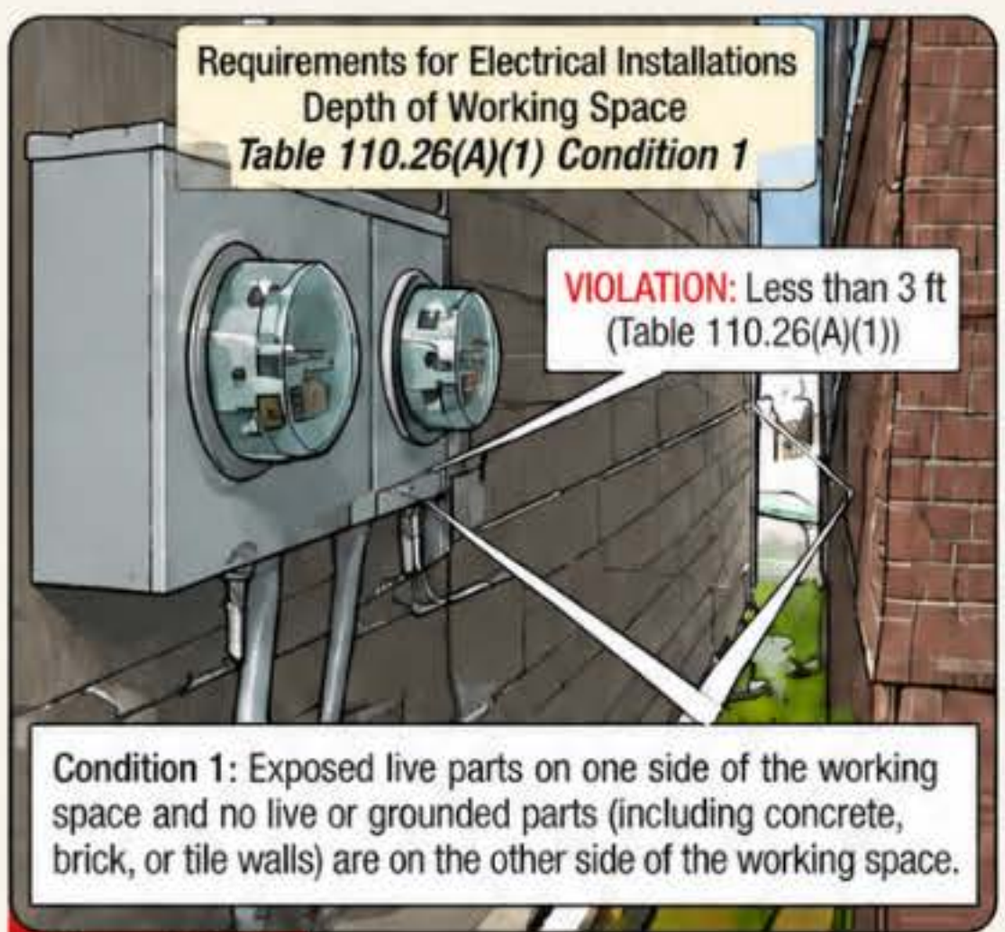


Figure 110-58

Author's Commentary:

If the working space is a platform, it must be sized to the working space requirements.

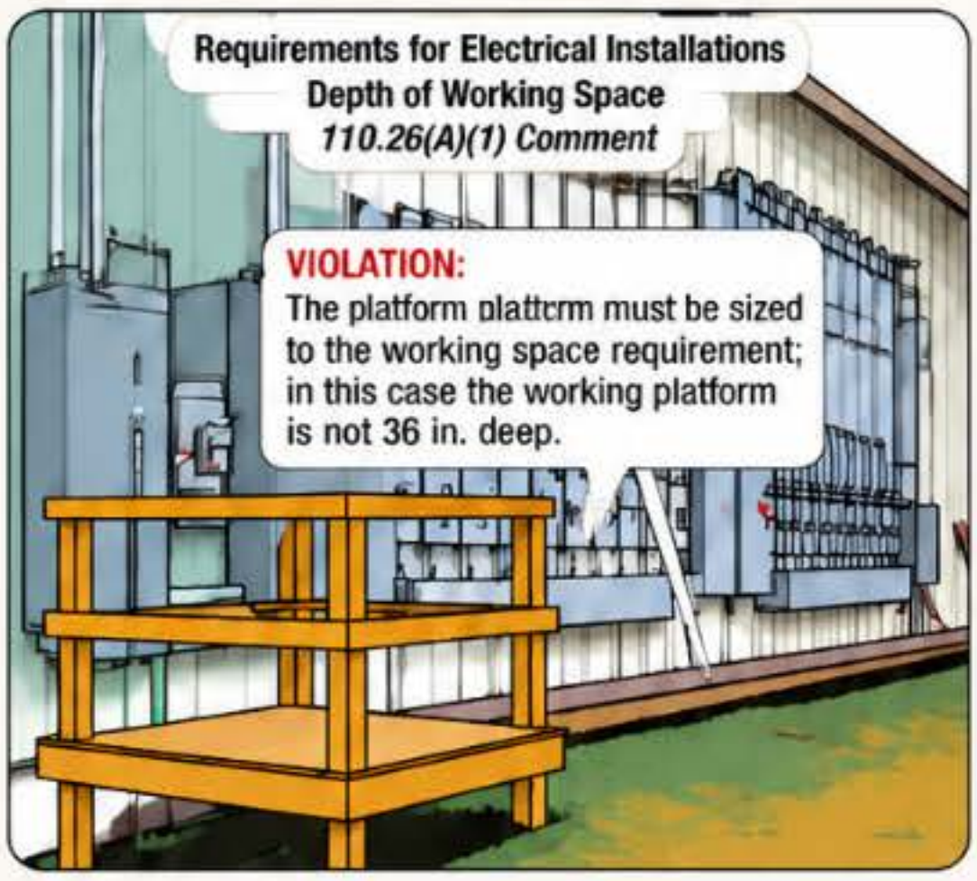
— Michael Hamilton

(a) Rear and Sides of Dead-Front Equipment. Working space is not required at the back or sides of equipment where all connections and all removable, adjustable, or serviceable parts are accessible from the front. **Figure 110-61**

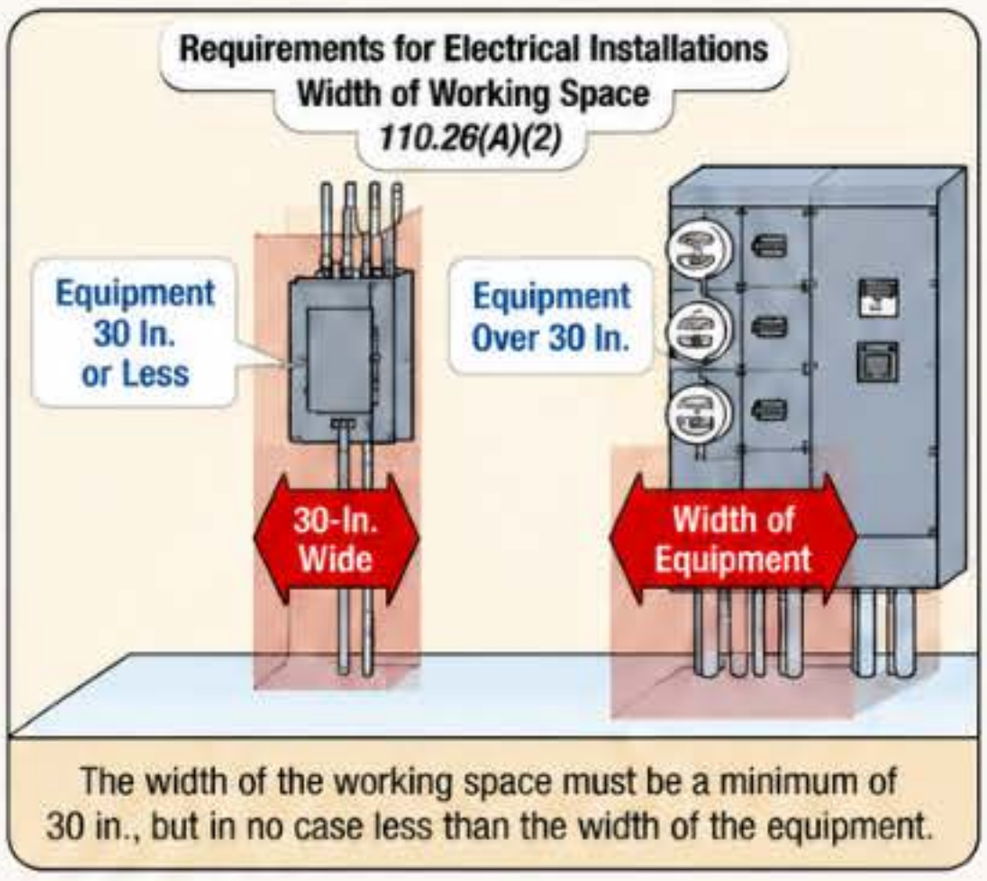
Author's Commentary:

Sections of equipment that require rear or side access to make field connections must be marked by the manufacturer on the front of the equipment. See 408.18(C).

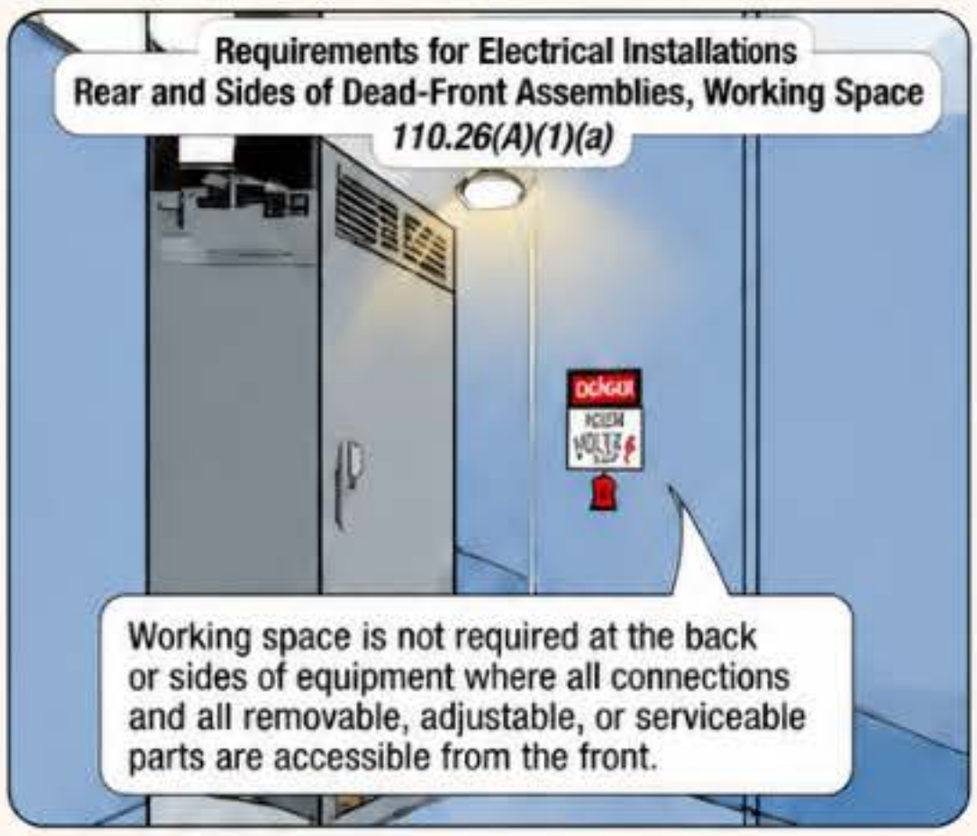
— Michael Hamilton



▸ Figure 110–61



▸ Figure 110–63

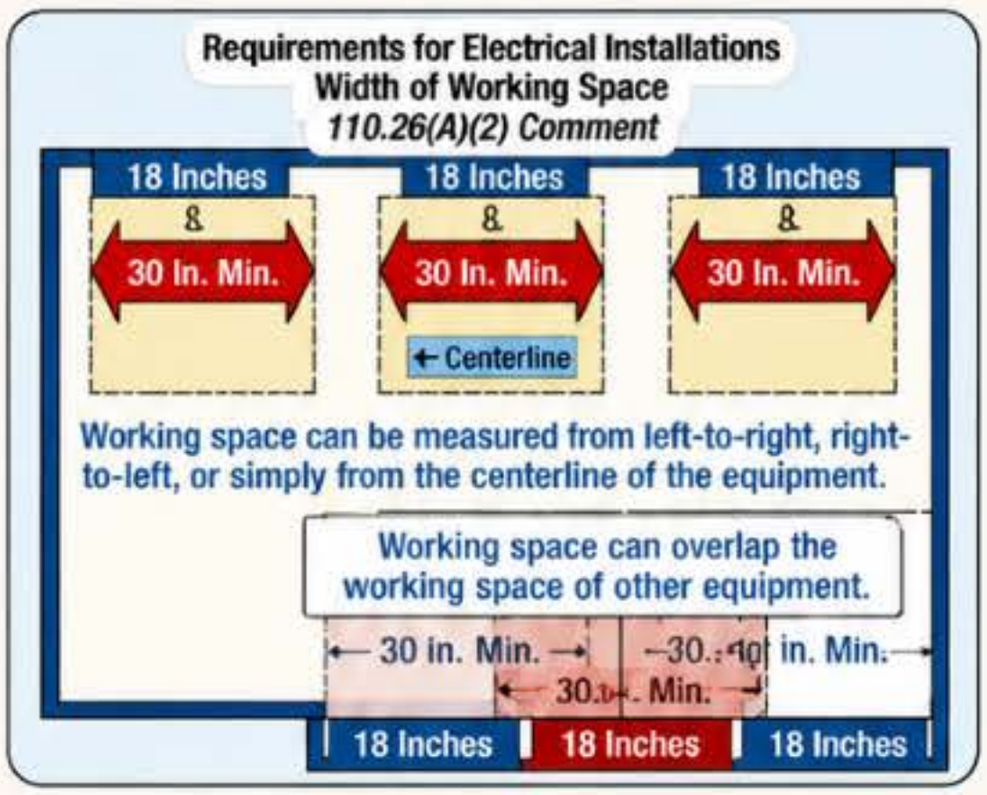


▸ Figure 110–62

(c) Existing Buildings. When electrical equipment is being replaced, Condition 2 working space is allowed between dead-front switchboards, switchgear, panelboards, or motor control centers located across the aisle from each other where ongoing maintenance and supervision follow written procedures. These written procedures have been adopted to prevent equipment on both sides of the aisle from being opened at the same time, and only authorized, qualified persons will perform the work.

(2) Width of Working Space. The width of the working space must be a minimum of 30 in., but in no case less than the width of the equipment. ▸ Figure 110–63

Author's Commentary:
The width of the working space can be measured from left-to-right, from right-to-left, or simply centered on the equipment and allow it to overlap the working space for any neighboring electrical equipment.
▸ Figure 110–64 ▸ Figure 110–65 — *Michael Hamilton.*

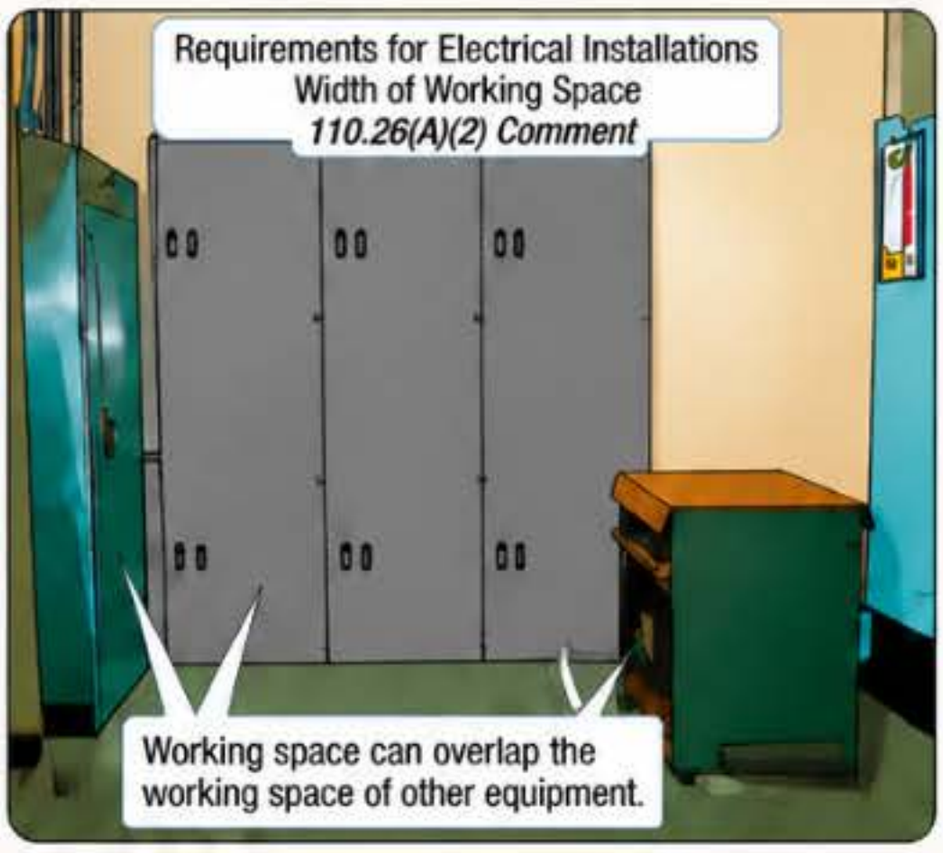


▸ Figure 110–64

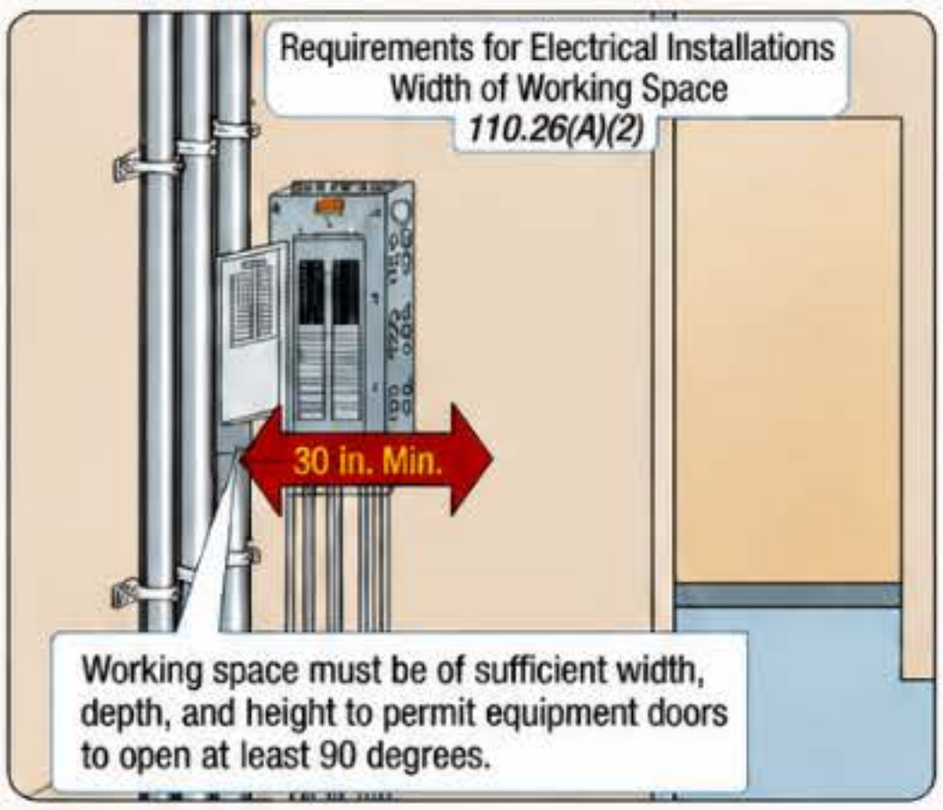
The working space must be of sufficient width, depth, and height to permit equipment doors to open at least 90 degrees. ▸ Figure 110–66

(3) Height of Working Space. The height of the working space must be clear and extend from the grade, floor, or platform to a height of 6½ ft or the height of the equipment. ▸ Figure 110–67

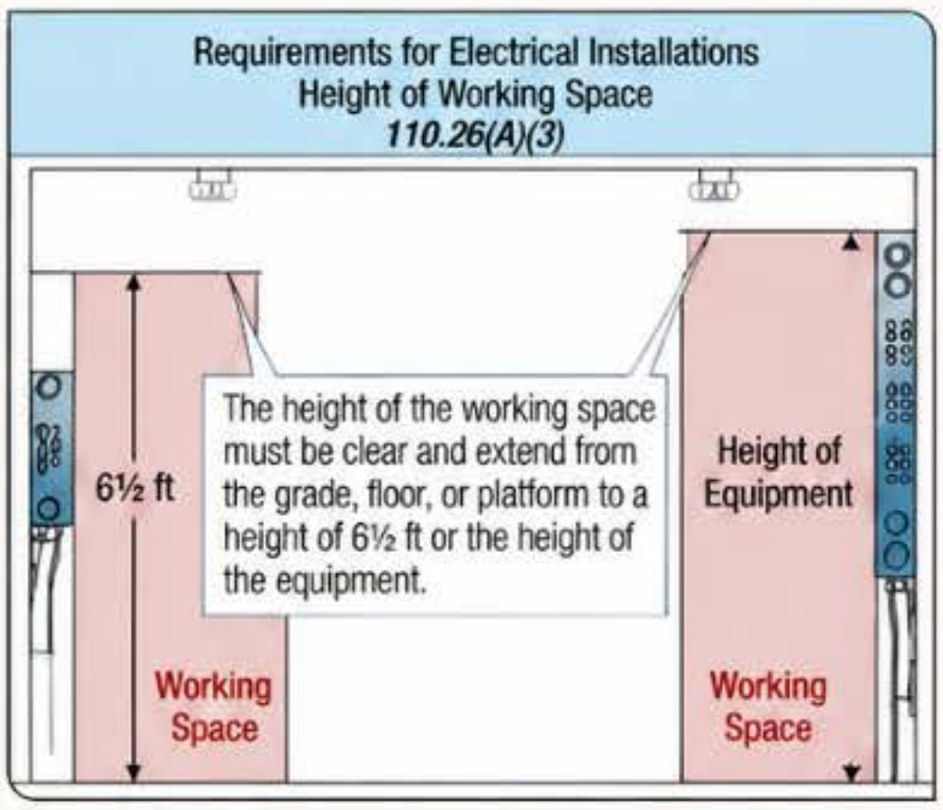
Requirements for Electrical Installations 110.26



▶Figure 110-65

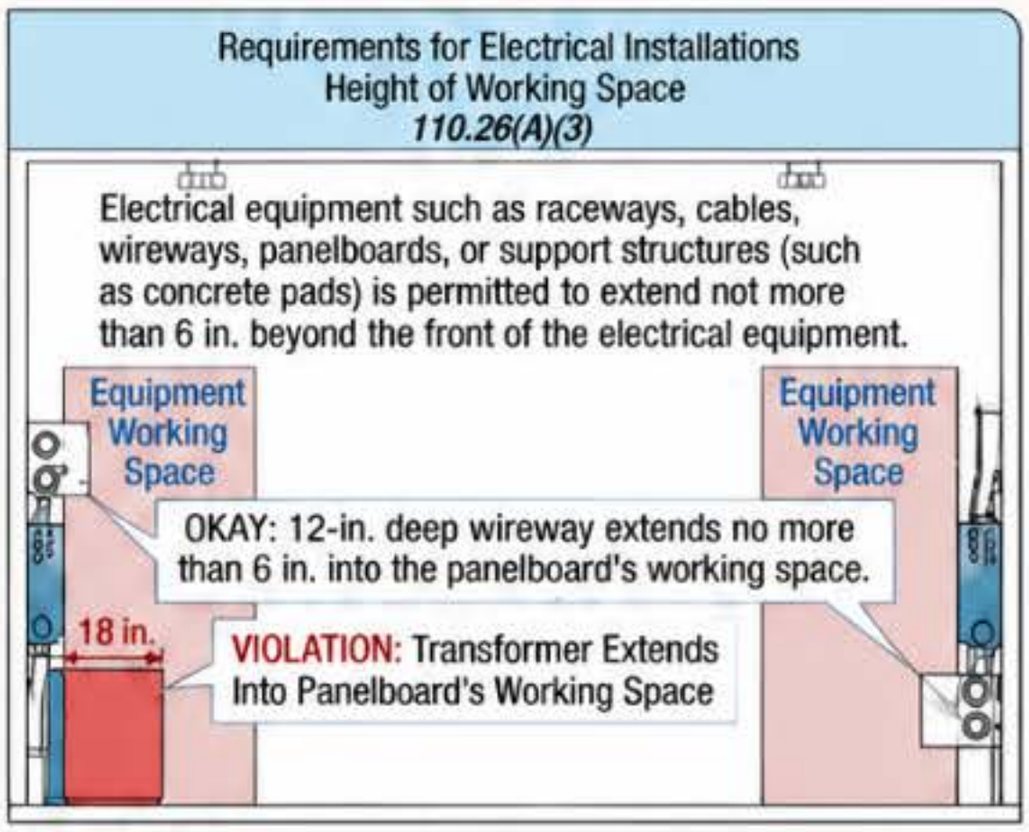


▶Figure 110-66

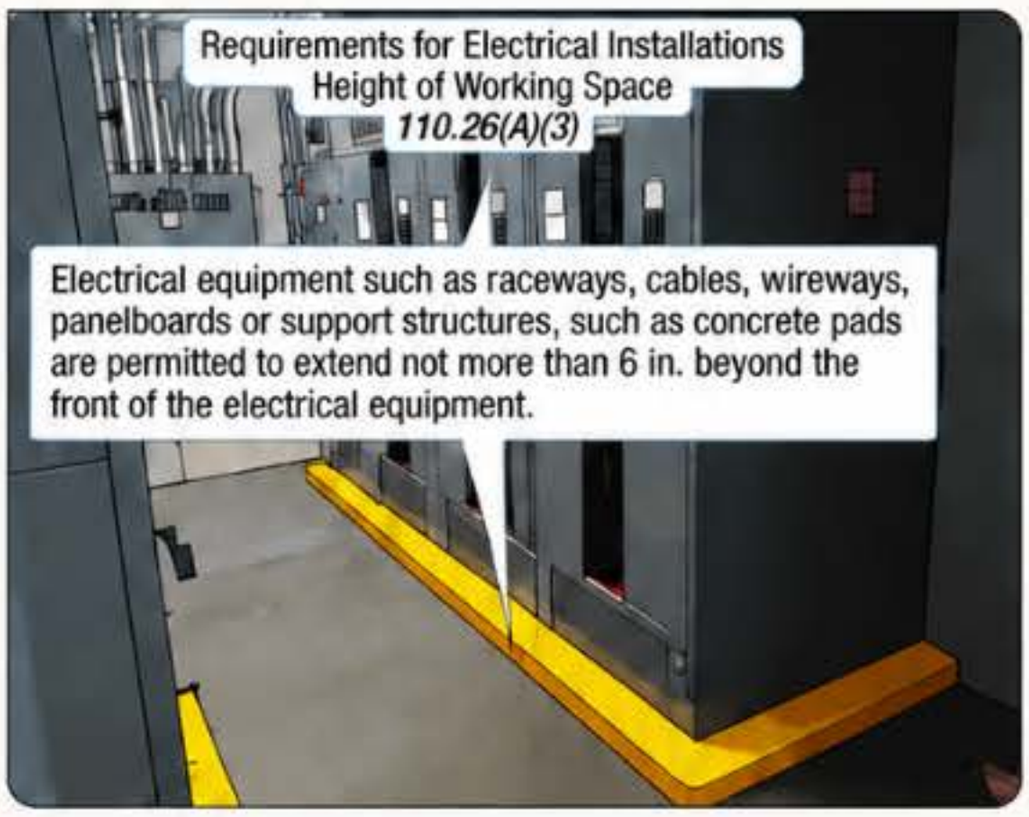


▶Figure 110-67

Electrical equipment such as raceways, cables, wireways, panelboards, or support structures (such as concrete pads) are permitted to extend not more than 6 in. beyond the front of the electrical equipment. ▶Figure 110-68 and ▶Figure 110-69



▶Figure 110-68



▶Figure 110-69

Ex 1: The minimum height of working space does not apply to a service disconnect or panelboards rated 200A or less located in an existing dwelling unit.

Ex 2: Meters are permitted in the working space.

(4) Limited Access. Where equipment is likely to require examination, adjustment, servicing, or maintenance while energized is located above a suspended ceiling or crawl space, all the following conditions apply:

110.26 | Requirements for Electrical Installations

(1) Equipment located above a suspended ceiling must provide an access opening at least 22 in. by 22 in. in size. For equipment in a crawl space, the opening must be accessible and not less than 22 in. by 30 in.

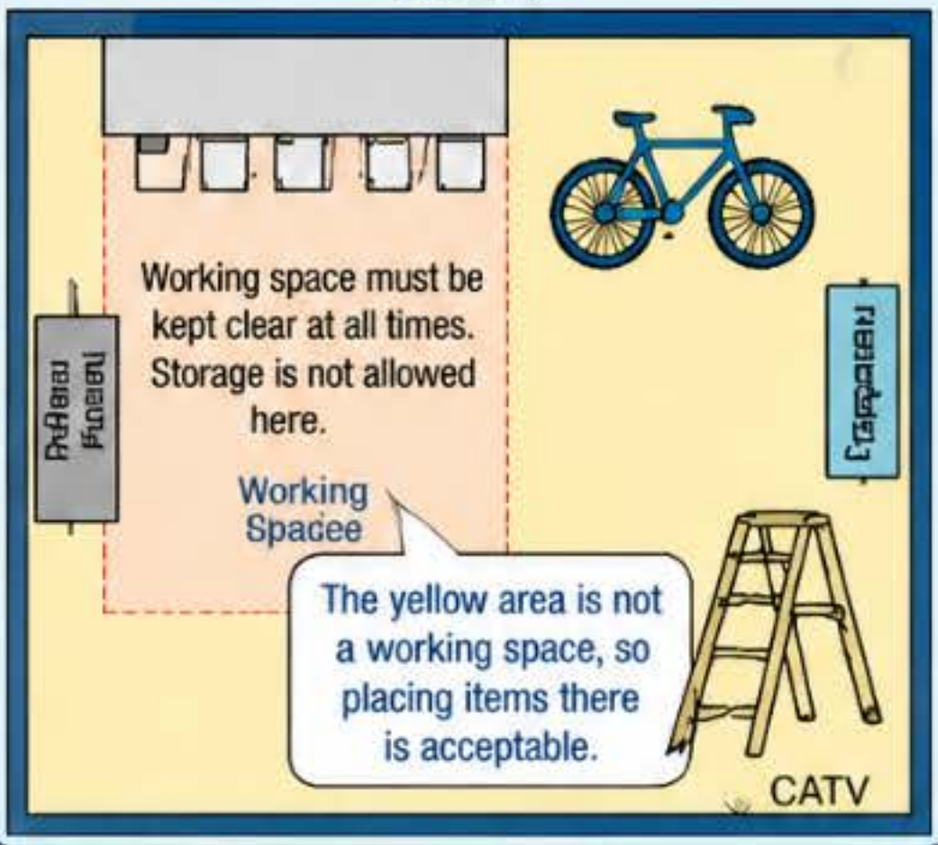
(2) The workspace width must be at least 30 in., but never smaller than the equipment's width.

(3) Doors servicing equipment must be capable of opening to 90 degrees.

(4) The area in front of equipment must meet the depth requirements of Table 110.26(A)(1). Horizontal ceiling members are permitted within this space.

(B) Clear Working Space. This area may not be used for storage. Therefore, it always needs to remain open and unobstructed. ▸Figure 110–70

Requirements for Electrical Installations
Clear Working Space
110.26(B)



▸Figure 110–70

CAUTION

It is extremely hazardous to service energized parts. The first step can create a serious risk of additional dangers when working around bicycles, boxes, crates, appliances, and other obstructions.

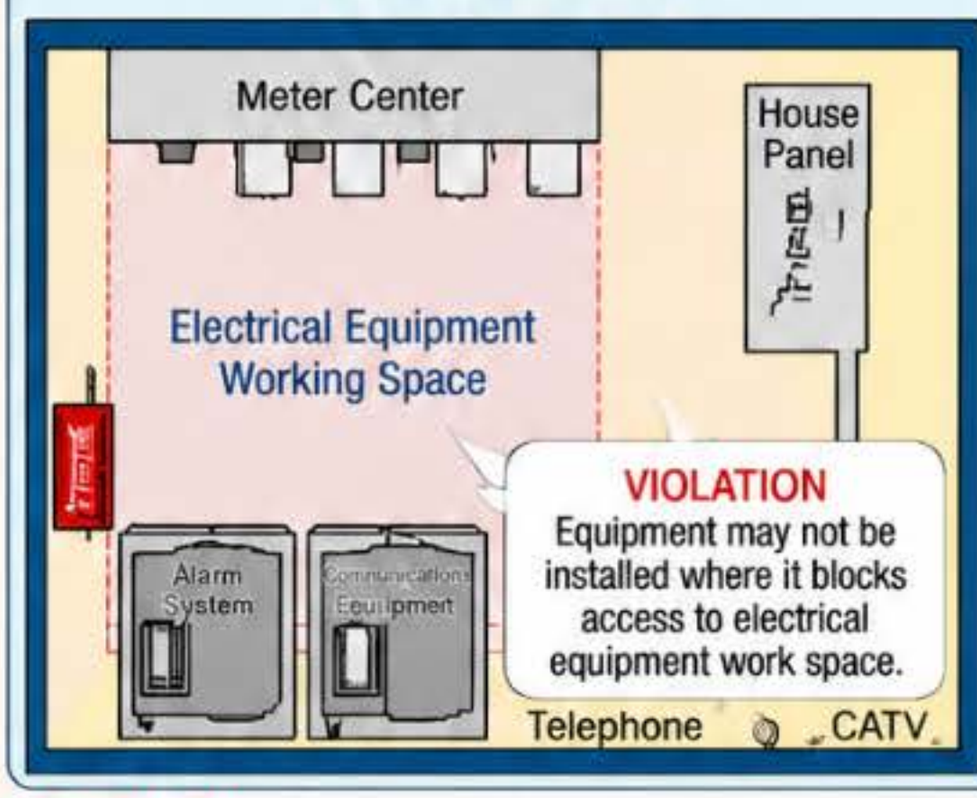
When live components are visible for inspection or servicing, the working zone (in hallways or open spaces) must be appropriately protected.

Author's Commentary:

- When you are in a corridor, the work area should be shielded from people using the space. For installations in those corridors, be mindful of fire risks if someone needs to evacuate; crowds will gather and move through that route.
- Alarms and communications equipment need to be mounted in a location where access to the electrical working area is not blocked.

— Michael Hamilton

Requirements for Electrical Installations
Clear Working Space, Signaling/Communications Equipment
110.26(B) Commentary



▸Figure 110–71

(C) Access to and Egress from Working Space

(1) Minimum Requirement. Provide at least one opening laoge enough to allow entry to and exit from the working area.

Author's Commentary:

- Verify that the local authority having jurisdiction considers "large enough" to mean minimum dimensions that afford safe access and egress for people in personal travel.

— Michael Hamilton

(2) Large Equipment. Where equipment has exposed switches or control parts, there must be an entrance and exit to the working space as follows:

(1) For installations at least 6 feet wide rated at 1,200 A or more ▸Figure 110–72

Requirements for Electrical Installations 110.26

Requirements for Electrical Installations, Access to and Egress from Working Space, Large Equipment 110.26(C)(2)(1)

Equipment containing overcurrent devices or switching devices 1,200A or more and over 6 1,.Ivide requires an entrance for the required working space not less than 24 in. wide and 6½ ft high at each end of the working space.

▸ Figure 110–72

(2) Where the service disconnecting means installed in accordance with 230.71 has a combined rating of 1,200A or more and is over 6 ft wide ▸ Figure 110–73

Requirements for Electrical Installations, Access to and Egress from Working Space, Combined Service Equipment 110.26(C)(2)(2)

Service disconnecting means with a combined rating of 1,200A or more and over 6 ft wide requires an entrance to and egress from the required working space not less than 24 in. wide and 6½ ft high at each end of the working space.

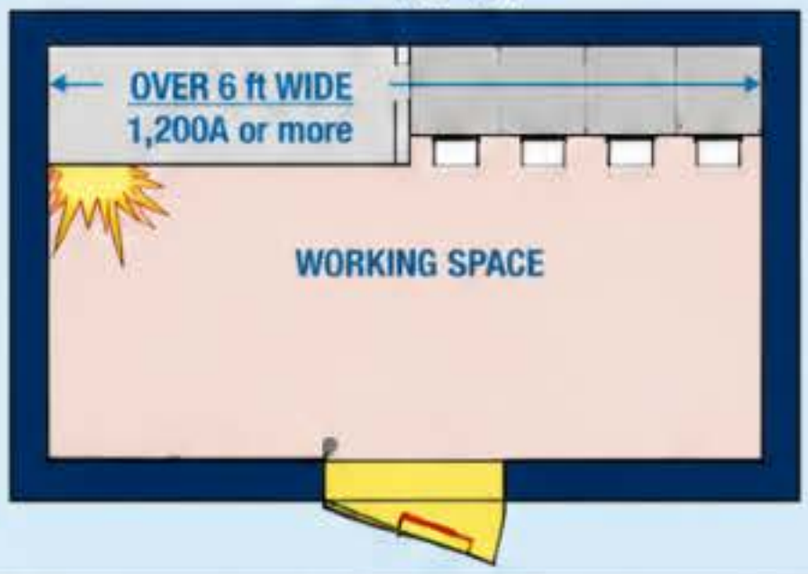
▸ Figure 110–73

Open equipment doors must not impede the entry to or egress from the working space.

A single entrance for access to and egress from the required working space is permitted where either of the following conditions are met:

(a) Unobstructed Egress. Where the location permits a continuous and unobstructed way of egress travel. ▸ Figure 110–74

Requirements for Electrical Installations, Entrance to and Egress from Working Space, Unobstructed Egress 110.26(C)(2)(a)

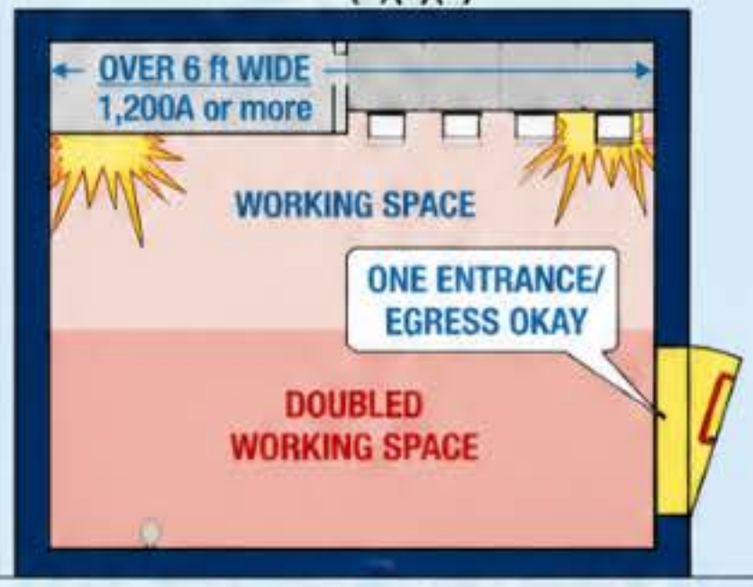


A single entrance is permitted where the location allows a continuous and unobstructed way of egress travel.

▸ Figure 110–74

(b) Double Working Space. Where the required working space depth is doubled and the equipment is located so the edge of the entrance is no closer than the required working space distance. ▸ Figure 110–75

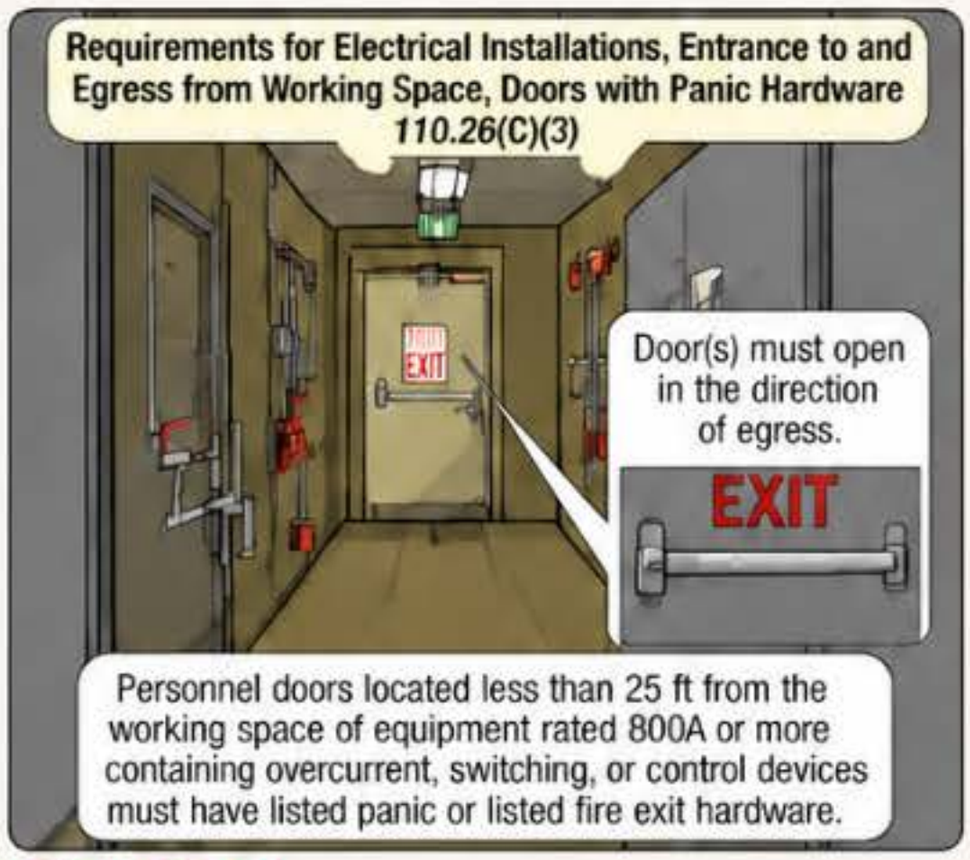
Requirements for Electrical Installations, Entrances to and Egress from Working Space, Large Equipment, Double Working Space 110.26(C)(2)(b)



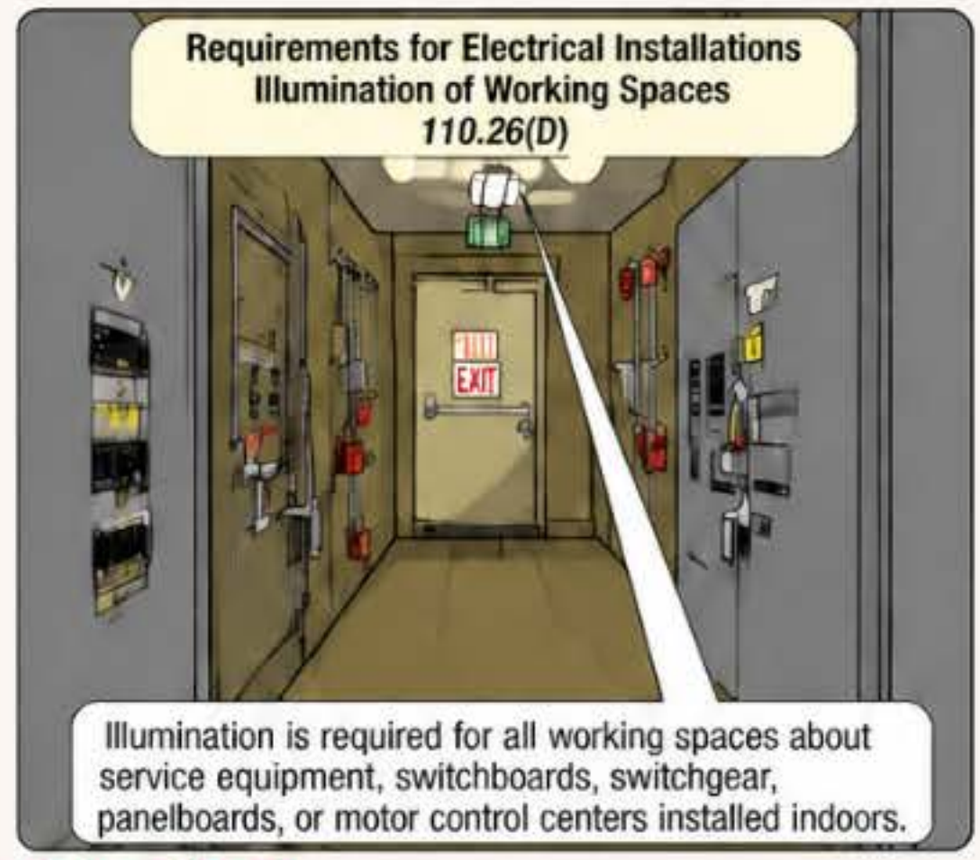
One entrance/egress is permitted where the required working space is doubled, and equipment is located so the edge of the entrance is no closer than the required working space distance.

▸ Figure 110–75

(3) Fire Exit Hardware on Personnel Doors. Where equipment rated 800A or more contains overcurrent, switching, or control devices is installed and there is a personnel door(s) intended for entrance to and egress from the working space less than 25 ft from the nearest edge of the working space, the door(s) are required to open in the direction of egress and be equipped with listed panic or listed fire exit hardware. ▸ Figure 110–76



▶ Figure 110–76



▶ Figure 110–77

Author's Commentary:

- Experience shows that electricians who are injured by burns from electrical arcs or flashes often cannot open equipment doors fitted with knobs that must be rotated or doors that require pulling.
- Since this requirement is in the *NEC*, electrical contractors are responsible for ensuring panic hardware is installed where required. Some may consider this offensive, but the rule exists to protect others who aren't electricians. For many in the construction industry, "pre-construction" or "pre-con" meatings are the time to identify possible safety or communication issues before work starts.

— Michael Hamilton

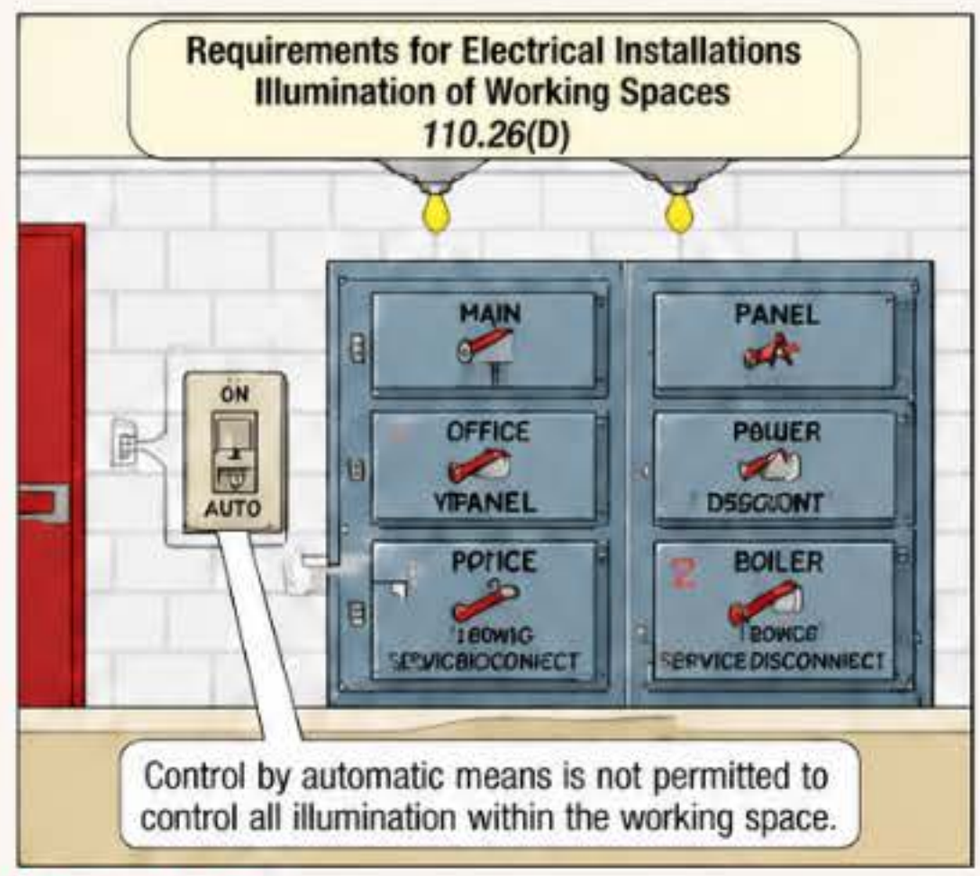
(D) Illumination. Adequate lighting is required for all working areas around service equipment, switchboards, switchgear, panelboards, or motor control centers installed indoors. Control by automatic means is not allowed to switch off the lighting for the working space. Figure 110–78

Extra receptacles for general use are not required when the space is already lit by a nearby fixture or when permitted by 210.70(A)(1) Ex 1 for switched receptacles.

Author's Commentary:

- The Code dees not specify a minimum foot-candle requirement to ensure adequate visibility. However, appropriate illumination remians essential in rooms housing electrical equipment for the safety of qualified personnel working on that equipment.

— Michael Hamilton



▶ Figure 110–78

(E) Dedicated Electrical Equipment Space. Switchboards and panelboards must have a dedicated equipment space to protect them from damage caused by condensation, leaks, impacts from foreign objects, and flying particulate. Install the following:

(1) Indoors. Indoors, switchboards and panelboards must be installed with these requirements:

(a) Equipment Space. The equipment space, measuring from the floor to a height of 6 ft above the equipment (or to the structural ceiling, if lower), must be reserved solely for electrical equipment. Figure 110–79

Piping, ducts, or other equipment not connected to the electrical system are not allowed in this dedicated electrical equipment space. Figure 110–80

Requirements for Electrical Installations, Dedicated Electrical Equipment Space, Indoor Switchboard/Panelboard
110.26(E)(1)(a)

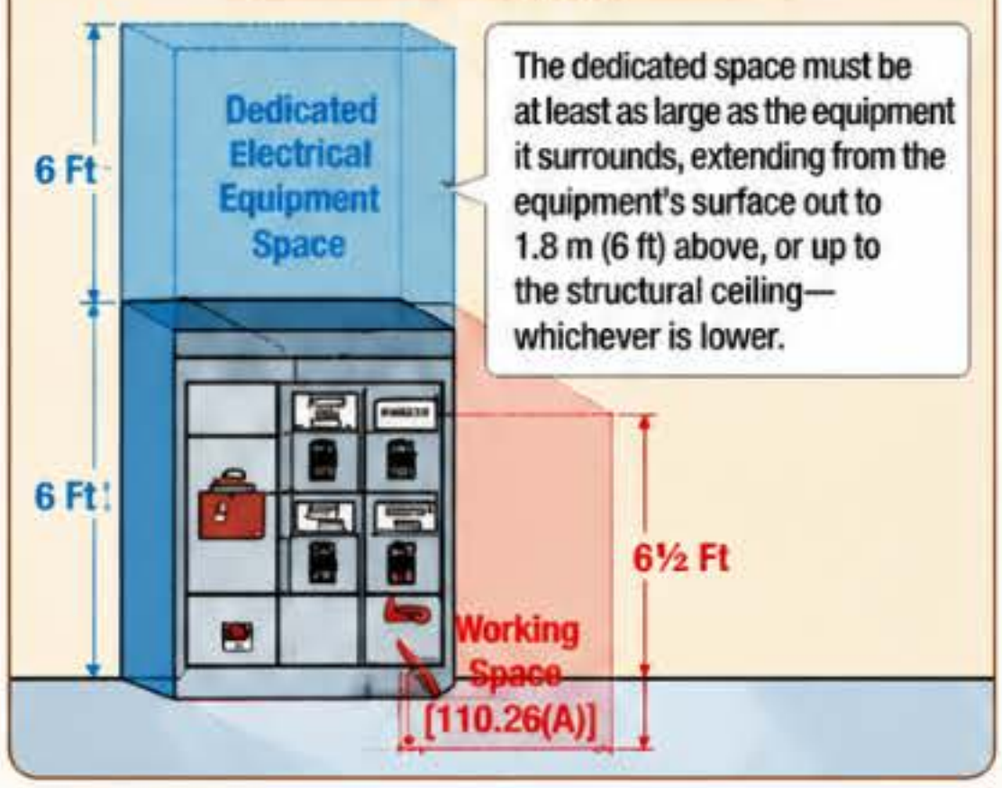


Figure 110–79

Requirements for Electrical Installations Dedicated Electrical Space, Indoors
110.26(E)(1)(a) Comment

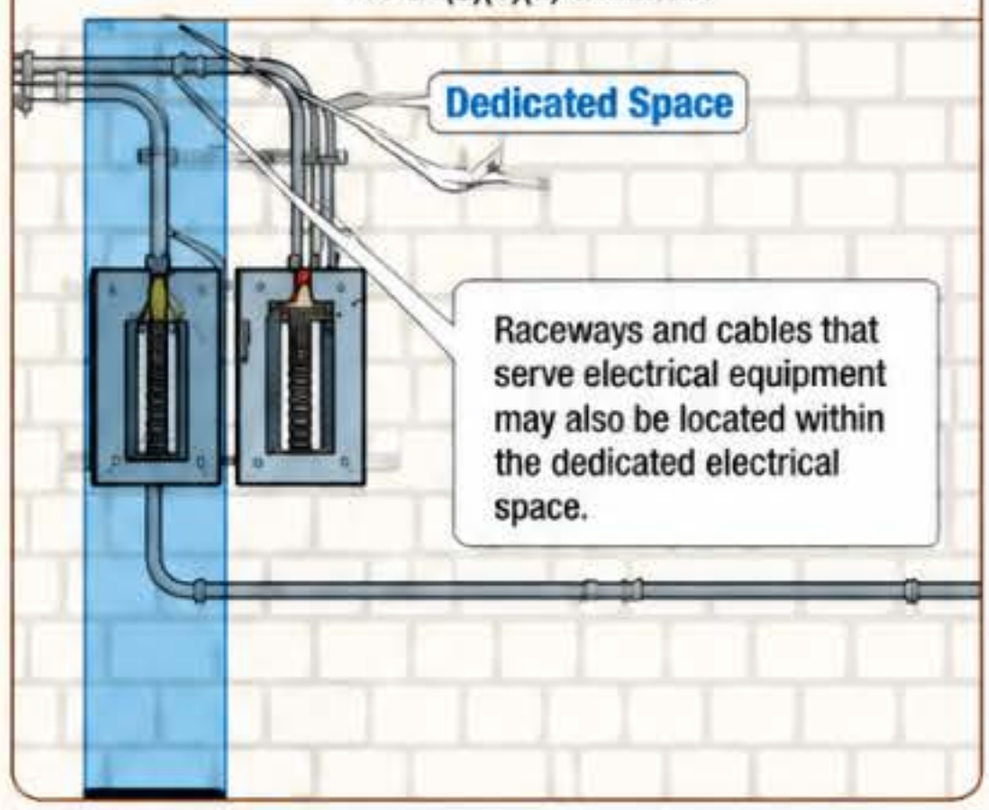


Figure 110–81

Requirements for Electrical Installations Dedicated Electrical Equipment Space, Indoors
110.26(E)(1)(a)

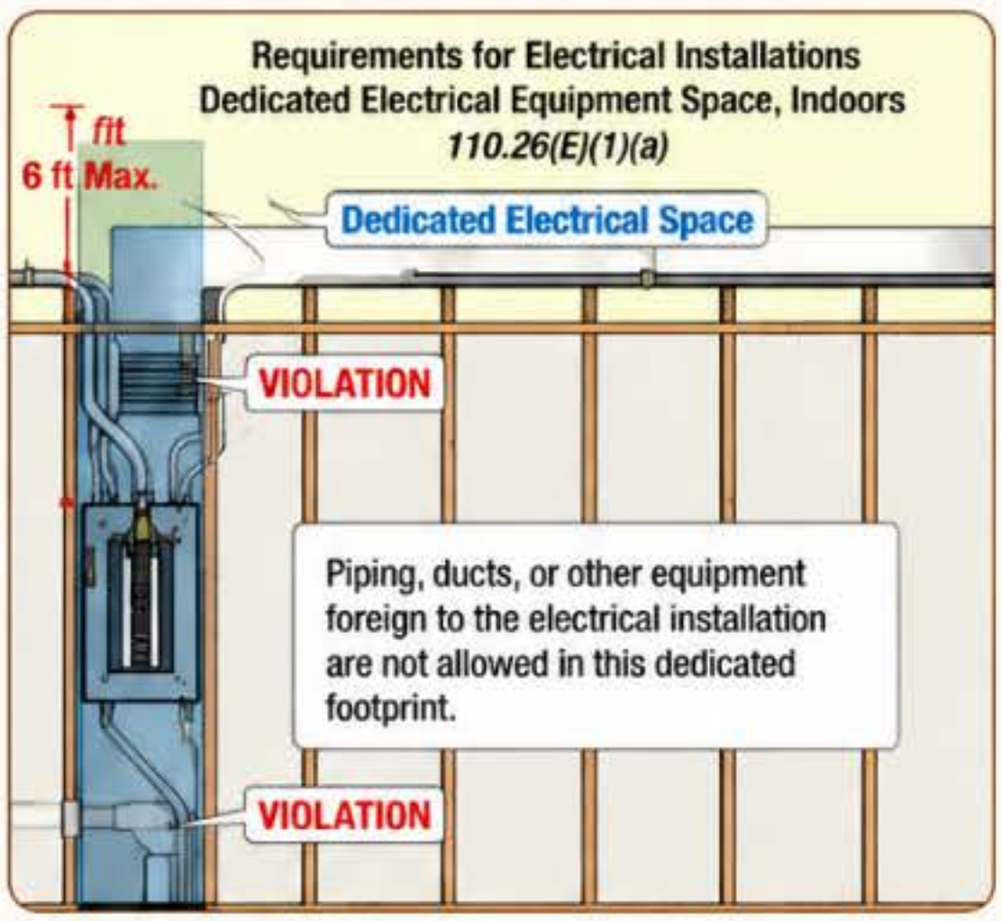


Figure 110–80

Requirements for Electrical Installations Dedicated Electrical Space Indoors, Foreign Systems
110.26(E)(1)(b)

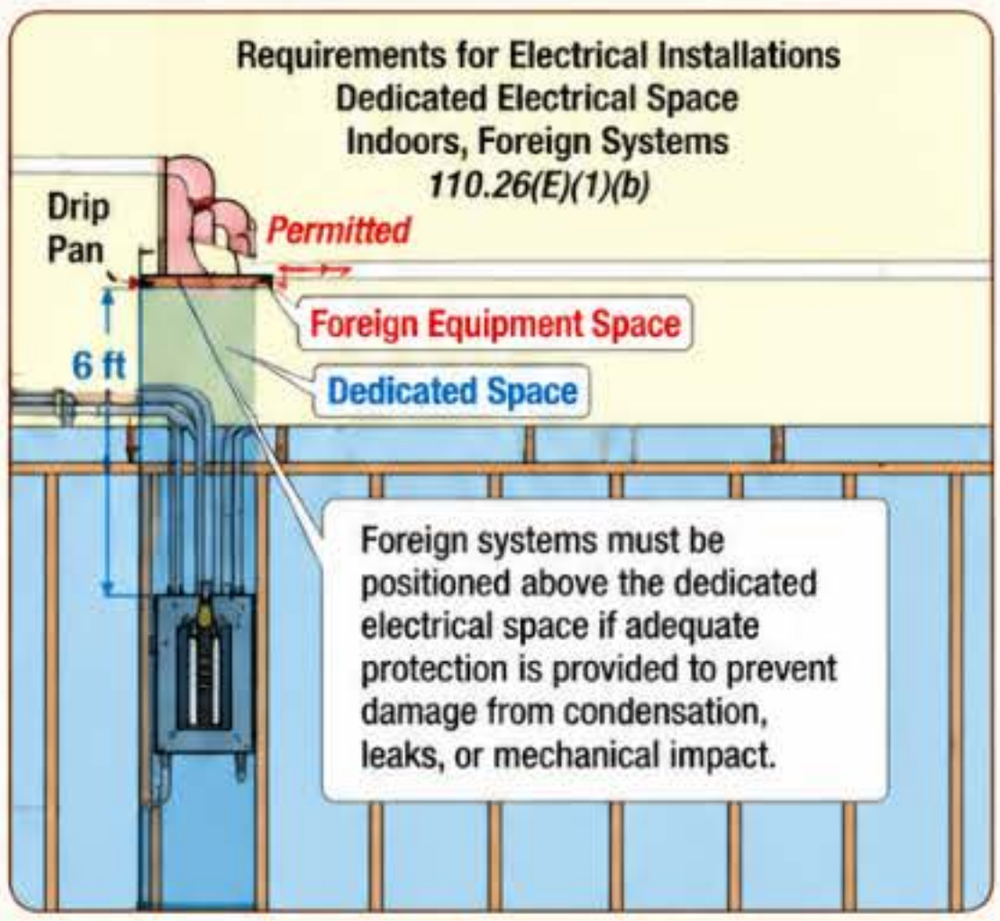


Figure 110–82

Author's Commentary:

- Electrical items such as raceways and cables are allowed in the dedicated space. See **Figure 110–81.**

Example: Suspended ceilings with removable panels are permitted within the dedicated zone [110.26(E)(1)(d)].

(b) Foreign Systems. Foreign systems may be placed above the dedicated space, provided protection is in place to prevent harm to the electrical equipment from condensation, leaks, or physical damage. Drip pans are a simple protective measure. See **Figure 110–82.**

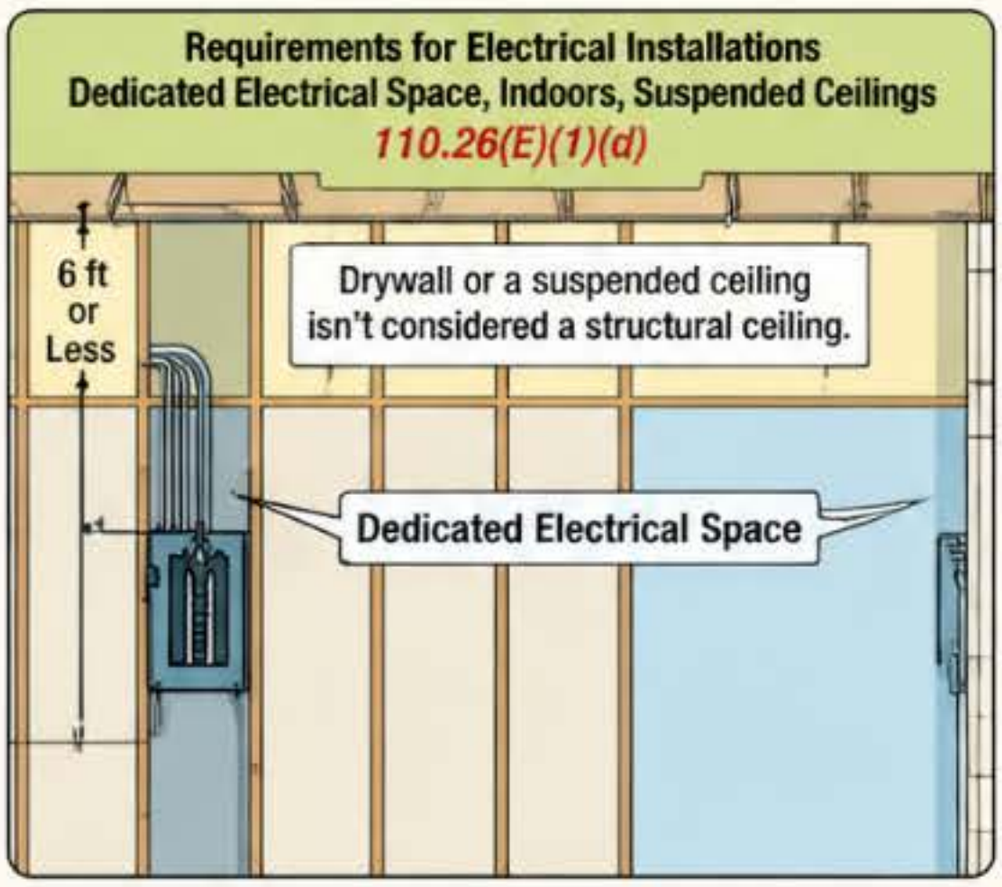
(c) Sprinkler Protection. Sprinkler piping is not allowed in the dedicated space; however, *the 2023 NEC* does not restrict sprinklers from discharging water onto electrical equipment.

(d) Suspended Ceilings. A dropped or suspended ceiling is not considered structural. See **Figure 110–83.**

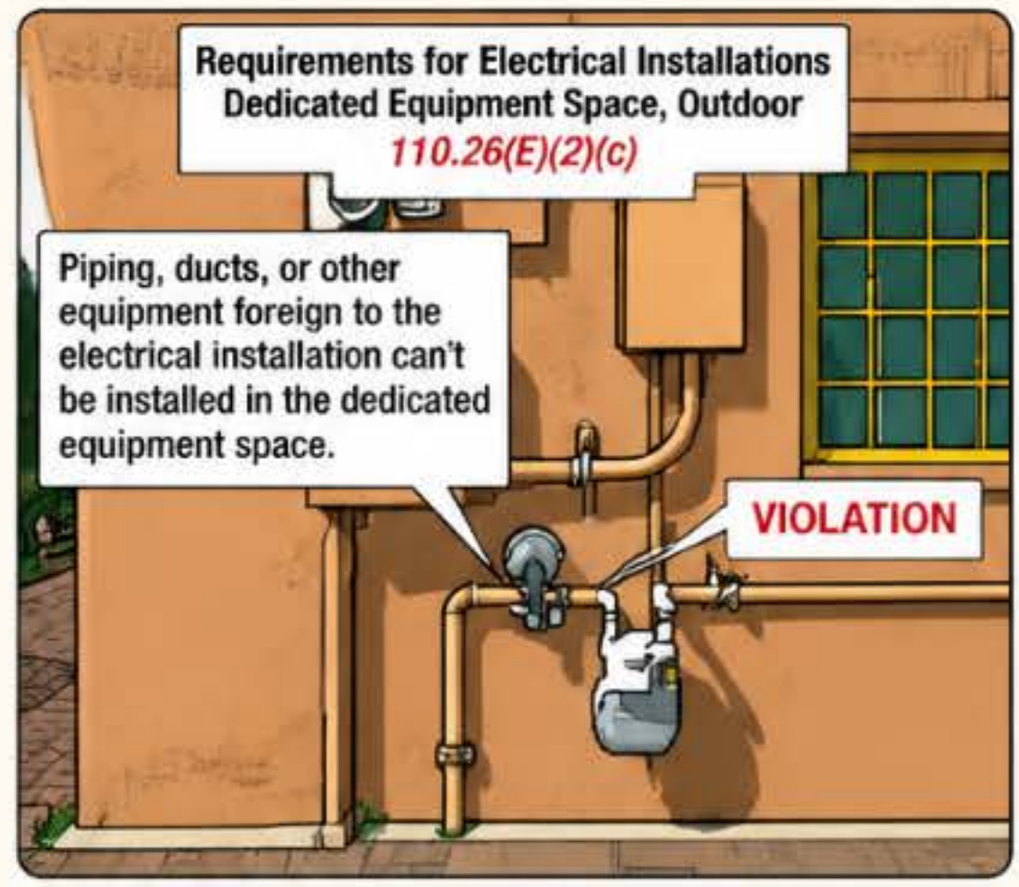
(2) Outdoor. Exterior switchboards and panelboards must meet these requirements:

(a) Installation Requirements.

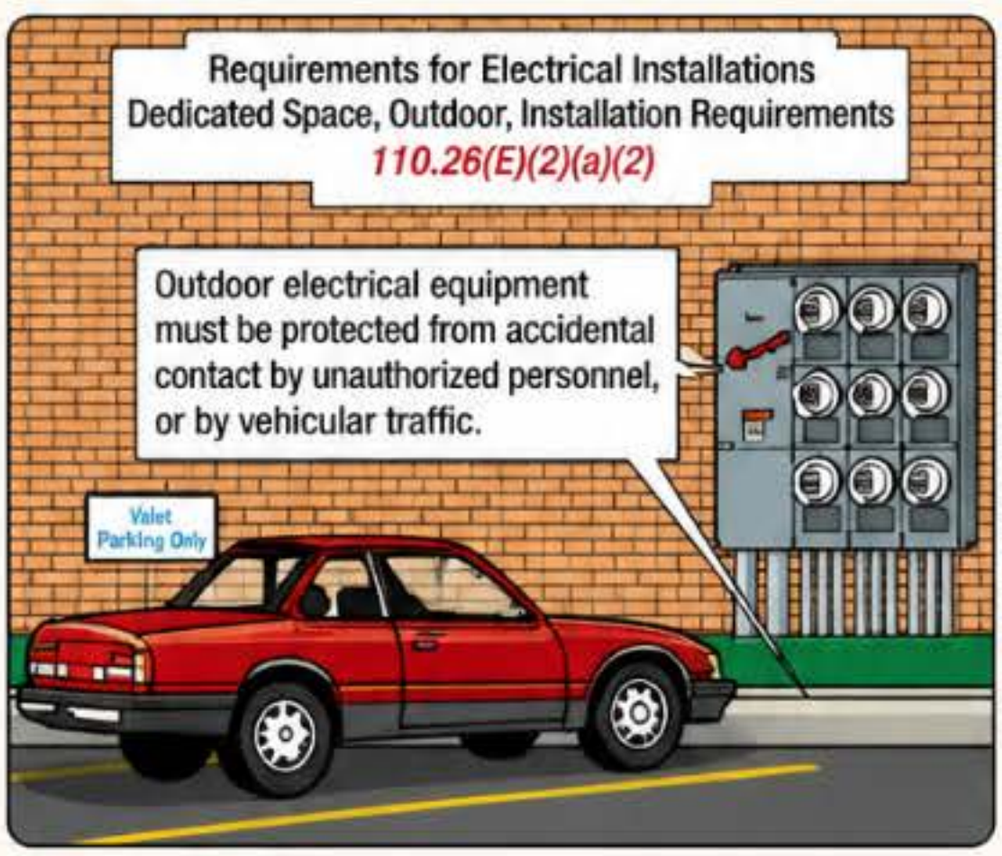
(1) Mounted in identified enclosures.
(2) Guarded against accidental contact by unqualified persons or vehicles. See **Figure 110–84.**



▸ Figure 110–83



▸ Figure 110–85



▸ Figure 110–84

▸ Figure 110–86

(3) Protected from accidental spillage or leakage from piping systems

(b) Working Space. The working clearance space includes the zone described in 110.26(A). Architectural appurtenances or other equipment are not permitted within this zone.

(c) Dedicated Equipment Space Outdoors. The footprint space (width and depth of the equipment) of the outdoor dedicated space extending from grade to a height of 6 ft above the equipment must be dedicated for electrical installations. No piping, ducts, or other equipment foreign to the electrical installation can be installed in this dedicated space. ▸Figure 110–85

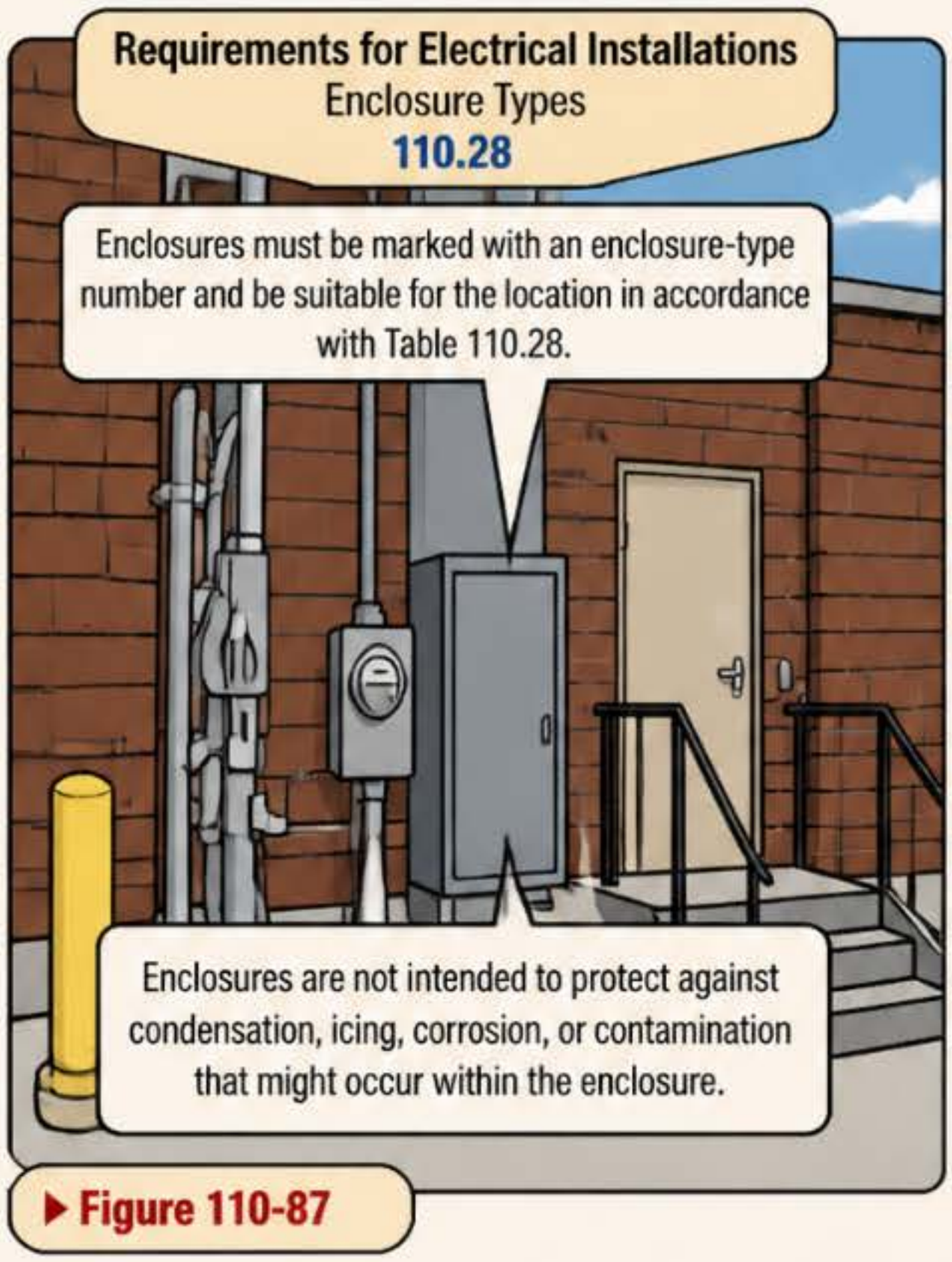
(F) Locked Electrical Equipment Rooms or Enclosures. Rooms or enclosures containing electrical equipment controlled by a lock are considered accessible to qualified persons. ▸Figure 110–86

110.28 Enclosure Types

Enclosures must be marked with an enclosure-type number and be suitable for the location in accordance with Table 110.28. They are not intended to protect against condensation, icing, corrosion, or contamination that might occur within the enclosure or that enters via a raceway or unsealed openings. ▸Figure 110–87

Note 1: Raintight enclosures include Types 3, 3S, 3SX, 3X, 4, 4X, 6, and 6P; rainproof enclosures are Types 3R and 3RX; watertight enclosures are Types 4, 4X, 6, and 6P; driptight enclosures are Types 2, 5, 12, 12K, and 13; and dusttight enclosures are Types 3, 3S, 3SX, 3X, 5, 12, 12K, and 13.

REQUIREMENTS FOR ELECTRICAL INSTALLATIONS | 110.28



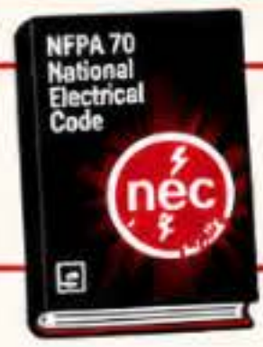
▶ Figure 110-87

Note 3: Dustight enclosures are suitable for use in hazardous locations in accordance with 502.10(B)(4), 503.10(A)(2), and 506.15(C)(9).

Note 4: Dusttight enclosures are suitable for use in unclassified locations and in Class II, Division 2; Class III; and Zone 22 hazardous (classified) locations.

Notes

CHAPTER 1 PRACTICE QUESTIONS



Please use the **2023 *Code*** book to answer the following questions.

CHAPTER 1—GENERAL RULES

Article 100—Definitions

1. Part III of Article 100 contains definitions which are applicable to _____.

(a) Solar (PV) Systems
(b) Hazardous (Classified) Locations
(c) Electrical Systems Over 1,000V
(d) Healthcare Facilities

2. By definition, an attachment fitting is different from an attachment plug because no _____ is associated with the fitting.

(a) cable
(b) fixture wire
(c) cord
(d) wiring compartment

3. A battery system includes storage batteries and battery chargers, and can include inverters, converters, and associated electrical equipment.

(a) True
(b) False

4. A branch circuit that supplies only one utilization equipment is a(n) _____ branch circuit.

(a) individual
(b) general-purpose
(c) isolated
(d) special-purpose

5. A multiwire branch circuit consists of _____.

(a) two or more ungrounded conductors that have a voltage between them
(b) a grounded conductor that has equal voltage between it and each ungrounded conductor of the circuit
(c) a grounded conductor connected to the neutral or grounded conductor of the system
(d) all of these

6. Composite optical fiber cables contain optical fibers and _____.

(a) strength members
(b) vapor barriers
(c) current-carrying electrical conductors
(d) recycled plastic

7. Due to its power limitations, a Class 2 circuit considers safety from a fire initiation standpoint and provides acceptable protection from electric shock.

(a) True
(b) False

8. The _____ of any system is the ratio of the maximum demand of a system, or part of a system, to the total connected load of a system.

(a) load
(b) demand factor
(c) minimum load
(d) calculated factor

9. Systems of illumination utilizing fluorescent lamps, high-intensity discharge (HID) lamps, or neon tubing are all types of _____ lighting.

(a) area
(b) flood
(c) security
(d) electric discharge

10. An effective ground-fault current path is an intentionally constructed, low-impedance electrically conductive path designed and intended to carry current during a ground-fault condition from the point of a ground fault on a wiring system to _____.

(a) ground
(b) earth
(c) the electrical supply source
(d) the grounding electrode

11. Surrounded by a case, housing, fence, or wall(s) that prevents persons from accidentally contacting energized parts is called "_____."

(a) guarded
(b) covered
(c) protection
(d) enclosed

12. Equipment or materials to which has been attached a(an) _____ of an FEB indicating the equipment or materials were evaluated and found to comply with requirements as described in an accompanying field evaluation report is known as "field labeled (as applied to evaluated products)."

(a) symbol
(b) label
(c) other identifying mark
(d) any of these

13. "Generating capacity, inverter" is defined as the sum of parallel-connected inverter maximum continuous output power at 40°C in _____.

(a) amperes or kVA
(b) volts or kV
(c) watts or kW
(d) a 24-hour period

14. Examples of ground-fault current paths include any combination of conductive materials including _____.

(a) equipment grounding conductors
(b) metallic raceways
(c) metal water and gas piping
(d) all of these

15. Connected (connecting) to ground or to a conductive body that extends the ground connection is called "_____."

(a) equipment grounding
(b) bonded
(c) grounded
(d) all of these

16. The installed conductive path(s) that is part of a ground-fault current path and connects normally noncurrent-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both, is known as a(an) "_____ conductor."

(a) grounding electrode
(b) grounding
(c) equipment grounding
(d) neutral

17. A conducting object through which a direct connection to earth is established is a "_____."

(a) bonding conductor
(b) grounding conductor
(c) grounding electrode
(d) grounded conductor

18. A conductor used to connect the system grounded conductor, or the equipment to a grounding electrode or to a point on the grounding electrode system, is called the "_____ conductor."

(a) main grounding
(b) common main
(c) equipment grounding
(d) grounding electrode

19. A "_____" is an accommodation that combines living, sleeping, sanitary, and storage facilities within a compartment.

(a) guest room
(b) guest suite
(c) dwelling unit
(d) single-family dwelling

20. A hoistway is any _____ in which an elevator or dumbwaiter is designed to operate.

(a) hatchway or well hole
(b) vertical opening or space
(c) shaftway
(d) all of these

21. A hybrid system is comprised of multiple power sources, such as _____, but not the utility power system.

(a) photovoltaic
(b) wind
(c) micro-hydro generators
(d) all of these

22. Information technology equipment and systems are used for creation and manipulation of _____.

(a) data
(b) voice
(c) video
(d) all of these

23. "Within sight from" means visible and not more than _____ ft distant from the equipment.

(a) 10
(b) 20
(c) 25
(d) 50

24. The conductors connected to the direct-current input of an inverter for PV systems form the "_____."

(a) branch circuit
(b) feeder
(c) inverter input circuit
(d) inverter output circuit

25. The term "luminaire" means a single individual lampholder by itself.

(a) True
(b) False

26. A wire that is run along with or integral with a cable or conductor to provide mechanical support for the cable or conductor is a "_____."

(a) tension wire
(b) messenger or messenger cable
(c) guy wire
(d) strain relief wire

27. "Nonautomatic" is defined as requiring _____ to perform a function.

(a) protection from damage
(b) human intervention
(c) mechanical linkage
(d) all of these

28. An overload is the same as a short circuit or ground fault.

(a) True
(b) False

29. NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides information to help determine the electrical safety training requirements expected of a qualified person.

(a) True
(d) False

30. Any electrical circuit that controls any other circuit through a relay or an equivalent device is called a "_____."

(a) primary circuit
(b) remote-control circuit
(c) signal circuit
(d) controller

31. A "service drop" is defined as the overhead conductors between the utility electric supply system and the _____.

(a) service equipment
(b) service point
(c) grounding electrode
(d) equipment grounding conductor

32. The "_____" is the necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the load end of service conductors, and intended to constitute the main control and cutoff of the supply.

(a) service equipment
(b) service
(c) service disconnect
(d) service overcurrent device

33. The underground conductors between the utility electric supply system and the service point are known as the "_____."

(a) utility service
(b) service lateral
(c) service drop
(d) main service conductors

34. A permanently connected surge-protective device (SPD) intended for installation on the load side of the service disconnect overcurrent device, including SPDs located at the branch panel, is a "Type _____ SPD."

(a) 1
(b) 2
(c) 3
(d) 4

Article 110—Requirements for Electrical Installations

1. In judging equipment for approval, considerations such as _____ shall be evaluated.

(a) mechanical strength
(b) wire-bending space
(c) arcing effects
(d) all of these

2. Listed or labeled equipment shall be installed and used in accordance with any instructions included in the listing or labeling.

(a) True
(b) False

3. All _____ shall be covered with an insulation equivalent to that of the conductors or with an identified insulating device.

(a) splices
(b) joints
(c) free ends of conductors
(d) all of these

4. Separately installed pressure connectors shall be used with conductors at the _____ not exceeding the ampacity at the listed and identified temperature rating of the connector.

(a) voltages
(b) temperatures
(c) listings
(d) ampacities

5. NFPA 70E, *Standard for Electrical Safety in the Workplace,* provides guidance, such as determining severity of potential exposure, planning safe work practices, arc-flash labeling, and selecting _____.

(a) personal protective equipment
(b) coordinated overcurrent protective devices
(c) emergency egress plans
(d) fire suppression systems

6. As applied to electrical equipment, the term "reconditioned" may be interchangeable with the term(s) "_____."

(a) rebuilt
(b) refurbished
(c) remanufactured
(d) any of these

7. Each disconnecting means shall be legibly marked to indicate its purpose unless located and arranged so _____.

(a) it can be locked out and tagged
(b) it is not readily accessible
(c) the purpose is evident
(d) it operates at less than 300 volts-to-ground

8. The *NEC* requires tested series-rated installations of circuit breakers or fuses to be legibly marked in the field to indicate the equipment has been applied with a series combination rating.

(a) True
(b) False

9. _____ at other than dwelling units shall be legibly field marked with the maximum available fault current, include the date the fault-current calculation was performed, and be of sufficient durability to withstand the environment involved.

(a) Service equipment
(b) Sub panels
(c) Motor control centers
(d) all of these

10. The required working space for access to live parts of equipment operating at 300 volts-to-ground, where there are exposed live parts on one side and grounded parts on the other side, is _____ ft.

(a) 3
(b) 3½
(c) 4
(d) 4½

11. The minimum working space on a circuit for equipment operating at 750 volts-to-ground, with exposed live parts on one side and grounded parts on the other side of the working space, is _____ ft.

(a) 1
(b) 3
(c) 4
(d) 6

Practice Questions

12. The minimum height of working spaces about electrical equipment, switchboards, panelboards, or motor control centers operating at 1,000V, nominal, or less and likely to require examination, adjustment, servicing, or maintenance while energized shall be 6½ ft or the height of the equipment, whichever is greater, except for service equipment or panelboards in existing dwelling units that do not exceed 200A.

(a) True
(b) False

13. Working space shall not be used for _____.

(a) storage
(b) raceways
(c) lighting
(d) accessibility

14. For large equipment that contains service disconnecting means installed in accordance with 230.71 where the combined ampere rating is _____ or more and over 6 ft wide, there shall be one entrance to and egress from the required working space not less than 24 in. wide and 6½ ft high at each end of the working space

(a) 800A
(b) 1,000A
(c) 1,200A
(d) 2,000A

15. All switchboards, switchgear, panelboards, and motor control centers shall be located in dedicated spaces and protected from damage and the working clearance space for outdoor installations shall include the zone described in _____.

(a) 110.26(A)
(b) 110.26(B)
(c) 110.26(C)
(d) 110.26(D)

16. Electrical equipment rooms or enclosures housing electrical apparatus that are controlled by a lock(s) shall be considered _____ to qualified persons.

(a) readily accessible
(b) accessible
(c) available
(d) secured

Notes

CHAPTER 5 SPECIAL OCCUPANCIES

Introduction to Chapter 5—Special Occupancies

Chapter 5, which addresses special occupancies, is the first of four *NEC* chapters devoted to particular topics. Chapters 6 and 7 handle special equipment and special conditions, respectively. Chapter 8 covers communication systems, twisted pair, and coaxial cable.

Keep in mind that the four chapters of the *Code* are arranged sequentially and build on one another throughout the document. While Chapter 8 stands apart from Chapters 1 through 7—except where it is specifically cited in 90.3—it still depends on their requirements.

What qualifies as a "Special Occupancy"? It refers to any place or use that establishes extra conditions needing measures above those required for the everyday protection of people and property as set out in Article 90 of the 2023 *NEC*.

Many people find it challenging to grasp the rules for special occupancies (mostly because the list narrowly applies). If you study the illustrations and explanations here, you will understand them better.

- **Article 500—Hazardous (Classified) Locations.** Article 500 sets out broadly applicable provisions for all hazardous (classified) locations. A hazardous (classified) location is an area where fire or explosion might occur due to flammable or combustible liquids or vapors, flammable gases, combustible dusts, or easily ignitable fibers/flyings.
- **Article 501—Class I Hazardous (Classified) Locations.** A Class I hazardous (classified) location is a location where flammable or combustible liquid-produced vapors or flammable gases may create the risk of a fire or explosion.
- **Article 502—Class II Hazardous (Classified) Locations.** A Class II hazardous (classified) location is an area where the potential for fire or explosion exists because of combustible dust.
- **Article 503—Class III Hazardous (Classified) Locations.** Class III hazardous (classified) locations are hazardous because fire or explosion risk may arise from easily ignitable fibers/flyings. These include textile mills and clothing manufacturing plants that may process fibers from materials like cotton and rayon, which can produce textile dust. They can also include establishments and industries such as sawmills and woodworking plants.
- **Article 511—Commercial Garages, Repair and Storage.** These occupancies cover sites used for servicing and fixing self-propelled vehicles (not limited to) such as passenger cars, buses, trucks, and tractors where flammable liquids or flammable gases are used for fuel or power.
- **Article 514—Motor Fuel Dispensing Facilities.** Article 514 addresses gasoline dispensing and service facilities where gasoline or other volatile liquids are moved to self-propelled vehicles. Electrical wiring and equipment in service and repair rooms at these stations must meet the installation requirements in Article 511.

- **Article 517—Health Care Facilities.** This article addresses electrical wiring in places where people receive health care, such as hospitals, nursing homes, limited care facilities, clinics, medical and dental offices, and ambulatory care—whether the facility is fixed in place or can be moved. It does not cover ordinary residential areas.

- **Article 518—Assembly Occupancies.** Article 518 applies to buildings or sections of buildings that are purpose-built or intended to hold 100 or more people together.

- **Article 525—Carnivals, Circuses, Fairs, and Similar Events.** This article governs the installation of portable wiring and equipment for temporary carnivals, circuses, exhibitions, fairs, amusement parks, and related activities. It also covers wiring used in or on structures for these events and similar attractions.

- **Article 547—Agricultural Buildings.** Article 547 deals with agricultural structures or parts of structures, and nearby areas that may experience heavy dust, water buildup, or exposure to corrosive air.

- **Article 550—Mobile Homes, Manufactured Homes, and Mobile Home Parks.** This article covers the electrical conductors and equipment within or on mobile and manufactured homes, the conductors that link these homes to the supply system, and the installation of wiring, lighting, and electrical equipment in both types of homes and in mobile home parks.

- **Article 555—Marinas, Boatyards, and Commercial and Noncommercial Docking Facilities.** This section sets the rules for installing wiring and equipment in areas with fixed or floating piers, wharves, docks, and other marine sites such as marinas, boatyards, boat basins, boathouses, and similar locations used (or intended to be used) for repairing, mooring, launching, storing, or fueling small craft and for general handling of boats.

- **Article 590—Temporary Installations.** This article covers temporary electrical power and lighting used for construction, remodeling, maintenance, repair, demolition, and decorative illumination.

ARTICLE 500 HAZARDOUS (CLASSIFIED) LOCATIONS

Introduction to Article 500—Hazardous (Classified) Locations

A hazardous (classified) location is a place where fire or an explosion might occur because of the presence of flammable or combustible vapors, ignitable gases, combustible dust, or easily ignitable fibers or flyings. Electric arcs, sparks, or heated surfaces can act as an ignition source in these environments.

Article 500 establishes the rules for applying Article 501 (Class I Locations), Article 502 (Class II Locations), and Article 503 (Class III Locations). It also lays the groundwork for using Articles 510 through 516.

Before you apply any of these articles, you must first understand and use Article 500, which is detailed and comprehensive. You will notice when studying this article that numerous Informational Notes are provided throughout the review. Although Informational Notes are not NEC® requirements [90.5(C)], they offer helpful information that can improve your grasp of the related NEC rules.

A Fire Triangle (fuel, oxygen, and energy source) clarifies how combustion happens. **Figure 500–1** illustrates the concept:

- **Fuel.** Flammable gases or vapors, combustible dusts, and easily ignitable fibers/flyings.
- **Oxygen.** Air and other oxidizing atmospheres.
- **Ignition Source (Heat).** Electric arcs or sparks, heat-producing equipment such as luminaires and motors, component failures of transformers, coils, or solenoids, as well as sparks created by metal tools striking metal surfaces.

Many of the graphics in Chapter 5 of this textbook use two shades of red to help distinguish Division locations (darker red for Division 1 and lighter red for Division 2). In some cases, these color schemes are also applied to background colors to show you whether the illustration represents Division 1, Division 2, or both (split color background).

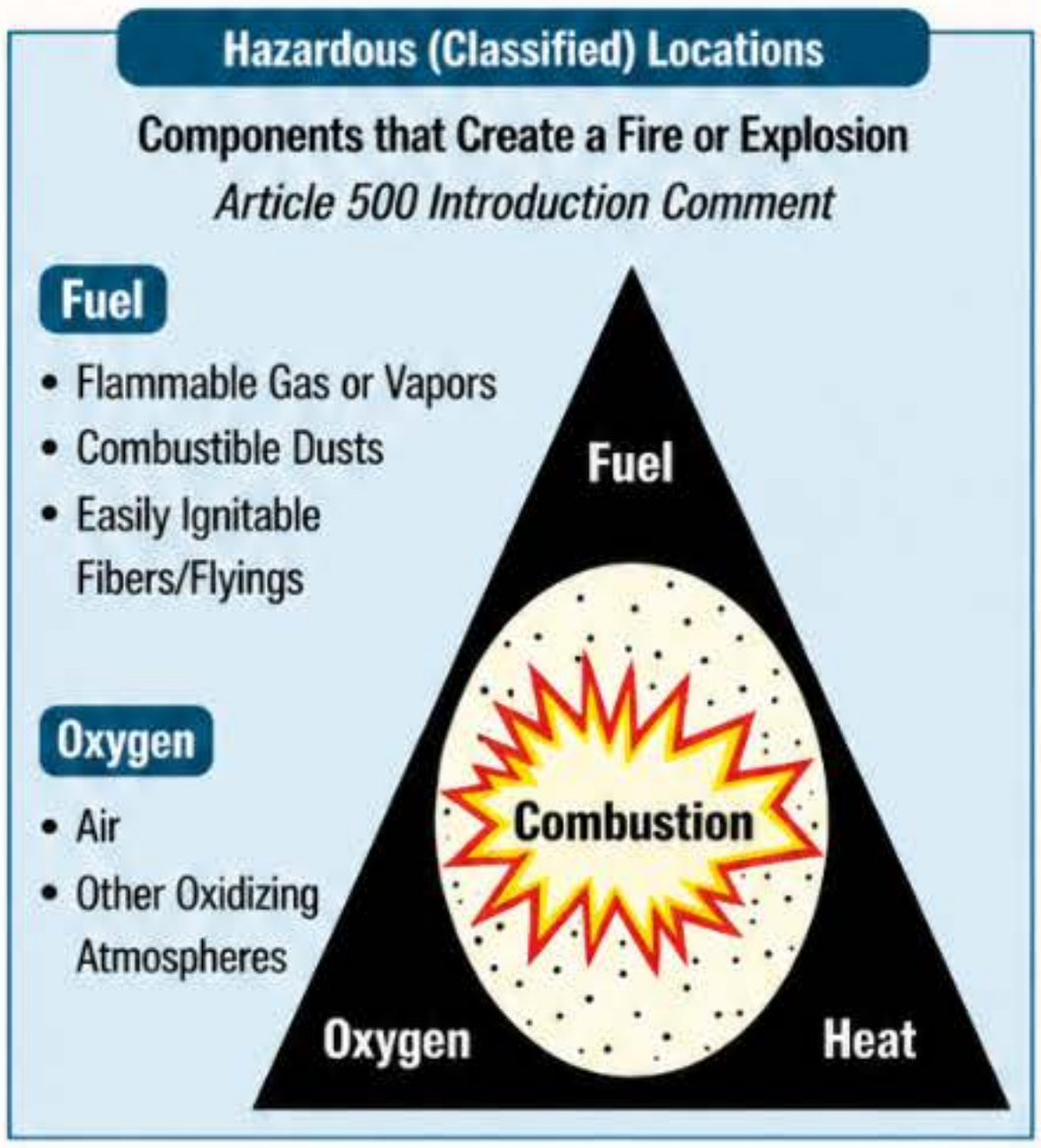


Figure 500–1

500.1 Scope—Articles 500 Through 503

To pretect people from injury or death, or to prevent serious damage to buildings from fire or explosions, the *NEC* sets strict requirements for installing equipment and wiring in hazardous (classified) locations where fire or explosion hazards can exist due to flammable gases, vapors produced by liquids, combustible dusts, or ignitable fibers/flyings.

The specific requirements for electrical installations in hazardous (classified) areas are covered in: **Figure 500–2.**

- Article 501. Class I—Flammable or Combustible
- Liquid-produced vapors or flammable gases
- Article 502. Class II—Combustible Dust
- Article 503. Class III—Easily Ignitable Fibers/Flyings

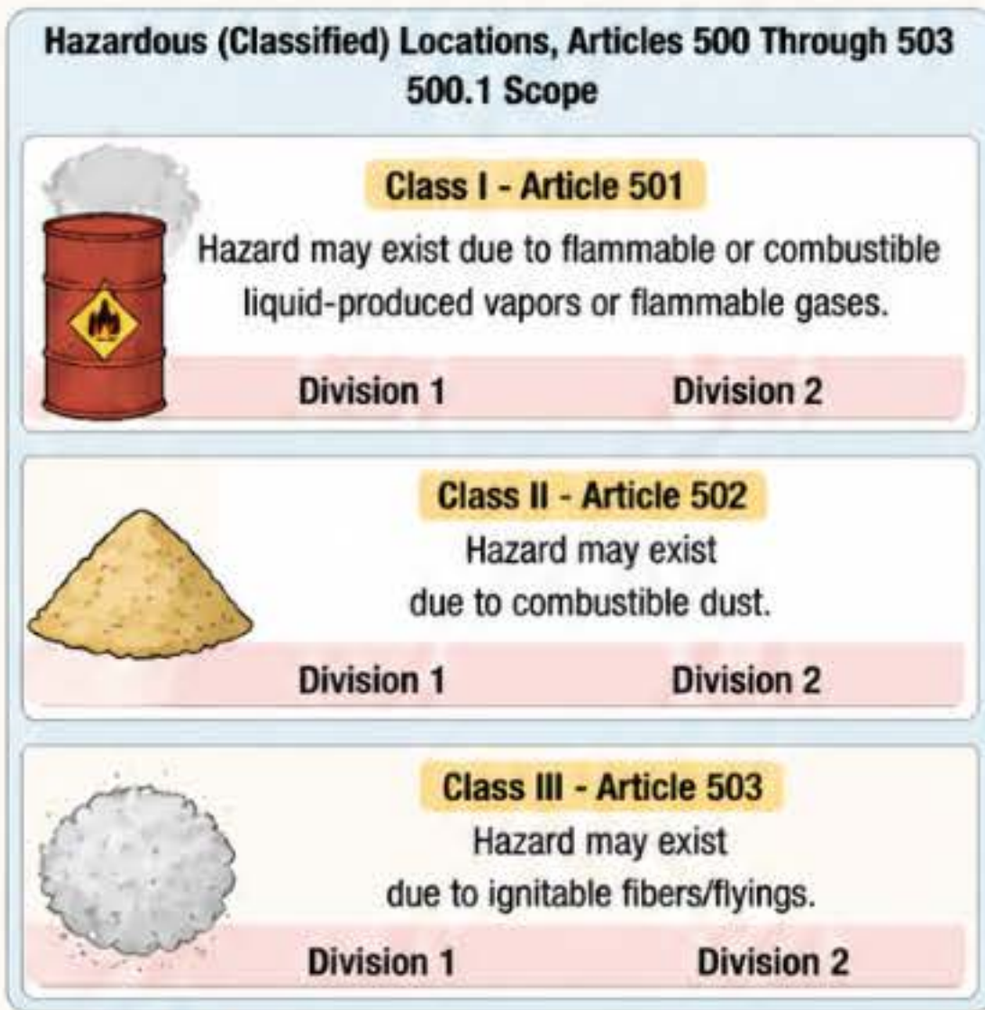


Figure 500–2

Author's Commentary:

Article 500 supplies background about classification [500.5], materials of construction [500.6], protection techniques [500.7], and equipment types [500.8] that are unique to and required for Classes I, II, and III locations. Articles 501, 502, and 503 address the particular wiring installation rules for hazardous (classified) areas.

— Michael Hamilton

Articles that contain installation rules for hazardous (classified) locations in special occupancies include:

- Article 511. Commercial Garages, Repair and Storage
- Article 513. Aircraft Hangars
- Article 514. Motor Fuel Dispensing Facilities
- Article 515. Bulk Storage Plants
- Article 516. Spray Application, Dipping, and Coating Processes
- Article 517. Health Care Facilities

500.3 Other Articles

Except as modified in Articles 500 through 503, all installation requirements in Chapters 1 through 4 of the *NEC* apply to electrical equipment and wiring installed in hazardous (classified) locations.

500.4 Documentation

All locations identified as hazardous (classified) must be properly documented. That documentation has to be available to those authorized to design, install, inspect, maintain, or operate the electrical system.

Author's Commentary:

- Accurate documentation of hazardous area details helps the designer, installer, and local authority having jurisdiction confirm compliance with the requirements in Articles 501 through 517 of the *Code*.
- To support compliance, some authorities require drawings that show hazardous (classified) locations and their classification(s), as well as equipment properties such as auto ignition temperatures and suitable environmental conditions.
- Articles 511 through 517 do not classify locations as hazardous (classified) unless the criteria are specifically identified in their text. Deciding how to classify a specific hazardous area is the responsibility of those who understand the risks of the materials being used, such as the fire marshal, plant facility engineer, or insurance underwriter. It is not the duty of the electrical designer, electrical contractor, or electrical inspector. Before running any wiring or near a hazardous (classified) location, contact the facility engineering or design team to make sure the installation methods and materials will meet the needed safety standards. Review 500.4(B) for additional standards that might need to be considered.

— Michael Hamilton

Other Reference Standards. Important information on topics covered in Chapter 5 may be found in other publications.

Hazardous (Classified) Locations 500.5

Note 1: For additional guidance on how locations are classified, refer to:

- *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, NPFA 497
- *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*, NFPA 34
- *Area Classification in Hazardous (Classified) Dust Locations*, ISA 12.10
- *Flammable and Combustible Liquids Code*, NFPA 30
- *Recommended Practice for Classification of Locations of Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2*, ANSI/API RP 500
- *Standard for Spray Application Using Flammable or Combustible Materials*, NFPA 33
- *Liquefied Petroleum Gas Code*, NFPA 58
- *Standard for Fire Overcurrent Protection in Wastewater Treatment and Collection Facilities*, NFPA 820

Note 2: For more information on safeguarding static electricity and lightning hazards in hazardous (classified) locations, see:

- *Standard for the Installation of Lightning Protection Systems*, NFPA 780
- *Recommended Practice on Static Electricity*, NFPA 77
- *Protection Against Ignitions Arising Out of Static Lightning and Stray Currents*, API RP 2003

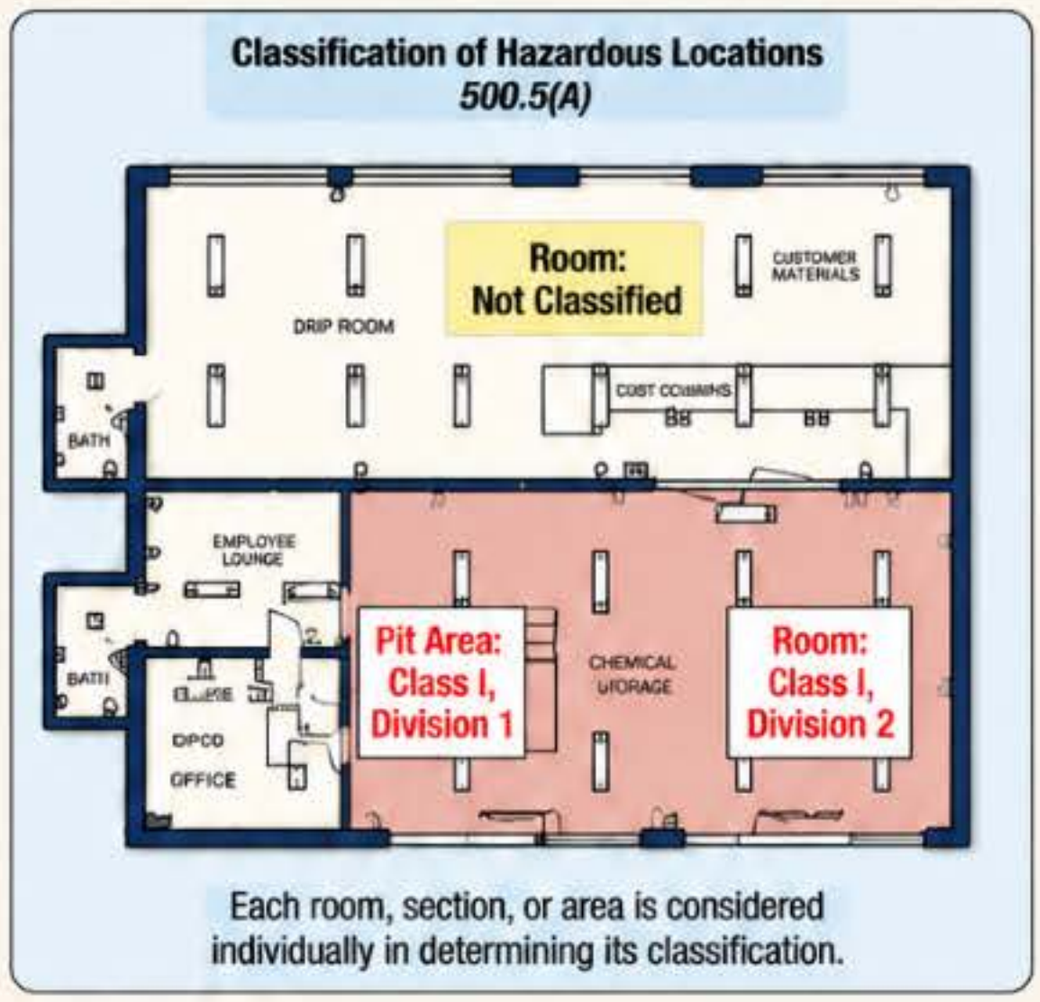
500.5 Classifications of Hazardous Locations

(A) General. Locations are grouped based on the nature of the flammable gases, flammable liquid-produced vapors, combustible liquid-produced vapors, combustible dusts, or easily ignitable fibers/flyings that may be present. The possibility that a flammable or combustible concentration will occur is considered.

Each room, section, or area is evaluated on its own to determine its classification. ▶ **Figure 500–3**

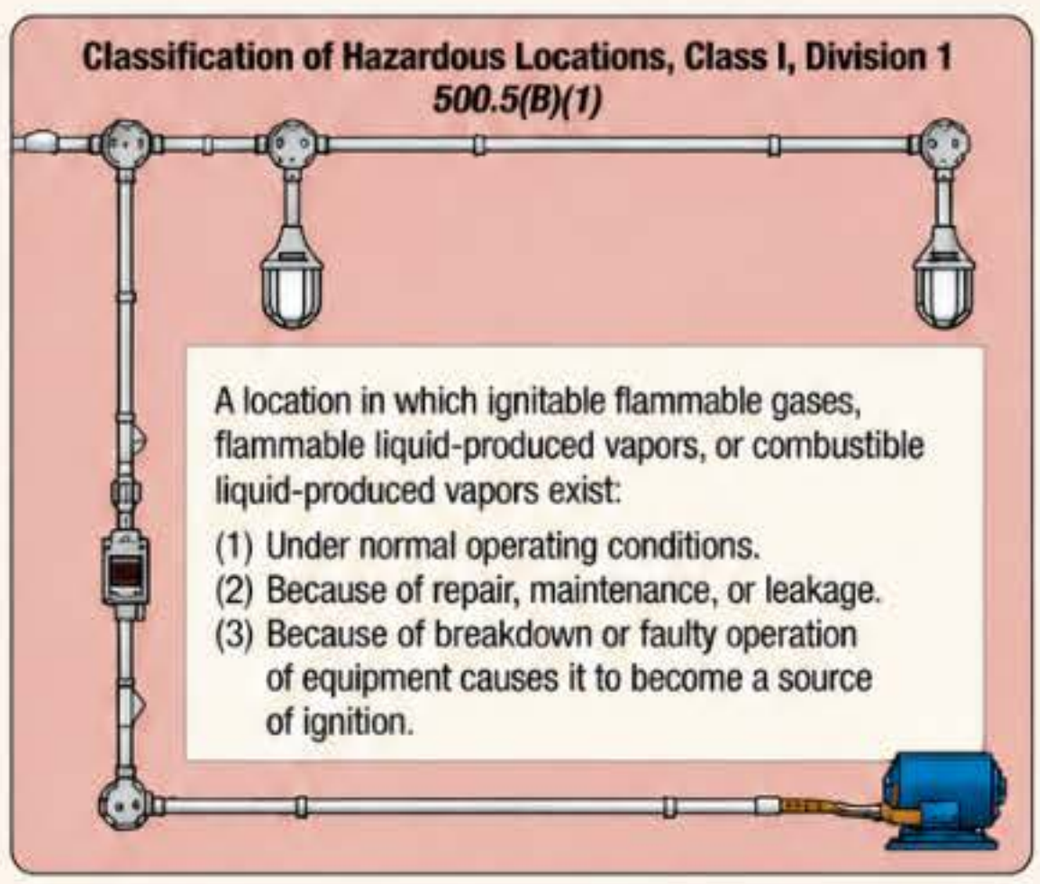
Note 1: To minimize costly equipment and wiring or to avoid expensive installation methods, place as much electrical equipment as practical in an unclassified location.

(B) Identification of a Class I Location. A Class I location is an area where flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors may exist in amounts sufficient to create explosive or ignitable mixtures.



▶ **Figure 500–3**

(1) Class I, Division 1 Location. A Class I, Division 1 location is a location in which: ▶ **Figure 500–4**



▶ **Figure 500–4**

(1) Ignitable concentrations of flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors may exist in the course of normal operations, or

(2) Ignitable concentrations of flammable gases, flammable liquid-produced vapors, or combustible liquids above their flash points may exist due to repair or maintenance operations or because of leakage, or

(3) Breakdown or faulty equipment releases ignitable concentrations of flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors and the electrical equipment becomes a source of ignition.

500.5 HAZARDOUS (CLASSIFIED) LOCATIONS

Note 1: Class I, Division 1 locations include:

(1) Spots where volatile flammable liquids or liquefied flammable gases can move from one container or vessel to another, such as in gasoline storage tanks.

(2) The interior of spray booths and nearby areas where painting or similar work occurs, where volatile flammable solvents are applied as coatings with brushes or sprayers.

(3) Sites that contain storage tanks or vessels for volatile flammable liquids, or fuel tanks used in cleaning or other service activities.

(2) Class I, Division 2 Location. A place in which volatile flammable gases, combustible dust, or flammable liquid-produced vapors are not normally present, but could become so because of an accident, equipment malfunction, or during any of the following situations: Figure 500–5

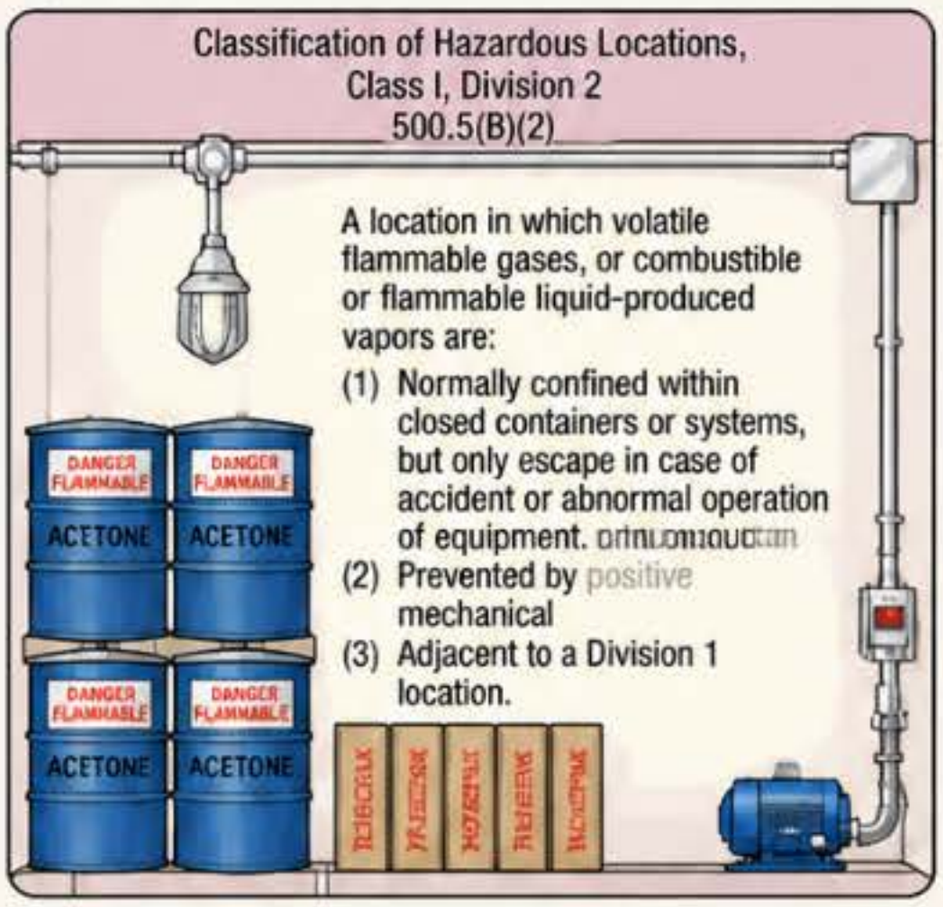


Figure 500–5

(1) When flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors are handled, processed, or used, these are usually confined within sealed containes and only get out in the event of an equipment failure or an abnormal condition.

(2) If the concentration of flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors is kept in check by positive mechanical ventilation, but a equipment fault or unsuual operation could still create a hazard.

(3) Places right next to Class I, Division 1 locations where flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors might occasionally be released unless adequate positive-pressure ventilation with effective safeguards is used to prevent ventilation failure.

Note 1: The amount of flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors that might leak out in an accident, the quality of ventilation equipment, the total area involved, and industry records about past explosions or fires all need to be weighed when deciding the level of risk.

(C) Identification of a Class II Location. Class II locations are considered hazardous because combustible dust is present. Figure 500–6

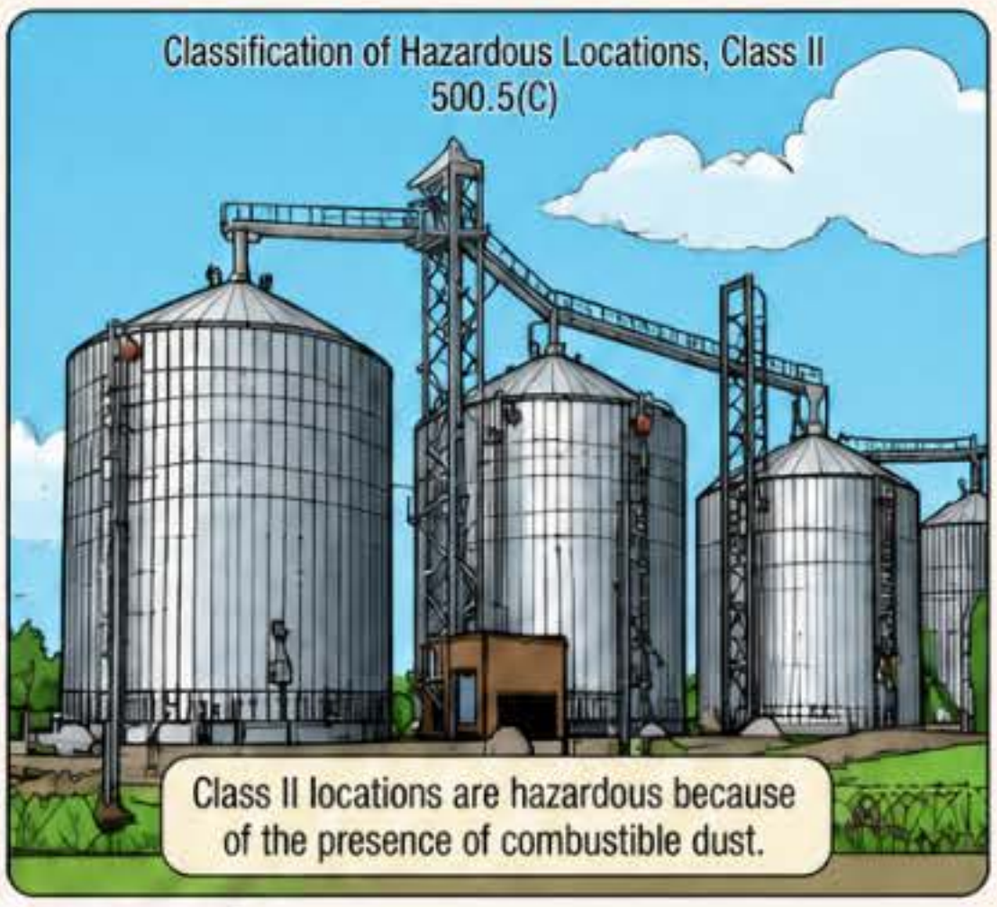


Figure 500–6

(1) Class II, Division 1 Location. A place where combustible dust may exist under any of the following circumstances:

(1) Under normal operating conditions, combustible dust is continuously or periodically suspended in the air in large enough amounts that it can ignite or explode, or

(2) If equipment malfunctions, it releases dust mixtures that can serve as a source of ignition, or

(3) Where Group E combustible dusts can be present in amounts sufficient to be hazardous in normal or abnormal operating conditions.

Note: Dusts that contain magnesium or aluminum are particularly hazardous, and extra caution is needed to prevent ignition and explosion.

(2) Class II, Division 2 Location. A place where combustible dust would become hazardous under any of the following conditions:

(1) If the combustible dust, because of abnormal operations, is present in the air in quantities sufficient to produce explosive or ignitable mixtures, or

(2) When combustible dust buildup is typically too small to affect the normal performance of electrical equipment, problems can still occur if an electrical malfunction causes that dust to become suspended in air.

(3) If such dust gathers on, in, or around electrical equipment, it may ignite when exposed to heating from the equipment or could be ignited by an abbormal operating condition or equipment failure.

Note 1: The amount of combustible dust present and the efficiency of the dust removal system are important factors when assigning an area classification.

(D) Identification of a Class III Location. A Class III area is any location where easily combustible fibers or other materials that can cause airborne fires are manufactured, processed, used, or handled. These operations are not expected to suspend dust in normal air quantities sufficient to create ignitable mixtures.

(1) Class III, Division 1 Location. A Class III, Division 1 area is any location where easily ignitable fibers or flyings are manufactured, handled, or used.

Note 1: Examples include parts of rayon, cotton, and other textile mills or clothing manufacturing plants, as well as facilities where wood byproducts (like sawdust and flyings) are reduced to powder or cut.

(2) Class III, Division 2 Location. A Class III, Division 2 area is any location where easily ignitable fibers or flyings are stored or handled other than during manufacturing.

500.6 Material Groups

For approval and classification purposes, air mixtures must comply with 500.6(A) and (B). ▸ **Figure 500–7**

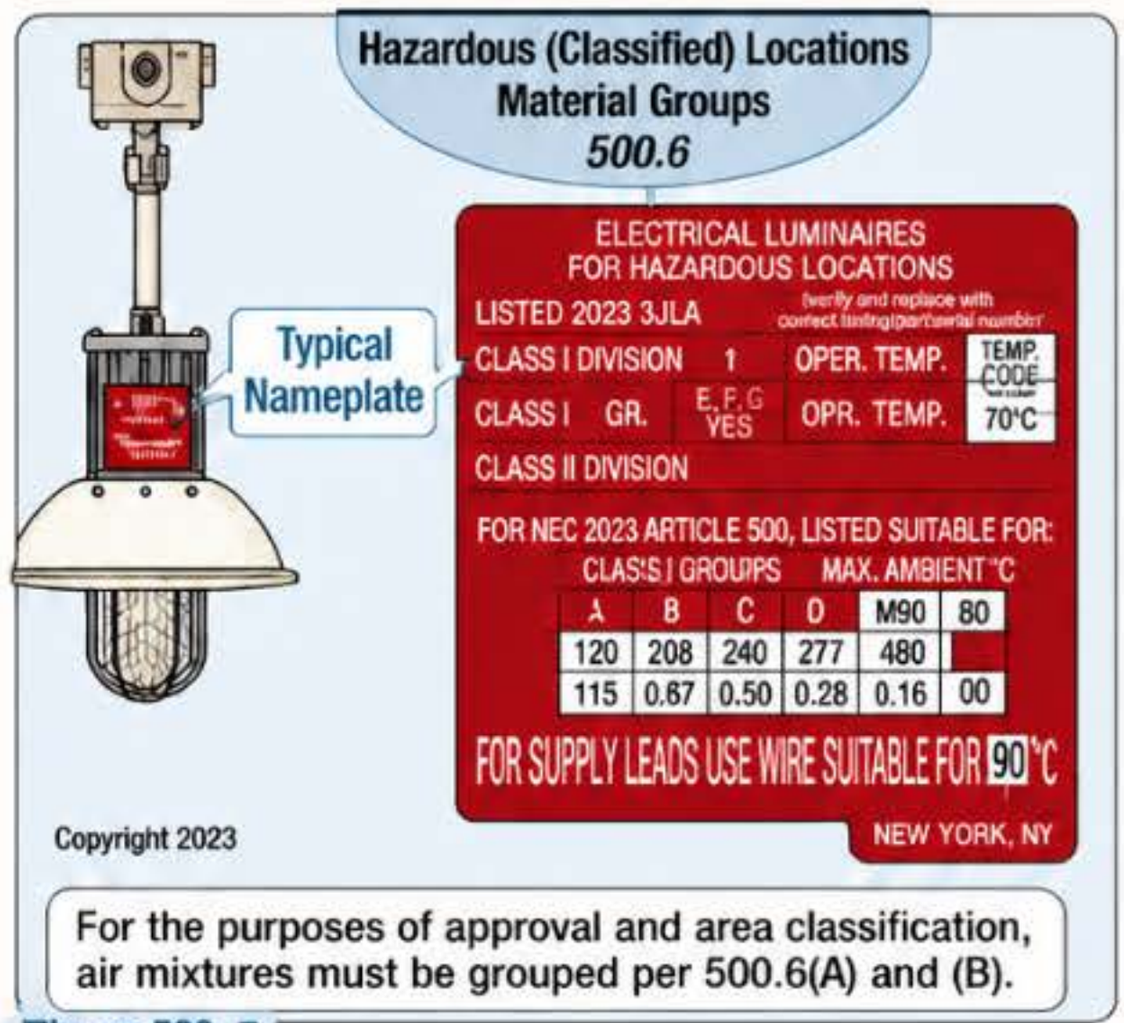


Figure 500–7

Author's Commentary:

- Consult 500.6(A) and (B) in the *NEC* to verify that equipment is listed for the correct group.
- The Cooper Crouse-Hinds *Code Digest* provides a full list of product classifications by group. It can be downloaded from www.coopercrouse-hinds.eu/en/service/brochures.html.

— Michael Hamilton

500.7 Protection Techniques

Electrical and electronic equipment in hazardous (classified) locations must be safeguarded using one or more of the following methods:

(A) Explosionproof Equipment. Explosionproof equipment is allowed in any Class 1 location when it is identified. ▸ **Figure 500–8**

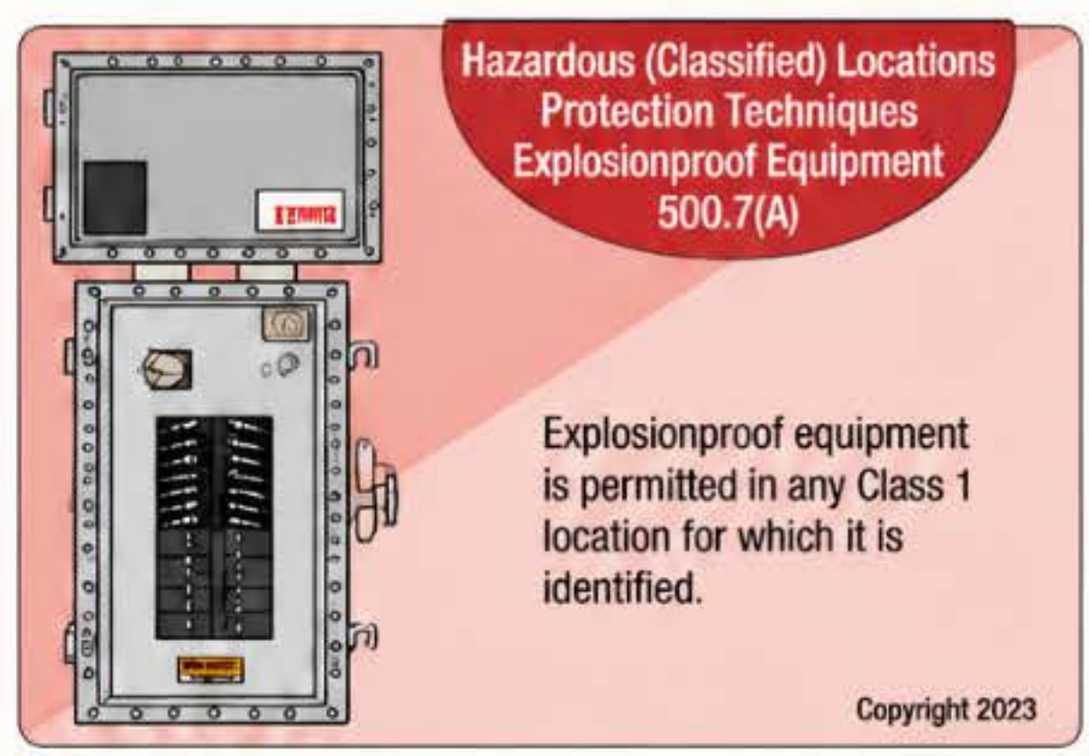


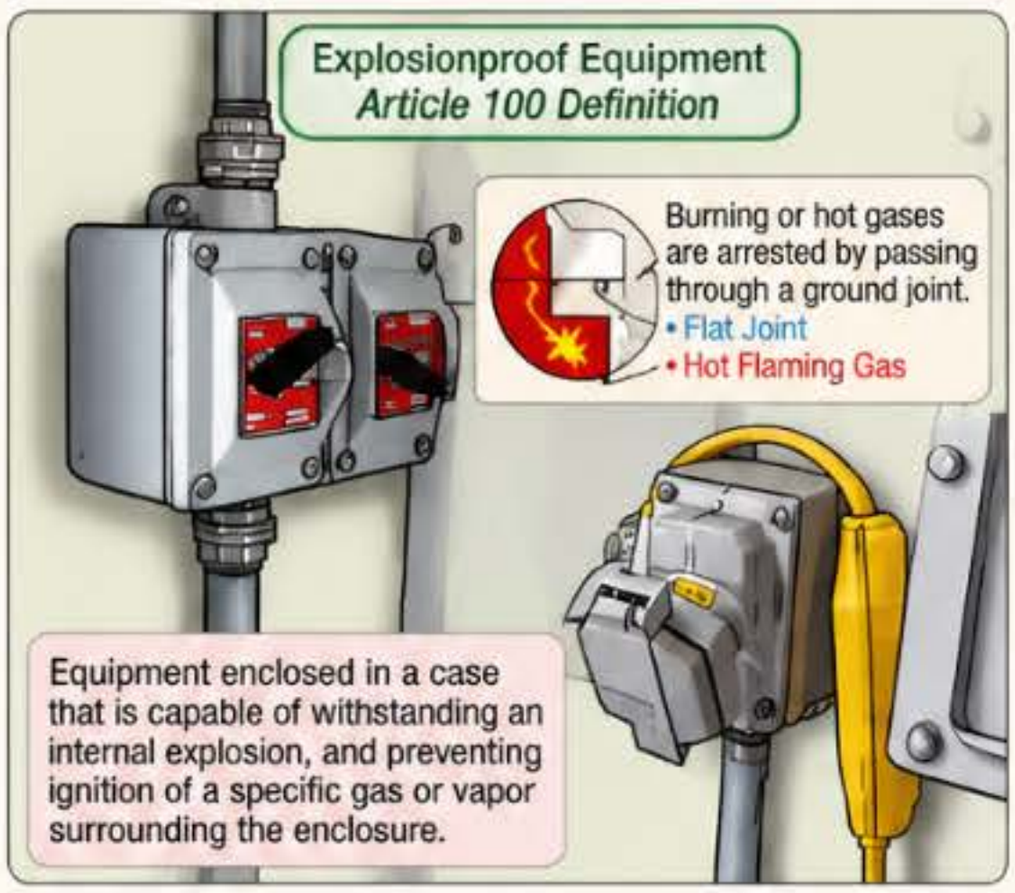
Figure 500–8

Author's Commentary:

- Explosionproof equipment is constructed to contain an internal explosion and to withstand the forces of the blast so that hot gases escaping the enclosure cannot ignite the surrounding atmosphere [Article 100]. ▸ **Figure 500–9**

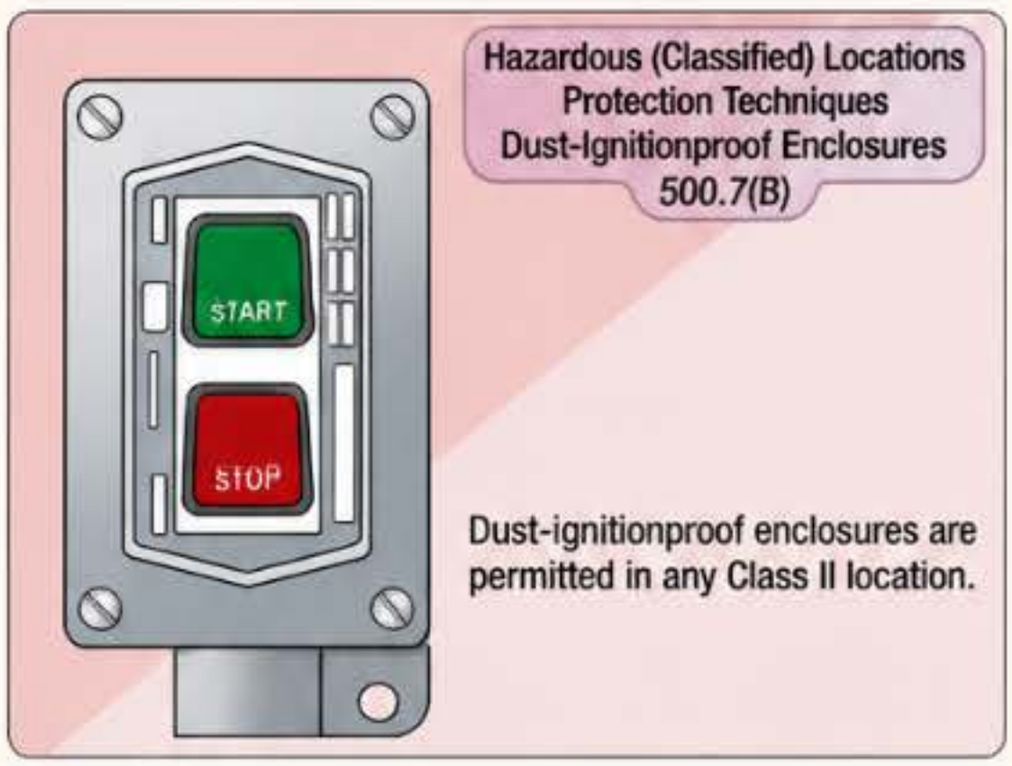
— Michael Hamilton

500.7 | Hazardous (Classified) Locations



▸ Figure 500-9

(B) Dust-ignitionproof Enclosures. Dust-ignitionproof enclosures are permitted in any Class II location. ▸ Figure 500-10



▸ Figure 500-10

Author's Commentary:

Dust-ignitionproof enclosures are built to keep dust out and to prevent arcs, sparks, or heat sources inside the enclosure from igniting external dust [Article 100].

— Michael Hamilton

(C) Dusttight Enclosures. Dusttight enclosures are permitted in Class II, Division 2 or any Class III location. ▸ Figure 500-11

(D) Purged and Pressurized Systems. Purged and pressurized systems are permitted for equipment in any hazardous (ilassified) locations for which they are identified. ▸ Figure 500-12

▸ Figure 500-11

▸ Figure 500-12

Author's Commentary:

"Purging" means supplying an enclosure with safe gas at a flow and pressure high enough to dilute the concentration of flammable gases, flammable liquid vapors, or combustible liquid-produced vapors to safe levels. "Pressurization" is supplying an enclosure with the same safe gas, with or without a continuous flow, at sufficient pressure to block the entry of combustible dust or ignitable fibers/flyings.

— Michael Hamilton

(I) Oil-Immersed Contacts. Oil-immersed make-and-break contacts can be installed in a Class I, Division 2 location.

(J) Hermetically Sealed Contacts. Hermetically sealed contacts can be installed in Class I, Division 2; Class II, Division 2; or Class III locations.

HAZARDOUS (CLASSIFIED) LOCATIONS | 500.8

Author's Commentary:

"Hermetically Sealed" means equipment that is closed so gases from the outside cannot get in. The seal is achieved using glass fusion or metal bonding—such as soldering, brazing, or welding—as described in Article 100.

— Michael Hamilton

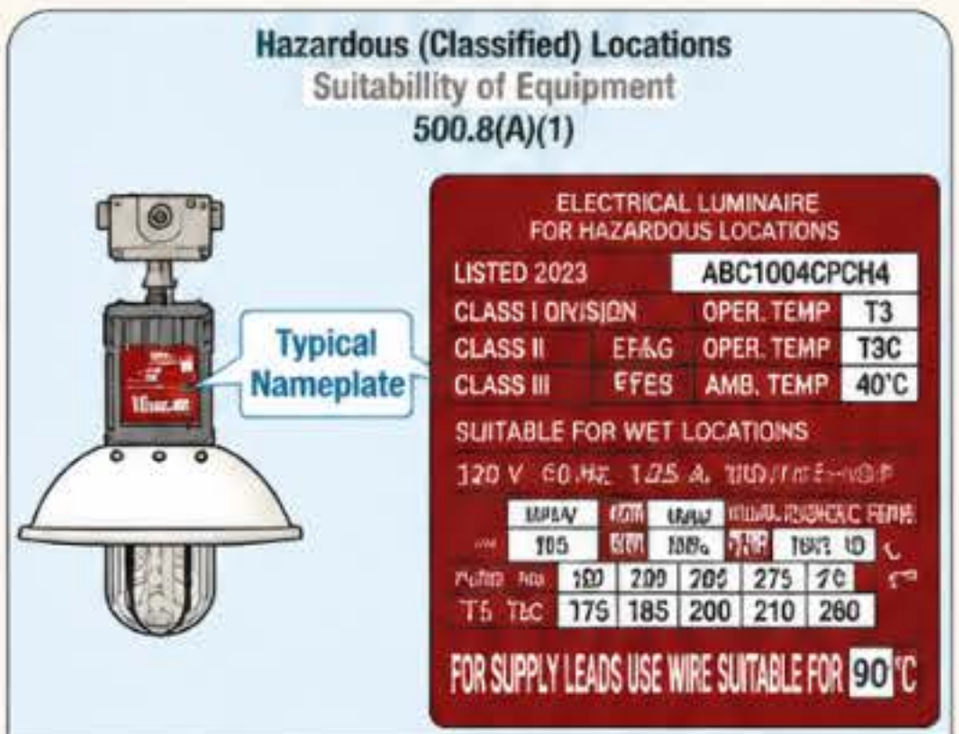
(P) Other Protection Techniques. Additional methods of protection for equipment used in hazardous (classified) locations are allowed.

500.8 Equipment

Articles 500 through 503 require that electrical equipment be built, installed, and maintained so it operates safely under the conditions of use.

(A) Suitability of Equipment. The suitability of equipment must be determined by any of the following:

(1) Listing or labeling. ▸**Figure 500–13**



Suitability of equipment can be determined by listing or labeling.

▸ **Figure 500–13**

(2) Field evaluation by a qualified testing laboratory or inspection agency concerned with product evaluation.

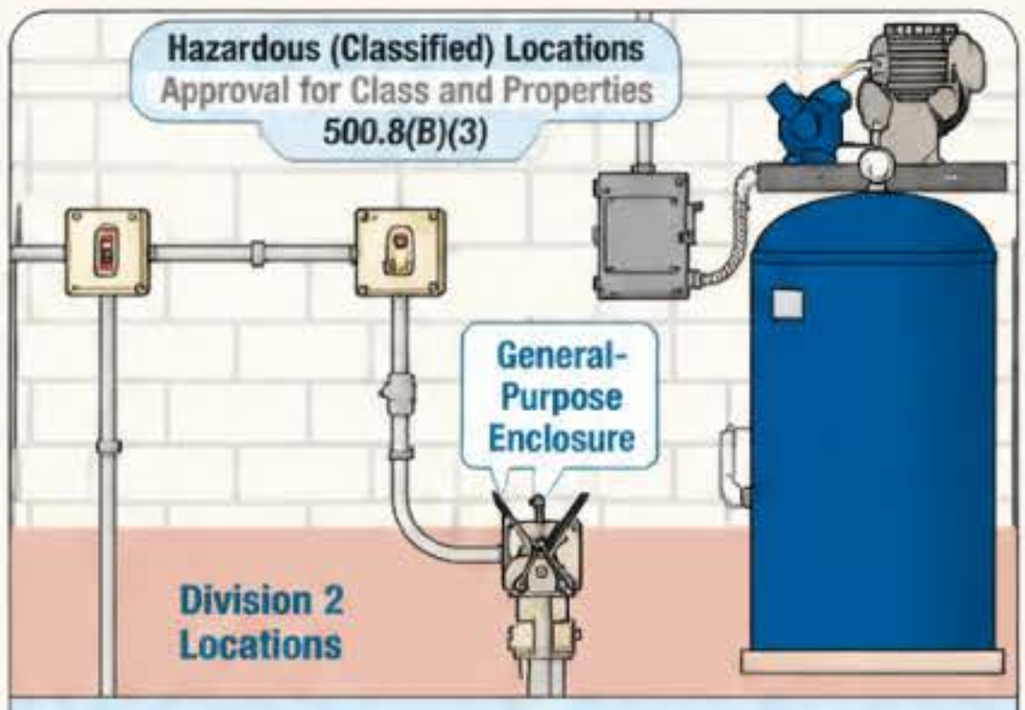
(3) Evidence acceptable to the authority having jurisdiction such as a manufacturer's self-evaluation or an owner's engineering judgment.

Note: Additional documentation may include certificates that show compliance with applicable equipment standards for special conditions of use and other pertinent information.

(B) Approval for Class and Properties.

(1) **Identified for Use.** Equipment installed in any hazardous (classified) location must be identified for the class and the explosive, combustible, or ignitable properties of the specific gas, vapor, dust, or fiber/flyings that will be present.

(3) A general-purpose enclosure without make-and-break contacts can be installed in Article 501, 502, and 503 Division 2 locations. ▸**Figure 500–14**

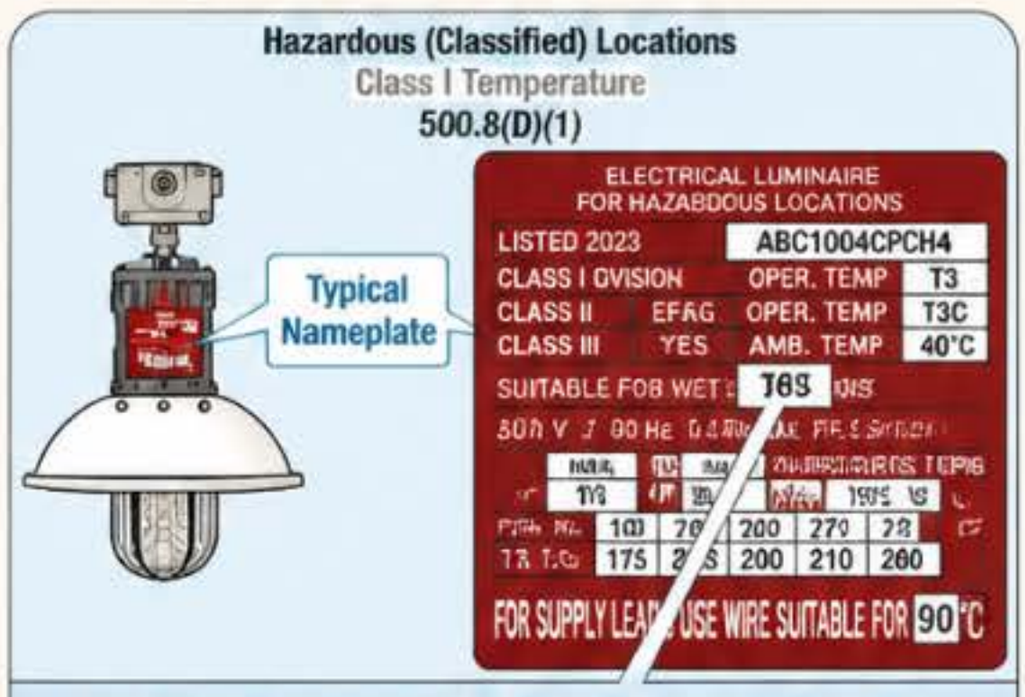


A general-purpose enclosure without make-and-break contacts can be installed in Article 501, 502, and 503 Division 2 locations.

▸ **Figure 500–14**

(D) Temperature.

(1) **Class I Temperature.** For Class I equipment, the Table 500.8(C) temperature marking must not exceed the autoignition temperature of the specific gas or vapor that may be encountered. ▸**Figure 500–15**



For Class I equipment, the temperature marking must not exceed the autoignition temperature of the specific gas or vapor that may be encountered.

▸ **Figure 500–15**

500.8 | Hazardous (Classified) Locations

Table 500.8(C) Classification of Maximum Surface Temperature

Maximum °C	Temperature °F	Temperature Class (T Code)
450	842	T1
300	572	T2
280	536	T2A
260	500	T2B
230	446	T2C
215	419	T2D
200	392	T3
180	356	T3A
165	329	T3B
160	320	T3C
135	275	T4
120	248	T4A
100	212	T5
85	185	T6

(2) Class I Temperature. Electrical equipment shall not have exposed surfaces that operate at a temperature above the autoignition temperature of the specific dust present in 500.8(C).

Author's Commentary:

This is achieved by verifying that the markings on the equipment (such as luminaires and motors) do not surpass the autoignition temperature of the gases, vapors, or dusts that might be encountered.

— Michael Hamilton

(E) Threading. All threaded raceways must be assembled so they are tight, resisting arcing where a ground-fault current may flow. This helps ensure the explosionproof, dust-ignitionproof, or dust-tight integrity of the raceway system is preserved.

(1) Equipment with Threaded Entries. Threaded entries for explosionproof equipment shall be constructed with a minimum of five full threads engaged.

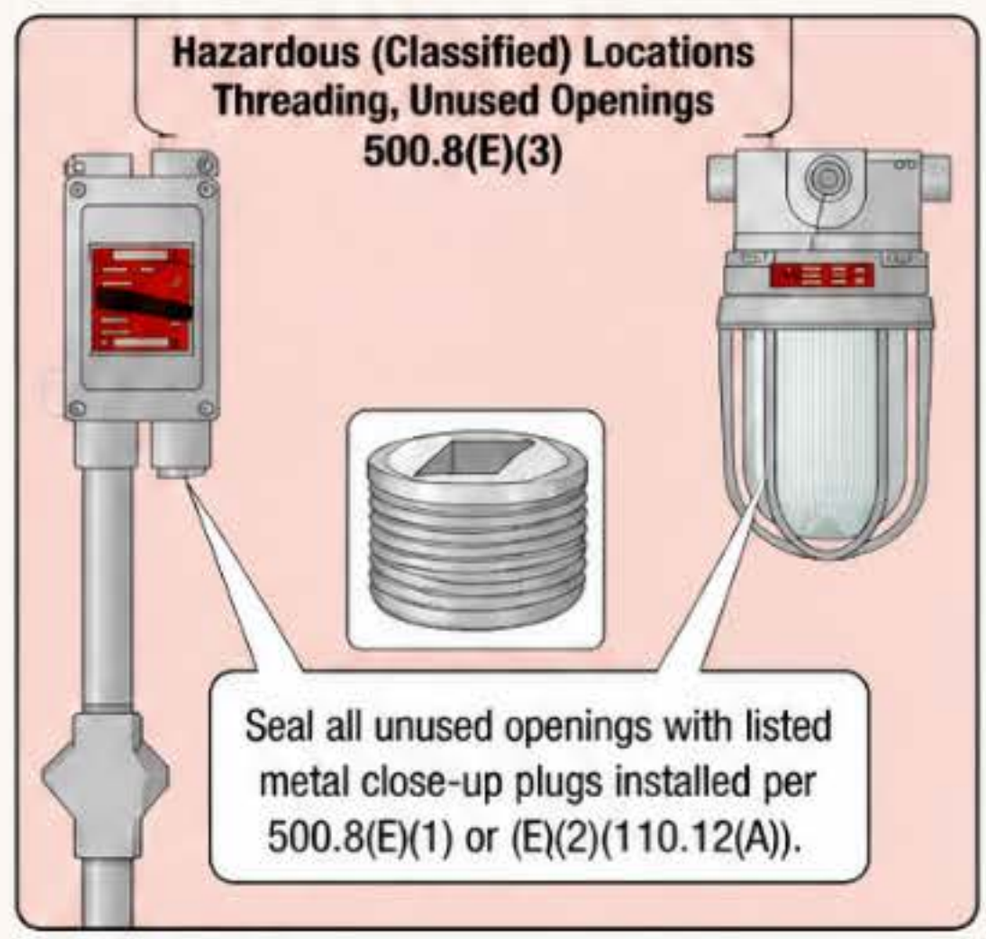
Example: Equipment labeled explosionproof with standard NPT entries must be built with four complete threads and one extra half thread engaged.

Author's Commentary:

- This requirement makes certain that any explosion occurring in a raceway or enclosure does not allow the expanding gases to cool off enough to pass through the threads. This keeps hot, flaming gases from igniting the outside atmosphere at thie classified site.
- It is assumed that the flammable mixtures outside the raceway will seep into the raceway network over time. The Code's objective is to contain any possible explosion within the raceway so it cannot ignite flammable mixtures in unclassified areas.

— Michael Hamilton

(3) Unused Openings. Any spare openings in raceways or any cable entry points must be firmly closed using listed metal close-up plugs as required by 500.8(E)(1) or (E)(2)(110.12(A)). ▶ **Figure 500–16.**



▶ **Figure 500–16**

ARTICLE 501 CLASS I HAZARDOUS (CLASSIFIED) LOCATIONS

Introduction to Article 501—Class I Hazardous (Classified) Locations

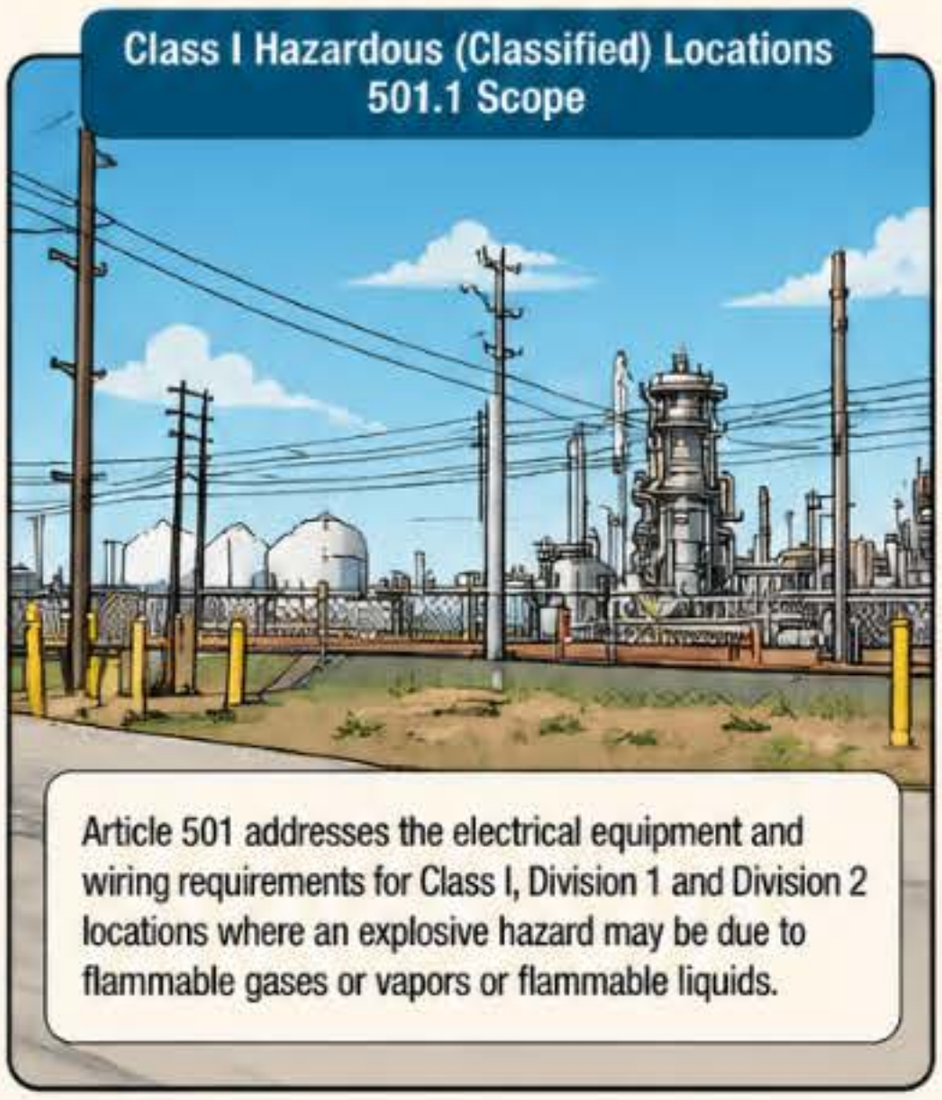
In environments where flammable or combustible gases, vapors, or liquids may be present to the point that they can form an explosive or fire-producing mixture, the area is considered a Class I location. Typical examples include fuel storage areas, solvent storage areas, grain processing facilities (when hexane is used), locations involving plastic extrusion where oil removal is part of the process, refineries, and paint storage areas.

Article 500 provides a general overview of nonhazardous (unclassified) locations, explains how Class I, II, and III locations are distinguished, and shows the differences between Divisions 1 and 2 within Class I and Class II. Article 501 presents the specific installation requirements for Class I, Division 1 and Division 2 locations, including acceptable wiring methods, sealing requirements, and equipment rules.

Part I. General

501.1 Scope

Article 501 addresses the electrical equipment and wiring requirements for Class I, Division 1 and Division 2 locations where an explosive hazard may be due to flammable gases or vapors or flammable liquids. ▸Figure 501–1



▸Figure 501–1

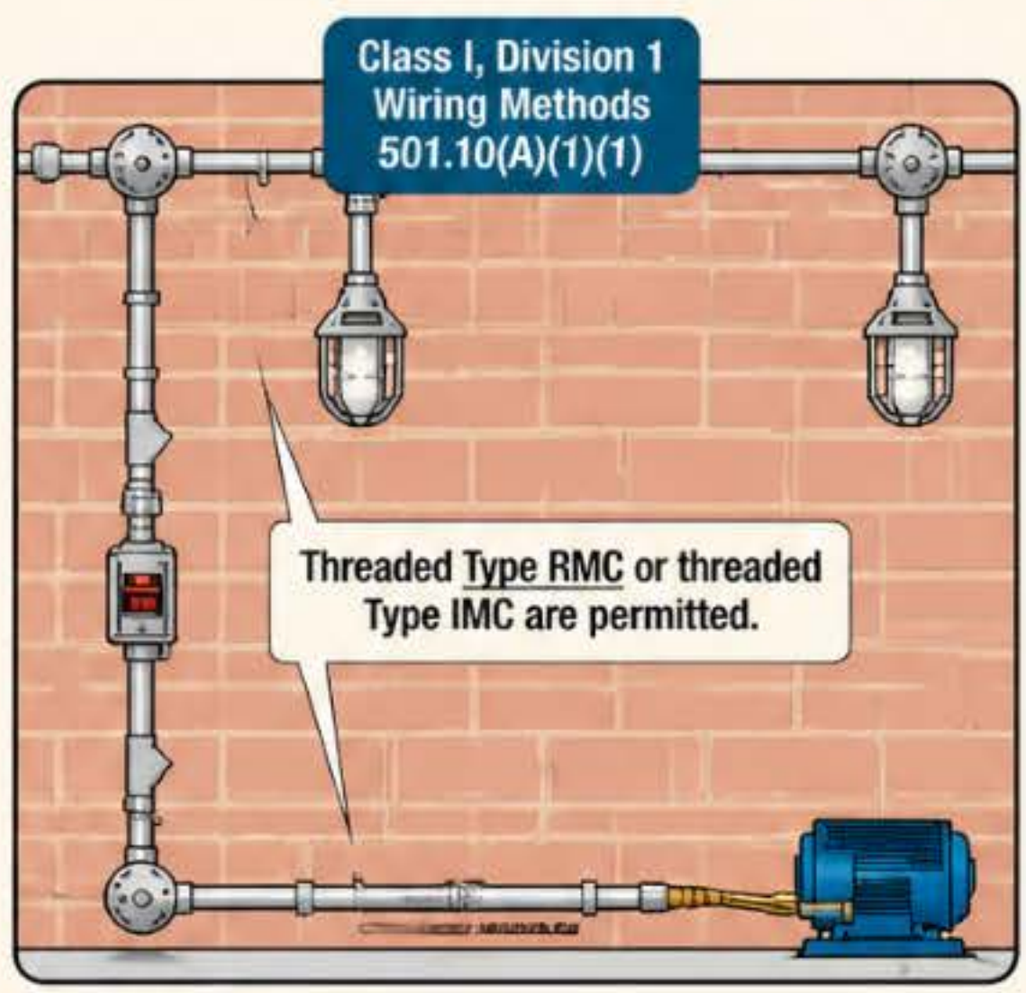
Part II. Wiring

501.10 Wiring Methods

(A) Class I, Division 1.

(1) General. Only the following wiring methods are permitted within a Class I, Division 1 location.

(1) Threaded rigid metal conduit (Type RMC) or threaded intermediate metal conduit (Type IMC). ▸Figure 501–2



▸Figure 501–2

Example: Conduit types PVC, RTRC, and HDPE are allowed underground provided the raceway is encased in at least 2 in. of concrete and has a cover depth (from the top of the conduit) of not less than 24 in. Measured from the top of the conduit, concrete encasement is not required when PVC, RTRC, or HDPE raceway is installed below fuel dispensers in accordance with 514.8 Exception 2.

(2) MI cable may be used if terminated with fittings that are listed for the specific location.

(2) Class 1, Division 1 Flexible Connections. When vibration or movement is expected or required, the following are allowed:

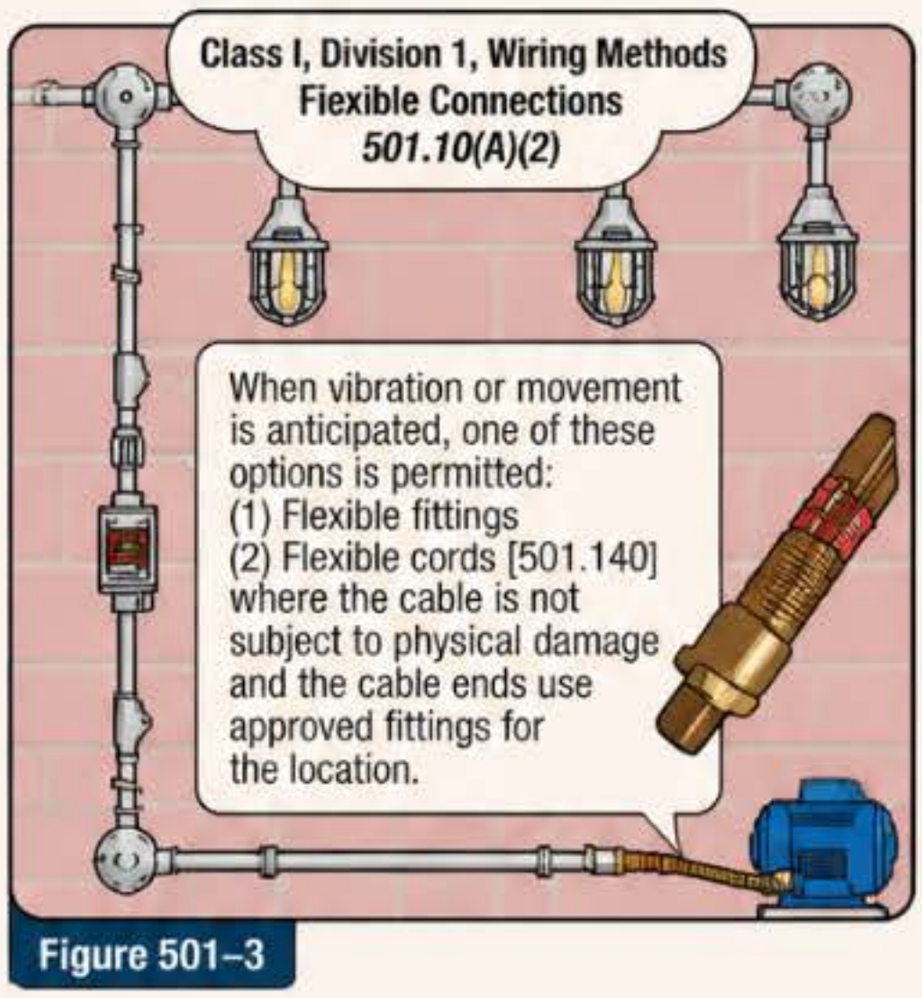


Figure 501–3

(1) Flexible fittings listed for the location.

(2) Flexible cords in accordance with 501.140, where the cable is not subject to physical damage and the cable terminates with fittings listed for the location.

(3) Boxes and Fittings. Equipment boxes and fittings must be approved for Class I, Division 1 locations. ▸Figure 501–4

(B) Class I, Division 2.

(1) General. Any wiring method listed for Class 1, Division 1 [501.10(A)] may be used in Class I, Division 2 locations.

(1) Rigid or intermediate metal conduit with listed threaded or threadless fittings. ▸Figure 501–5

(2) Enclosed gasketed wireways.

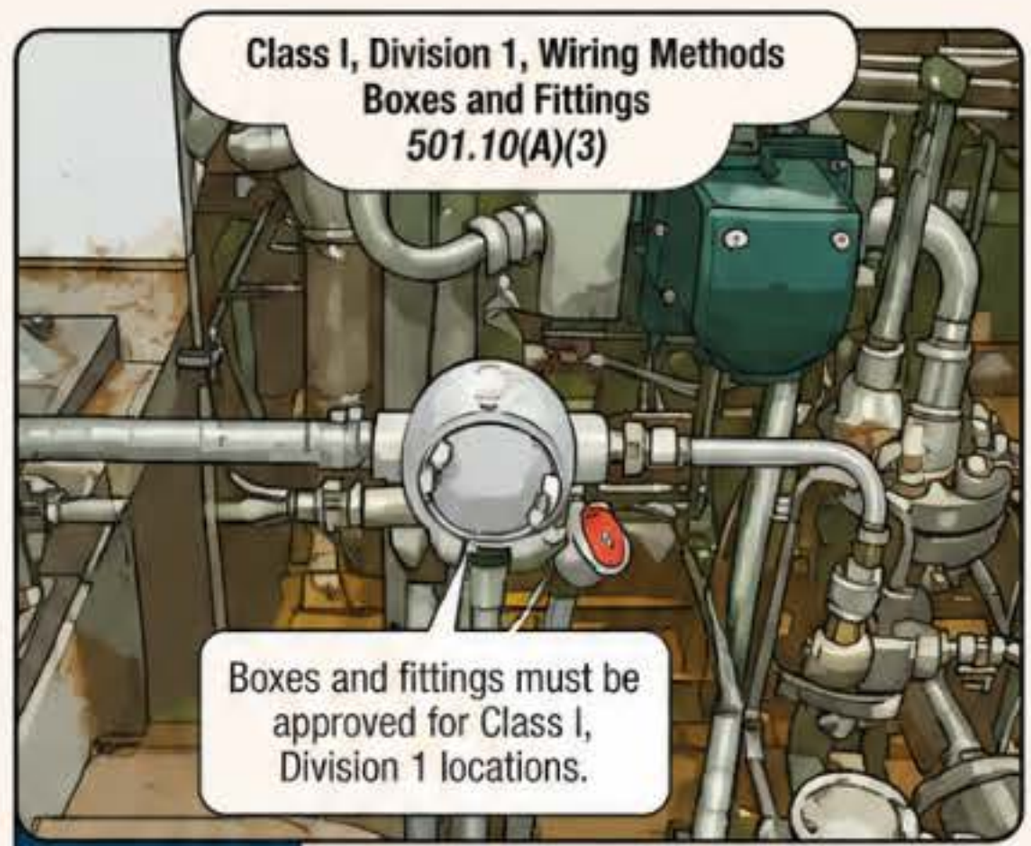


Figure 501–4

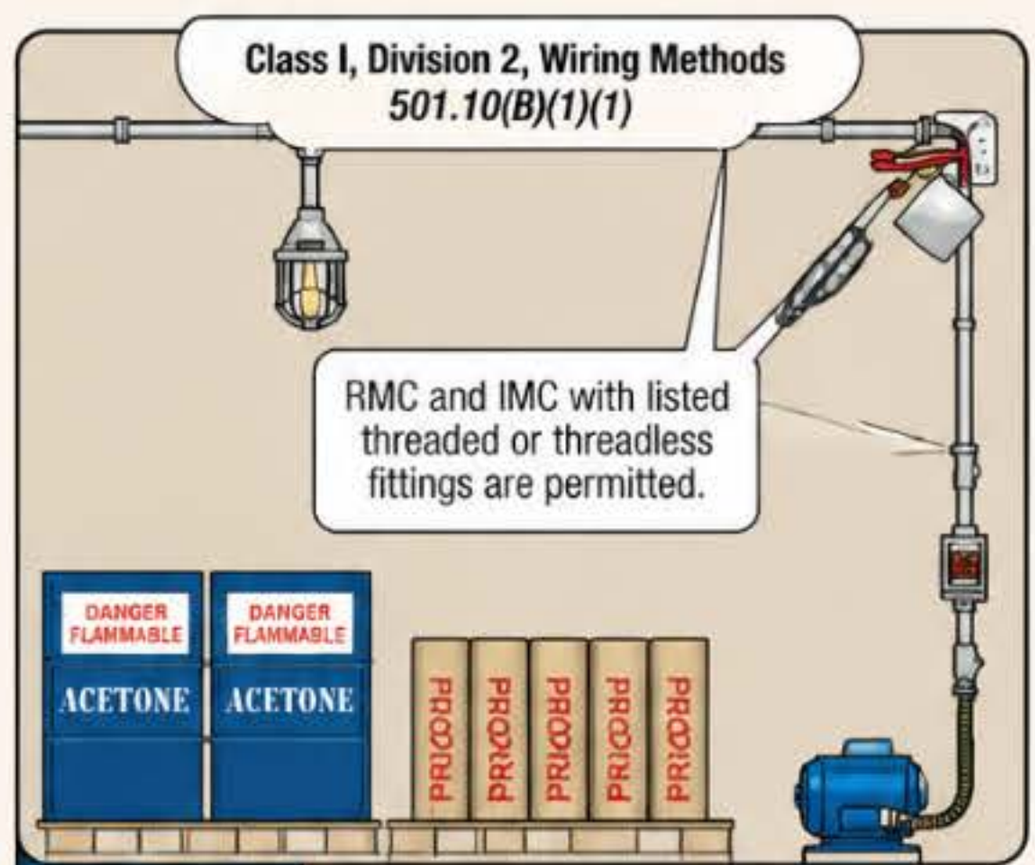


Figure 501–5

(3) Types PLTC and PLTC-ER cable terminated in accordance with Parts II and III of Article 725. Type PLTC-ER cable must include an equipment grounding conductor in addition to any drain wire that might be present.

(4) Types ITC and ITC-ER cable as permitted in 727.4. Type ITC-ER cable must include an equipment grounding conductor in addition to a drain wire.

(5) Types MC, MV, TC, or TC-ER cable terminated with listed fittings, including installation in cable tray systems. Type TC-ER cable must include an equipment grounding conductor in addition to any drain wire that might be present.

(6) Where metallic conduit does not provide adequate corrosion protection, any of the wiring methods listed above are allowed.

Class I Hazardous (Classified) Locations | 501.15

a. Reinforced thermosetting resin conduit (RTRC), factory elbows, and related fittings must be identified with the suffix "-XW."

b. Rigid metal conduit with a PVC coating (RMC), factory elbows, and associated fittings.

c. Intermediate metal conduit with a PVC coating (IMC), factory elbows, and associated fittings.

d. Electrical systems in industrial facilities that are open to the public may be installed only under a maintenance program supervised by qualified personnel. Installers who are not qualified may use Schedule 80 PVC conduit, elbows, and fittings.

(7) Types OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN, and OFC optical fiber cables may be placed in cable trays or raceways per 501.10(B)] and must be sealed according to 501.15.

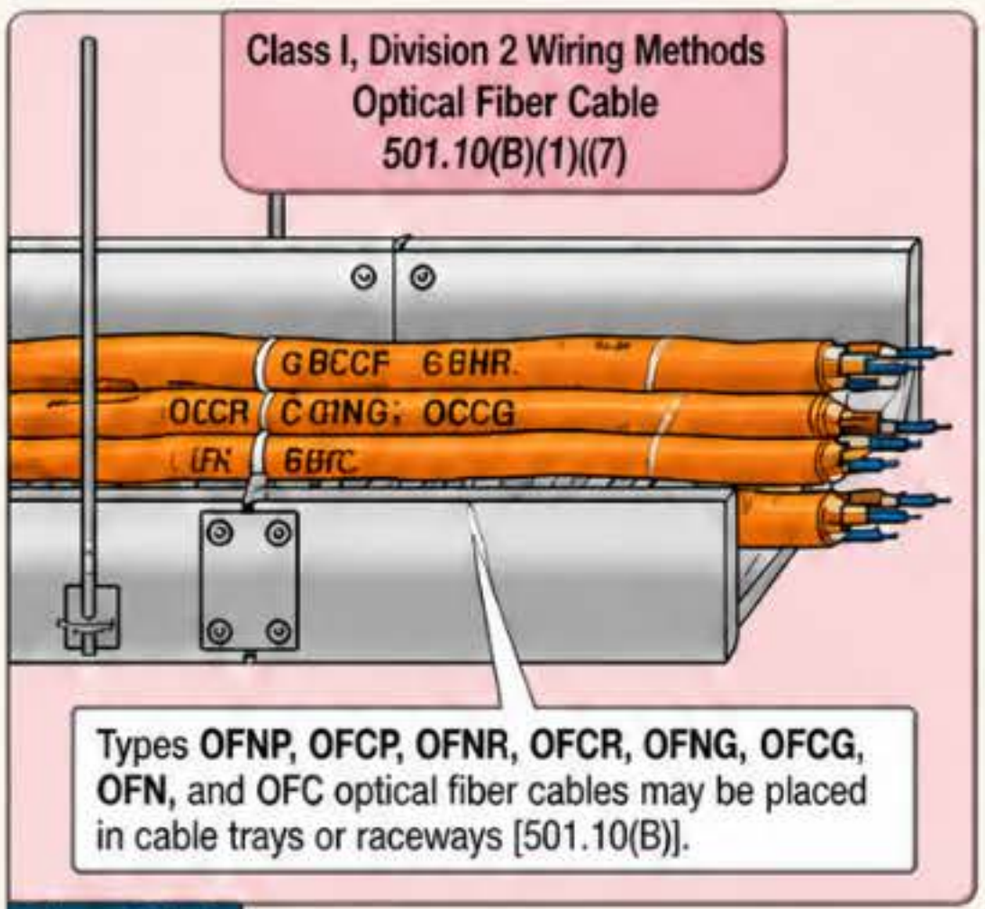


Figure 501–6

(8) Cablebus.

(2) Class 1, Division 2 Flexible Connections. If flexibility is required, the following are allowed: Figure 501–7

(1) Listed flexible metal fittings.

(2) Flexible metal conduit with listed fittings.

(3) Interlocked Type MC cable with listed fittings.

(4) Liquidtight flexible metal conduit with listed fittings.

(5) Liquidtight flexible nonmetallic conduit with listed fittings.

(6) Flexible cords for extra-hard service with an equipment grounding conductor and listed fittings.

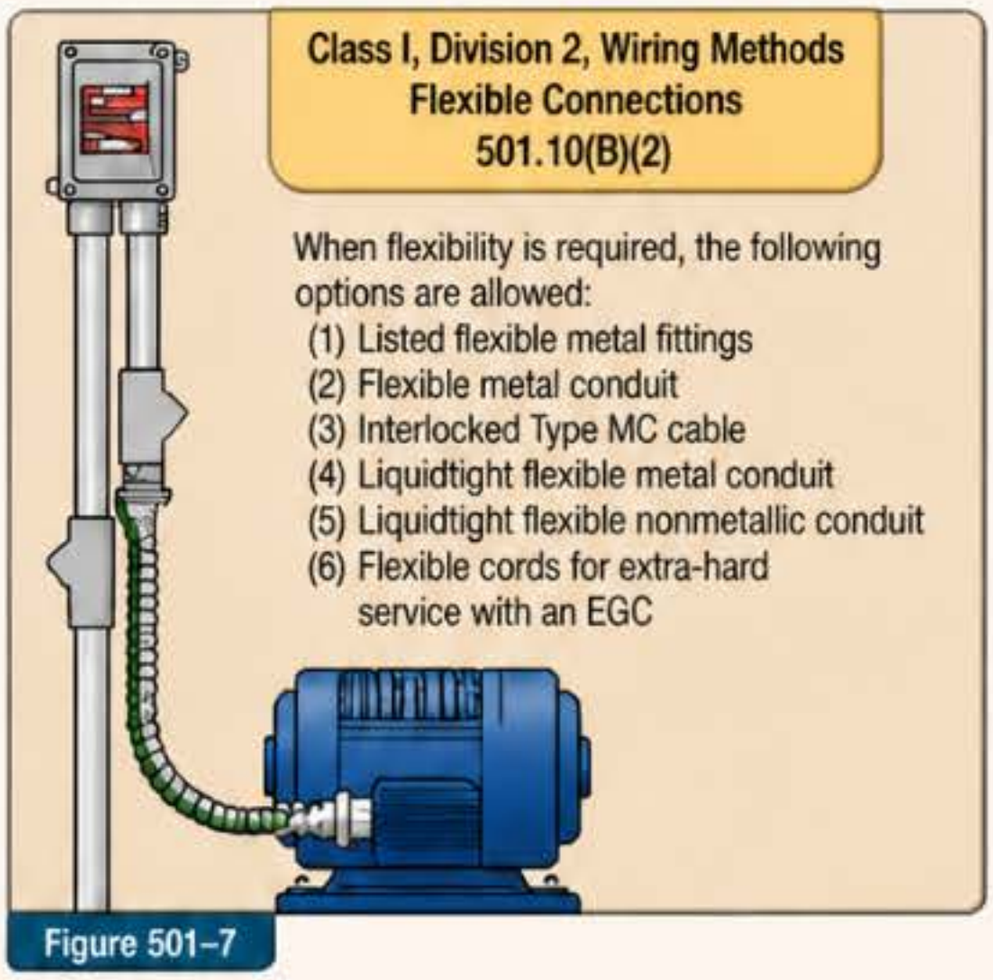


Figure 501–7

AUTHOR'S COMMENTARY:

Flexible cords, when used, must meet the requirements of 501.140.

— Michael Hamilton

(4) Boxes and Fittings. General-purpose enclosures and fittings in Class 1, Division 2 locations are allowed unless the enclosure includes make-and-break contacts.

501.15 Raceway and Cable Seals

Raceway and cable systems must comply with 501.15(A) through (F).

Note 1: Raceway and cable seals must be installed to: Figure 501–8

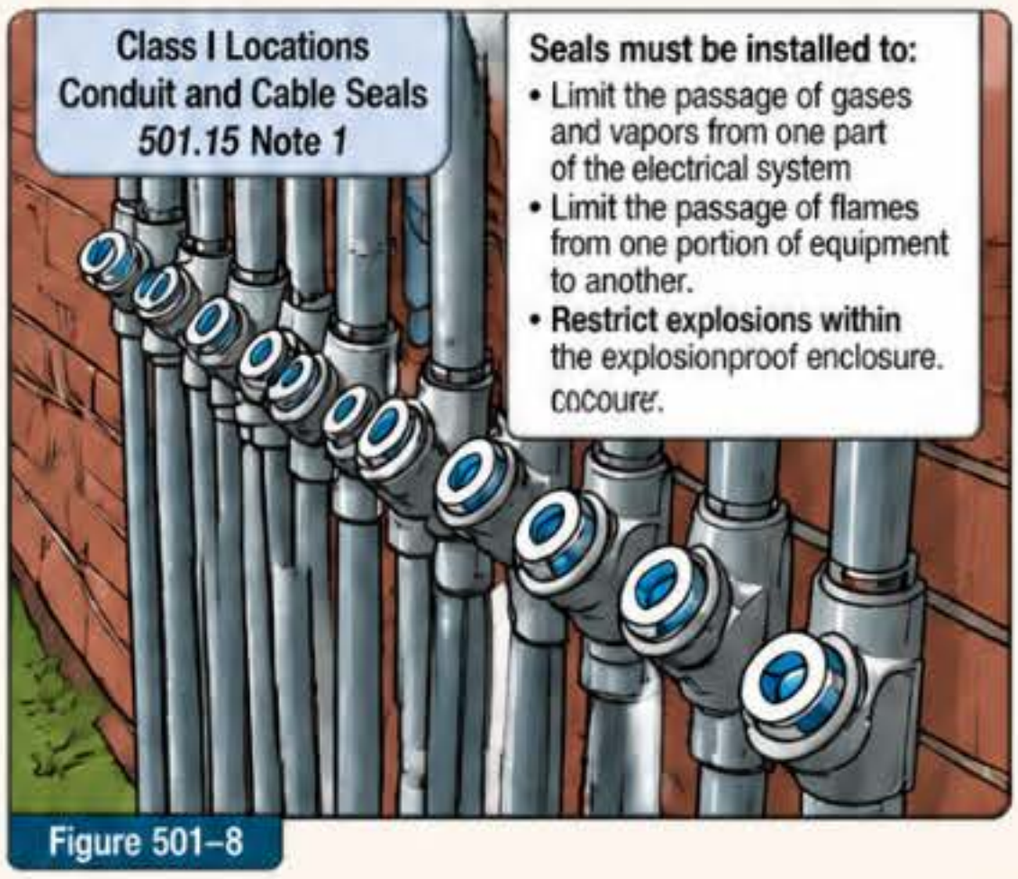


Figure 501–8

501.15 | Class I Hazardous (Classified) Locations

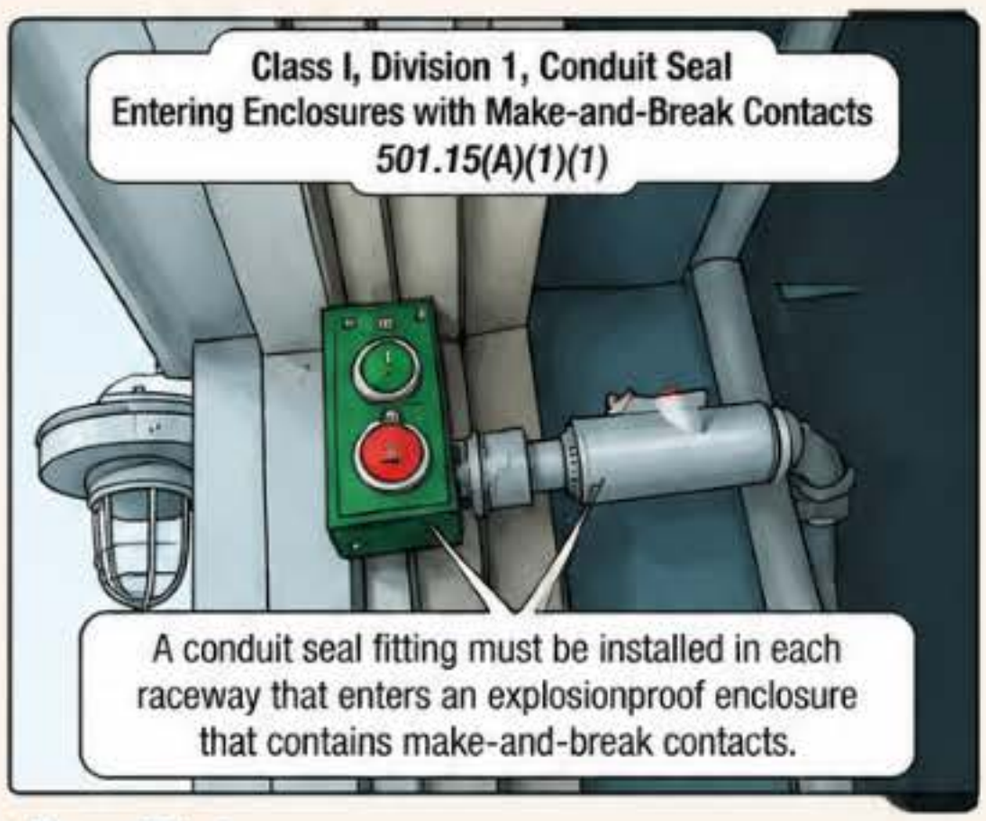
- Keep gases or vapors from traveling from one piece of electrical equipment to another through the raceway or cable.
- Prevent flames from moving from one area of electrical equipment to another through the raceway or cable.

Within enclosures used in explosive locations, maintain internal explosions inside the explosionproof enclosure.

(A) Conduit Seal—Class I, Division 1. At Class I, Division 1 locations, conduit seals must be provided as follows:

(1) Entering Enclosures. Every raceway that penetrates an explosionproof enclosure must be sealed if one of the following applies:

(1) The enclosure contains make-and-break contacts that can spark. ▸Figure 501–9



▸Figure 501–9

Ex: A conduit seal is not required if the make-and-break contacts are:

(1) Within a hermetically sealed chamber. ▸Figure 501–10

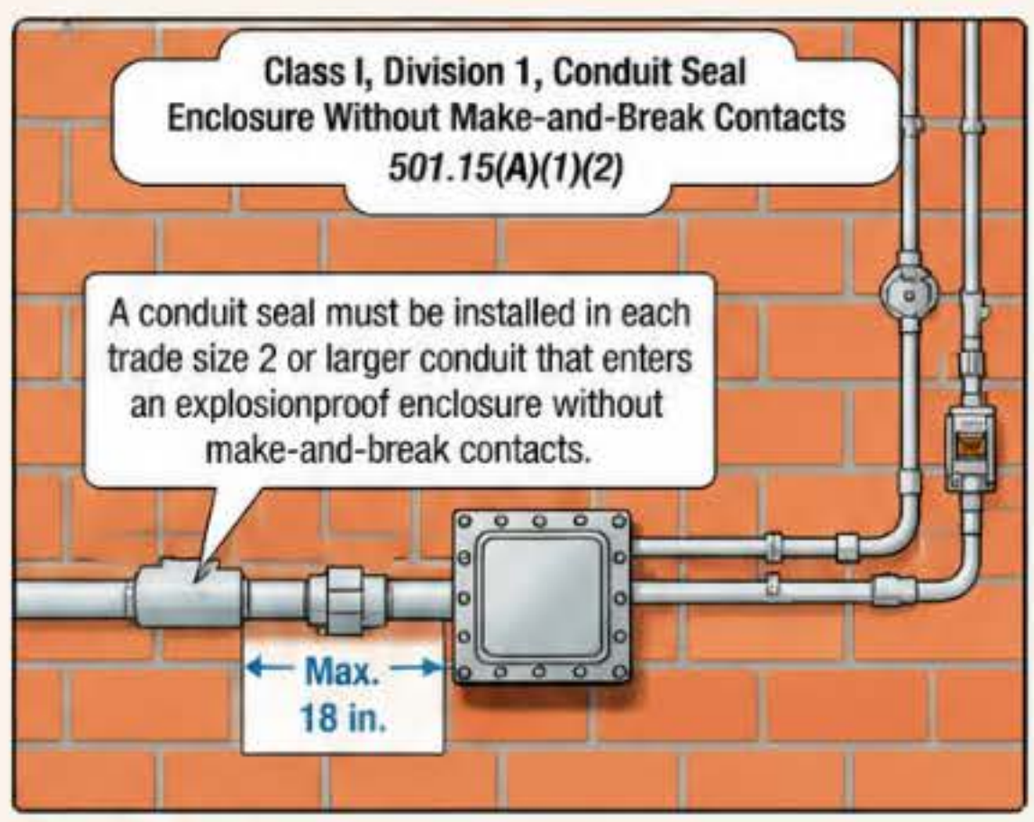
(2) Immersed in oil in accordance with 501.115(B)(1)(2).

(3) Contained within an enclosure that is marked "Leads Factory Sealed," "Factory Sealed," "Seal not Required," or the equivalent.

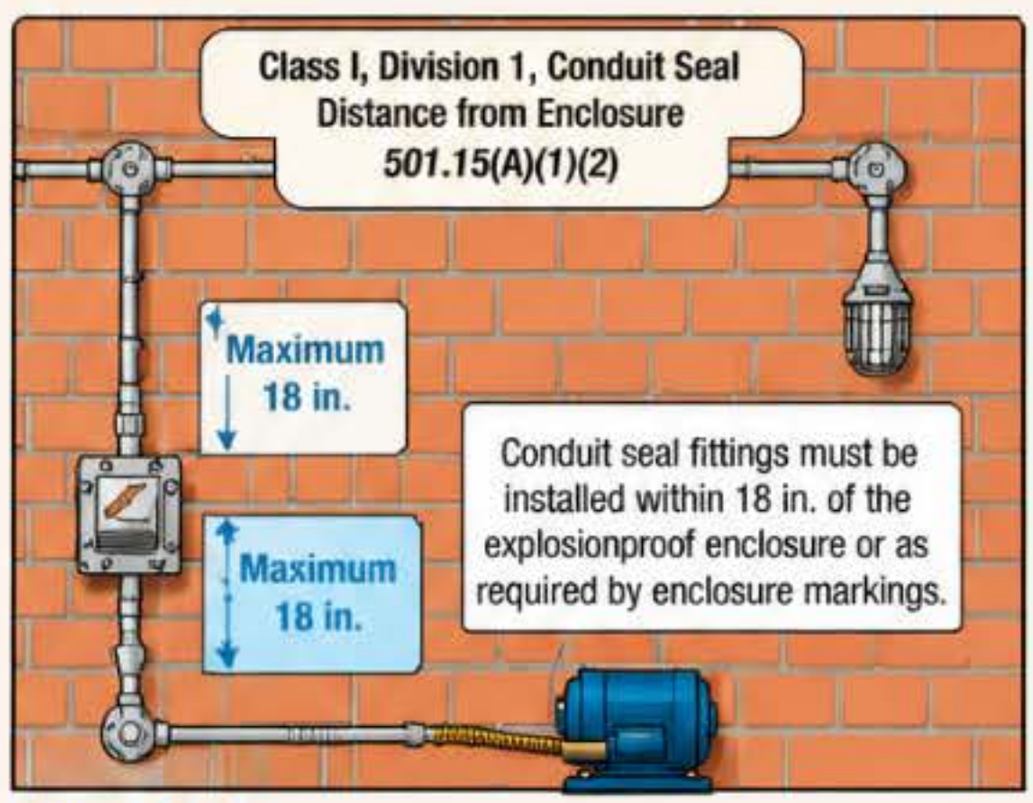
(2) If a trade size 2 or larger conduit enters any explosionproof enclosure without a make-and-break contact. ▸Figure 501–11

The conduit seal fitting must be installed within 18 in. of the explosionproof enclosure or as required by the enclosure markings. ▸Figure 501–12

▸Figure 501–10



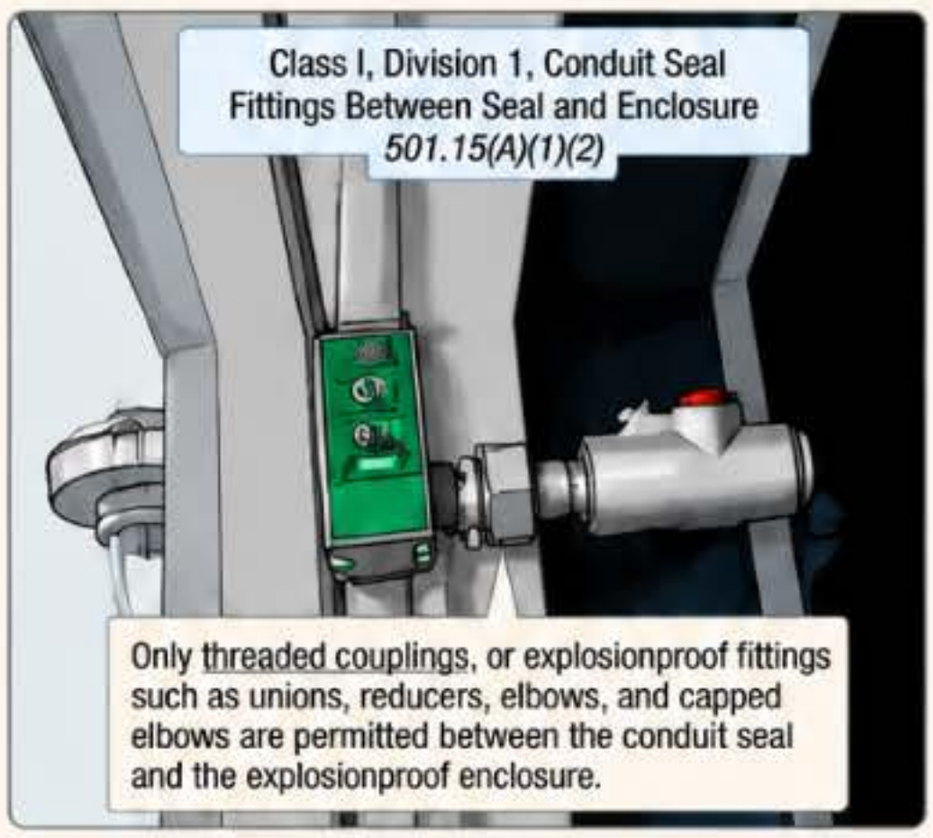
▸Figure 501–11



▸Figure 501–12

DEFINITIONS | From Michael Hamilton Publications

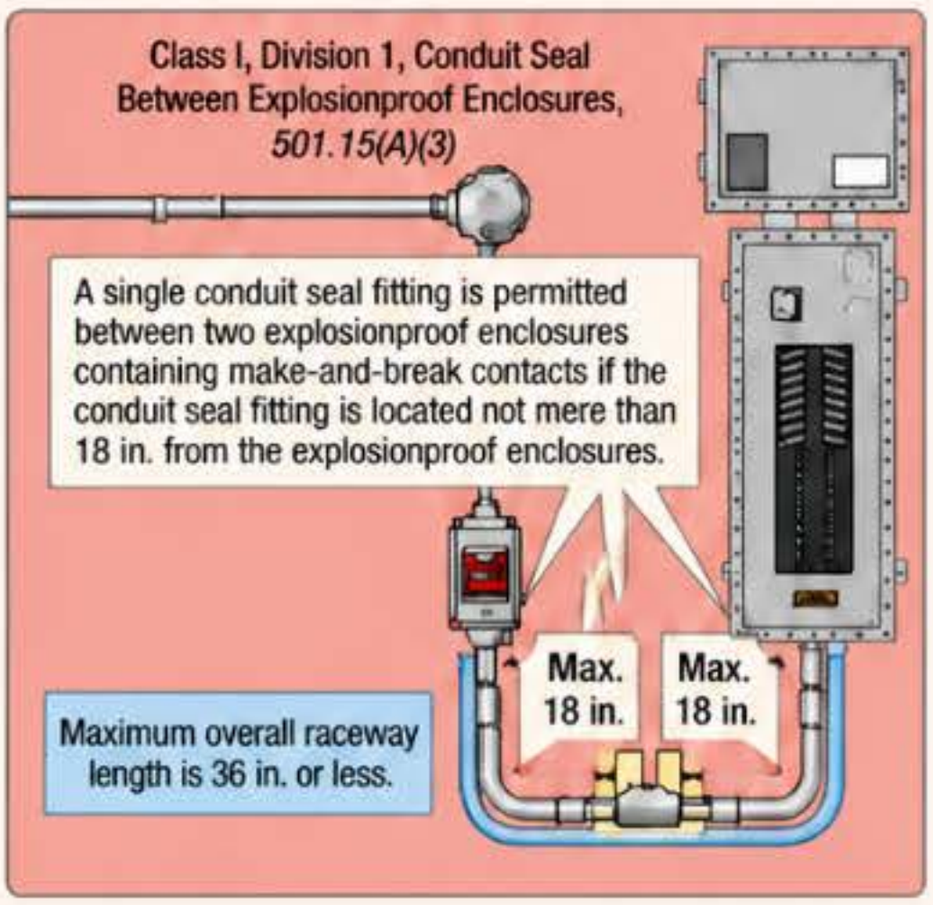
Only threaded couplings, or explosionproof fittings such as unions, reducers, elbows, and capped elbows are allowed at the conduit seal and at the explosionproof enclosure. Figure 501–13



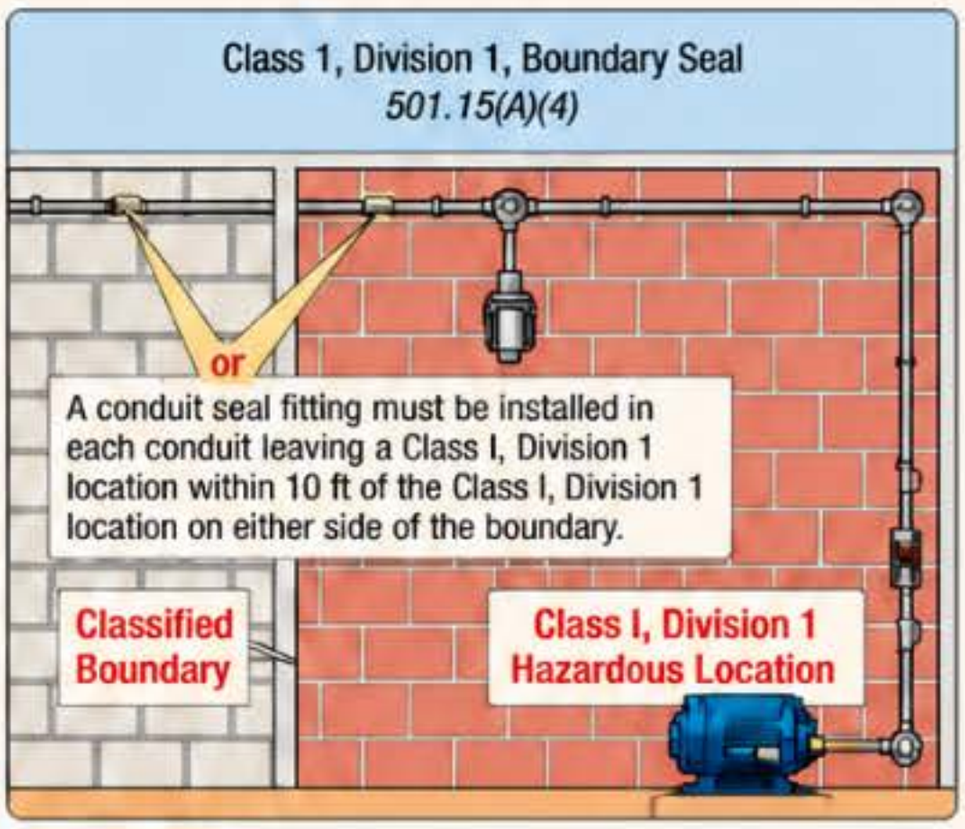
▶ Figure 501–13

(2) Pressurized Enclosures. A conduit seal fitting must be installed in each conduit that is not pressurized where the conduit enters a pressurized enclosure. The conduit seal fitting must be installed within 18 in. of the pressurized enclosure.

(3) Between Explosionproof Enclosures. A single conduit seal fitting is permitted between two explosionproof enclosures if not more than 36 in. long containing make-and-break contacts if the conduit seal fitting is located not more than 18 in. from the explosionproof enclosures. Figure 501–14

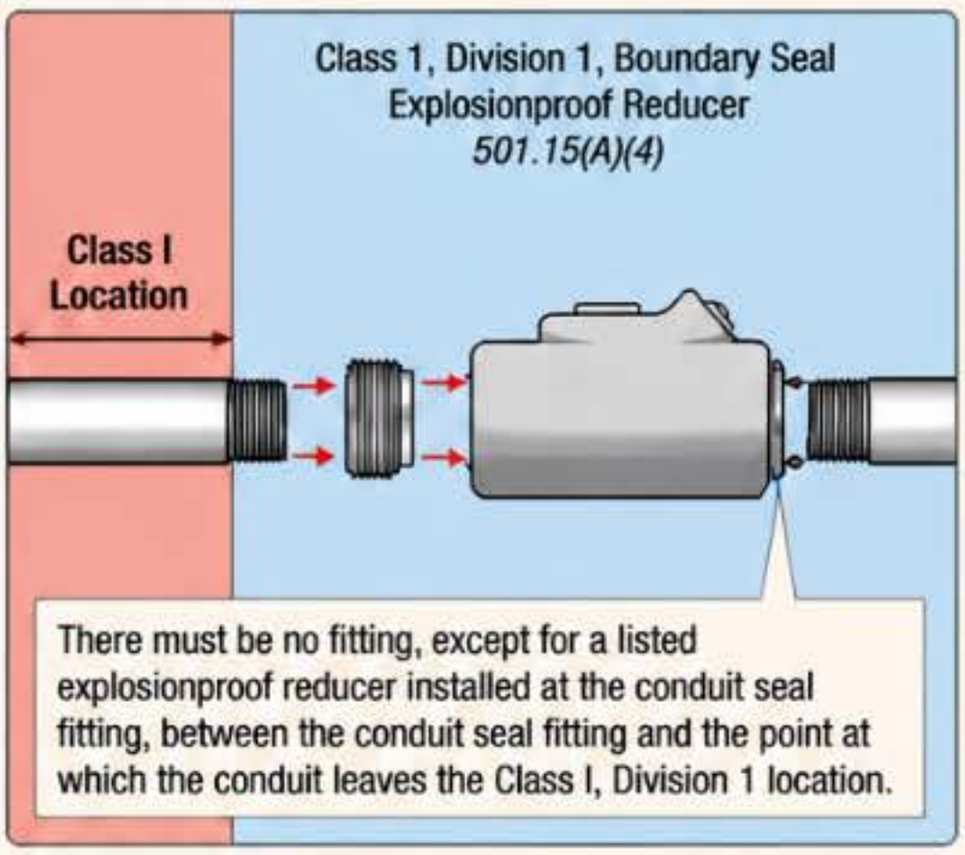


(4) Class I, Division 1 Boundary Seal. A conduit seal fitting must be installed in each conduit that leaves a Class I, Division 1 location within 10 ft of the Class I, Division 1 location on either side of the boundary. Figure 501–15



▶ Figure 501–15

There must be no fitting, except for a listed explosionproof reducer installed at the conduit seal fitting, between the conduit seal fitting and the point at which the conduit leaves the Class I, Division 1 location. Figure 501–16



▶ Figure 501–16

Ex 1: A conduit boundary seal fitting is not required for a conduit that passes completely through the Class I, Division 1 area unbroken with no fittings installed within 12 in. of either side of the boundary. Figure 501–17

501.15 | Class I Hazardous (Classified) Locations

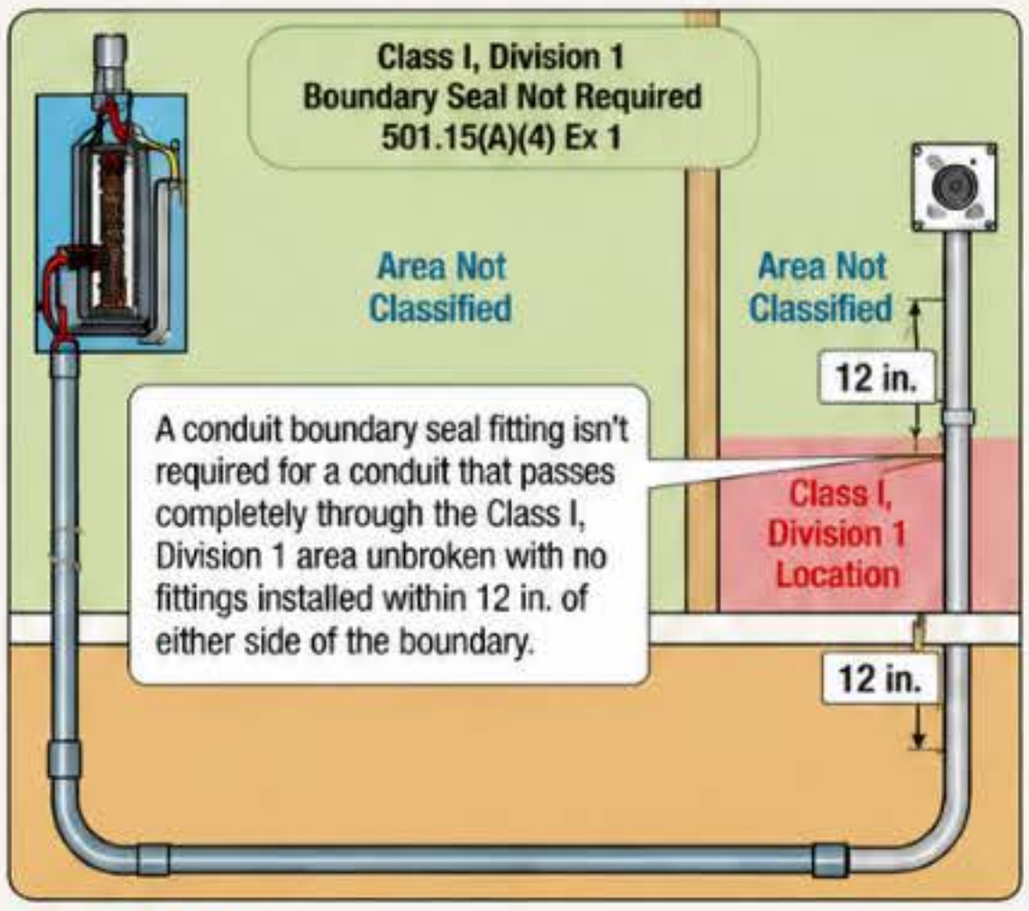


Figure 501-17

Ex 2: If the conduit boundary is below grade, the conduit seal can be located above grade. There must be no fitting, except for a listed explosionproof reducer installed at the conduit seal fitting, between the conduit seal fitting and the point at which the conduit emerges from below grade. Figure 501-18

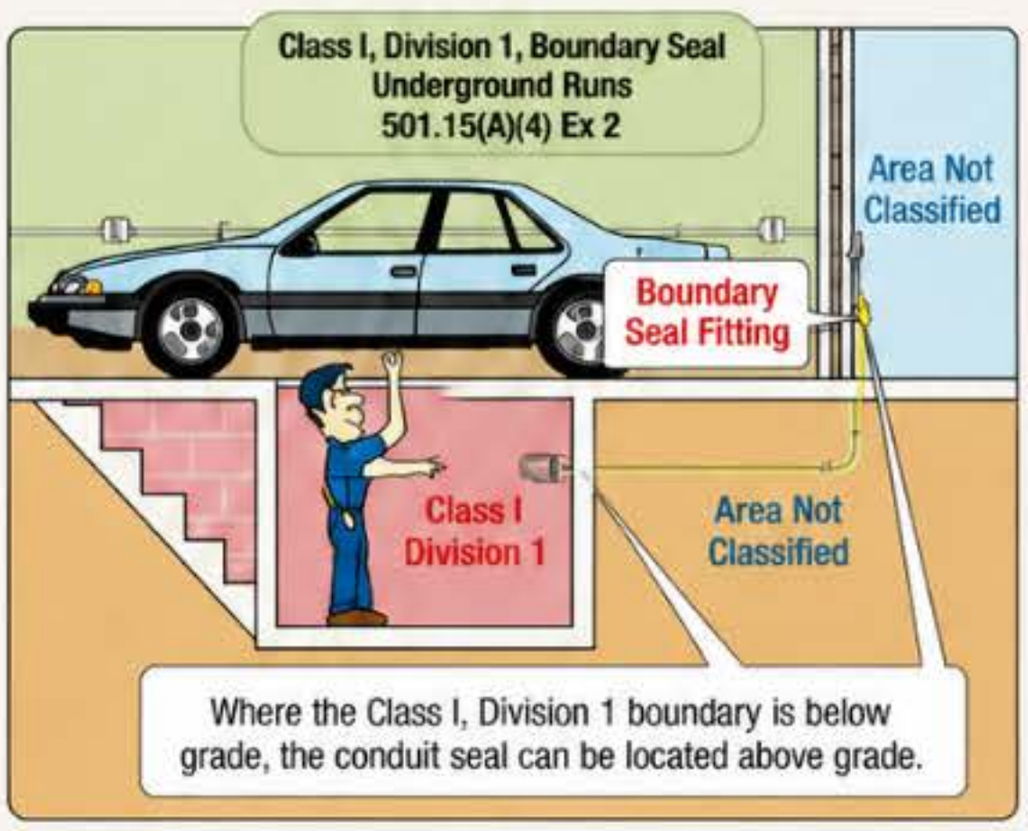


Figure 501-18

Author's Commentary:

- The wiring method between the conduit seal fitting and the Class I, Division 1 boundary must be rigid metal conduit or intermediate metal conduit [501.10(A)(1)(1)].

— Michael Hamilton

(B) Conduit Seal, Class I, Division 2. In Class I, Division 2 locations, conduit seals must be located as follows:

(1) Enclosures with Make-and-Break Contacts. A conduit seal fitting must be installed in each raceway that enters an explosion-proof enclosure that contains make-and-break contacts. The seal fitting must be installed within 18 in. of the explosionproof enclosure [501.15(A)(1)(1) and (A)(3)]. The raceway between the seal and enclosure must be rigid or intermediate metal conduit in accordance with 501.10(A). Figure 501-19

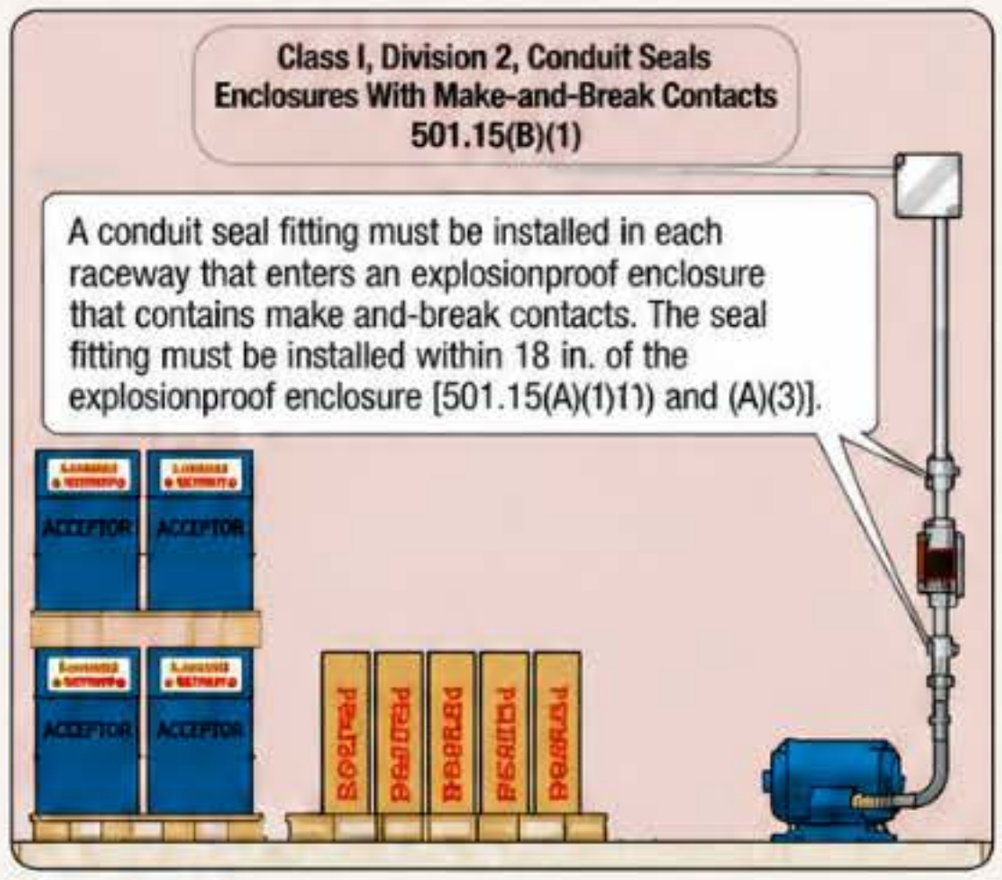


Figure 501-19

(2) Boundary Seal at Unclassified Location. A conduit seal fitting must be installed in each raceway that leaves a Class I, Division 2 location within 10 ft of the Class I, Division 2 location on either side of the boundary. Figure 501-20

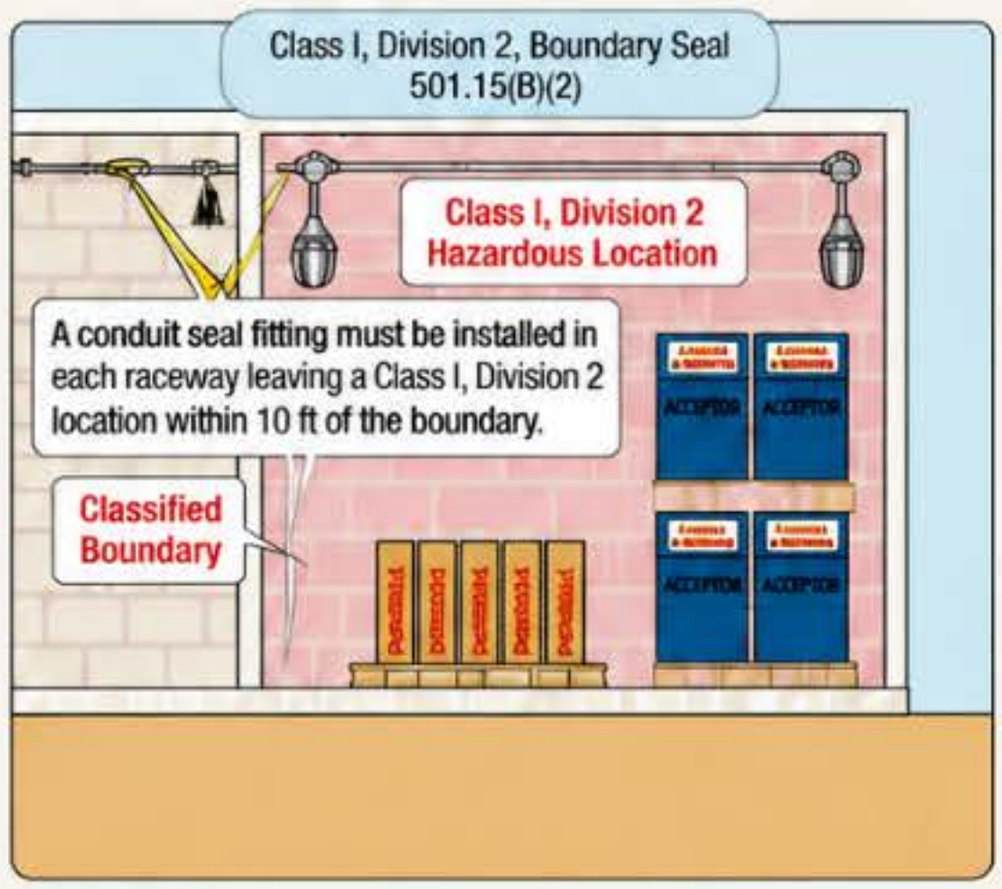
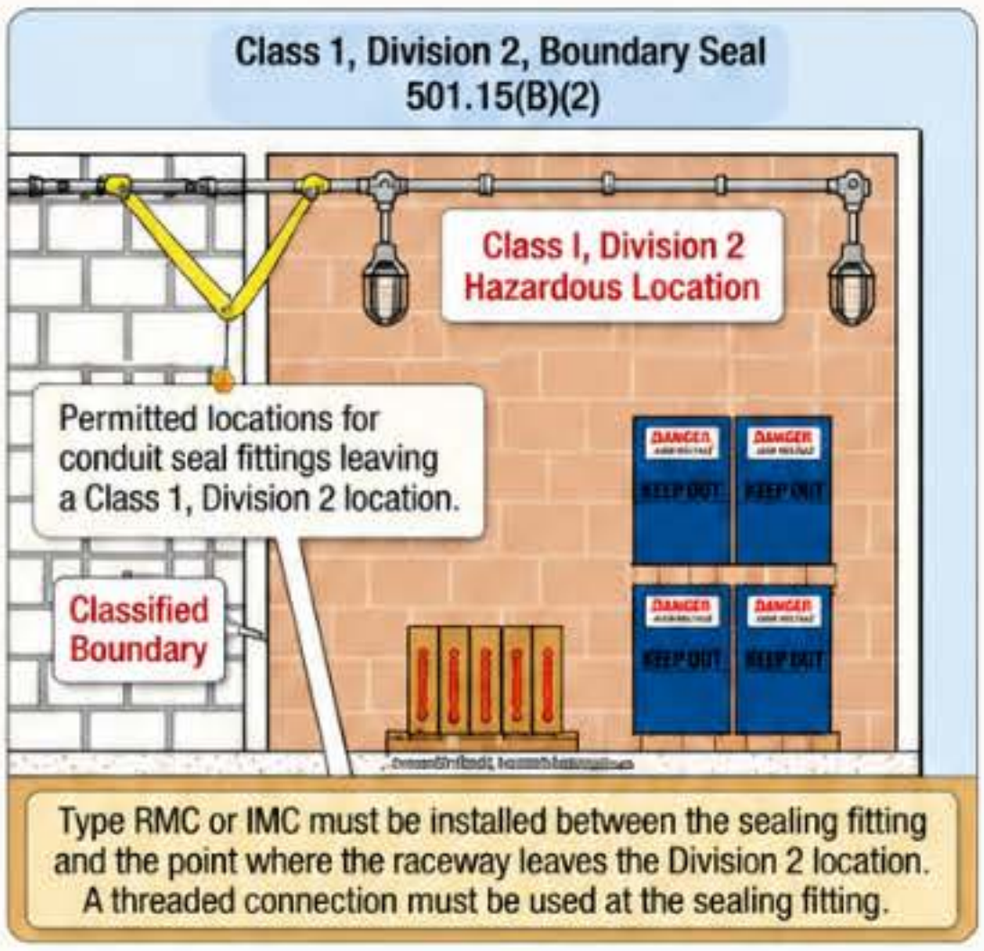


Figure 501-20

DEFINITIONS | From Michael Hamilton Publications

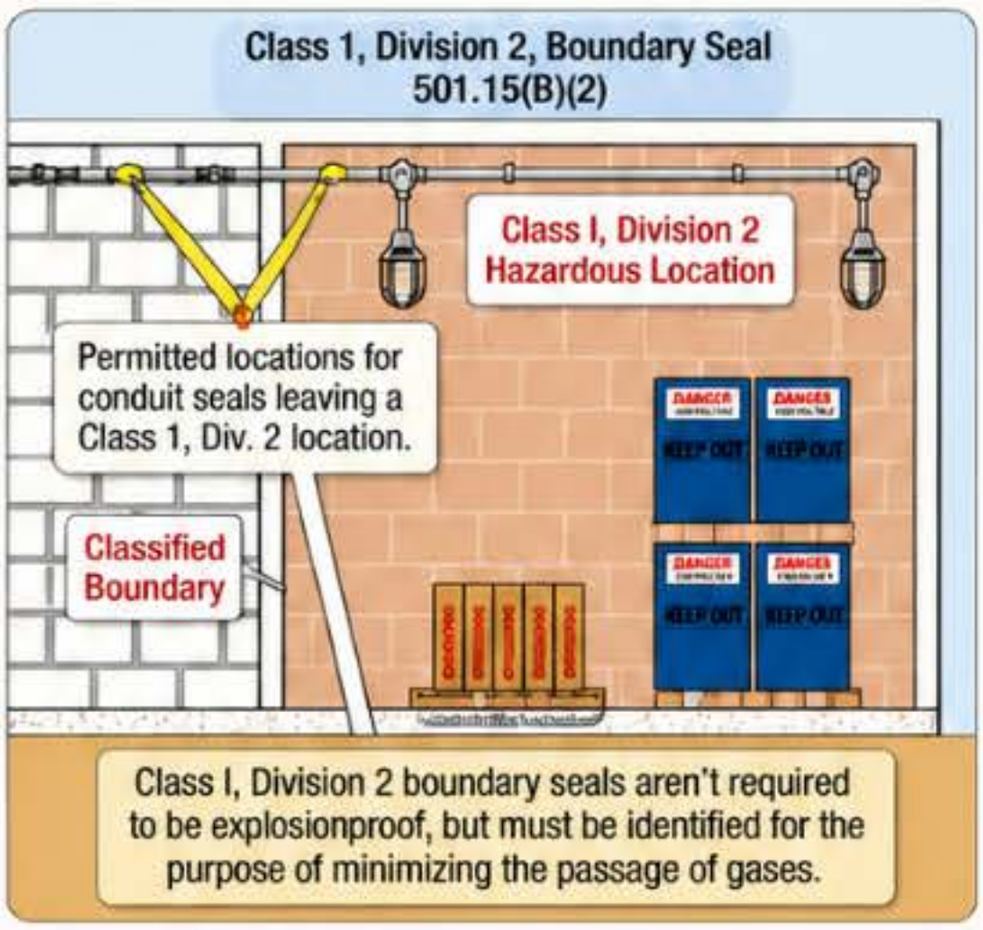
Rigid metal conduit or intermediate metal conduit must be placed between the sealing fitting and the spot where the raceway exits the Division 2 area, and the raceway has to be threaded into the sealing fitting. *Figure 501–21*



▸ Figure 501–21

There must be no fitting, except for a listed explosionproof reducer installed at the conduit sealing fitting, between the conduit seal fitting and the point at which the raceway leaves the Class I, Division 2 location.

The Class 1, Division 2 boundary seal is not required to be explosionproof, but it must be identified to minimize the passage of gases under normal operating conditions and be accessible. *Figure 501–22*



▸ Figure 501–22

Author's Commentary:

- The Class I, Division 2 boundary seal is not required to be listed for the Class 1, Division 2 use and an explosionproof seal off compound is not required, see 501.15(C) Ex.
- A type C conduit outlet body with the use of Polywater® FST™ Foam Duct Sealant meets the requirements of 501.15(B)(2).

— Michael Hamilton

Ex 1: A raceway boundary seal fitting is not required for a metal raceway that passes completely through the Class I, Division 2 area unbroken with no fittings installed within 12 in. of either side of the boundary.

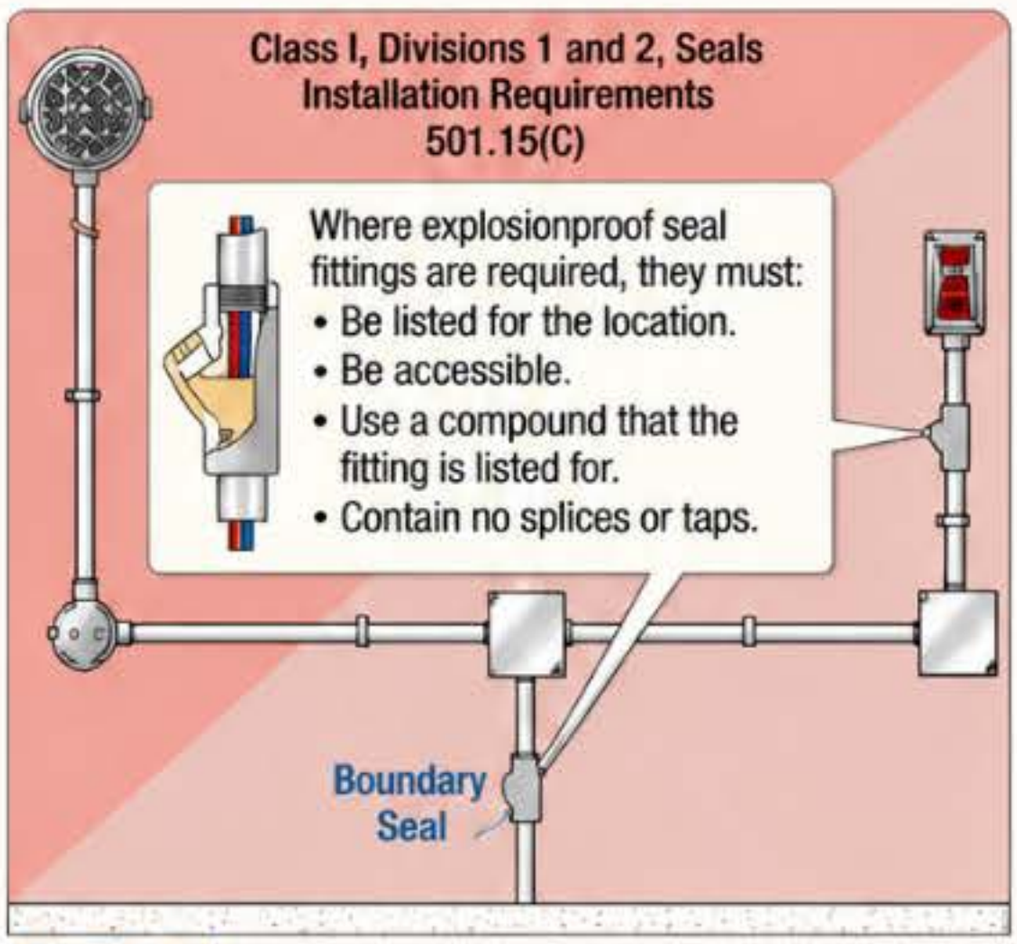
Ex 2: A raceway boundary seal fitting is not required for raceways that terminate in an unclassified location where the metal conduit transitions to cable trays, cables, ventilated busways, MI cable, or open wiring if:

(1) The unclassified location is located outdoors or the unclassified location is indoors and the conduit system is entirely in one room.

(2) The raceways do not terminate at an enclosure containing an ignition source in normal operation.

Ex 3: A boundary seal fitting is not required for a raceway that passes from an enclosure or a room that is unclassified as a result of pressurization, into a Class I, Division 2 location.

(C) Conduit Seal, Installation Requirements. If explosionproof sealing fittings are required in Class I, Division 1 and 2 locations, they must comply with the following: *Figure 501–23*



▸ Figure 501–23

501.15 | CLASS I HAZARDOUS (CLASSIFIED) LOCATIONS

Ex: A Class 1, Division 2 boundary seal that is not required to be explosionproof in accordance with 501.15(B)(2) is not required to comply with the requirements of 501.15(C).

(1) Fittings. All sealing fittings must be identified for their intended site and for the sealing compound used, and they must be readily accessible.

(2) Compound. Any sealing compound used must be equipped with a seal, applied in a manner that stops the passage of vapors or gases, and be able to withstand the environment around it at a melting temperature of at least 93°C (200°F).

(3) Thickness of Compounds. Except for the fittings listed in the *Code*, the thickness of the conduit seal compound installed in complete seals cannot be less than the trade size of the sealing fitting, and never less than ½ in.

(4) Splicess and Taps. Splices and taps are not allowed inside a conduit seal fitting.

(6) Number of Conductors or Optical Fiber Cables. The total cross-sectional area of all conductors and optical fiber tubes is limited to no more than 25 percent of the cross-sectional area of the rigid metal conduit of the same trade size, except when the Code specifically names a higher percentage.

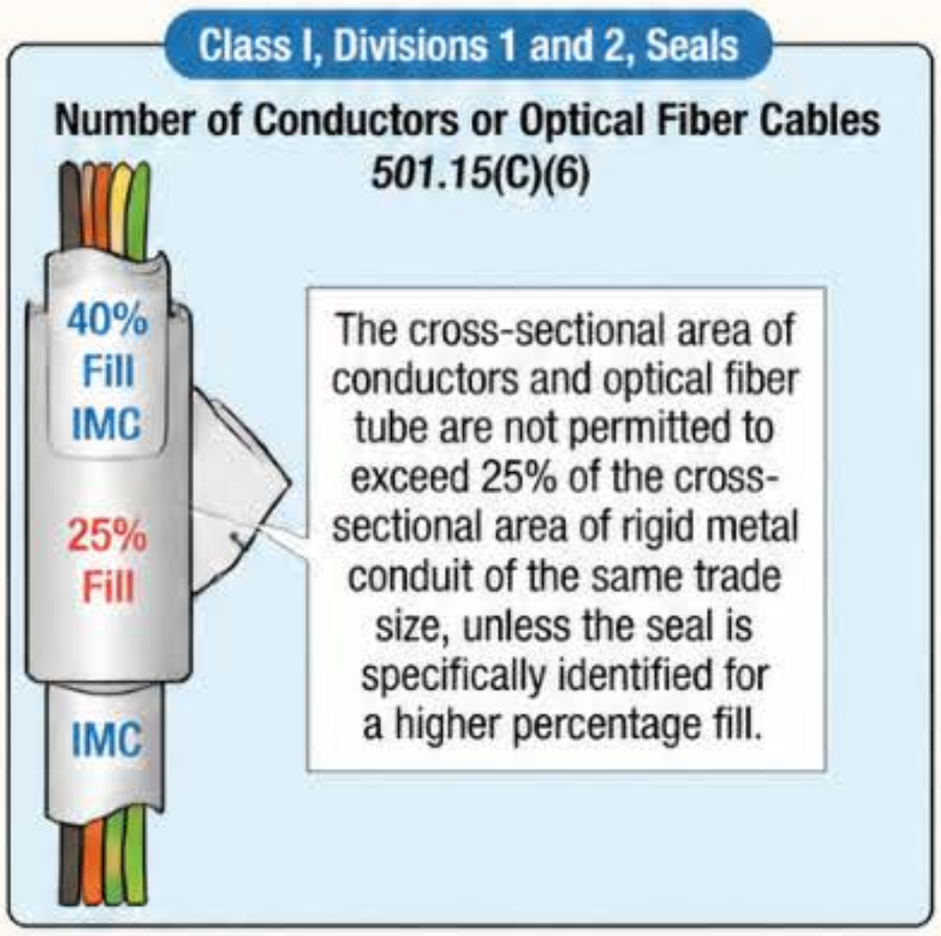


Figure 501-24

(D) Cable Seal—Class I, Division 1. In Class I, Division 1 locations, seal fittings must be located as follows:

(1) Terminations. All cables must be closed off at every termination point with sealing fittings that meet 501.15(C). Because Type MC-HL cable is inherently gas-tight due to its construction, terminations need sealing compounds that wrap around each individual insulated conductor to minimize the movement of gases or vapors.

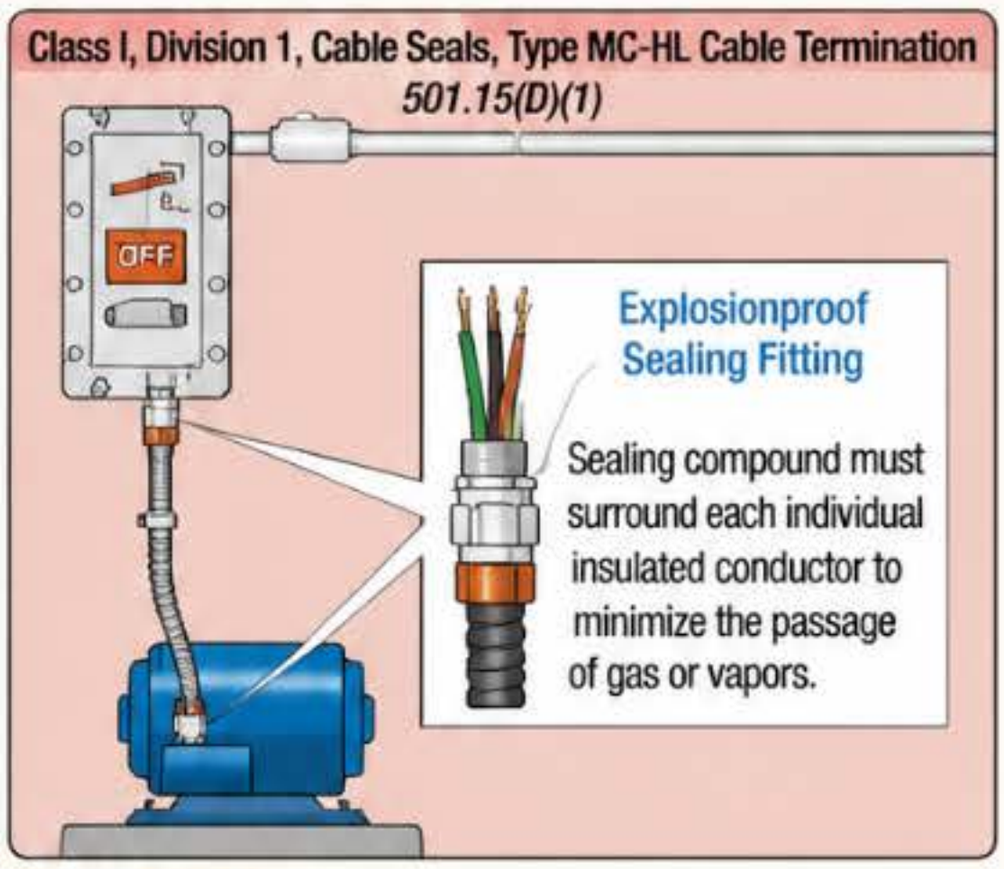


Figure 501-25

Seal fittings for cables entering enclosures must be installed within 18 in. of the enclosure or as required by the enclosure marking. Only explosionproof fittings such as unions, threaded couplings, reducers, elbows, and capped elbows may be installed between the cable seal fitting and the enclosure.

Ex: The removal of shielding material or the separation of the twisted pairs is not required within the seal fitting.

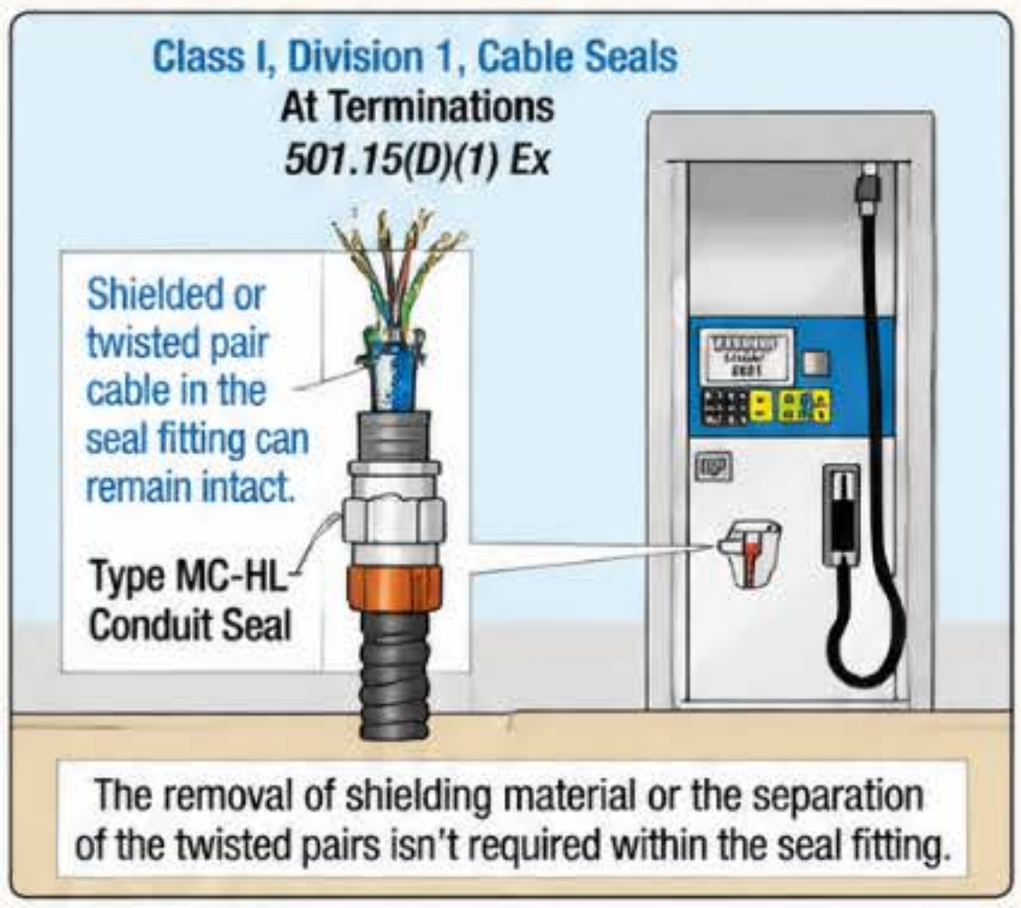
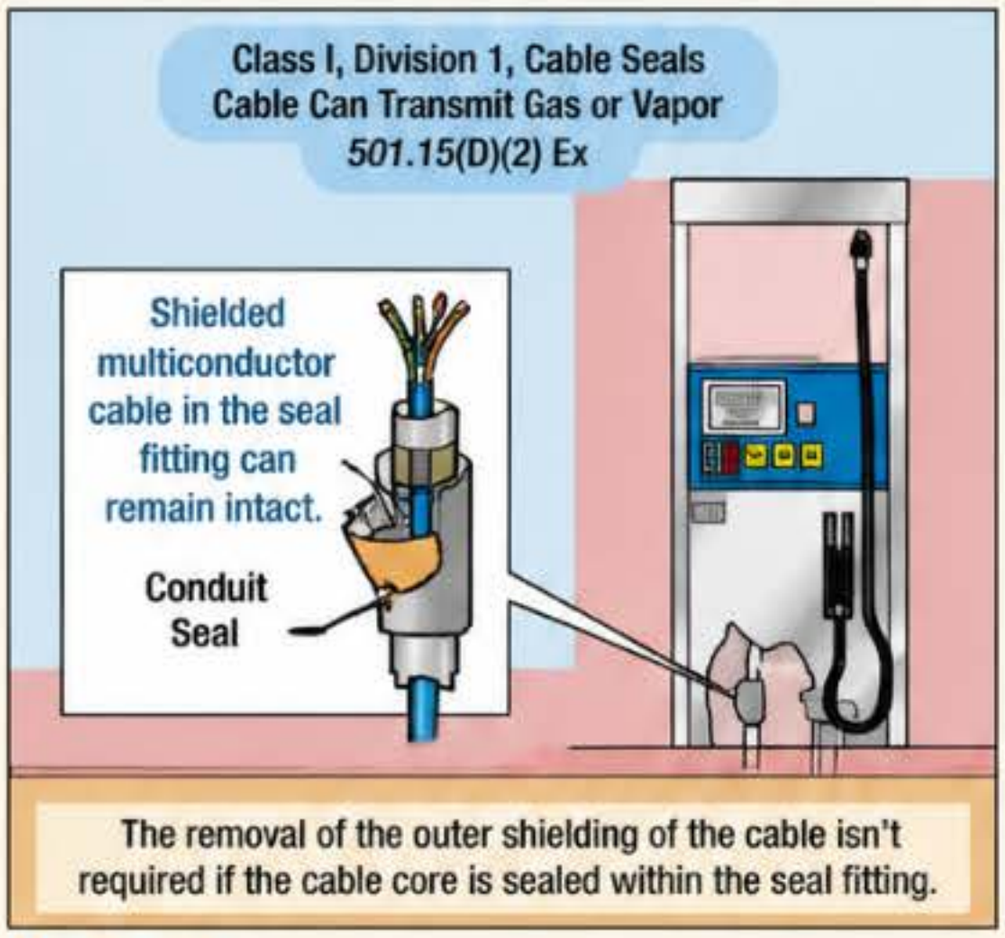


Figure 501-26

DEFINITIONS | From Michael Hamilton Publications

(2) Cables Capable of Transmitting Gases or Vapors in a Raceway. that include cables must be sealed after the cable jacket and any other coverings are removed. This sealing compound must completely surround each individual insulated conductor or optical fiber tube so that gas and vapor movement through the raceway is minimized.

Example: It is not necessary to remove the outer sheath of multiconductor cables. A core seal is required within the conduit seal fitting to close around the cable cores. ▸ Figure 501-27



▸ Figure 501-27

(3) Cables Not Capable of Transmitting Gases or Vapors in a Raceway. Each multiconductor cable installed within a raceway is regarded as a single conductor if the cable design prevents the passage of gases or vapors through the cable core.

(E) Cable Seal, Class I, Division 2. In Class I, Division 2 locations, cable seals are to be installed as follows:

Example: Seals are not required in a Class 1, Division 2 location if the cable passes through the location and has an unbroken gas or vapor-tight sheath.

(1) Multiconductor Cable. Multiconductor or optical fiber cables that enter an explosionproof enclosure must be sealed after the jacket and any other coverings are removed. The sealing compound must surround each insulated conductor or optical fiber tube in a manner that minimizes the passage of gases and vapors.

Cables or optical fibers installed within a raceway must be sealed in accordance with 501.15(D)(2) or (D)(3).

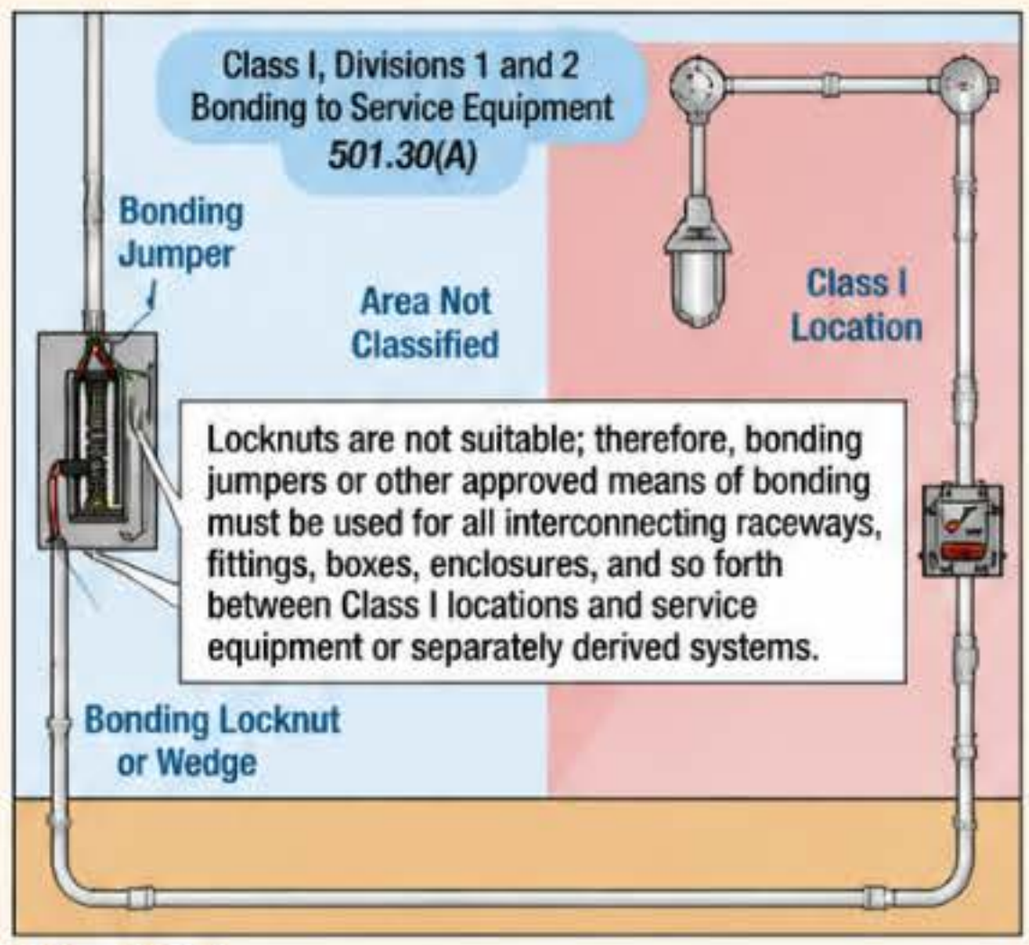
Example 2: Removing shielding material or separating twisted pairs is not required within the conduit seal fitting.

(4) Cable Seal, Boundary. Cables without a gas/vaportight continuous sheath must be sealed at the boundary of the Class I, Division 2 location in a manner that reduces the migration of gases or vapors into an unclassified area.

501.30 Grounding and Bonding

Due to the risk of explosion from electrical equipment in hazardous (classified) locations [500.5], electrical continuity of metal parts of equipment and raceways must be maintained regardless of the circuit voltage.

(A) Bonding. Locknuts are not appropriate for bonding in hazardous (classified) locations; therefore, bonding jumpers or other approved methods must be used for all interconnecting raceways, fittings, boxes, enclosures, and any connections between Class I locations and service equipment or separately derived systems. ▸ Figure 501-28

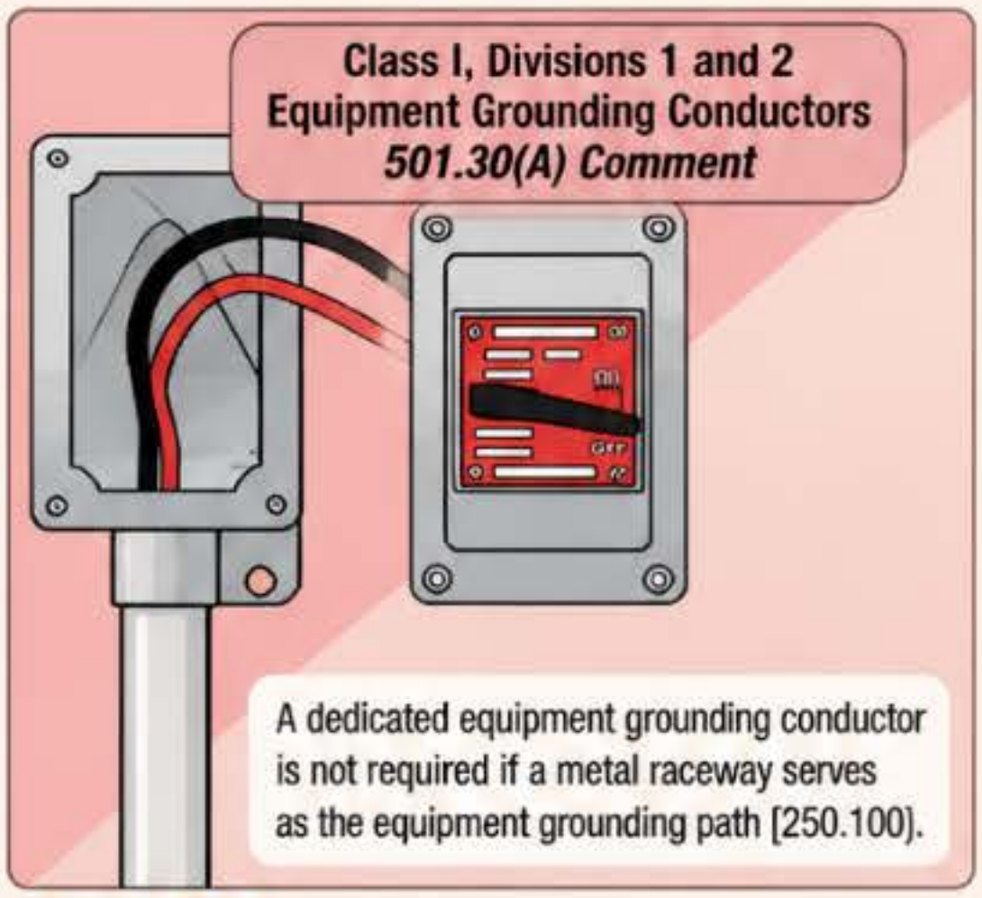


▸ Figure 501-28

Author's Commentary:

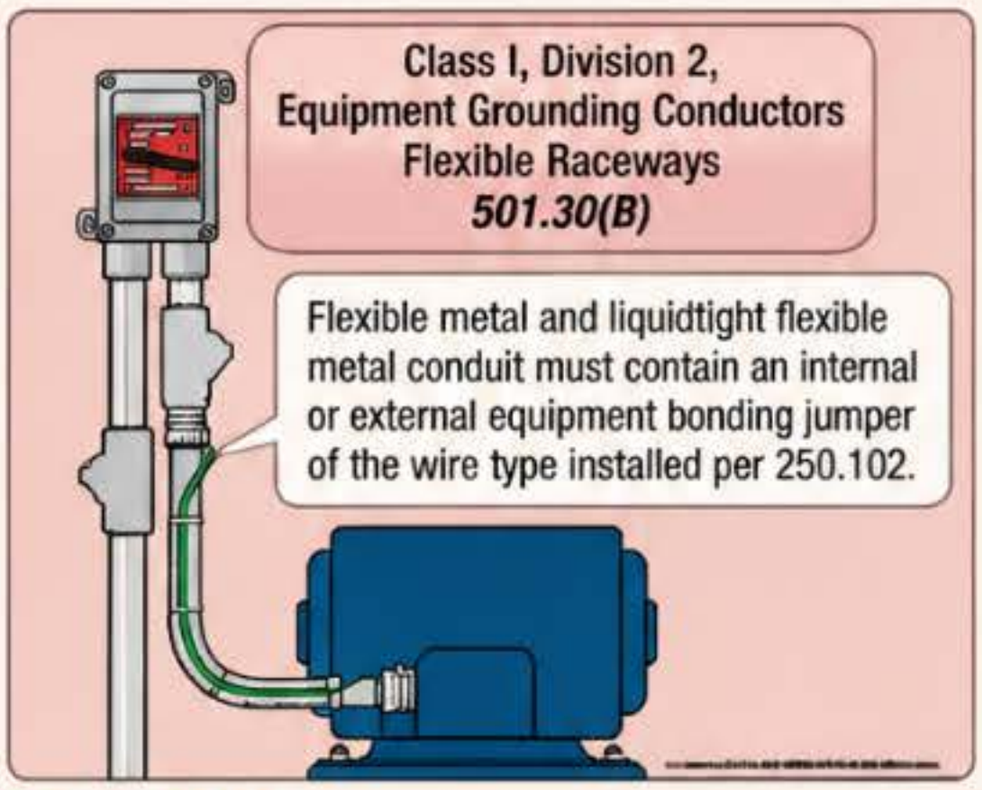
- Regardless of the circuit voltage, electrical continuity of metal parts of equipment and raceways in hazardous (classified) locations must be ensured by using-type locknuts, wedges, or bushings with bonding jumpers [250.92(B)(4)]; whether or not equipment grounding conductors or the wire type are installed in the raceway [250.100]. Locknuts alone are insufficient.
- A separate equipment grounding conductor is not required if a metal raceway is used for equipment grounding. Threaded couplings and hubs made up wrench-tight provide a satisfactory low-impedance fault current path [250.100].

— Michael Hamilton



▸ Figure 501–29

(B) Equipment Grounding Conductor, Flexible Raceway. Where flexible metal conduit or liquidtight flexible metal conduit is installed as permitted by 501.10(B)(2) or (4), an equipment bonding jumper of the wire type must be installed in accordance with 250.102. ▸ Figure 501–30

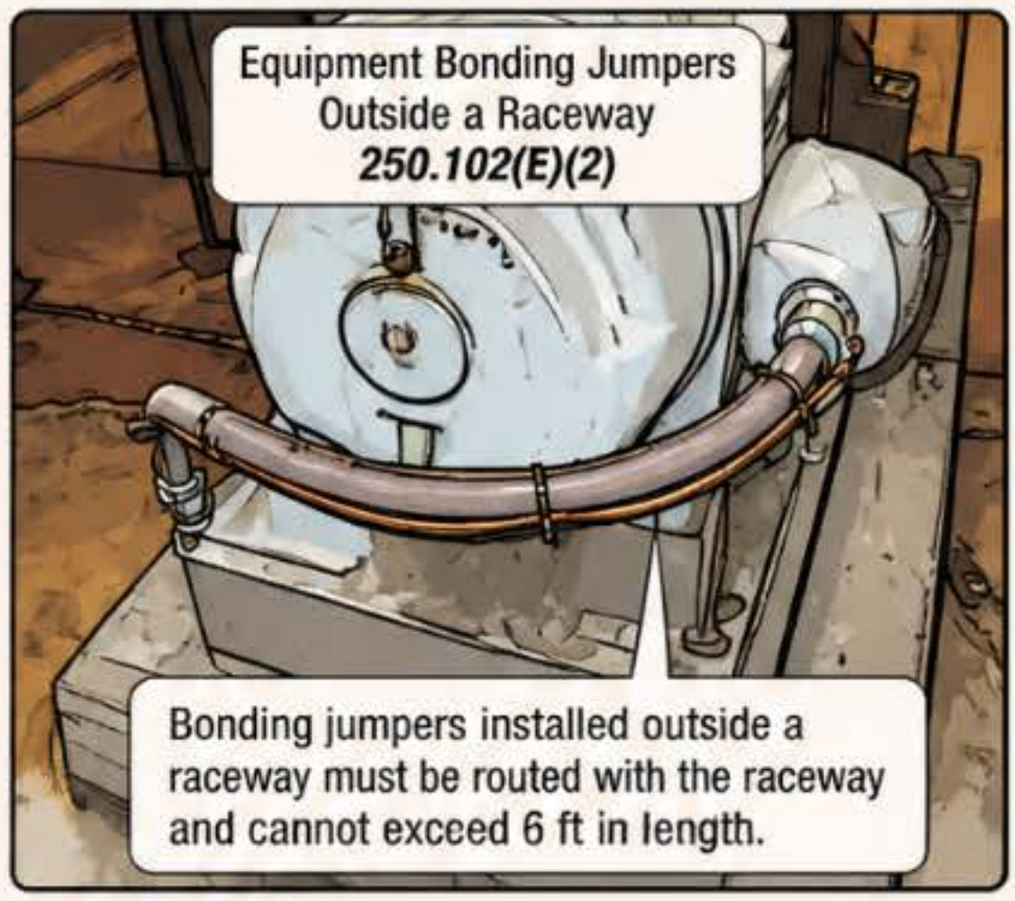


▸ Figure 501–30

Author's Commentary:
Load side bonding jumpers are sized in accordance with Table 250.122 based on the rating of the overcurrent protective device [250.102(D)]. Where installed outside a raceway, the length of the bonding jumper is restricted to no more than 6 ft, and it must be routed with the raceway [250.102(E)(2)].

— Michael Hamilton

▸ Figure 501–31



▸ Figure 501–31

Part III. Equipment

501.115 Enclosures Containing Make-and-Break Contact Devices

(A) Class I, Division 1. Enclosures containing switches, circuit breakers, motor controllers, and fuses (including pushbuttons, relays, and similar make-and-break contact devices) must be identified for use in a Class I, Division 1 location. ▸ Figure 501–32

(B) Class I, Division 2.

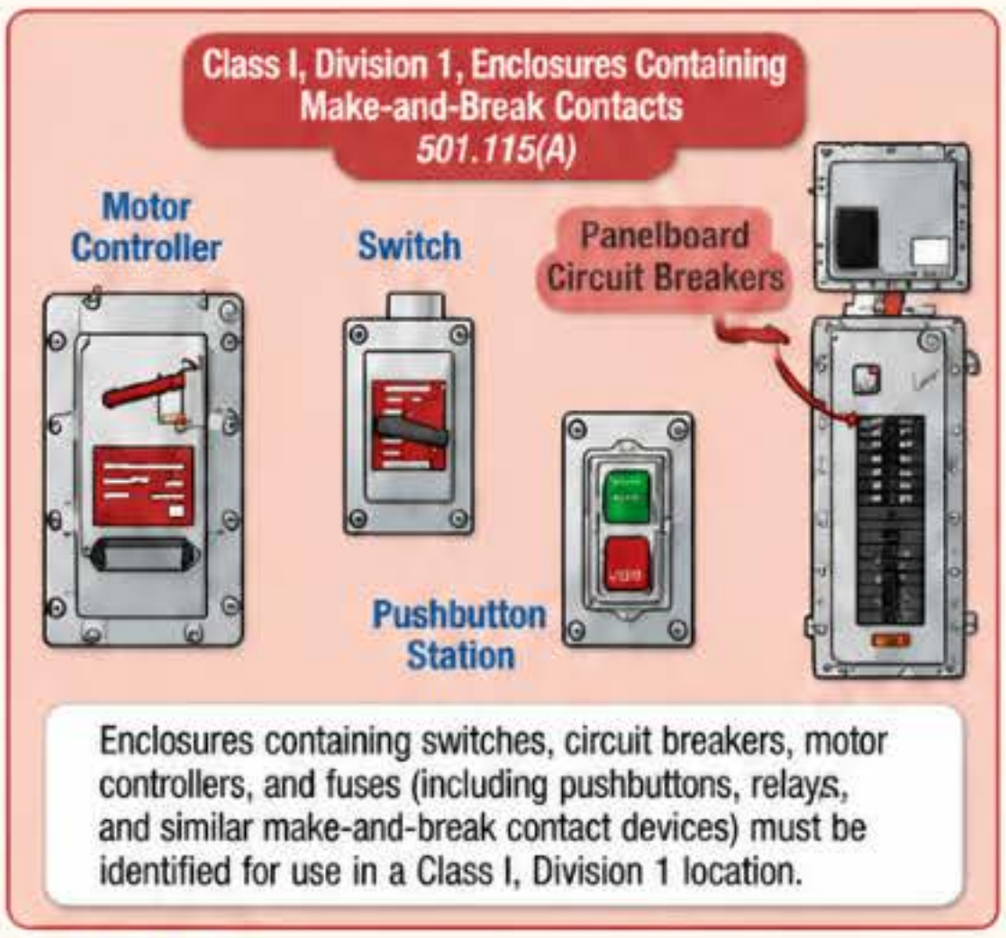
(1) Type Required. Enclosures that contain circuit breakers, motor controllers, fuses, pushbuttons, relays, and other make-and-break contact devices must be identified for use in a Class I, Division 1 location in accordance with 501.105(A). ▸ Figure 501–33

Make-and-break contact devices can be installed in general-purpose enclosures if any of the following conditions are met:

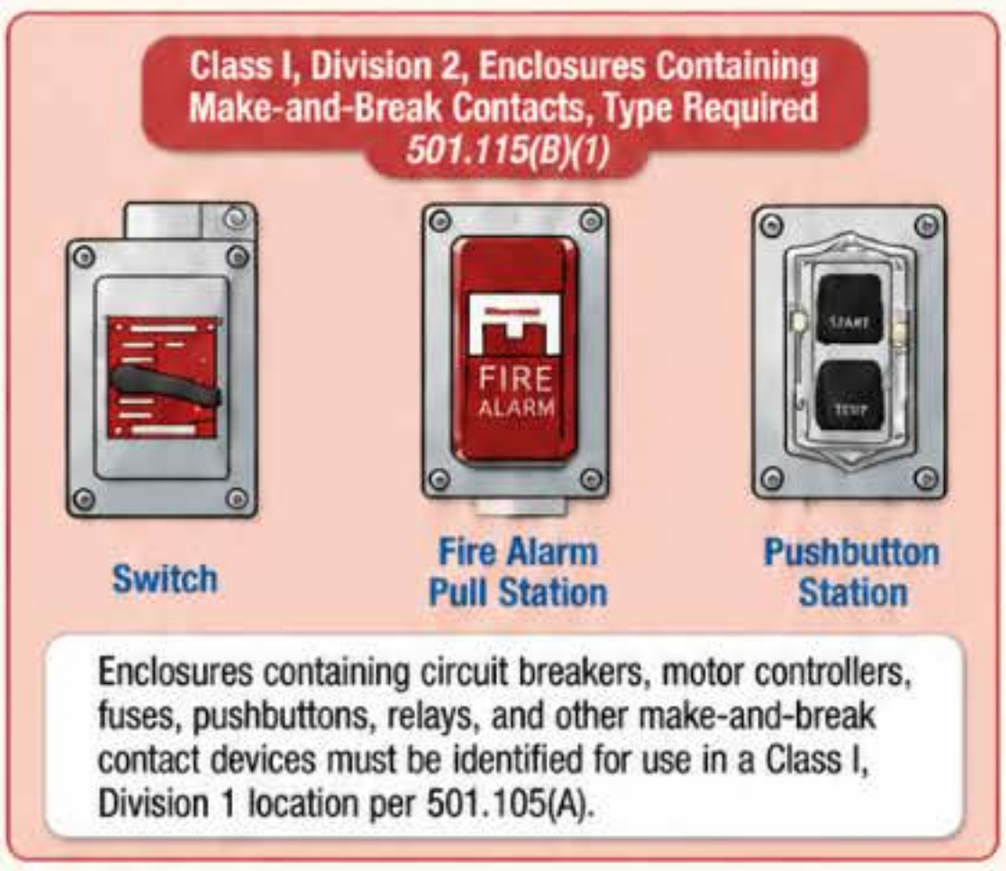
(1) The interruption of current occurs within a hermetically sealed chamber.

(2) The make-and-break contacts are oil-immersed.

DEFINITIONS | From Michael Hamilton Publications



▶ Figure 501–32



▶ Figure 501–33

(3) The interruption of current occurs within an enclosure identified for the location and marked "Leads Factory Sealed" "Factory Sealed" "Seal not Required," or the equivalent.

501.125 Motors and Generators

(A) Class I, Division 1. Motors and generators installed in a Class I, Division 1 location must be:

(1) Identified for Class I, Division 1 locations, or be

(2) Of the totally enclosed type supplied with positive-pressure ventilation and arranged to automatically de-energize if the air supply fails.

(3) Of the totally enclosed inert gas-filled type and arranged to automatically de-energize if the gas supply fails.

(4) Submerged in a liquid flammable only when vaporized and mixed with air and arranged to automatically de-energize if the liquid is reduced to atmospheric pressure (vaporized).

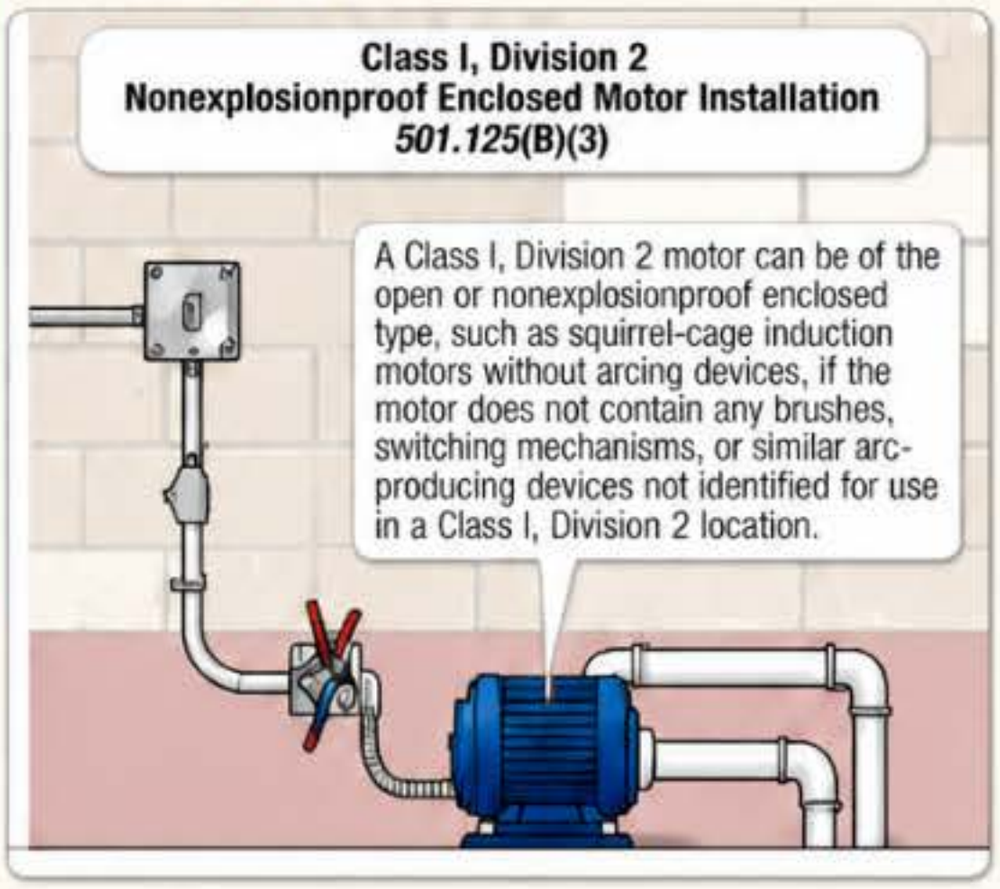
Totally enclosed motors of the types specified in 501.125(A)(2) or (A)(3) must be designed so no external surface has an operating temperature in excess of 80 percent of the autoignition temperature of the gas or vapor involved. A device must be provided to de-energize the motor or sound an alarm if the temperature exceeds the designed limits.

(B) Class I, Division 2. Motors and generators installed in a Class I, Division 2 location must comply with the following:

(1) Be identified for Class I, Division 2 locations.

(2) Be identified for Class I, Division 1 locations where make-and-break contacts are present.

(3) If of the open or nonexplosionproof enclosed type, the motor must not contain any brushes, switching mechanisms, or similar arc-producing devices not identified for use in a Class I, Division 2 location, such as squirrel-cage induction motors without arcing devices. ▶ Figure 501–34



▶ Figure 501–34

501.130 Luminaires

(A) Class I, Division 1. Luminaires installed in a Class I, Division 1 location must comply with the following:

(1) Luminaires. Luminaires must be identified for the Class I, Division 1 location. ▶ Figure 501–35

501.135 Class I Hazardous (Classified) Locations

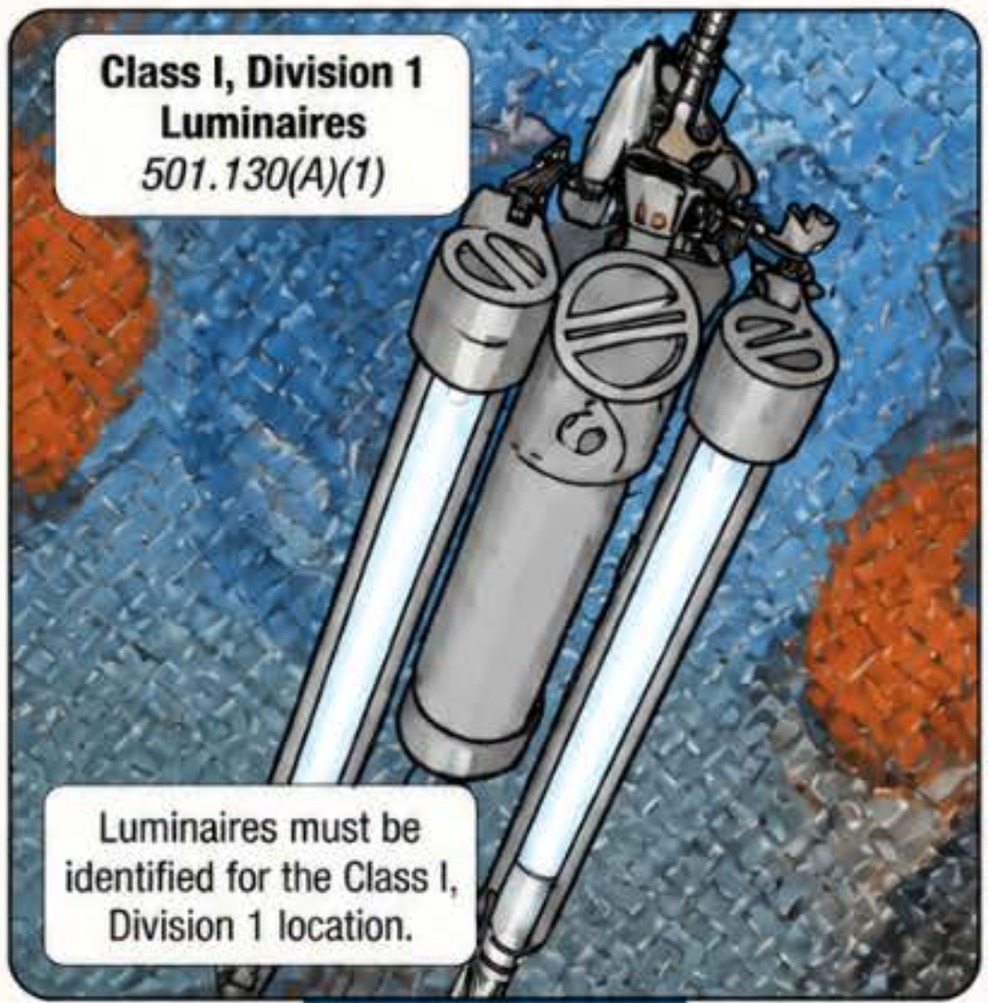


Figure 501–35

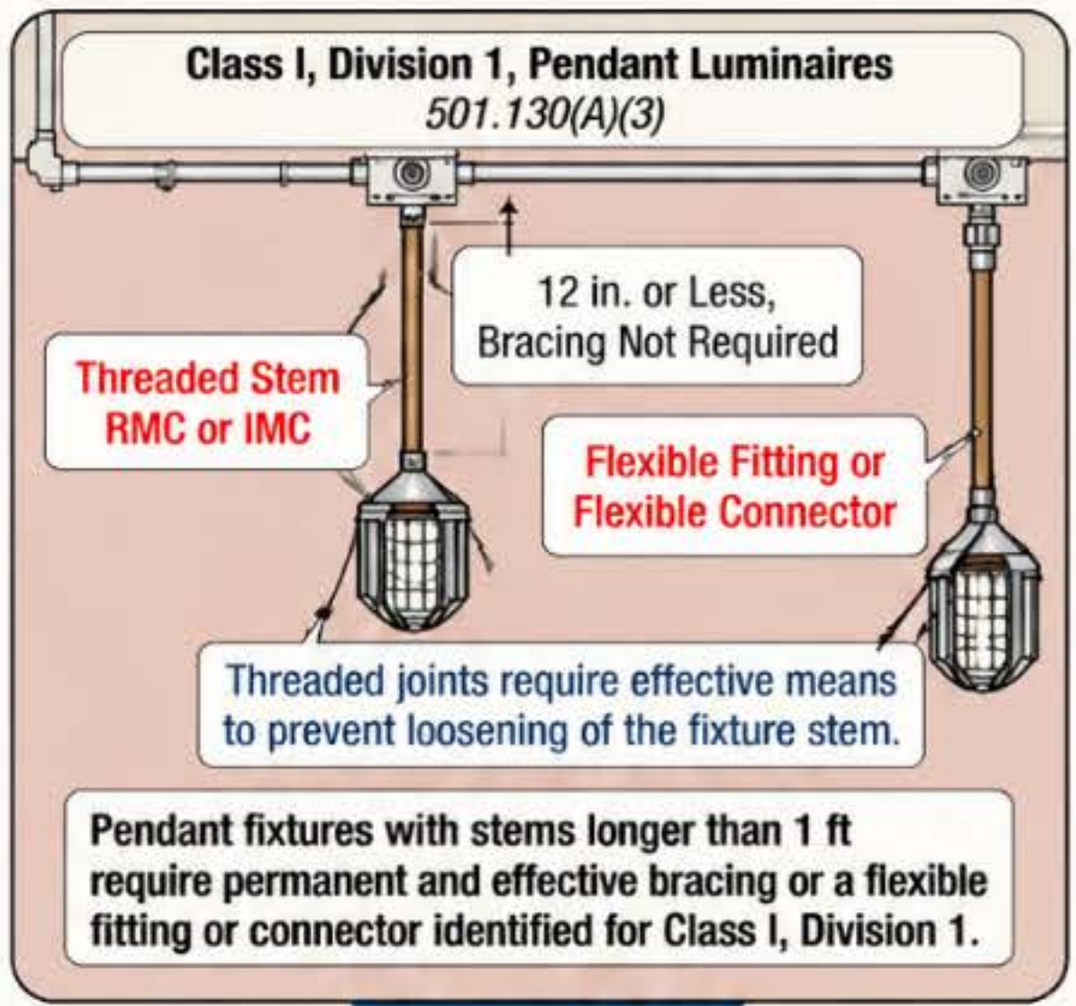


Figure 501–36

Author's Commentary:

Electrical raceway sealing isn't required for listed Class I, Division 1 explosionproof luminaires. This is because the lamp compartment is separated from the wiring area or is sealed from the wiring compartment according to the listing requirements.

— Michael Hamilton

(2) Physical Damage. Luminaires must be protected against physical damage by a suitable guard or by the location.

(3) Pendant Luminaires. Pendant luminaires can be suspended and supplied by threaded rigid metal conduit or threaded steel intermediate conduit stems. Provide threaded joints with set screws or other means so the stems cannot loosen. Stems longer than 12 in. need permanent and effective lateral bracing, or use a flexible fitting or connector marked for Class I, Division 1.

(4) Boxes and Fittings. Boxes or fittings that support luminaires must be identified for a Class I location.

(B) Class I, Division 2. Luminaires installed in a Class I, Division 2 location must meet the following criteria:

(1) Luminaires. If the lamp temperature exceeds 80 percent of the autoignition temperature of the gas or vapor, luminaires must be identified for a Class I, Division 1 location.

(2) Physical Damage. Luminaires must be protected from physical damage by suitable guards or by location.

(3) Pendant Luminaires. Pendant luminaires must be suspended by threaded rigid metal conduit stems, threaded steel intermediate metal conduit stems, or other approved means. Threaded joints need set screws or other devices to stop the fixture stems from loosening. Stems longer than 12 in. must have permanent and effective lateral bracing, or an identified flexible fitting or connector.

(4) Portable Lighting. Lisd portable lighting equipment for use in Class I, Division 1 locations, unless the luminaire is on movable stands and connected by a flexible cord as allowed in 501.140.

501.135 Utilization Equipment

Utilization equipment—such as heaters, motors, switches, circuit breakers, and fuses—must comply with 501.135(A) and (B):

(A) Class I, Division 1. In Class I, Division 1 locations, all utilization equipment must be identified for use in Class I, Division 1 locations.

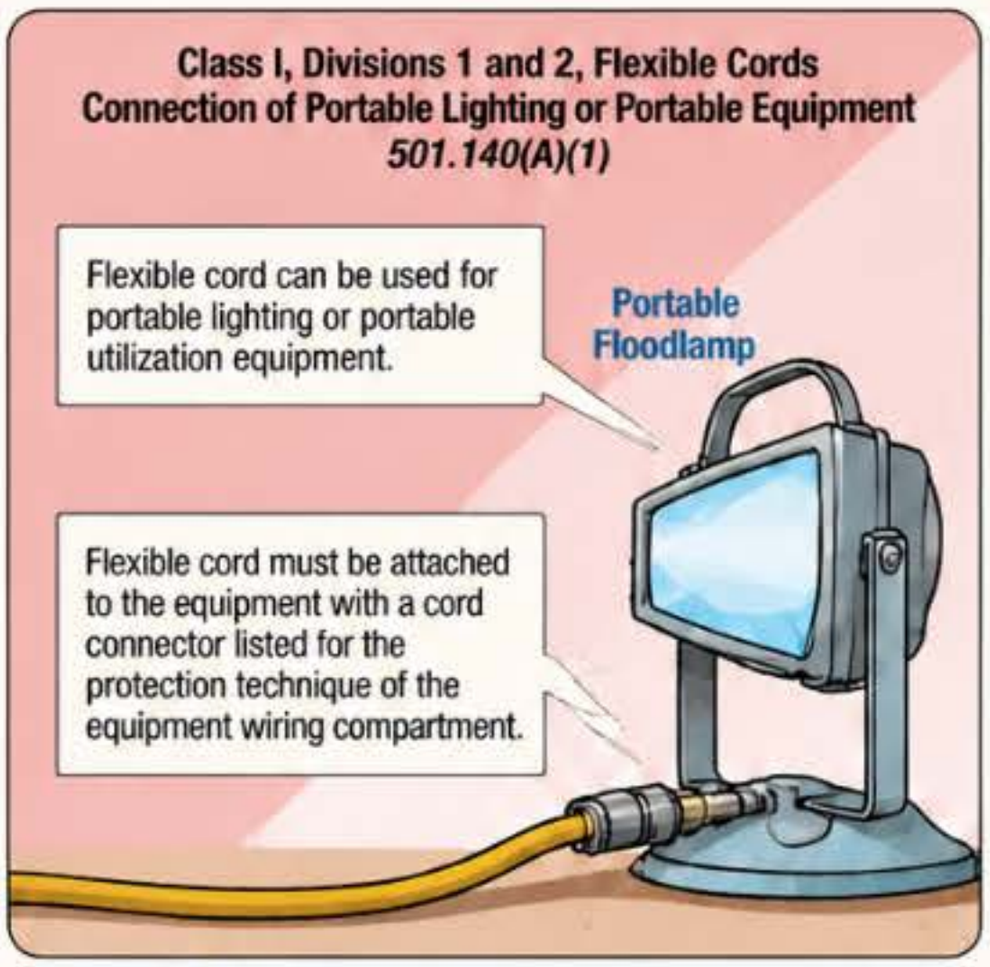
(B) Class I, Division 2. In Class I, Division 2 locations, all utilization equipment must be identified for use in Class I, Division 2 locations.

501.140 Flexible Cords, Class I, Divisions 1 and 2

(A) Permitted Uses. Flexible cord is permitted for:

DEFINITIONS | From Michael Hamilton Publications

(1) A connection is made for portable lighting or other portable equipment by attaching the flexible cord to the device using a cord connector that's appropriate for the protection method of the device's wiring compartment. The connector plug must also comply with the requirements of 501.140(B)(4).
▸ Figure 501–37



▸ Figure 501–37

(2) In workplaces where maintenance and engineering oversight ensure that only qualified personnel install and service the system, the wiring methods in 501.10(A) can be relaxed to provide the needed flexibility for portable electrical equipment, while still ensuring the flexible cord is shielded from physical damage by its location or by a suitable guard.

(3) Flexible cords for submersible pumps can be removed without allowing water to enter the wet-pit. The cord may be extended from the wet-pit to the power source or out of the power source area along a suitable raceway.

(B) Installation. If flexible cords are used, they must:

(1) Be designated for extra-hard use.

(2) Include an equipment grounding conductor.

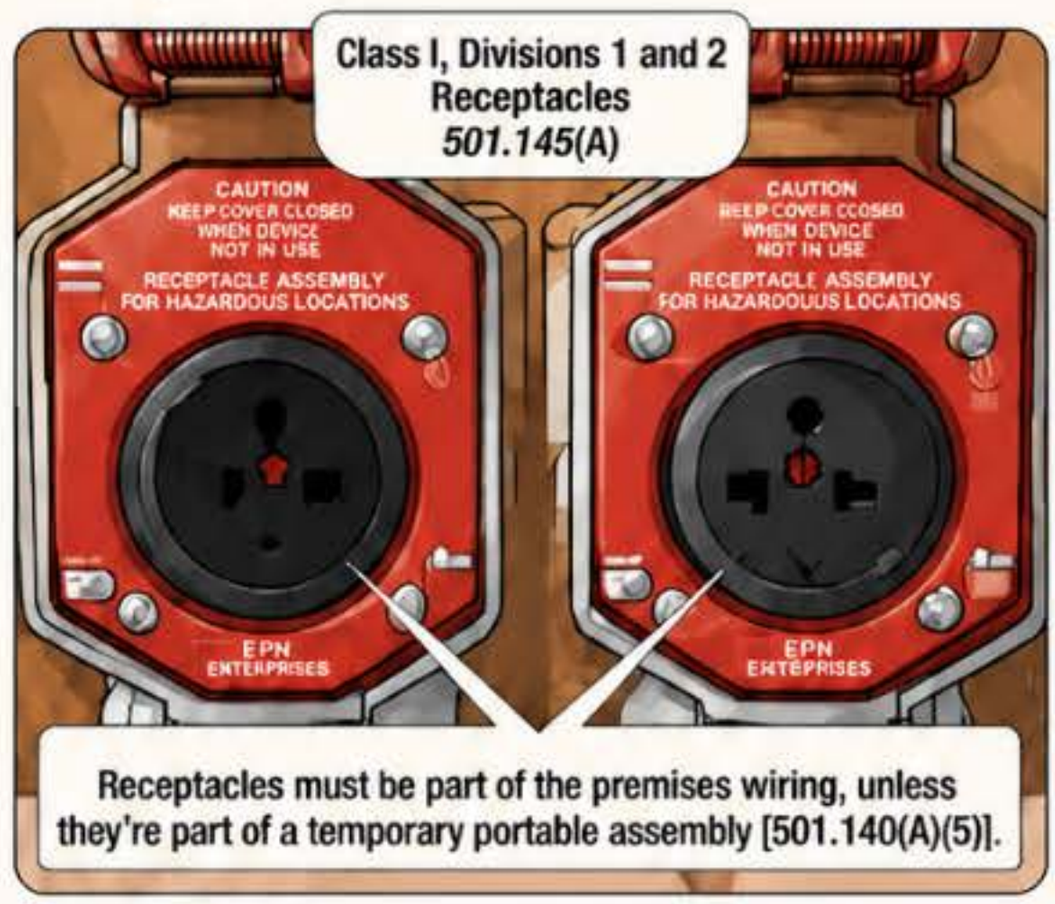
(3) Be supported so that no tension is transmitted to the termination connections.

(4) In Divisions 1 or 2 areas where enclosures, fittings, or boxes must be explosionproof, the flexible cord must end in a cord connector or attachment plug from the approved list for that location, or a listed flexible cord connector sealed as required. Where explosionproof fittings are not required, the flexible cord must end with either a listed flexible cord connector or a listed attachment plug.

(5) The cord must be continuous in length. When 501.140(A)(5) applies, it must run unbroken from the power source to the temporary portable assembly and from that assembly to the portable equipment.

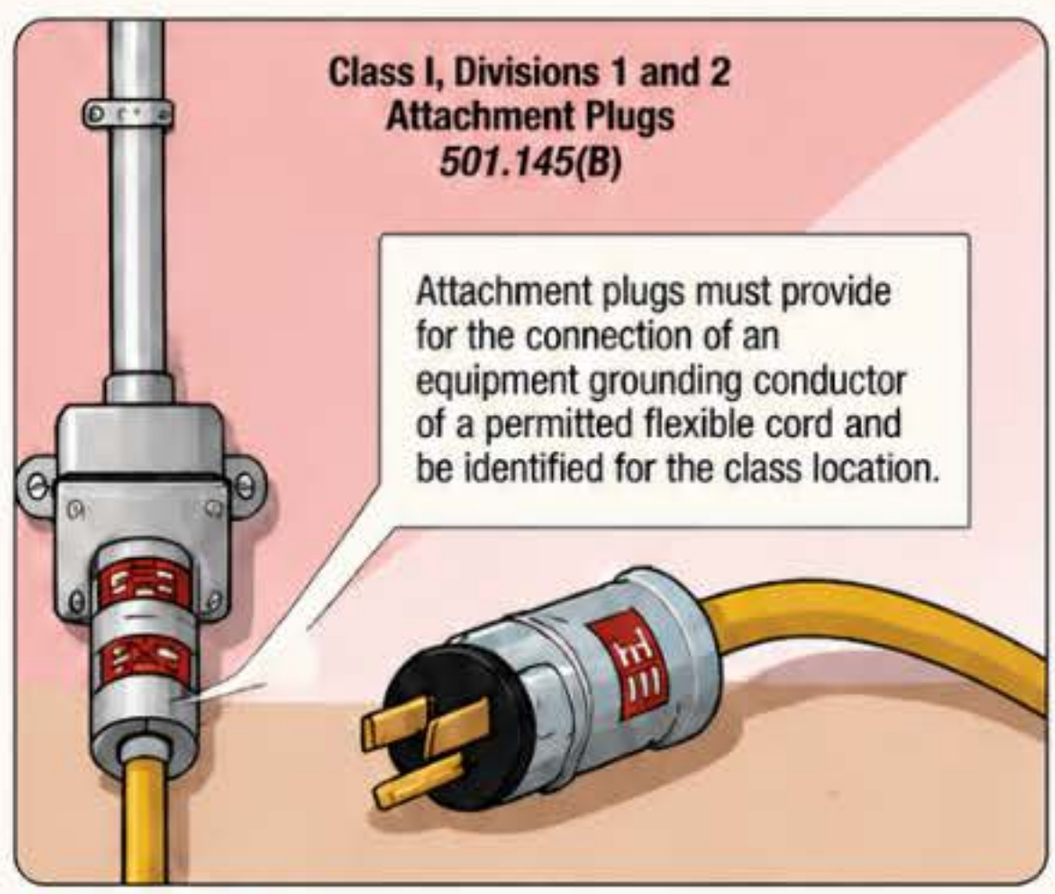
501.145 Receptacles and Attachment Plugs

(A) Receptacles. Receptacles must be part of the premises wiring, unless they are included in a temporary portable assembly [501.140(A)(5)].
▸ Figure 501–38



▸ Figure 501–38

(B) Attachment Plugs. Attachment plugs must provide for the connection of an equipment grounding conductor of a permitted flexible cord and be identified for the class location [501.30].



▸ Figure 501–39

Author's Commentary:

- Refer to the meanings of "Attachment Plug" and "Receptacle" as defined in Article 100.
- Any receptacle that is permitted for use in Class I locations may be one of the following types:
  - **Interlocked Switch Receptacle.** This receptacle includes a built-in rotary switch interlocked with the plug attachment. The plug must be withdrawn from the receptacle before it can be inserted or removed.
  - **Manual Interlocked Receptacle.** The attachment plug is inserted into the receptacle; rotating it then moves the receptacle's switching contacts.
  - **Delayed Action Receptacle.** This receptacle needs an attached plug and is designed so that any electrical arc is contained inside an explosionproof chamber within the device.

— Michael Hamilton

501.150 Limited-Energy and Communications Systems

(A) Class I, Division 1. Low-voltage, limited-energy, and communications systems (twisted pair and coaxial cable) in a Class I, Division 1 location must be installed in accordance with 501.10(A), 501.15(A), and 501.15(C).

Author's Commentary:

- Wiring methods, enclosures, conduit seals, and other equipment used for limited-energy and communications systems—no matter the voltage—must be installed using the same installation practices as those required for power conductors.

— Michael Hamilton

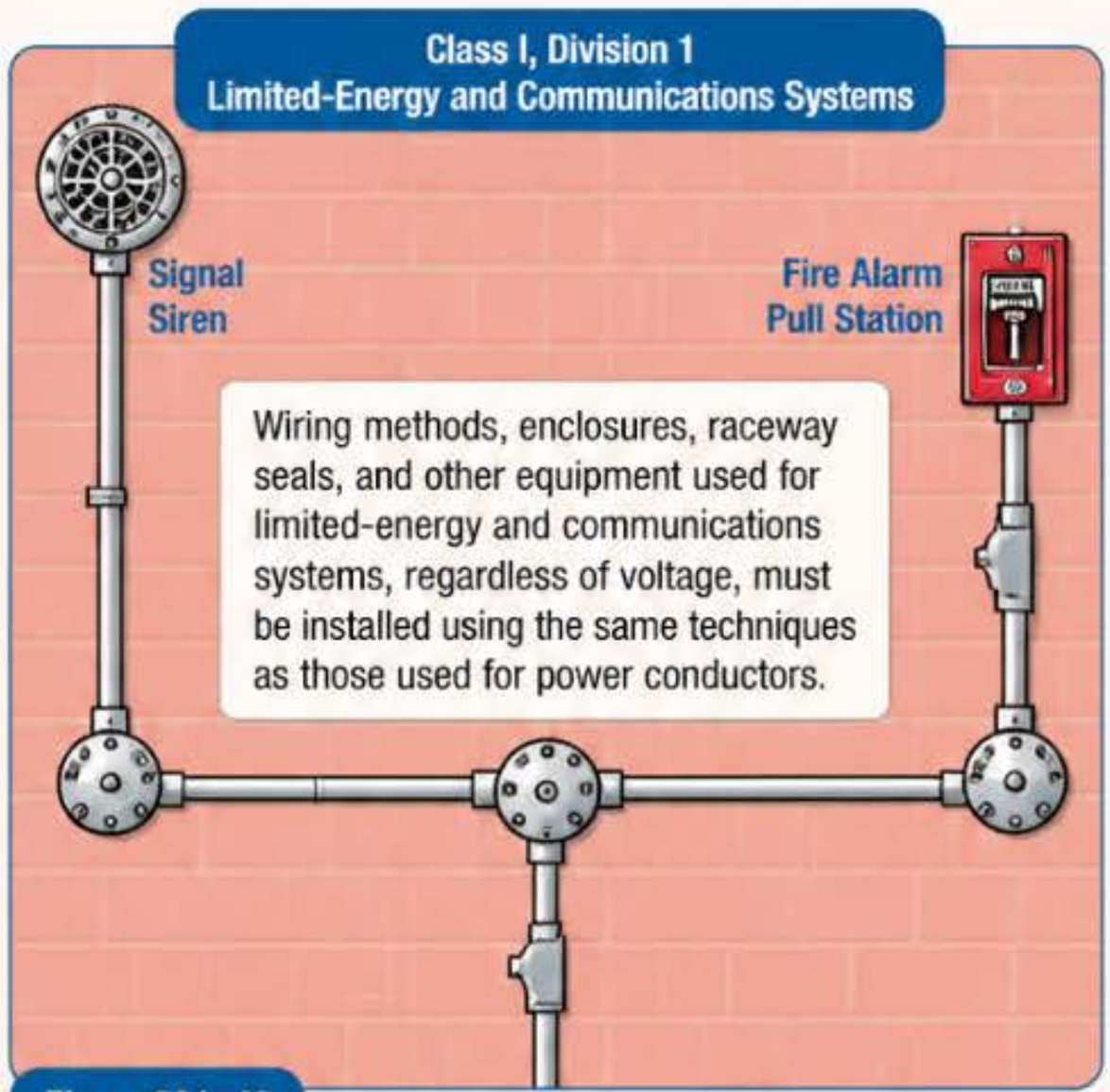


Figure 501–40

(B) Class I, Division 2.

(1) Enclosures. General-purpose enclosures are permitted, unless the enclosure contains make-and-break contacts. An enclosure identified for a Class I, Division 1 location must not be used where the enclosure contains make-and-break contacts [501.105(A)].

Examples of situations where general-purpose enclosures are allowed if the contacts are:

(1) Immersed in oil.

(2) Housed within a chamber that is hermetically sealed against the entry of gases or vapors.

(3) Part of intrinsically safe circuits.

(4) Part of an identified intrinsically safe component.

(4) Wiring Methods and Seals. Wiring methods in a Class I, Division 2 location must use threaded rigid metal conduit, intermediate metal conduit, flexible metal conduit, or liquidtight flexible conduit with the fittings listed for these systems. Additionally, Types MI, MC, TC, ITC, and PLTC cables with approved fittings are permitted [501.10(B)]. Raceway and cable seals must be installed in accordance with 501.15(B) and 501.15(C).

ARTICLE 502 CLASS II HAZARDOUS (CLASSIFIED) LOCATIONS

Introduction to Article 502—Class II Hazardous (Classified) Locations

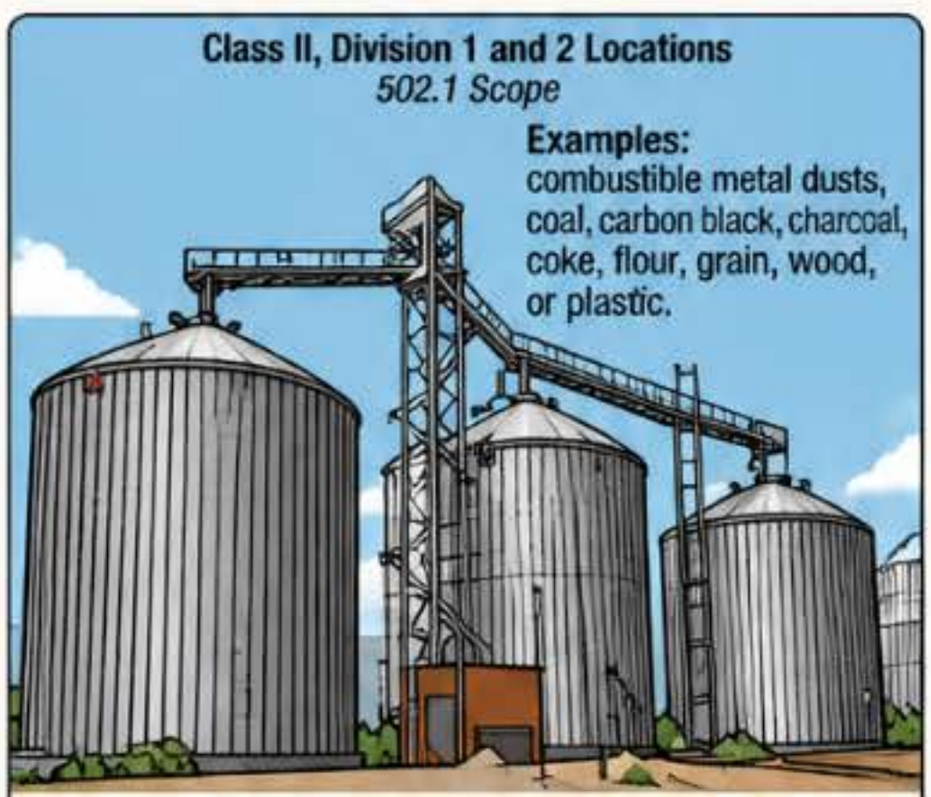
When an area contains ignitable dust in the air, the location is treated as a Class II location. Typical examples include flour mills, grain silos, coal bins, storage areas for wood pulp, and munitions plants.

Article 502 provides a logical arrangement similar to Article 501 and helps in choosing equipment and wiring methods for Class II locations, while distinguishing between Class II, Division 1 and Class II, Division 2 requirements.

Part I. General

502.1 Scope

Article 502 sets out the rules for selecting and installing electrical equipment and wiring in Class II, Divisions 1 and 2 locations where fire or explosion could result from combustible dust. ▸ Figure 502–1



Article 502 covers the requirements for electrical equipment and wiring in Class II, Division 1 and 2 locations.

▸ Figure 502–1

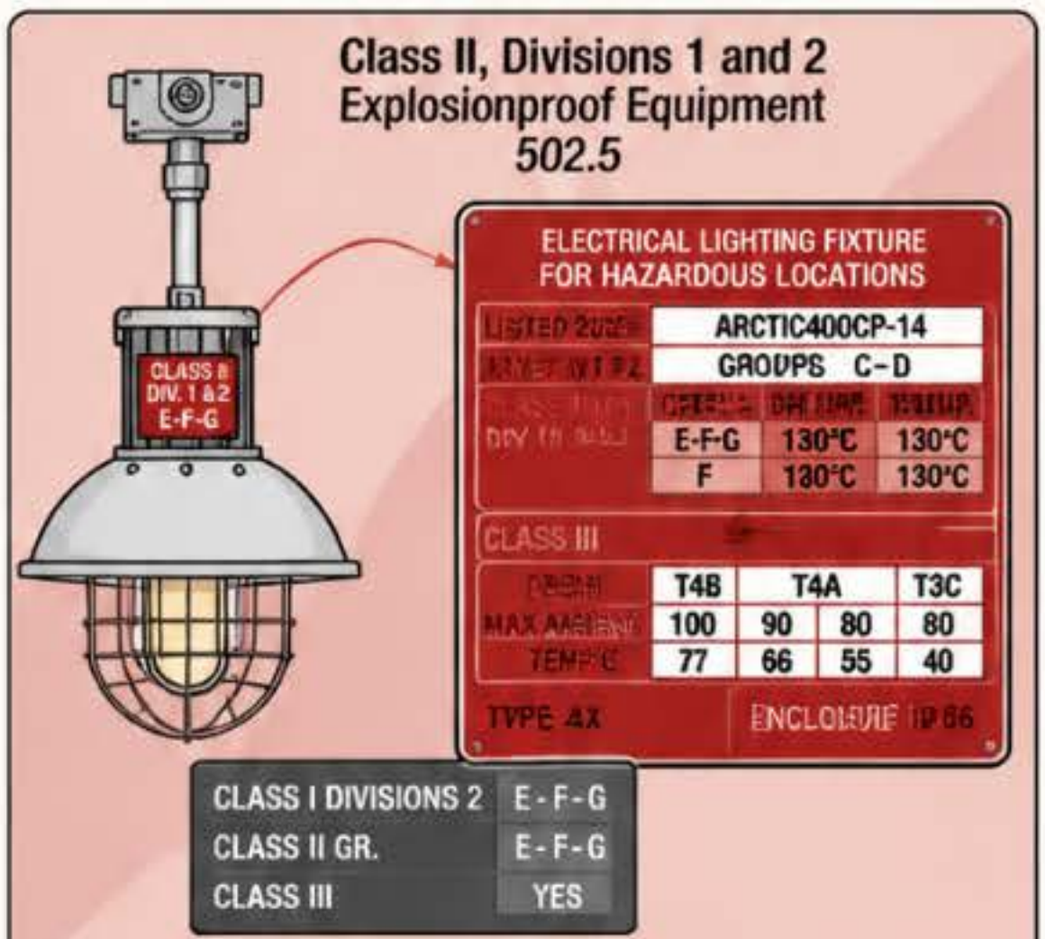
Author's Commentary:

Combustible dusts—such as metal dust, coal, carbon black, charcoal, coke, flour, grain, wood, plastic, and various chemicals—can float in air at levels that may form explosive or easily ignitable mixtures [500.5(C) and 500.8]. Refer to the definition of "Combustible Dust" in Article 100.

— Michael Hamilton

502.5 Explosionproof Equipment

Equipment listed as explosionproof must not be used in a Class II location unless that location has been identified as Class II. ▸ Figure 502–2



Explosionproof equipment must not be installed in Class II location unless the location is identified as Class II.

▸ Figure 502–2

Part II. Wiring

502.10 Wiring Methods

(A) Class II, Division 1.

(1) **General.** The following wiring techniques are permitted in a Class II, Division 1 location: ▸ Figure 502–3

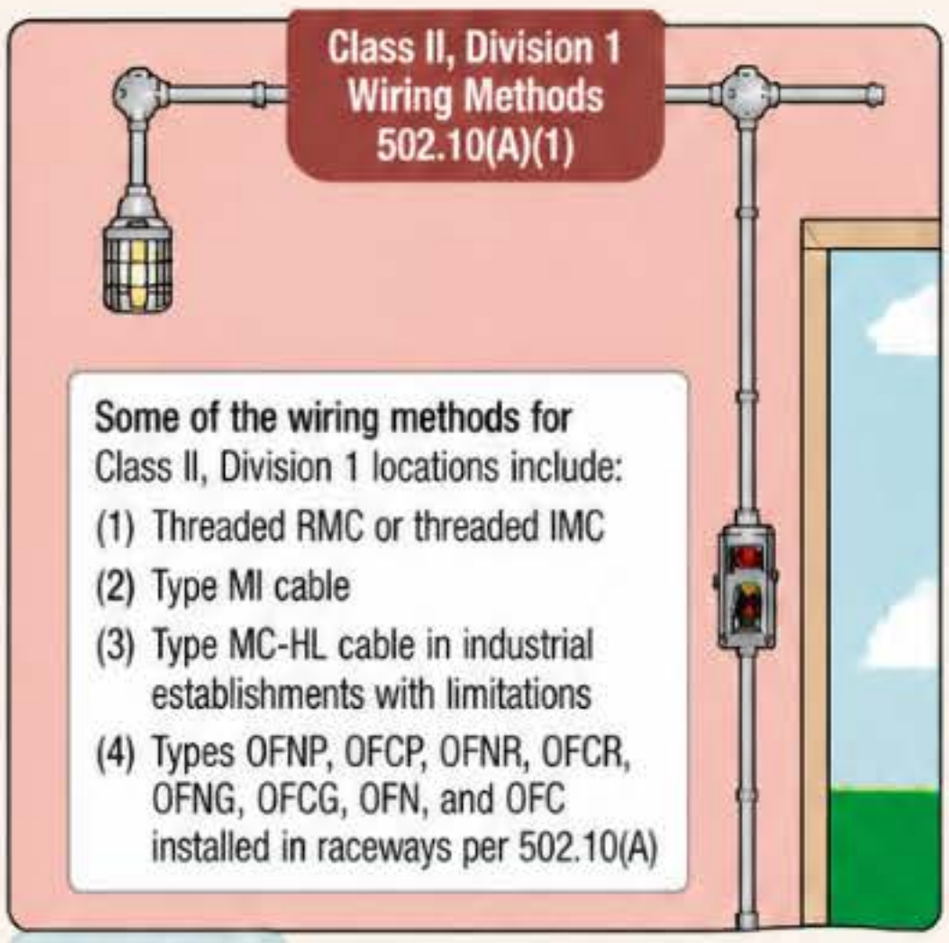


Figure 502–3

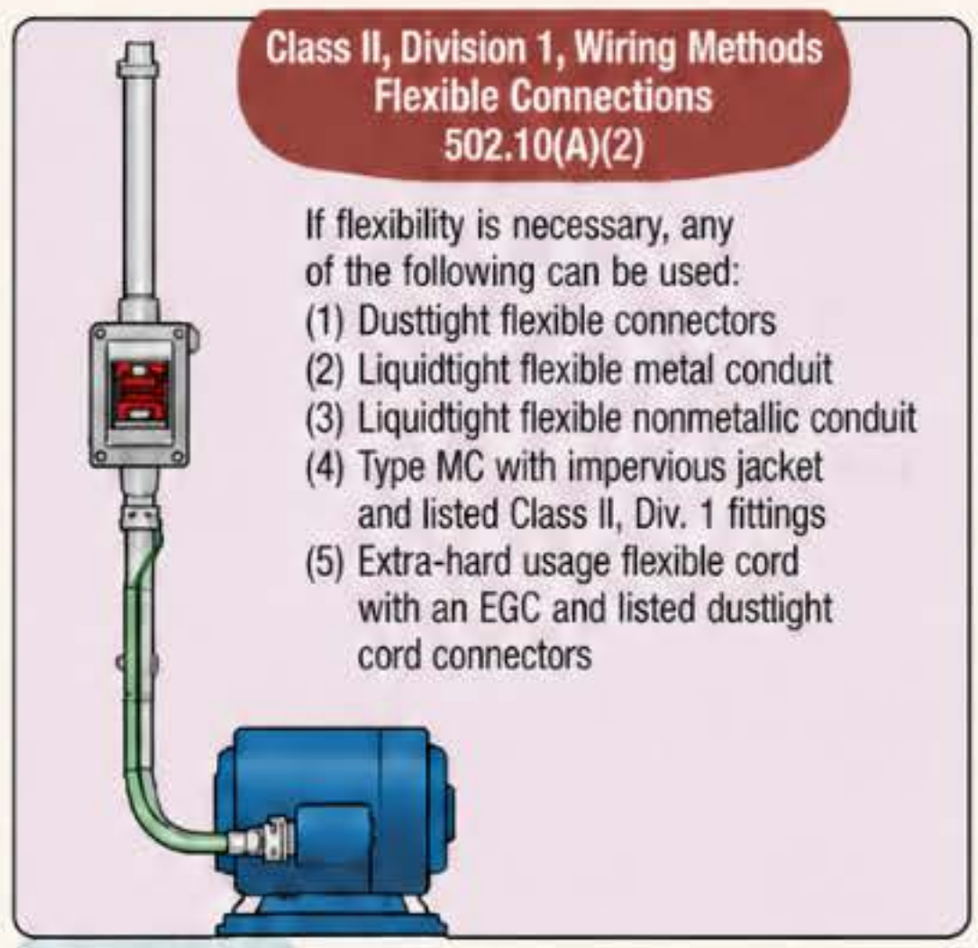


Figure 502–4

(1) Threaded rigid metal conduit or threaded intermediate metal conduit.

(2) Type MI cable terminated with fittings that are listed for the location.

(3) In industrial establishments with restricted public access where only qualified persons will service the installation, MC-HL cable listed for use in Class II, Division 1 locations with a gas/vapor-tight continuous corrugated metallic sheath, an overall jacket of suitable polymeric material, a separate equipment grounding conductor(s) sized in accordance with 250.122 based on the rating of the overcurrent protective device, and terminated with fittings that are listed for the location.

(4) Types OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN, and OFC optical fiber cable can be installed in raceways [502.10(A)] and must be sealed in accordance with 502.15.

(2) Flexible Connections. If flexibility is necessary, any of the following wiring methods are permitted in a Class II, Division 1 location: ▸ Figure 502–4

(1) Dusttight flexible connectors.

(2) Liquidtight flexible metal conduit (Type LFMC) with listed fittings.

(3) Liquidtight flexible nonmetallic conduit (Type LFNC) with listed fittings.

(4) Interlocked armor Type MC cable with an impervious jacket and termination fittings listed for Class II, Division 1 locations.

(5) Flexible cords listed for extra-hard usage, containing an equipment grounding conductor and terminated with listed dusttight flexible cord connectors. The flexible cord must be installed in accordance with 502.140.

(3) Boxes and Fittings. Boxes and fittings must be provided with threaded bosses and must be dustight. Boxes and fittings in which taps, joints, or terminal connections are made, or used in locations where dusts are of a combustible nature [500.6(B)(1) Group E], must be identified for Class II locations. ▸ Figure 502–5

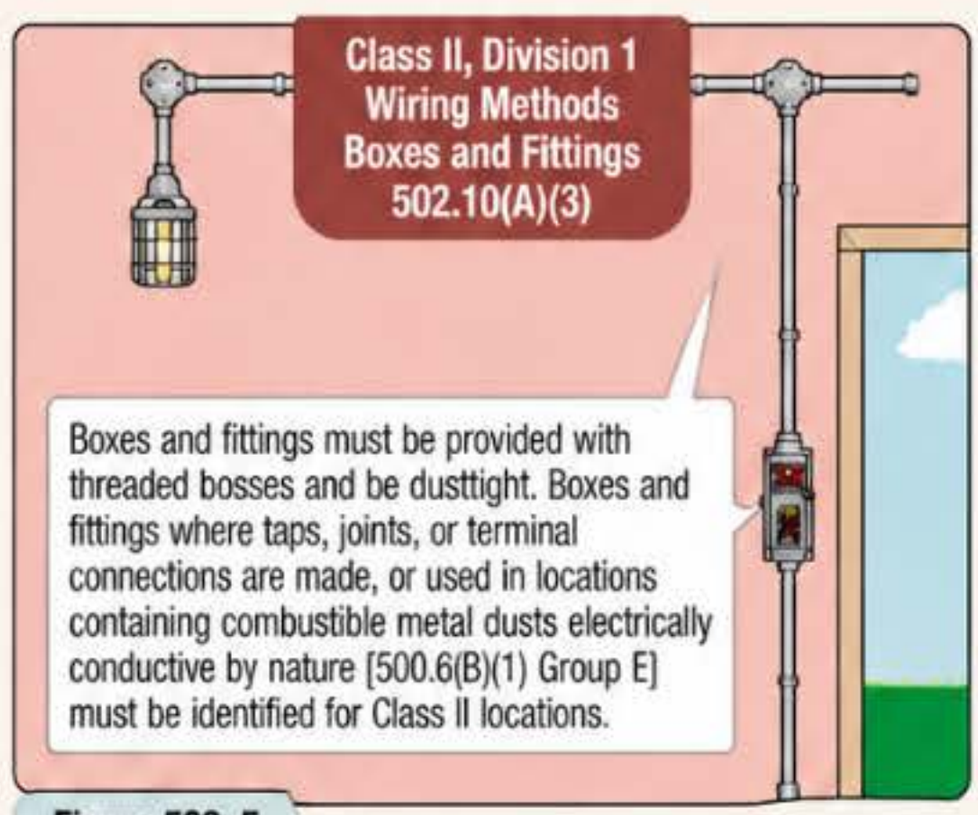


Figure 502–5

(B) Class II, Division 2.

(1) General. In Class II, Division 2 locations, the following wiring methods are permitted: ▸ Figure 502–6

CLASS II HAZARDOUS (CLASSIFIED) LOCATIONS | 502.15

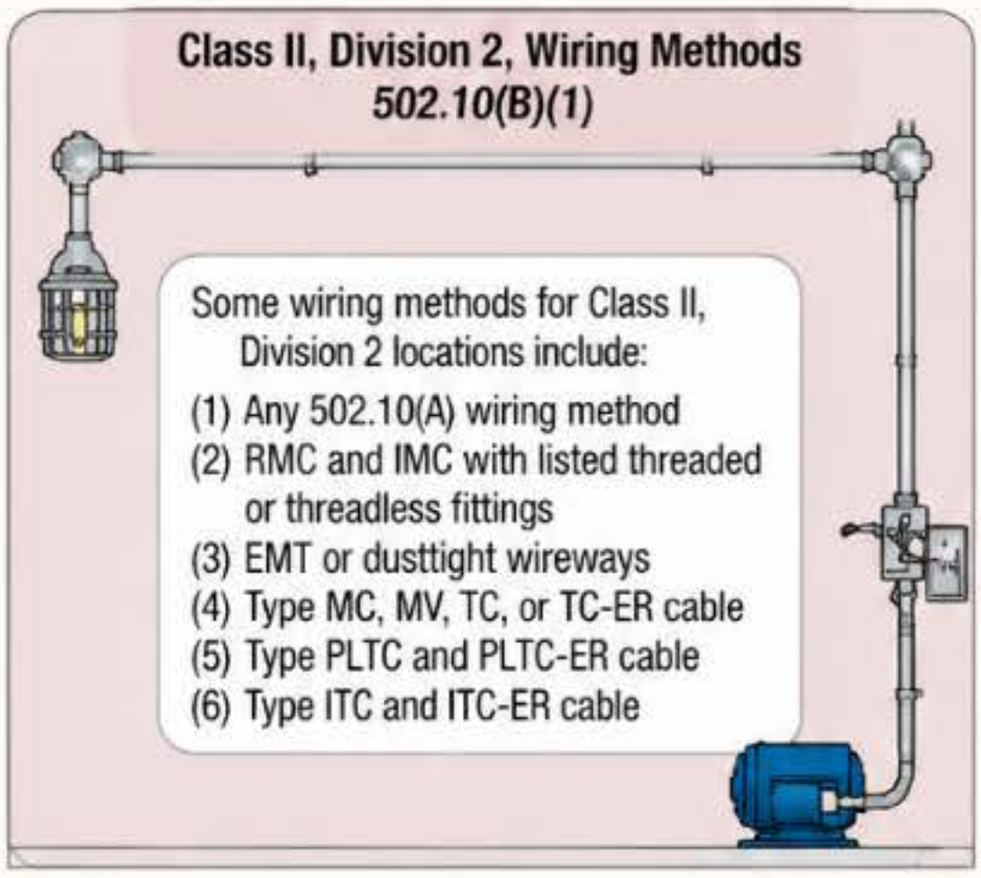


Figure 502–6

(1) Any of the wiring methods in 502.10(A).

(2) Rigid metal conduit (RMC) and intermediate metal conduit (IMC) with listed threaded or threadless fittings.

(3) Electrical metallic tubing (EMT) or dusttight wireways.

(4) Type MC, MV, TC, or TC-ER cable, including installation in cable tray systems. Type TC-ER cable must include an equipment grounding conductor in addition to any drain wire that might be present. The cable must be terminated with listed fittings.

(5) Type PLTC and PLTC-ER cable in accordance with Parts II and III of Article 725, including installation in cable tray systems. The cable must be terminated with listed fittings. Type PLTC-ER cable must include an equipment grounding conductor in addition to a drain wire that might be present.

(6) Type ITC and ITC-ER cable as permitted in 727.4 and terminated with listed fittings. Type ITC-ER cable must include an equipment grounding conductor in addition to a drain wire.

(7) Where metal conduit will not provide sufficient corrosion resistance, any of the following are permitted:

a. Listed reinforced thermosetting resin conduit (RTRC), factory elbows, and associated fittings, all marked with the suffix "-XW".

b. PVC-coated rigid metal conduit (RMC), factory elbows, and associated fittings.

c. PVC-coated intermediate metal conduit (IMC), factory elbows, and associated fittings.

d. In industrial establishments with restricted public access, where the conditions of maintenance and supervision ensure that only qualified persons service the installation, Schedule 80 PVC conduit, factory elbows, and associated fittings.

(8) Types OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN, and OFC optical fiber cables can be installed in cable trays or raceways [502.10(B)] and must be sealed in accordance with 502.15. ▸Figure 502–7

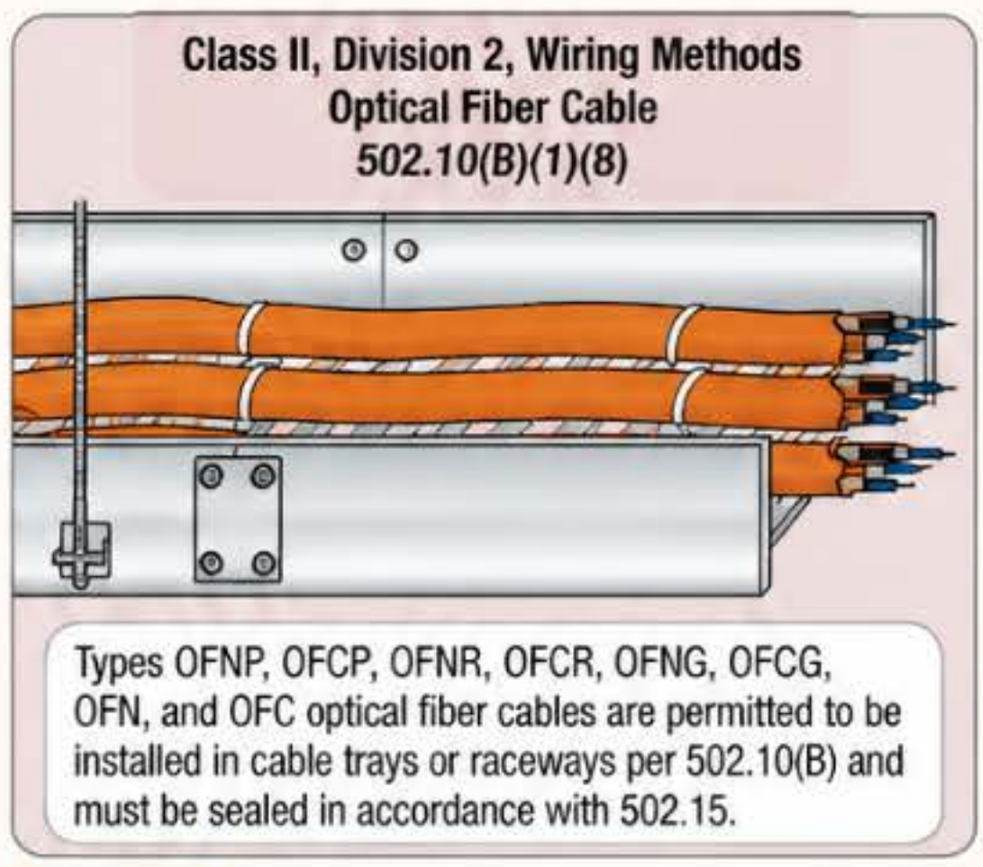


Figure 502–7

(2) Flexible Connections. If flexibility is required, wiring methods complying with 502.10(A)(2) are permitted in a Class II, Division 2 location.

(4) Boxes and Fittings. Boxes and fittings in Class II, Division 2 areas must be dustight. ▸Figure 502–8

Author's Commentary:

A standard weatherproof box with a cover and gasket satisfies this requirement.

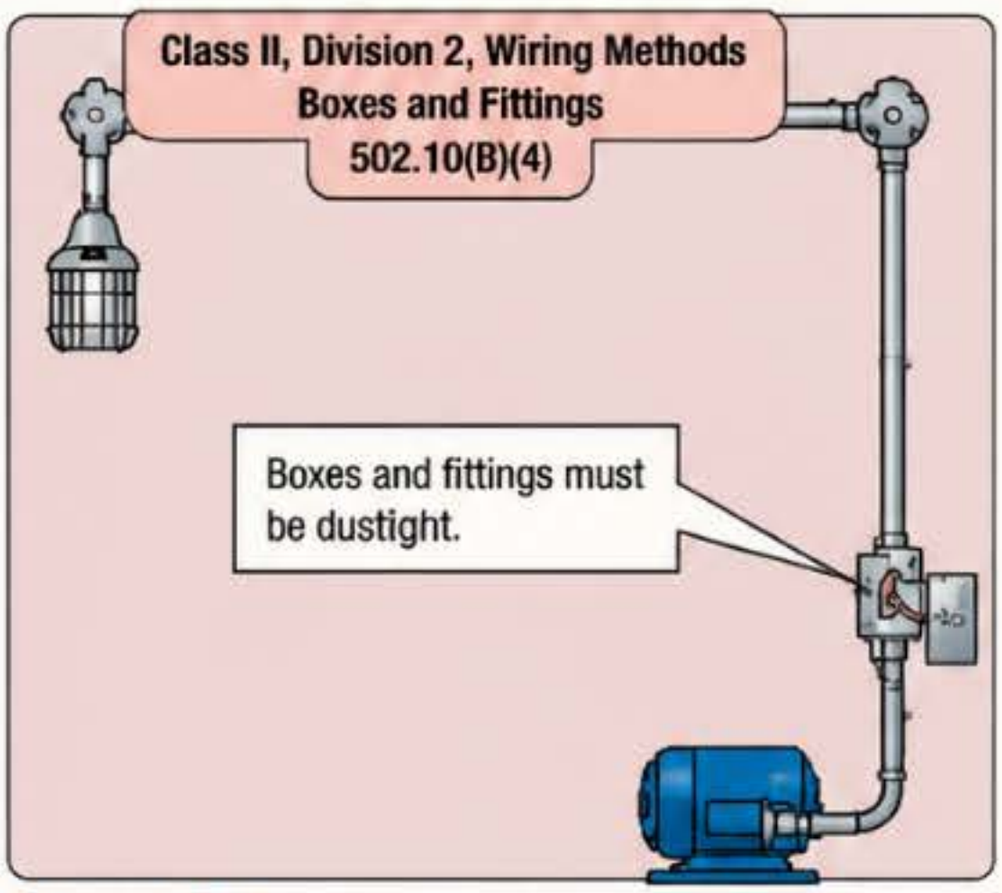
— Michael Hamilton

502.15 Sealing

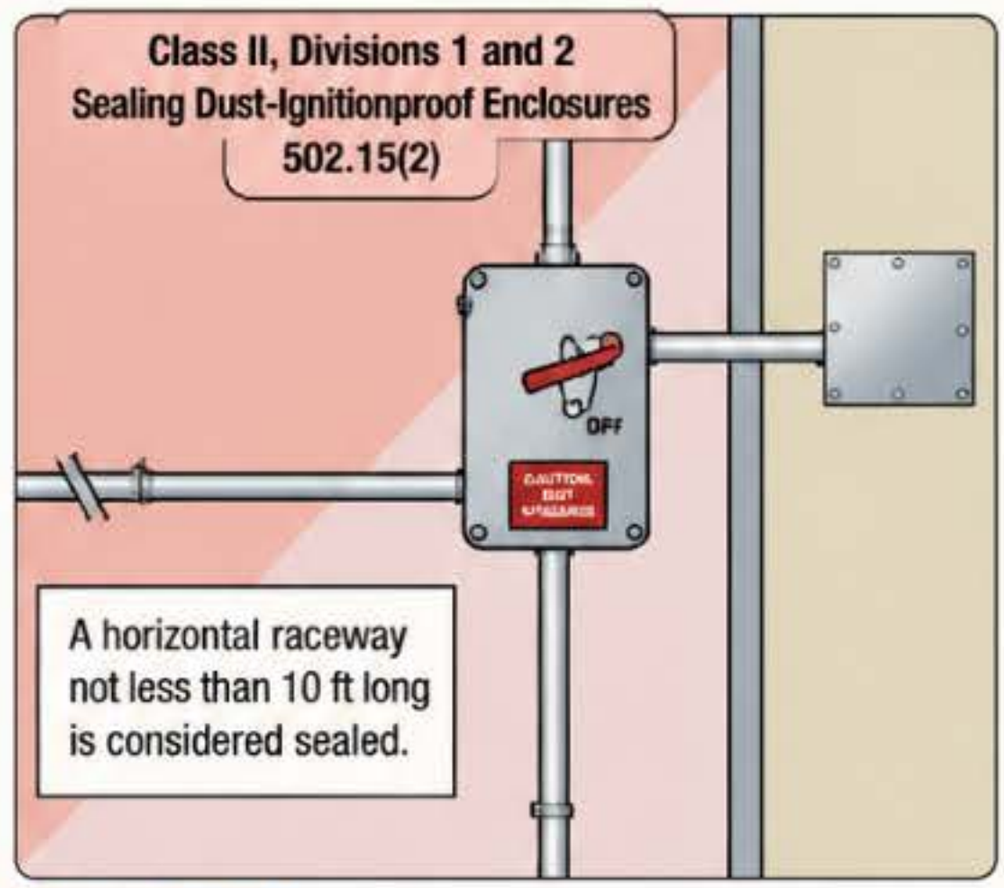
In Class II, Division 1 and 2 locations, dust must be prevented from entering the required dust-ignitionproof enclosure from a raceway by any of the following methods:

(1) A permanent and effective seal, such as sealing putty [502.15 Note]. ▸Figure 502–9

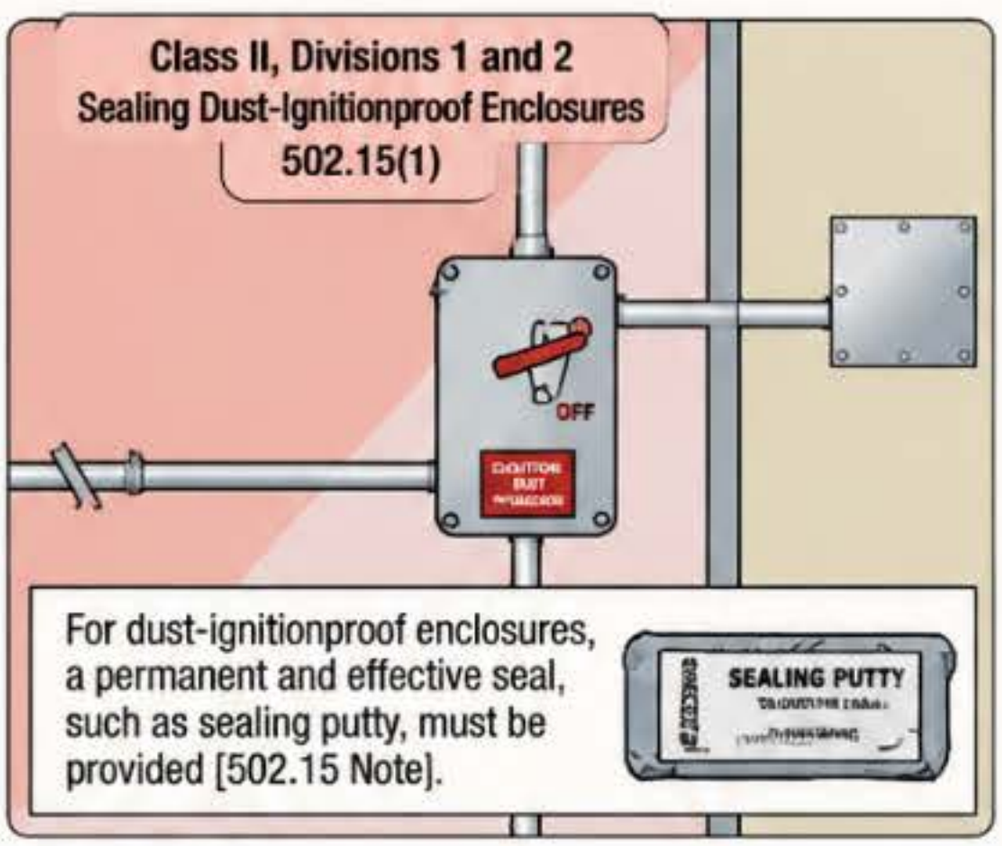
502.30 | Class II Hazardous (Classified) Locations



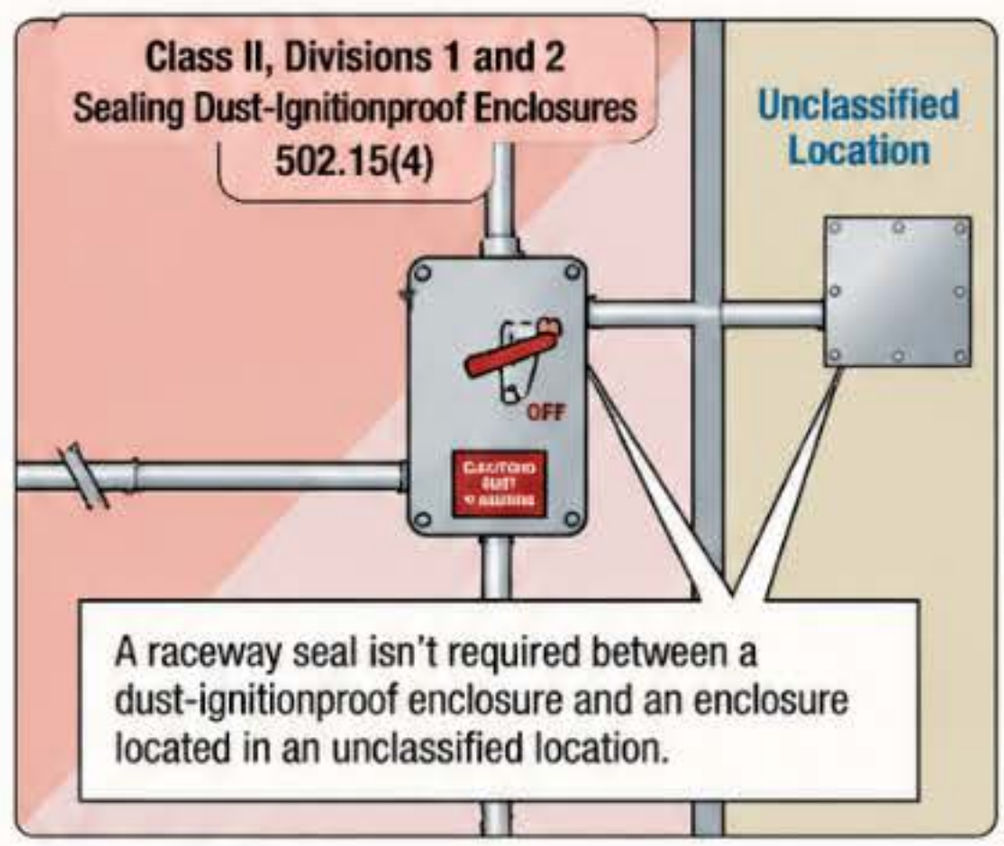
▶ Figure 502–8



▶ Figure 502–10



▶ Figure 502–9



▶ Figure 502–11

(2) A horizontal raceway not less than 10 ft long. ▶Figure 502–10

(3) A vertical raceway that extends downward for not less than 5 ft from the dust-ignitionproof enclosure.

(4) A raceway installed in a manner equivalent to (2) or (3) that extends only horizontally and downward from the dust-ignitionproof enclosure.

A conduit seal is not required between a dust-ignitionproof enclosure and an enclosure located in an unclassified location. ▶Figure 502–11

Sealing fittings for Class II locations must be accessible and are not required to be explosionproof.

Note: Electrical sealing putty is one method of sealing.

502.30 Grounding and Bonding

Due to the extreme risk associated with electrical installations in hazardous (classified) locations [500.5], equipment metal parts and raceways must be bonded and connected to electrical ground in a manner that ensures minimal potential for energized conditions.

(A) Bonding. Locknuts are not acceptable for bonding in hazardous (classified) locations; therefore, bonding jumpers or other approved means must be used. Such methods of bonding shall be applied to all raceways, fittings, boxes, enclosures, and so forth between Class II locations and service disconnects or the grounding point of a separately derived system. ▶Figure 502–12

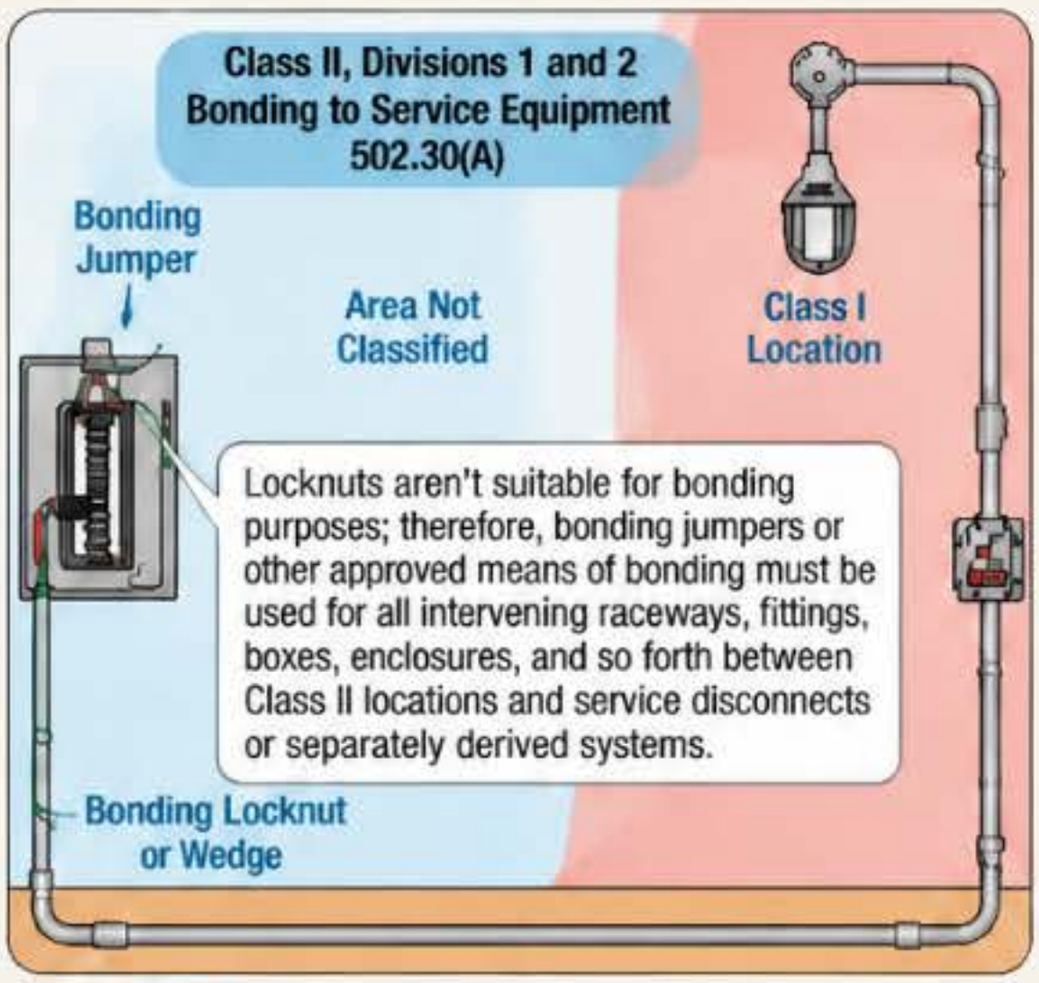


Figure 502-12

Author's Commentary:

A separate equipment grounding conductor may be unnecessary if a metal raceway is already used for equipment grounding. Threaded couplings and hubs made up with wrench-tight can supply a low-impedance ground-fault path [250.100].

— Michael Hamilton

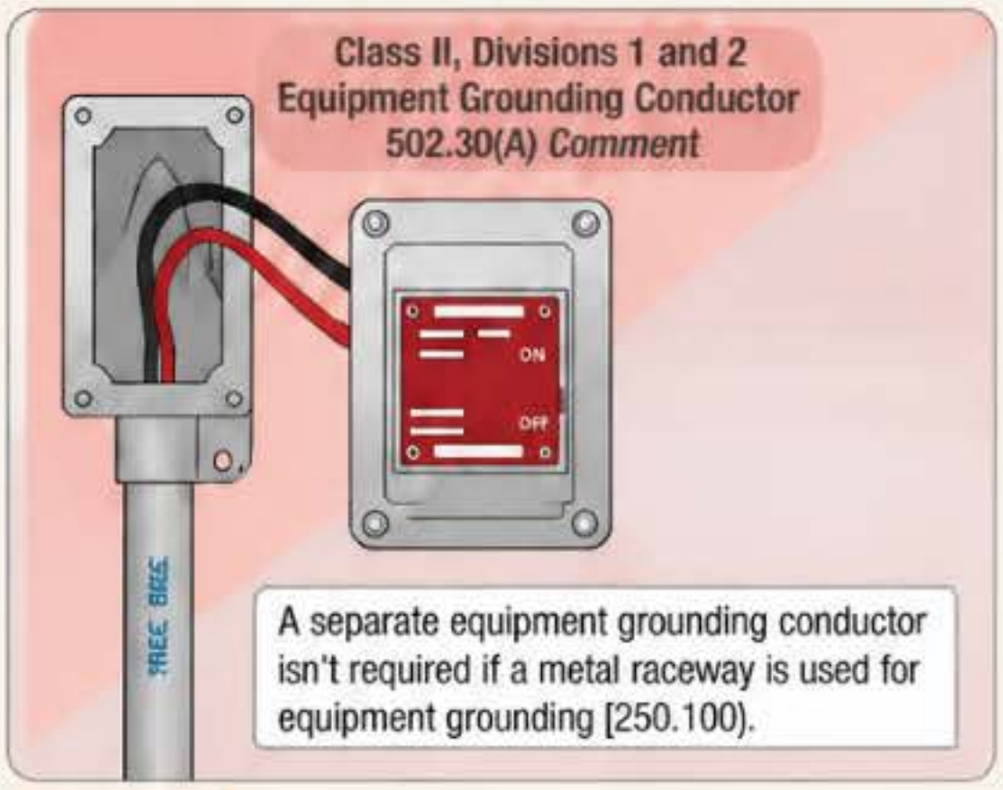


Figure 502-13

Author's Commentary:

The bonding requirements for Class 2 locations match those for 501.30(A) Class 1 locations. See 250.94(B)(4).

— Michael Hamilton

(B) Equipment Grounding Conductor, Type LFMC. Where liquid-tight flexible metal conduit is installed as permitted by 502.10(A)(2), an equipment bonding jumper of the wire type must be installed in accordance with 250.102. Figure 502-14

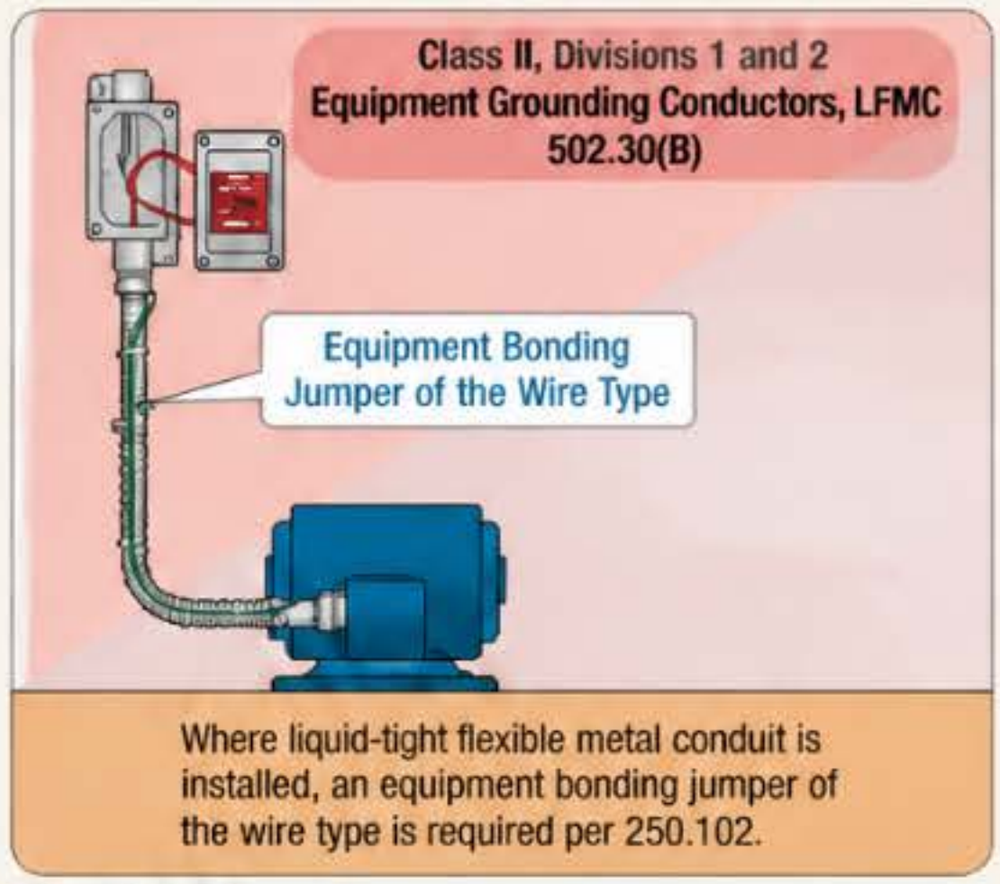


Figure 502-14

Author's Commentary:

Load side bonding jumpers must be sized in accordance with 250.122 based on the rating of the overcurrent protective device [250.102(D)], and where the bonding jumper is installed outside of a raceway, the length of the bonding jumpers are not permitted to exceed 6 ft and they must be routed with the raceway [250.102(E)(2)].

— Michael Hamilton

Part III. Equipment

502.115 Enclosures Containing Make-and-Break Contacts

(A) Class II, Division 1. Enclosures for switches, circuit motor controllers, fuses, pushbuttons, relays, and similar devices must be identified for a Class II, Division 1 location. Figure 502-16

(B) Class II, Division 2. Enclosures for fuses, switches, circuit breakers, and motor controllers (including pushbuttons, relays, and similar devices) must be dusttight or identified for a Class II, Division 2 location. ▸Figure 502-17

Author's Commentary:

A standard weatherproof box with a cover and gasket this requirement.

— Michael Hamilton

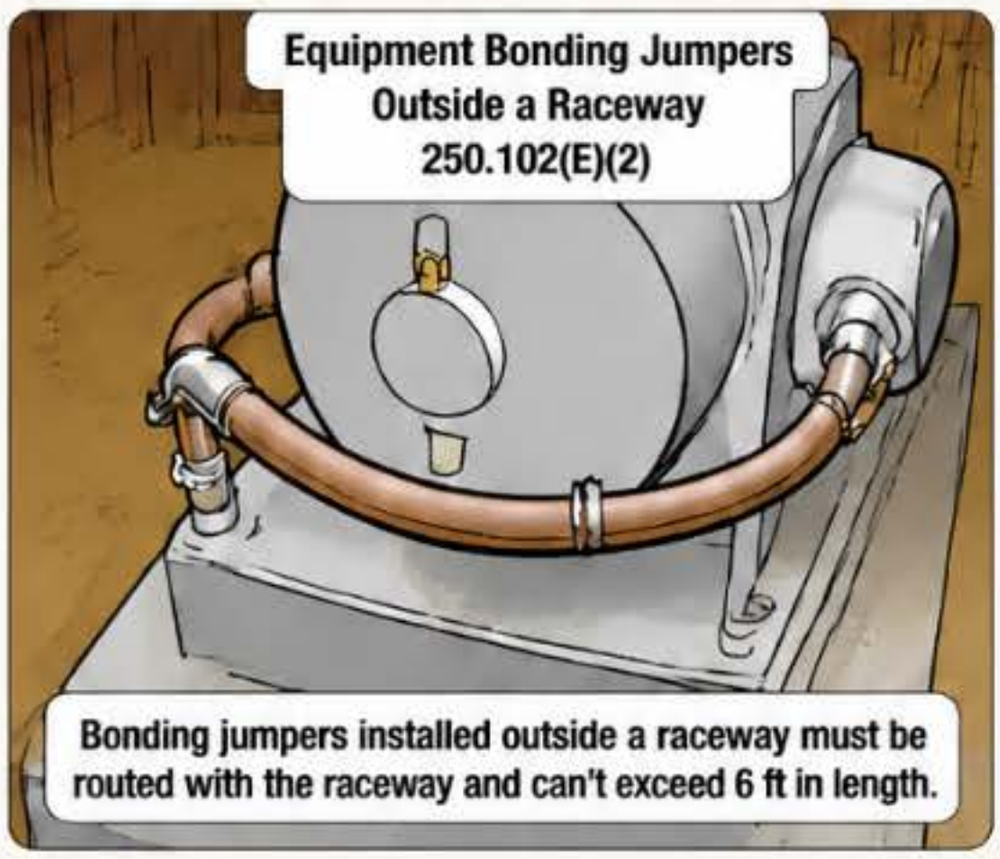


Figure 502–15

Figure 502–16

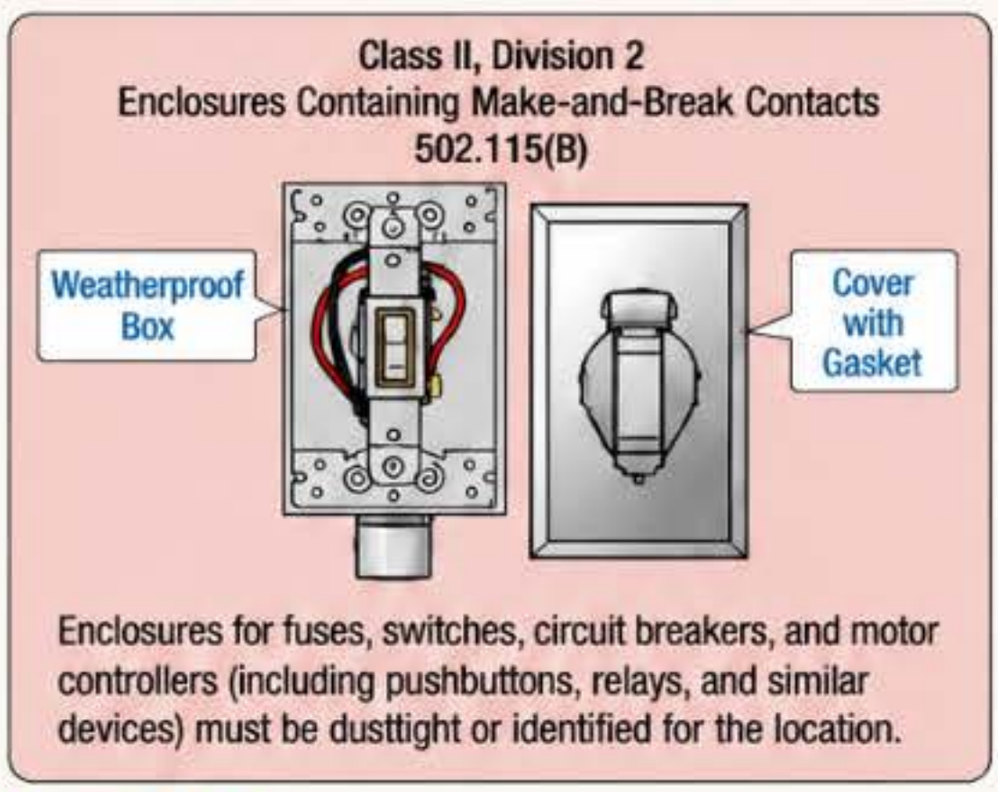


Figure 502–17

502.125 Motors and Generators

(A) Class II, Division 1. Motors and generators must be:

(1) Identified for the location.

(2) Of the totally enclosed pipe-ventilated type.

(B) Class II, Division 2. Motors and generators must be totally enclosed nonventilated, pipe-ventilated, water-air-cooled, fan-cooled, or be dust-ignitionproof.

502.130 Luminaires

(A) Class II, Division 1. Luminaires must comply with the following:

(1) Marking. Luminaires must be identified for the location and clearly marked for the type and maximum wattage of the lamp. Figure 502–18

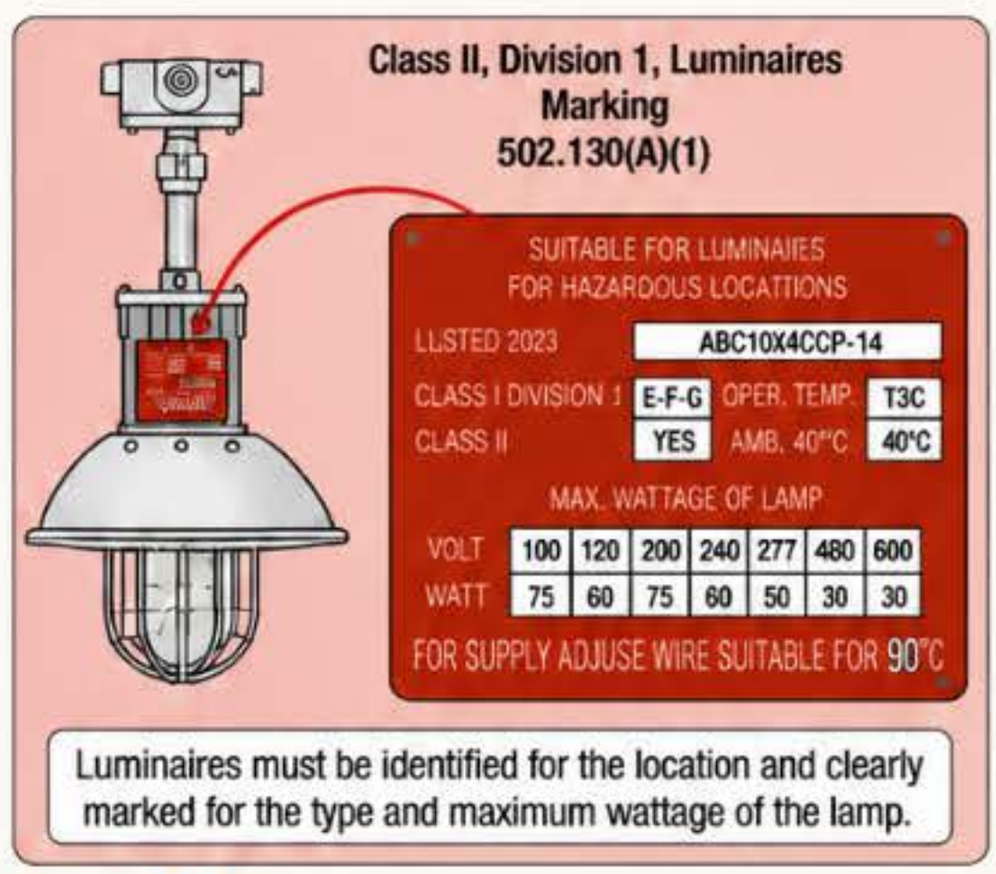


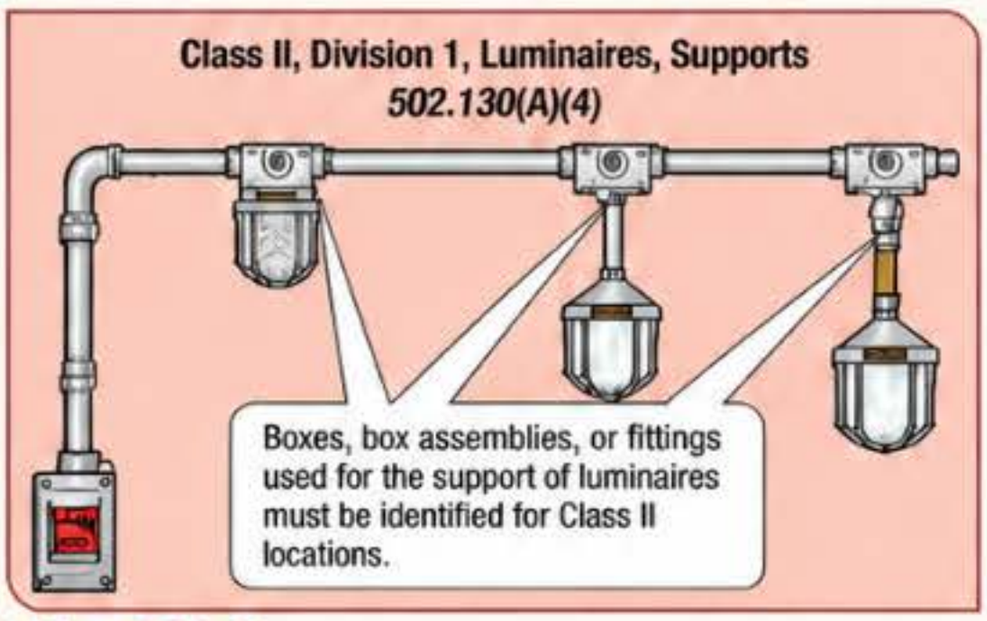
Figure 502–18

(2) Physical Damage. Luminaires must be protected from physical damage by suitable guards or by location. ▸Figure 502–19

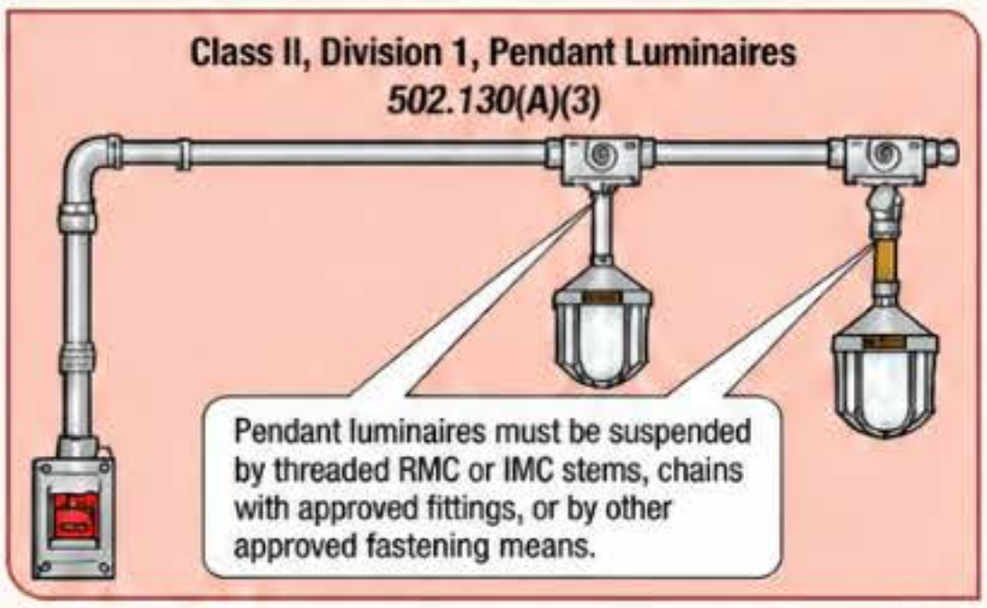
(3) Pendant Luminaires. Pendant luminaires must be suspended by threaded rigid metal conduit stems, threaded steel intermediate metal conduit stems, by chains with approved fittings, or by other approved means. Figure 502–20

Threaded joints must be provided with set screws or other effective means to prevent loosening. For stems longer than 1 ft, permanent, effective bracing, or a flexible fitting or connector listed for the Class II, Division 1 location must be provided not more than 1 ft from the point of attachment to the supporting box/fitting.

▸ Figure 502–19



▸ Figure 502–21



▸ Figure 502–20

Flexible cord approved for severe-duty applications is allowed to be used for the wiring between an outlet box or fitting and a pendant luminaire when the equipment contains a grounding conductor and is terminated with fittings that are listed for the location in accordance with 502.130(A)(2)(5). ▸ Figure 502

(4) Supports. Boxes, box assemblies, or fittings used to support luminaires must be identified for use in Class II locations. ▸ Figure 502–21

(B) Class II, Division 2 Luminaires must meet the following:

(1) Portable Lighting Equipment. Portable lighting devices must carry a marking suitable for the location.

(2) Fixed Lighting. Luminaires must be enclosed in housings that are resistant to dust intrusion or otherwise labeled for the location.

(3) Physical Damage. Luminaires must be protected from physical impact by effective guards or by being installed where the risk of damage is eliminated.

(4) Pendant Luminaires. Hanging luminaires shall be suspended from rigid threaded metal conduit stems, threaded intermediate metal conduit extensions, or chains fitted with hardware that has been reviewed and approved by the authority having jurisdiction or through some other method that the authority having jurisdiction has approved.

For drops longer than 1 foot, permanent bracing or a flexible connector must be provided within 1 foot of the connection to the support box or fitting. A flexible cord designed for hard use may be used as the connection between an outlet box or fitting and a pendant luminaire when it terminates with a listed flexible cord connector that maintains the enclosure integrity; however, the flexible cord cannot be used to support the luminaire.

502.140 Flexible Cords

(A) Permitted Uses. Flexible cord is allowed for the following applications:

(1) Portable Lighting or Portable Utilization Equipment. The flexible cord must be connected to the equipment using a cord connector identified for the appropriate wiring method, such as one rated for dust-ignitionproof use.

▸ Figure 502–22

An attachment plug of the grounding type that complies with 502.145 must be used.

(B) Installation. Where flexible cords are installed, they must meet all of the following criteria:

(1) They must be of a type specifically recognized for use in harsh service conditions.

Author's Commentary:

The requirements above make sure that lighting equipment in hazardous places is protected against physical harm, securely supported, and connected with the correct types of flexible cords. These rules help reduce the risk of ignition and keep installations safe and in full compliance.

— Michael Hamilton

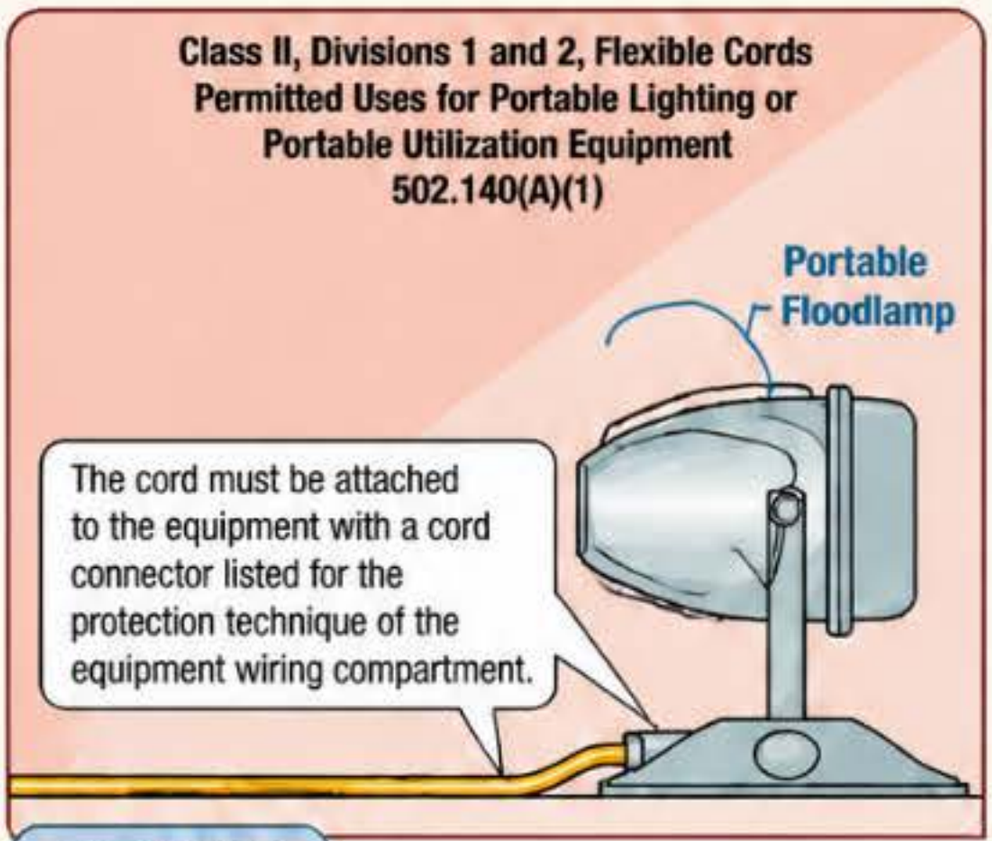


Figure 502–22

(2) Contain an equipment grounding conductor complying with 400.23.

(3) Be supported in such a manner that there will be no tension on the terminal connections.

(4) In Division 1 locations, the flexible cord must terminate with a flexible cord connector listed for the location or a listed flexible cord connector installed with a seal listed for the location. In Division 2 locations, the flexible cord must be terminated with a listed dusttight flexible cord connector.

502.145 Receptacles and Attachment Plugs

Receptacles and attachment plugs must be identified for the location.

(A) Class II, Division 1.

(1) Receptacles. In Class II, Division 1 locations, receptacles must be part of the premises wiring.

(2) Attachment Plugs. Attachment plugs must be of the type that provides for connection to the equipment grounding conductor of the flexible cord.

(B) Class II, Division 2.

(1) Receptacles. In Class II, Division 2 locations, receptacles must be part of the premises wiring.

(2) Attachment Plugs. Attachment plugs must be of the type that provides for connection to the equipment grounding conductor of the flexible cord.

502.150 Limited-Energy and Communications Systems

(A) Class II, Division 1. Signaling, alarm, remote-control, and communications systems must comply with the following:

(1) Contacts. Switches, circuit breakers, relays, contactors, fuses, and current-breaking contacts for bells, horns, howlers, sirens, and other devices in which sparks or arcs may be produced must be within enclosures that are dusttight or otherwise identified for the location. ▶ Figure 502–23

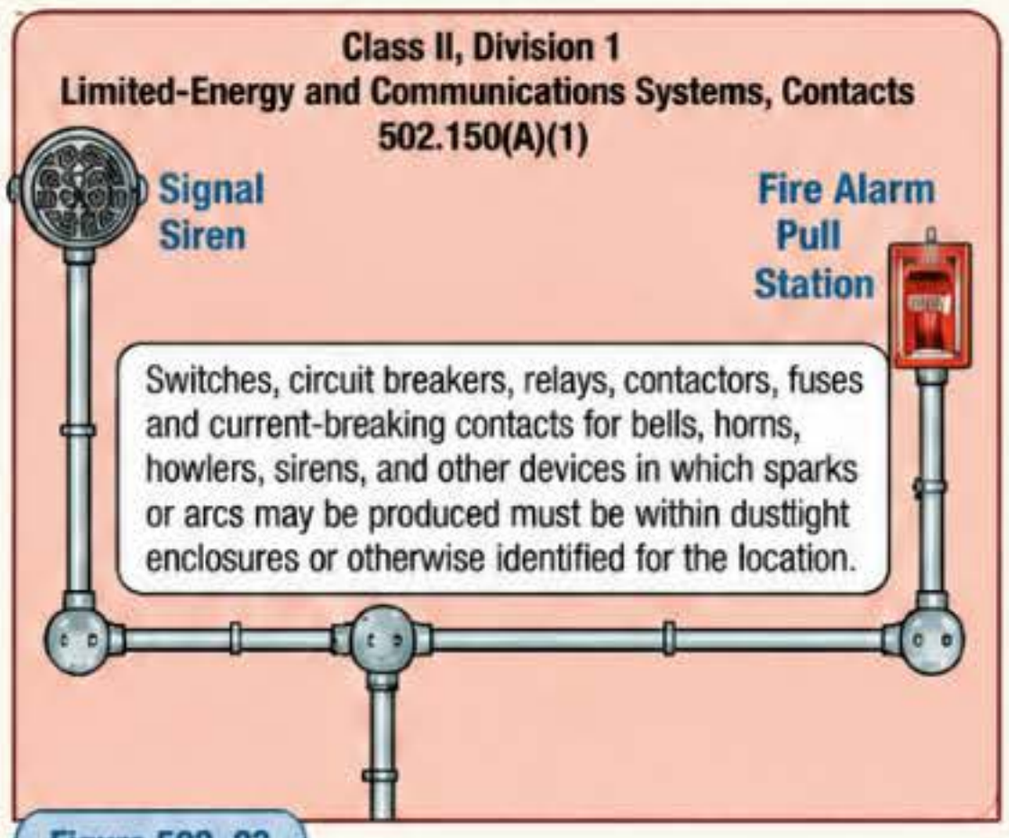


Figure 502–23

Author's Commentary:
The types of enclosures permitted for general-purpose-contacts depend on the environment and whether the contacts are protected by immersion in oil or by being sealed from the entrance of dust.

— Michael Hamilton

(B) Class II, Division 2

Signaling, alarm, remote-control, and communications systems must comply with the following:

(1) Contacts. Contacts must comply with 502.150(A)(1) or be installed in enclosures that are dusttight or otherwise identified for the location.

(2) Transformers. The windings and terminal connections of transformers must be provided with dusttight metal enclosures.

Author's Commentary:
Transformers in Division 2 areas must have their windings and terminals enclosed in metal housings that keep out dust.

— Michael Hamilton

ARTICLE 503 CLASS III HAZARDOUS (CLASSIFIED) LOCATIONS

Introduction to Article 503—Class III Hazardous (Classified) Locations

The scope of Class III locations can be somewhat complex, and interpreting it may present challenges. If you have easily ignitable fibers or flyings in a facility, there is a good chance a Class III area exists. You might encounter these spaces in sawmills, textile mills, and fiber processing plants. Often, the difference between a Class II location and a Class III location comes down to particle size. The term "Combustible Dust" in Article 100 refers to particles that are 500 microns or smaller. In essence, that is about three one-hundredths of an inch. If the predominant material is coarser than that, Article 503 may not apply.

Author's Commentary:

- Article 100 defines "Combustible Dust" as dust particles that are 500 microns in size or smaller. That is approximately $3/100$ of an inch!

— Michael Hamilton

Part I. General

503.1 Scope

Article 503 establishes the rules for electrical equipment and wiring used with all voltages in Class III, Division 1 and 2 locations. These are places where fire or explosion dangers might exist because of easily ignitable fibers or fine materials that can form combustible flyings when handled, machined, or otherwise processed. These conditions are not typically airborne in large enough quantities to create ignitable mixtures [500.5(D)]. ▸ Figure 503–1

Class III, Division 1 and 2 Locations
503.1 Scope

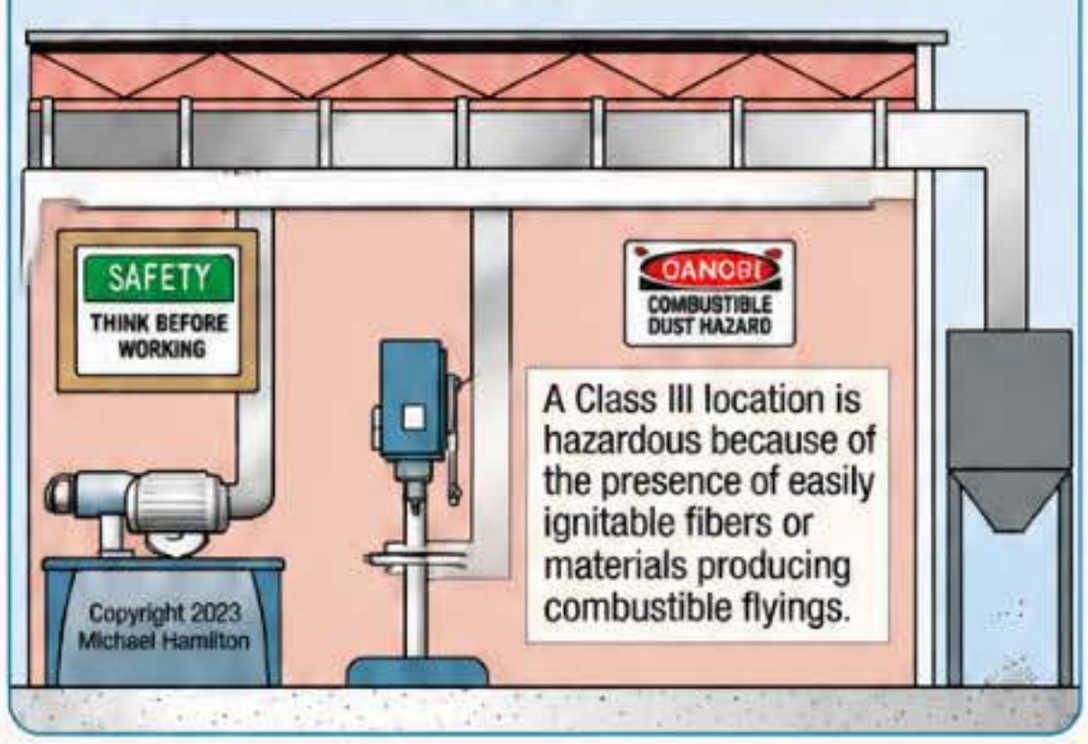


Figure 503–1

Part II. Wiring

503.10 Wiring Methods

The wiring methods permitted in Class III locations include:

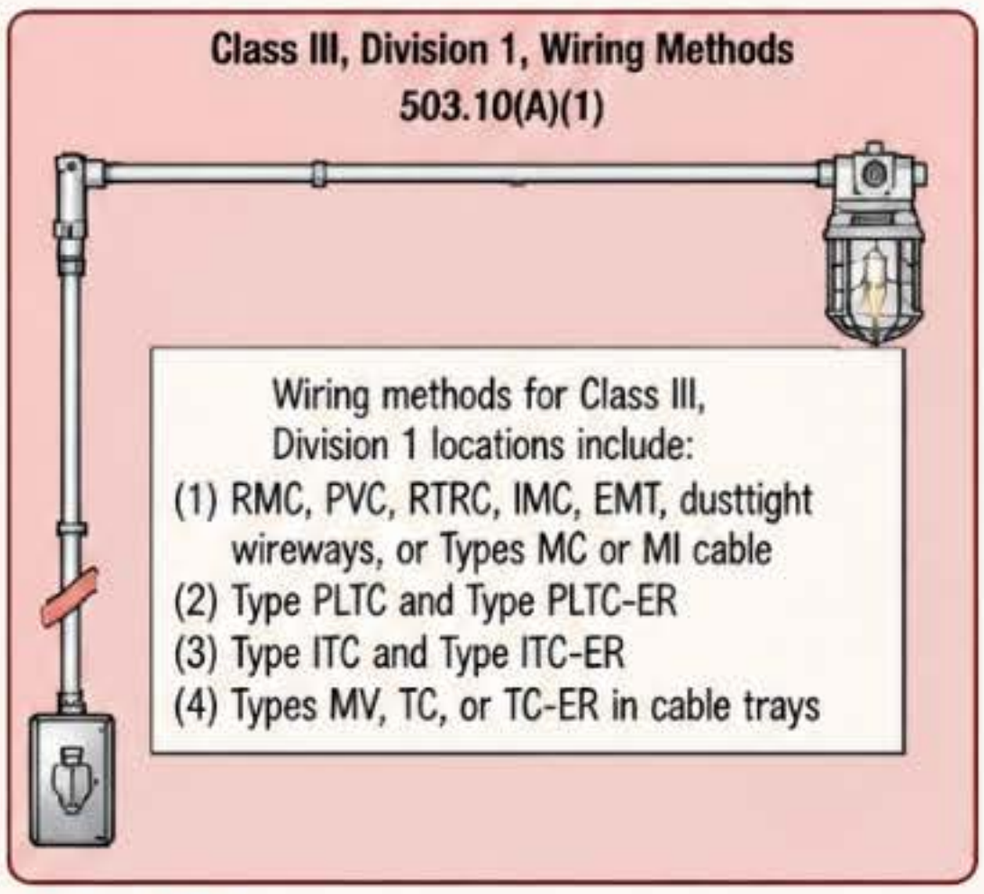
(A) Class III, Division 1 Location.

(1) General. The following wiring methods can be installed in a Class III, Division 1 location: ▸ Figure 503–2

(1) Rigid metal conduit (Type RMC), PVC conduit, RNC conduit, (rigid nonmetallic conduit), intermediate metal conduit (Type IMC), electrical metallic tubing (EMT), dusttight wireways, or Types MC or MI cable terminated with fittings that are listed.

(2) Types PLTC and PLTC-ER cable terminated with listed fittings in accordance with Parts II and III of Article 725. Type PLTC-ER cable must include an equipment grounding conductor in addition to any drain wire that might be present.

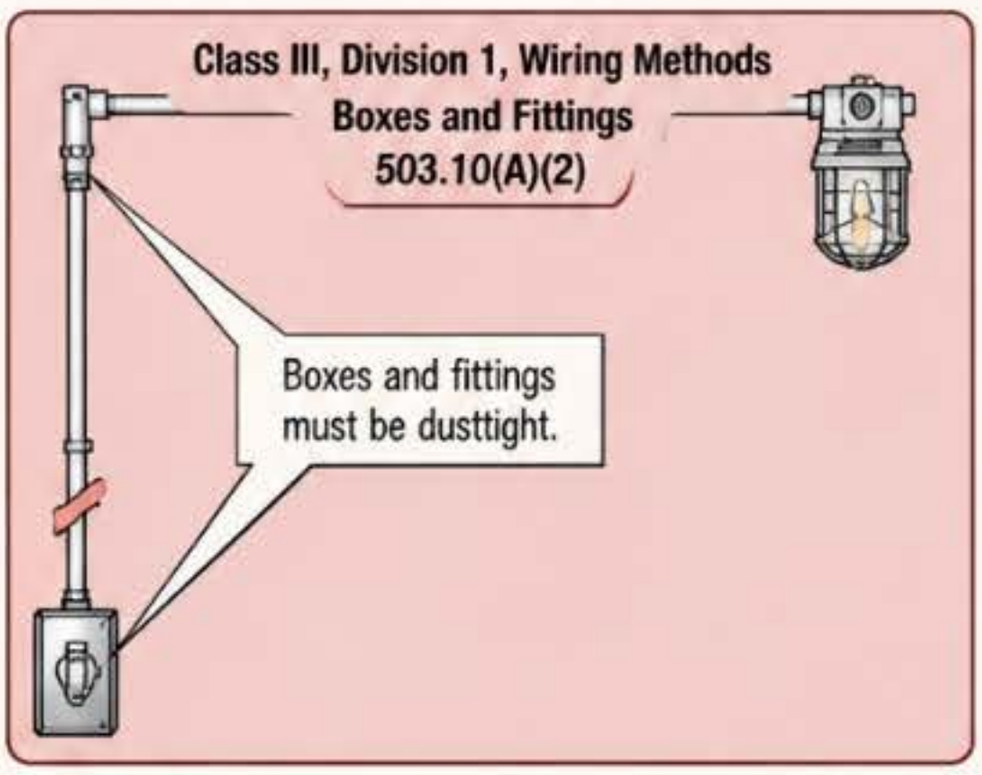
(3) Type ITC and ITC-ER cable as permitted in 727.4 and terminated with listed fittings. Type ITC-ER cable must include an equipment grounding conductor in addition to a drain wire.



▸ Figure 503–2

(4) Types MV, TC, or TC-ER cable including installation in cable tray systems. Type TC-ER cable must include an equipment grounding conductor in addition to any drain wire that might be present. The cable must be terminated with listed fittings.

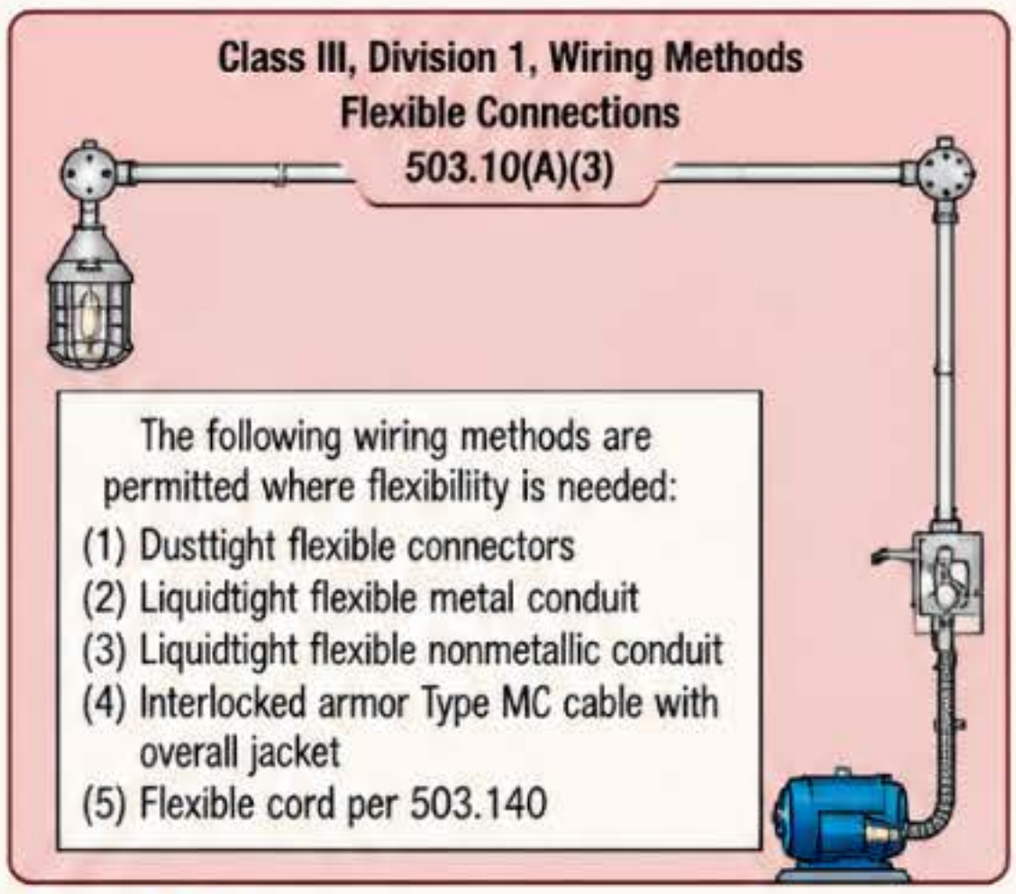
(2) Boxes and Fittings. Boxes and fittings must be dustight. ▸ Figure 503–3



▸ Figure 503–3

Author's Commentary:
A standard weatherproof box with a cover and gasket meets this requirement.
— Michael Hamilton

(3) Flexible Connections. Where flexibility is needed, the following can be used: ▸ Figure 503–4



▸ Figure 503–4

(1) Dusttight flexible connectors.

(2) Liquidtight flexible metal conduit (Type LFMC) with listed fittings.

(3) Liquidtight flexible nonmetallic conduit (Type LFNC) with listed fittings.

(4) Interlocked armor Type MC cable having an overall jacket of suitable polymeric material and installed with listed dustight termination fittings.

(5) Flexible cord in accordance with 503.140.

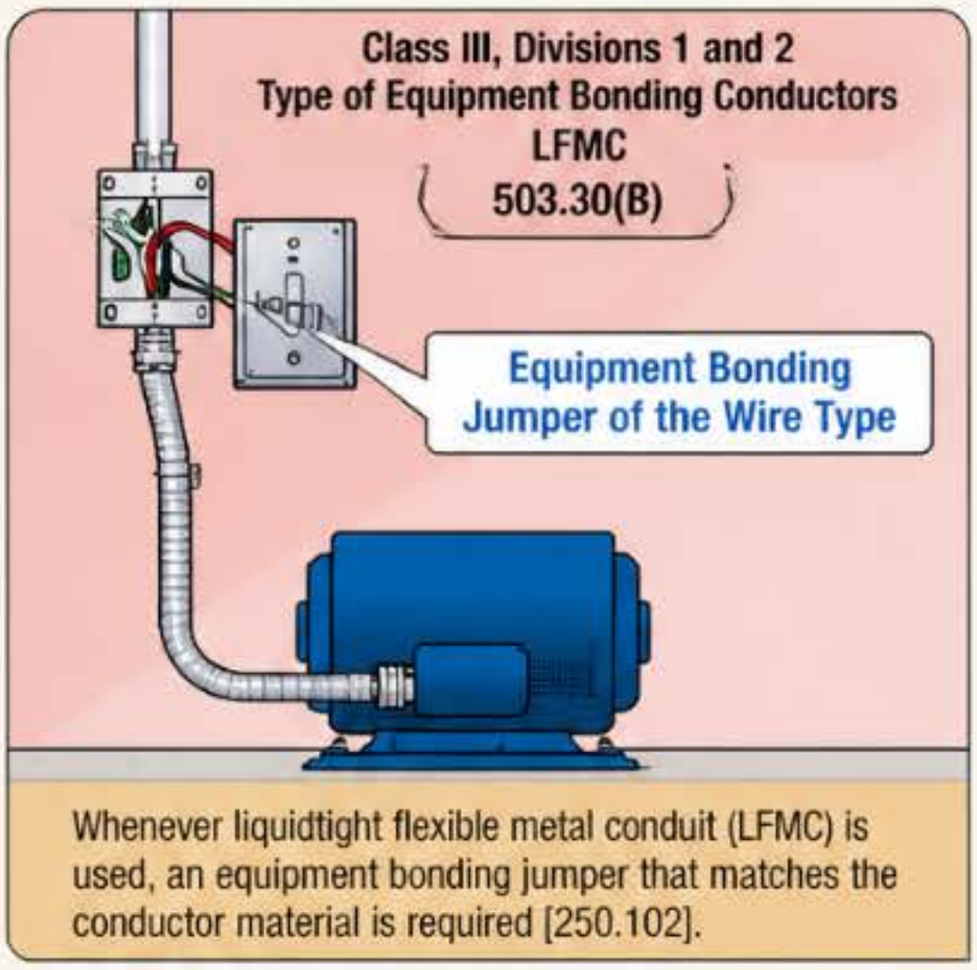
(B) Class III, Division 2 Location. The wiring methods listed in 503.10(A) must be used in a Class III, Division 2 location.

503.30 Grounding and Bonding

Because of the explosive conditions associated with electrical installations in hazardous (classified) locations [500.5], electrical continuity of the metal parts of equipment and raceways must be ensured regardless of the voltage of the circuit.

(A) Bonding. Locknuts are not suitable for bonding purposes in hazardous (classified) locations; therefore, bonding jumpers or other approved means of bonding must be used. Such means of bonding apply to all intervening raceways, fittings, boxes, and enclosures between Class III locations and service disconnects.

(B) Type of Equipment Bonding Conductor. Where liquidtight flexible metal conduit is installed [503.10(A)(3)], an equipment bonding jumper of the wire type must be installed in accordance with 250.102. ▸ Figure 503–5



Whenever liquidtight flexible metal conduit (LFMC) is used, an equipment bonding jumper that matches the conductor material is required [250.102].

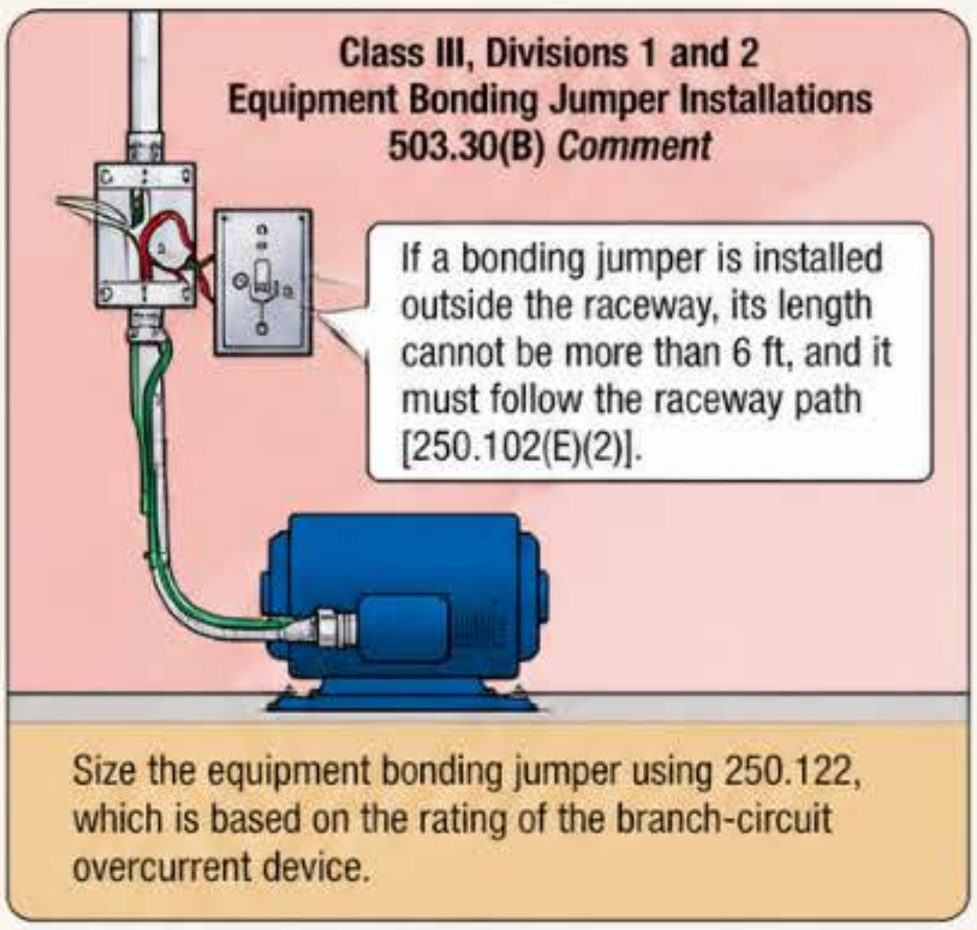
Figure 503–5

Author's Commentary:

Bonding jumpers that connect the load side must be selected in accordance with 250.122, which is based on the rating of the overcurrent protective device [250.102(D)]. These bonding jumpers are installed outside raceways, their length cannot exceed 6 ft, and they must follow the raceway path [250.102(E)(2)].

— Michael Hamilton

Figure 503–6



Size the equipment bonding jumper using 250.122, which is based on the rating of the branch-circuit overcurrent device.

Figure 503–6

Part III. Equipment

503.115 Enclosures Containing Make-and-Break Contacts

In Class III locations, all switches, circuit breakers, motor controllers, and fuses—as well as other devices intended to interrupt current during normal operation—must be installed in dusttight enclosures. ▸ Figure 503–7

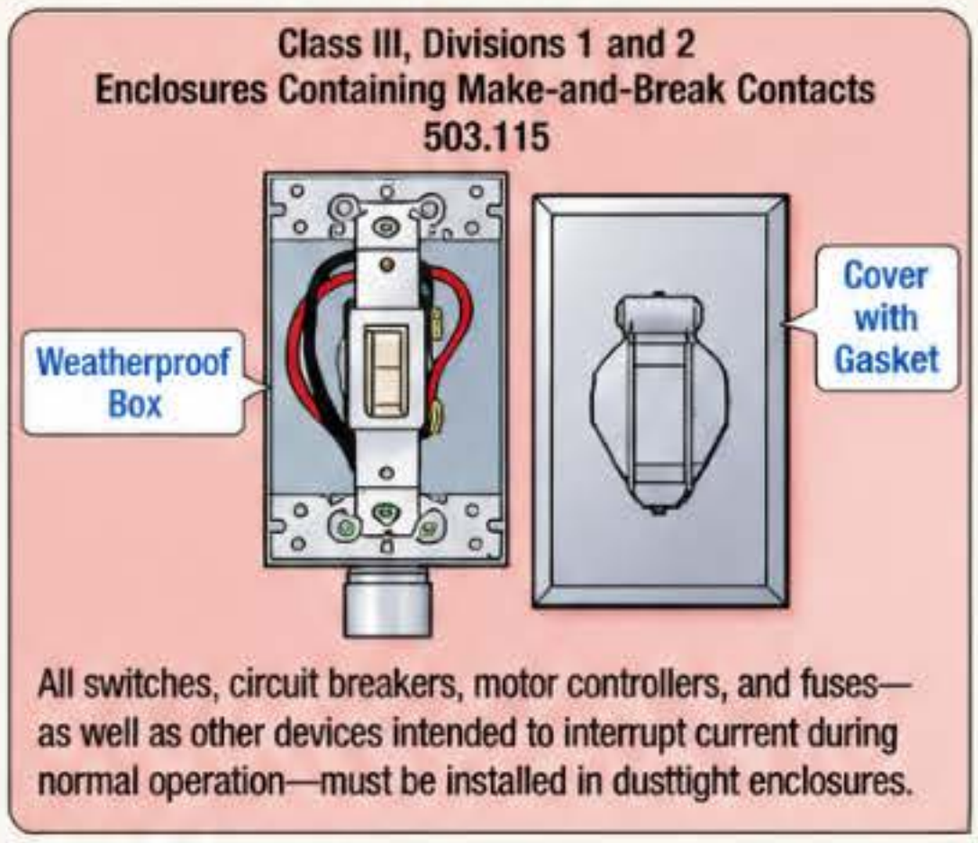


Figure 503–7

Author's Commentary:

A standard weatherproof box fitted with a cover and gasket satisfies this requirement.

— Michael Hamilton

503.125 Motors and Generators

Motors and generators installed in Class III locations must be completely enclosed, nonventilated, use pipe ventilation, or be cooled by a fan.

503.130 Luminaires

Luminaires installed in Class III locations must comply with these requirements:

(A) Fixed Lighting. Luminaires must be designed to minimize the entrance of fibers/fluff and to prevent the escape of sparks, burning material, or hot metal.

▸ Figure 503–8

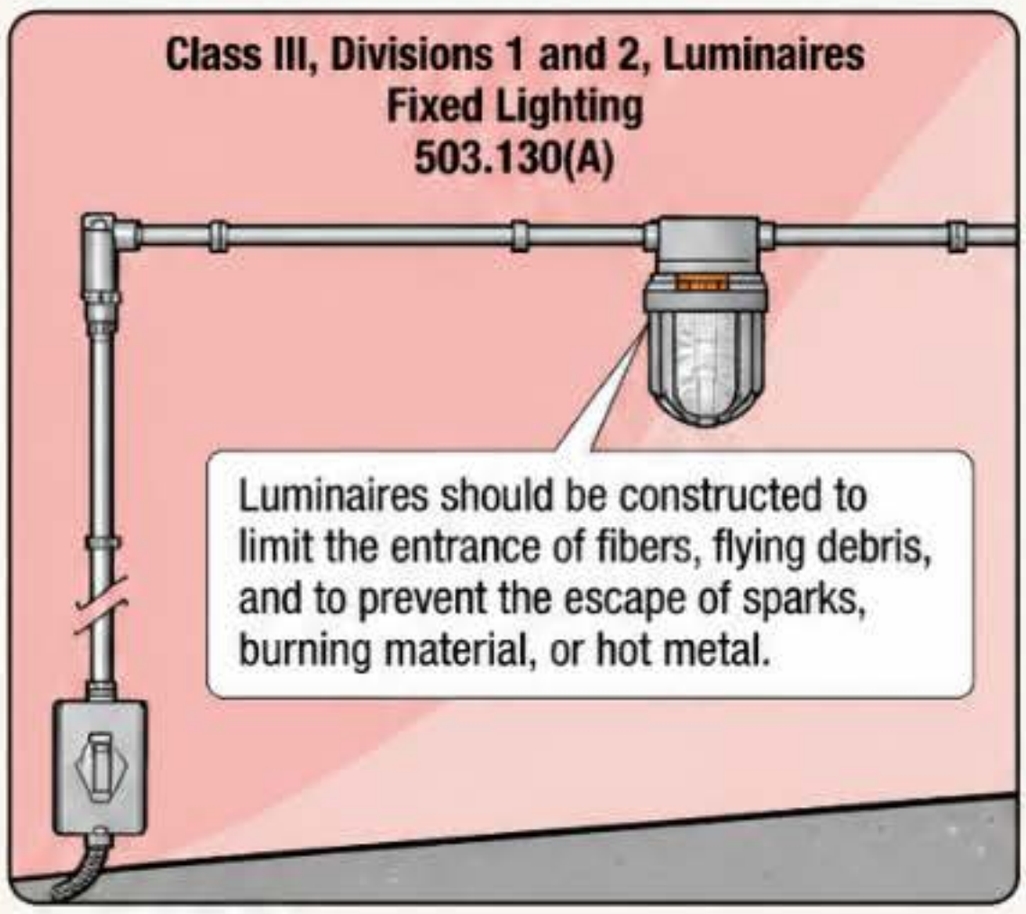


Figure 503–8

(B) Physical Damage. Luminaries exposed to potential impact must be guarded by enclosures designed for that protection.

(C) Pendant Luminaires. Suspended luminaires must be hung from rigid metal stems with threaded rigid metal conduit, rigid intermediate metal conduit (IMC), threaded metal tubing of the proper wall thickness, or chains fitted with approved hardware.

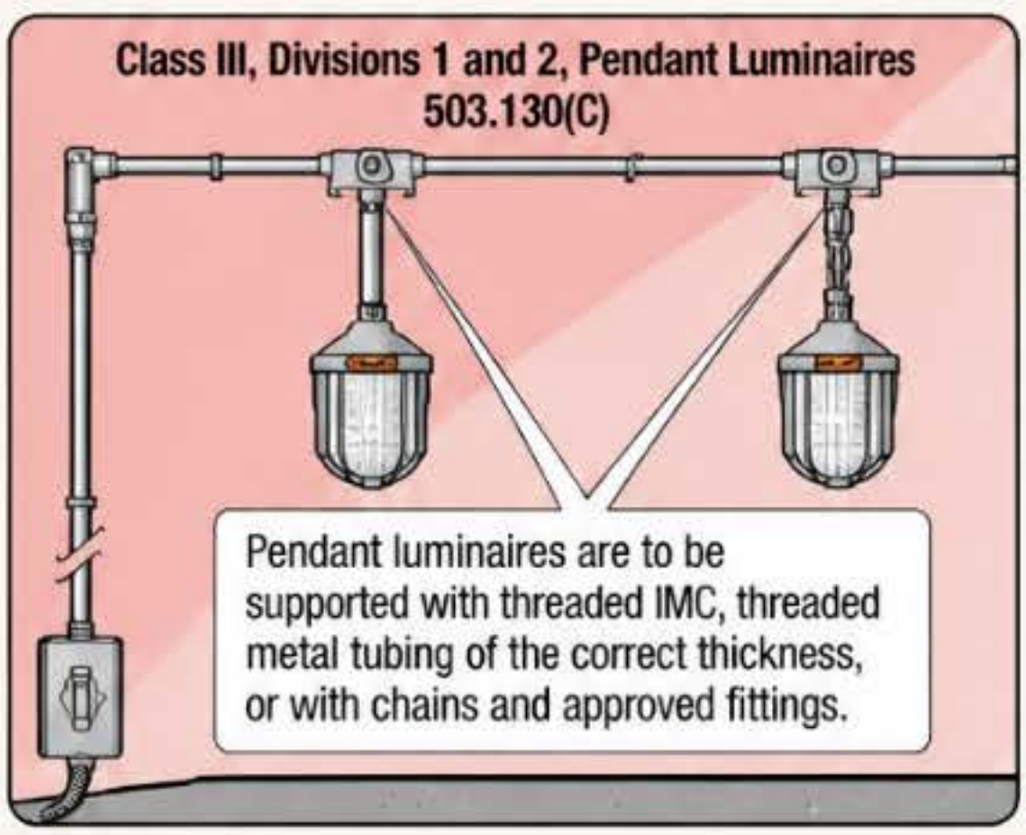


Figure 503–9

When stems exceed one foot in length, bracing against side-to-side movement is required no more than one foot above the lower end of the stem. This bracing may be by an approved fitting or a flexible connector, located within one foot of the attachment point at the supporting box or fitting.

(D) Portable Luminaire Equipment. Hand-carried luminaire equipment must have handles and be fitted with guards that provide solid protection. Each unit must be of the unswitched type and cannot include a receptacle for attaching additional equipment.

503.140 Flexible Cords

Flexible cords must:

1. Be of the extra-hard usage type.
2. Include an equipment grounding conductor.
3. Be supported so there is no tension on the connections.
4. End with a listed dusttight connector.

503.145 Receptacles and Attachment plugs

Receptacles and attachment plugs in Class III locations must be positioned to reduce the likelihood of fibers or debris accumulation or entry from airborne materials.

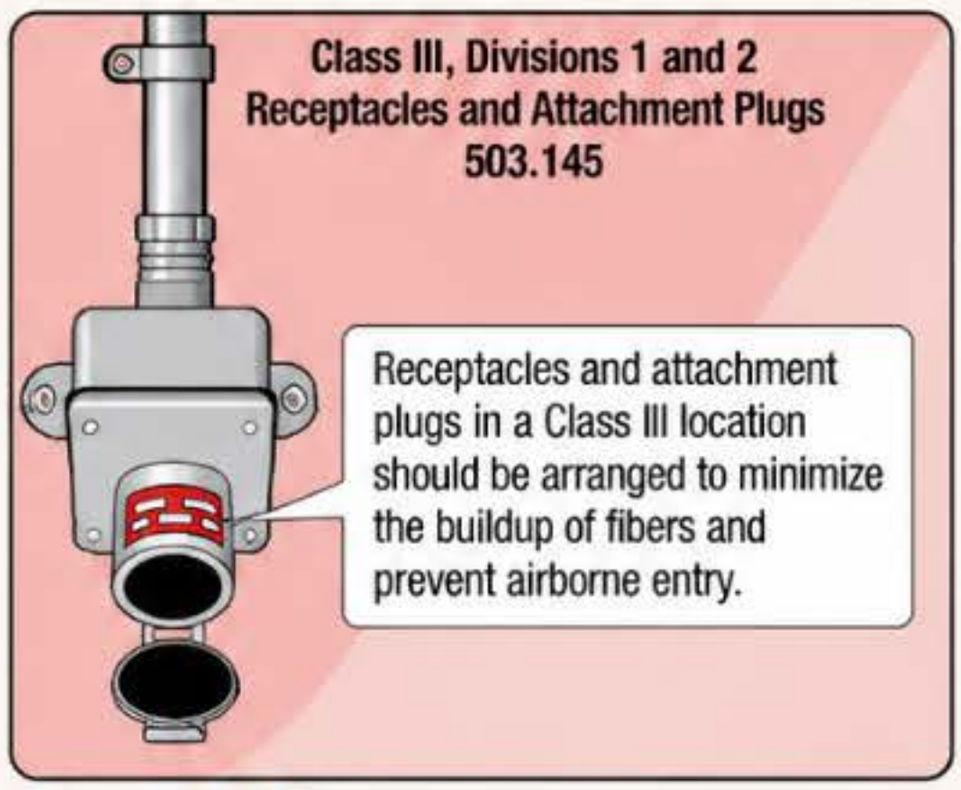


Figure 503–10

Example: General-purpose grounding-type receptacles that are easy to access can be used for routine cleaning and mounted to reduce the entry of fibers or debris.

503.150 Limited-Energy and Communications Systems

Signaling equipment, remote-control systems, and local loudspeaker systems must follow Article 503 requirements for wiring, switches, transformers, resistors, motors, luminaires, and related components.

ARTICLE 511 COMMERCIAL GARAGES, REPAIR AND STORAGE

Introduction to Article 511—Commercial Garages, Repair and Storage

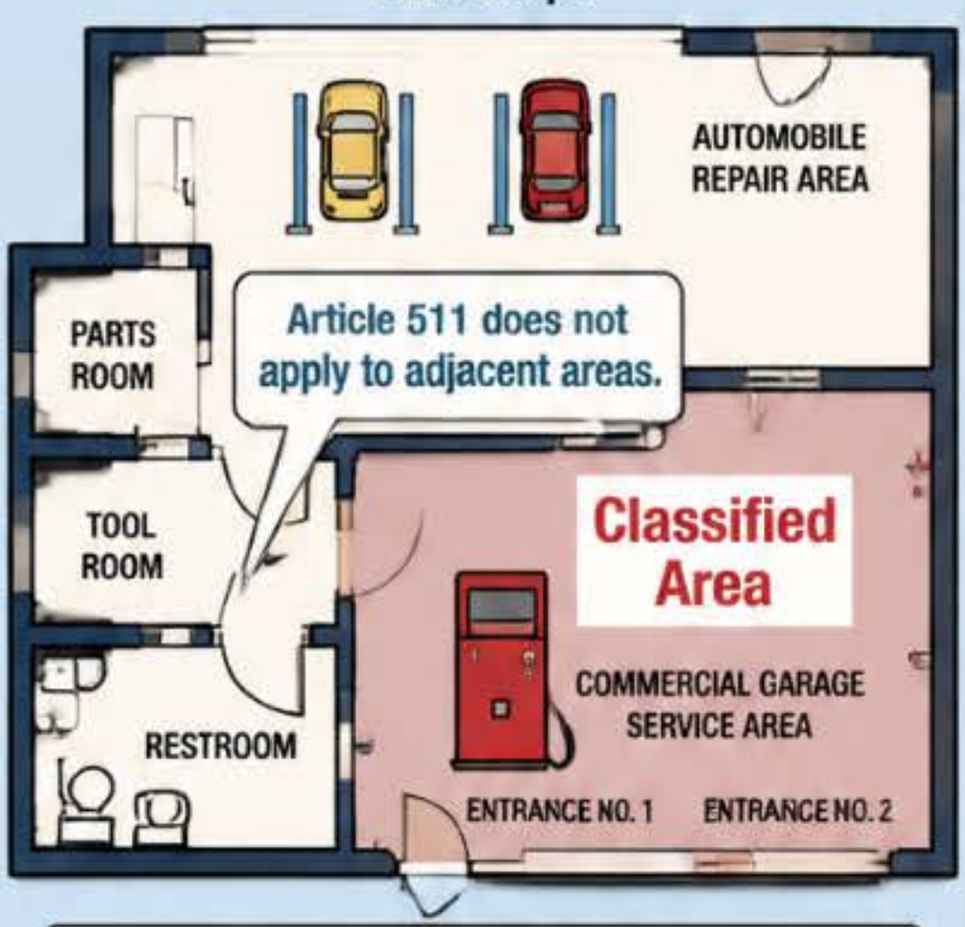
Article 511 deals with locations where vehicles are serviced or repaired and where volatile flammable liquids or flammable gases may be present for fueling purposes.

To apply the rules correctly, it is important to determine if the facility is a major or minor repair garage. Another key factor is whether there is a pit located below the floor. Mechanical ventilation plays a vital role and can affect how a space is classified. Read this material closely, study the illustrations, and you will see that the Article 511 requirements are not as hard to understand as they might first appear.

511.1 SCOPE

Article 511 applies to locations used for service and repair of self-propelled vehicles. This includes passenger cars, buses, trucks, tractors, and similar equipment in which volatile flammable liquids or flammable gases may be present for fueling or to generate power. **Figure 511-1**

Commercial Garages, Repair and Storage
511.1 Scope



Article 511 covers sites used for the servicing and repair of self-propelled vehicles where volatile flammable liquids or gases are stored for fuel or power purposes.

▶ **Figure 511-1**

Author's Commentary:

- Areas covered by Article 511 include automotive service and repair shops; service and repair garages for commercial vehicles such as trucks and tractors; and repair garages for fleets of cars, buses, and trucks, as well as establishments that service motorcycles and all-terrain vehicles (ATVs).
- This article does not apply to garages that service diesel-fueled or electrically powered vehicles.
- The definitions used in this article can be found in Part III of Article 100.

— Michael Hamilton

511.3 CLASSIFICATION OF HAZARDOUS AREAS

General. Areas where flammable liquids or gaseous fuels are stored, handled, or transferred, or where electrical wiring and equipment are installed, must be classified according to the requirements for Class I, Division 1 or 2 hazardous (classified) locations.

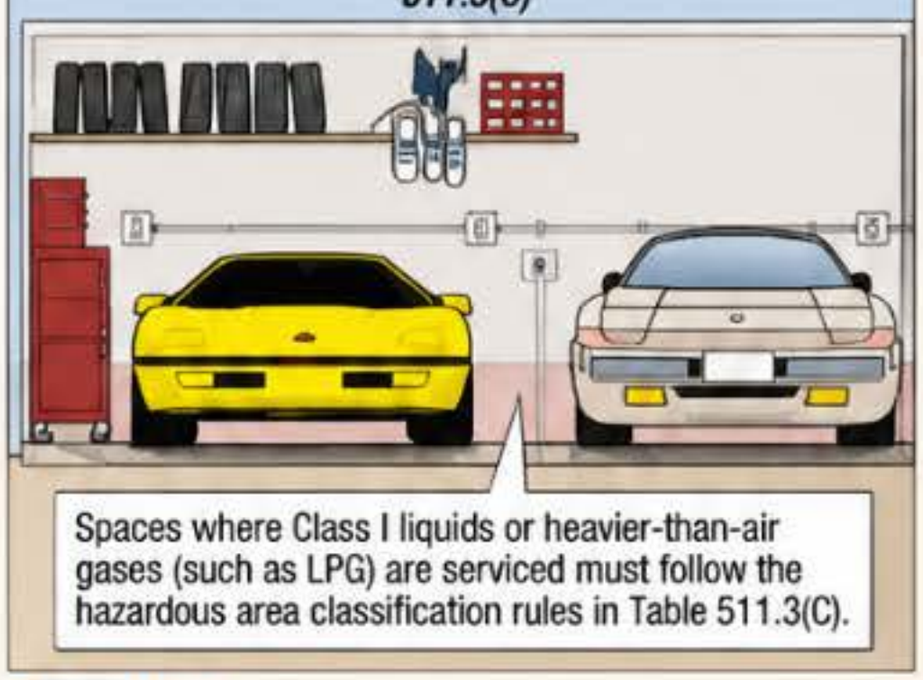
(A) Parking Garages. Parking or storage garages do not need to be classified.

(B) Repair Garages, With Dispensing. Repair garages that dispense motor fuels, whether major or minor, must be classified as required by Table 514.3(B)(1).

511.7 Commercial Garages, Repair and Storage

(C) Major and Minor Repair Garages. Any space where vehicles that run on flammable liquids or heavier-than-air gases—such as LPG—are serviced, the hazardous area classification rules in Table 511.3(C) must be applied. ▸ **Figure 511–2**

Commercial Garages, Repair and Storage, Area Classification Major and Minor Repair Garages
511.3(C)



▸ **Figure 511–2**

> **Author's Commentary:**
> NFPA 30A, *"Code for Motor Fuel Dispensing Facilities and Repair Garages,"* is a valuable source for fire safety at fuel dispensing operations and vehicle repair facilities.
>
> — *Michael Hamilton*

(D) Major Repair Garages. Spaces where vehicles using lighter-than-air gases—such as hydrogen or natural gas—are repaired, dismantled, or stored must follow the hazardous area classification rules in Table 511.3(D).

> **Author's Commentary:**
> The rules for vehicles fueled by lighter-than-air gases (such as hydrogen and natural gas) are for repairs, storage, and minor repair work. Those provisions do not appear in Table 511.3(D).
>
> — *Michael Hamilton*

(E) Modifications to Classification.

(1) Classification of Adjacent Areas. Neighboring spaces are not classified if they are not mechanically ventilated at four or more air changes per hour, or if walls or enclosures provide an effective barrier from the classified area. ▸ **Figure 511–3**

(2) Alcohol-Based Windshield Washer Fluid. Spaces used to store, handle, or dispense motor vehicle windshield washer fluid that contains alcohol are unclassified unless otherwise listed in 511.3.

Commercial Garages, Repair and Storage Classification of Adjacent Areas
511.3(E)(1)

Spaces next to classified locations are not classified if they are not mechanically ventilated, or if walls or partitions separate the adjacent space from the classified area.

▸ **Figure 511–3**

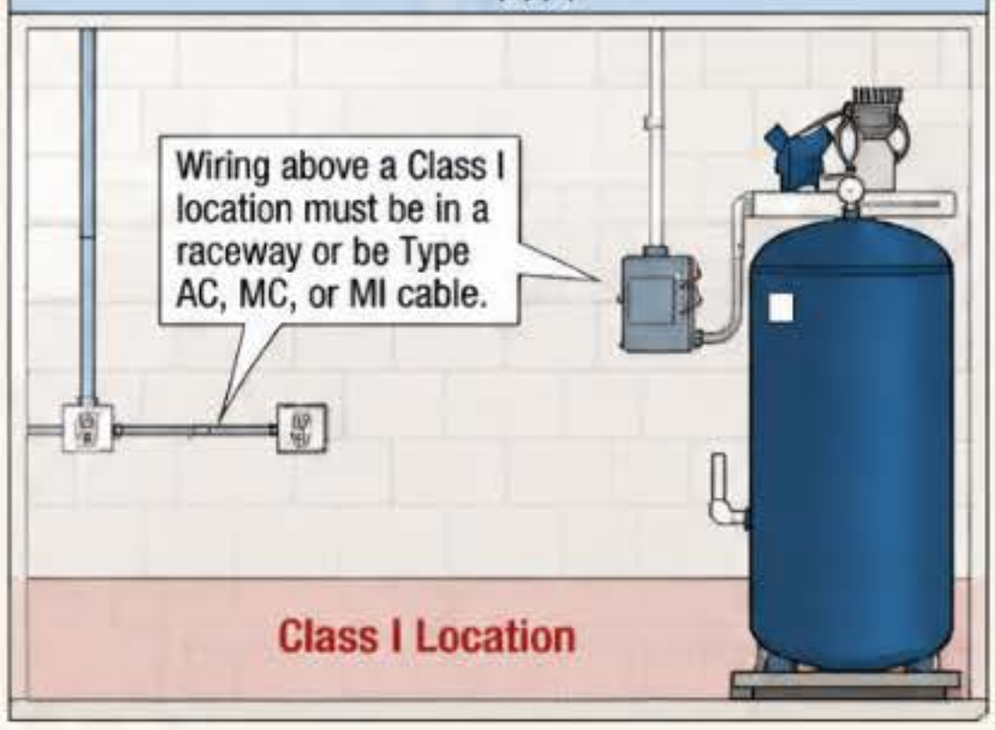
> **Author's Commentary:** Windshield washer fluid is nonflammable.
>
> — *Michael Hamilton*

511.7 Wiring and Equipment Above Hazardous (Classified) Locations

(A) Wiring Above Class I Locations.

(1) Fixed Wiring. Permanent wiring above a Class I hazardous (classified) location must be routed in raceways or be of Type AC, MC, or MI cable. ▸ **Figure 511–4**

Commercial Garages, Repair and Storage Fixed Wiring
511.7(A)(1)



▸ **Figure 511–4**

Commercial Garages, Repair and Storage 511.9

(2) Pendant (Drop-Cords). Flexible cords used for pendant lighting in the kinds of work covered here must be the type approved for that purpose and listed for hard usage.

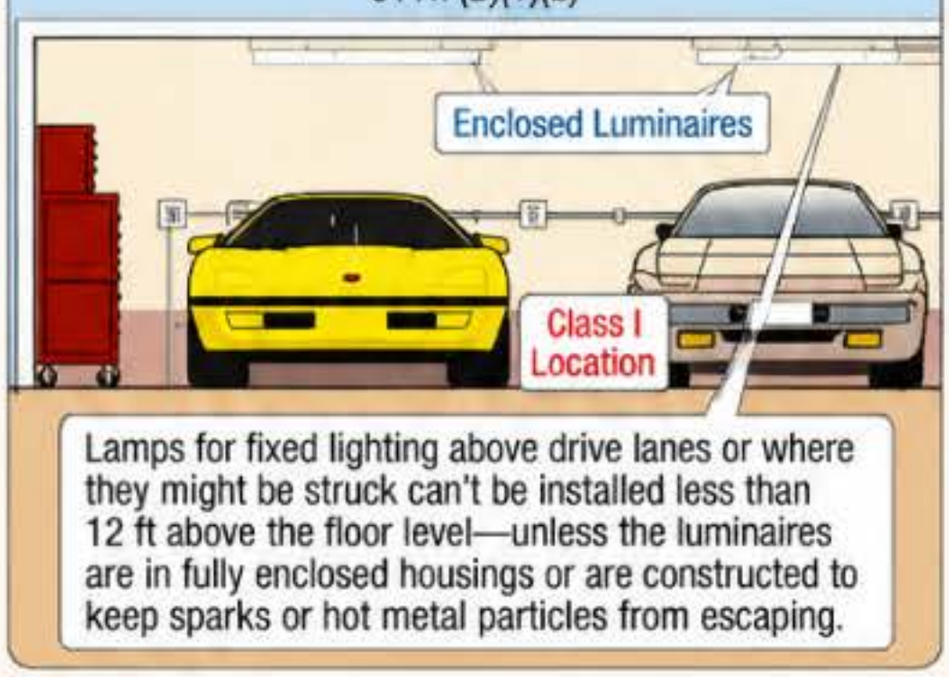
(B) Equipment Above Class I Locations.

(1) Fixed Electrical Equipment. Electrical devices mounted in a set position must be located at or above the level of any identified Class I area.

(a) Arcing Equipment. Equipment that may produce arcs or sparks must be installed no closer than 12 ft above the floor or be completely enclosed or built in so hot metal particles cannot escape.

(b) Fixed Lighting. Lighting for fixed mounting above drive lanes or any area where it could be struck must be placed at least 12 ft above the floor level—unless the fixtures are kept in a fully enclosed housing or are constructed to prevent the escape of sparks or hot metal fragments. • **Figure 511–5**

Commercial Garages, Repair and Storage
Fixed Lighting
511.7(B)(1)(b)



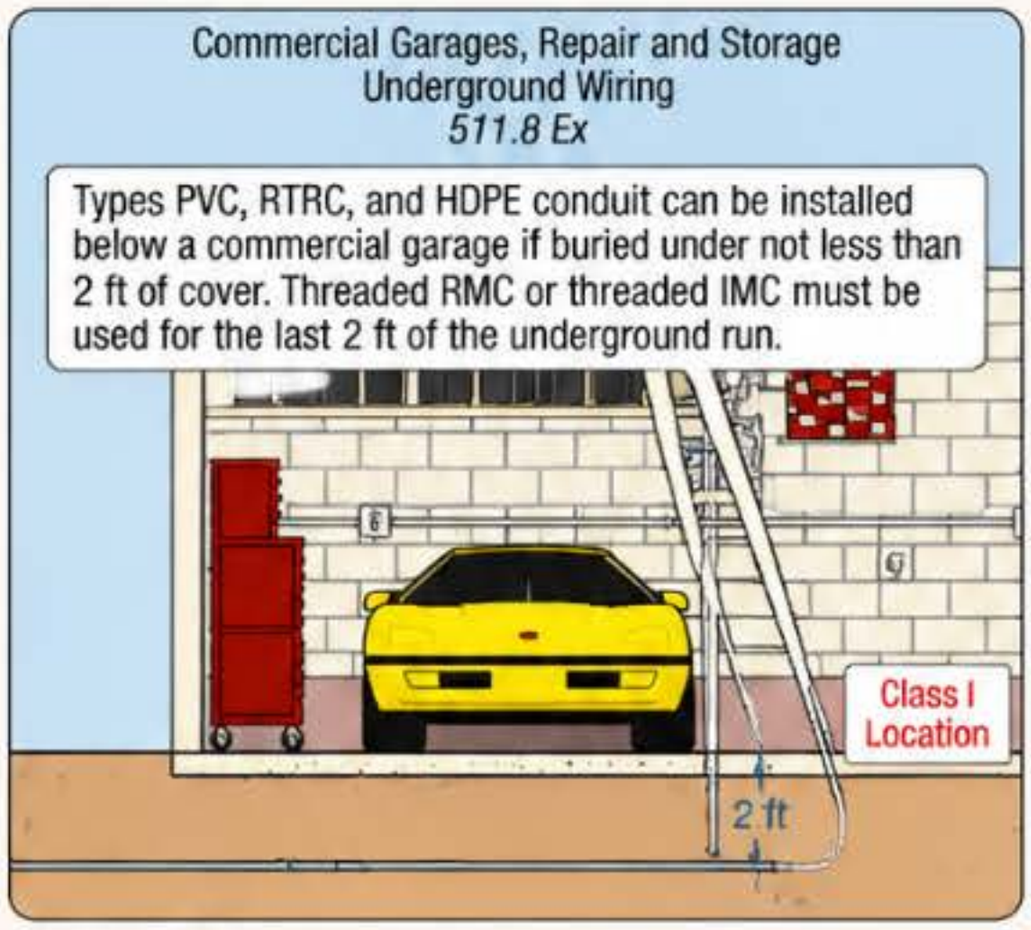
▸ **Figure 511–5**

511.8 Underground Wiring Below Class I Locations

Wiring below a commercial garage must be in threaded rigid metal conduit or in intermediate metal conduit.

Example: Type PVC conduit, Type RTRC conduit, and Type HDPE conduit may be installed below a commercial garage if buried under at least 2 ft of cover. Threaded rigid metal conduit or threaded intermediate metal conduit must be used for the last 2 ft of the underground run. • **Figure 511–6**

Commercial Garages, Repair and Storage
Underground Wiring
511.8 Ex



▸ **Figure 511–6**

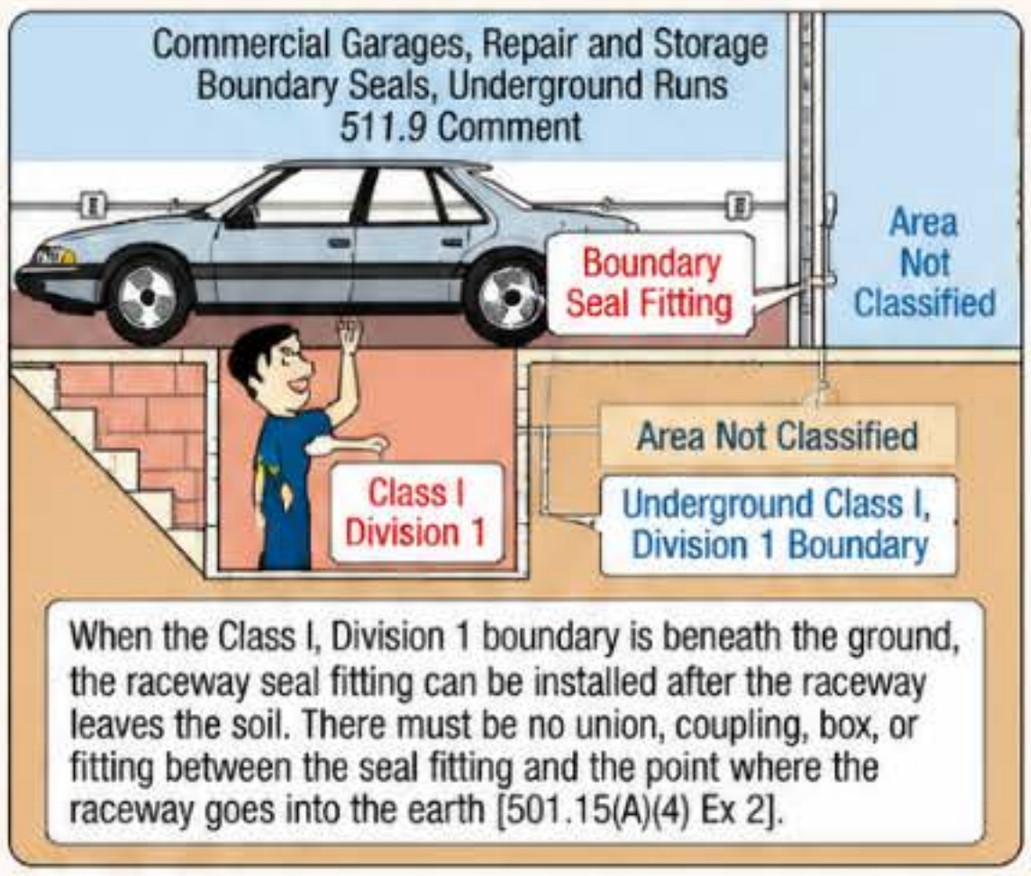
511.9 Seals

Raceway, cable, and boundary seals must be installed following 501.15. They apply both to horizontal and to vertical boundaries that define Class I locations.

Author's Commentary:
When the Class I, Division 1 boundary is beneath the ground, the conduit seal fitting can be put in after the raceway exits the soil. There can be no unions, couplings, boxes, or fittings (except explosionproof reducing bushings) between the seal fitting and the point where the raceway enters the earth [501.15(A)(4) Ex 2].

— Michael Hamilton

Commercial Garages, Repair and Storage
Boundary Seals, Underground Runs
511.9 Comment



▸ **Figure 511–7**

511.10 | Commercial Garages, Repair and Storage

511.10 Special Equipment

(A) Battery Charging Equipment. Battery chargers and batteries being charged are not allowed to be located within an area classified in accordance with 511.3(B).

511.12 GFCI-Protected Receptacles

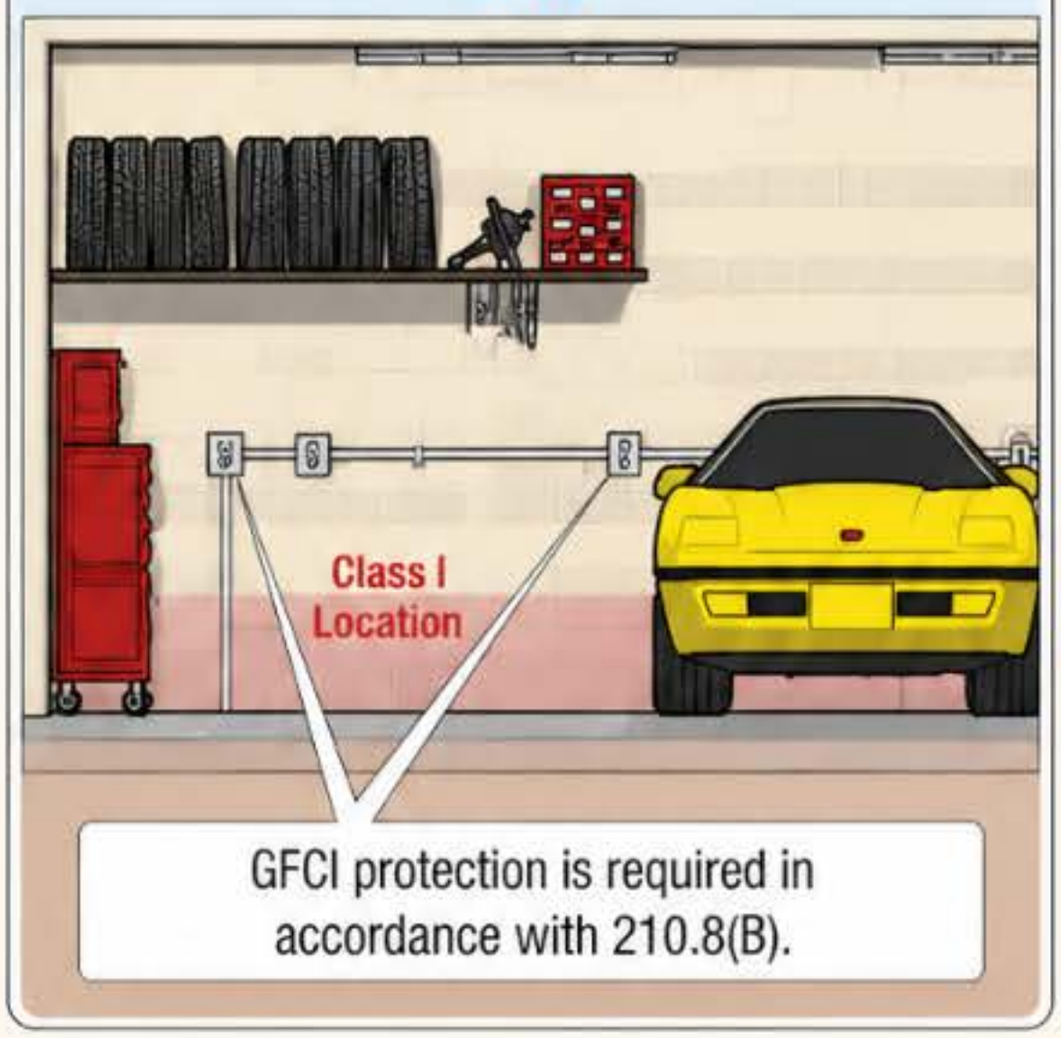
GFCI protection is required in accordance with 210.8(B).
▶ Figure 511-8

Author's Commentary:

- GFCI protection must be used for receptacles rated up to 50A, single-phase, and for receptacles up to 100A, three-phase that are supplied by circuits rated 150V to ground or less per 210.8(B).

— Michael Hamilton

Commercial Garages, Repair and Storage
GFCI-Protected Receptacles
511.12



▶ Figure 511-8

ARTICLE

514 MOTOR FUEL DISPENSING FACILITIES

Introduction to Article 514—Motor Fuel Dispensing Facilities

This article covers the part of an installation where fuel is kept and transferred from storage tanks into the fuel tanks of motor vehicles, boats, or into containers that are listed and approved.

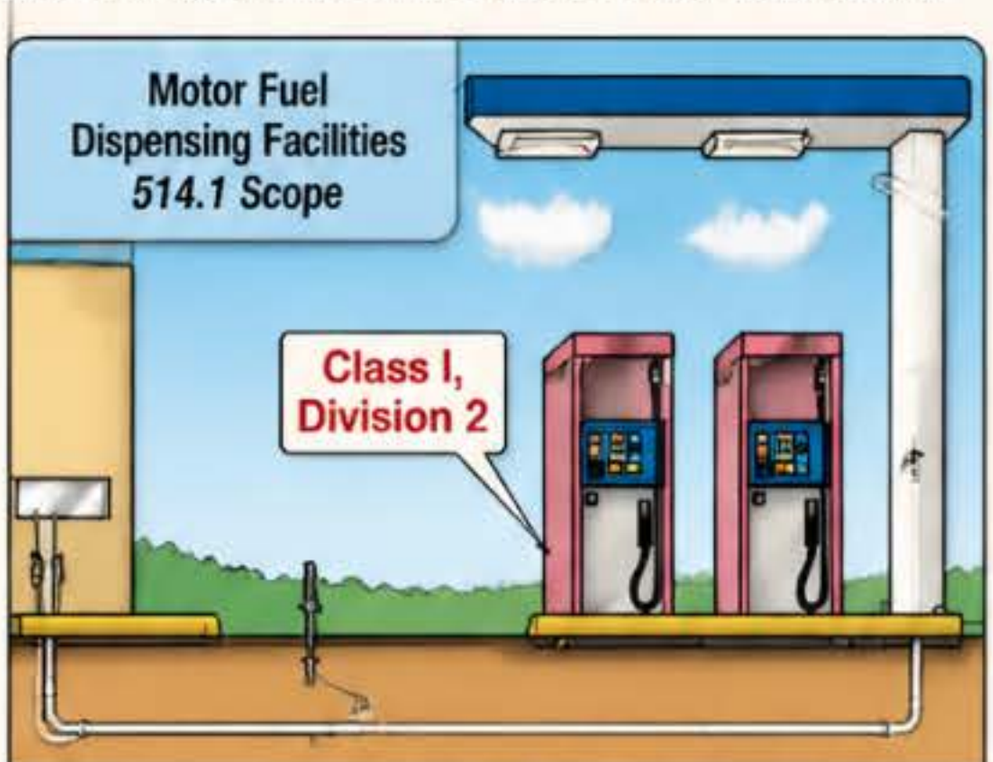
The largest table in this article accounts for nearly half of its length. It does not specify any electrical requirements, itemize materials, or list electrical equipment. Its purpose is to help you decide which classification a motor fuel dispensing area falls under. The rest of the article gives the electrical rules for those classifications and points you to other articles that provide additional details.

Author's Commentary:
Diesel fuel is not a flammable liquid. Therefore, equipment for dispensing diesel and the wiring connected to it are not required to meet the hazardous (classified) location rules of Article 514 [514.3(A)]. Other provisions in this article still remain in effect.

— Michael Hamilton

514.1 Scope

Article 514 applies to motor fuel dispensing facilities, marine/motor fuel dispensing facilities, motor fuel dispensing facilities located inside buildings, and fleet vehicle motor fuel dispensing facilities.



Article 514 applies to motor fuel and marine/motor fuel dispensing facilities, motor fuel dispensing facilities located inside buildings, and fleet vehicle motor fuel dispensing facilities.

▶ Figure 514–1

514.3 Classification of Locations

(A) Unclassified Locations. If the authority having jurisdiction determines that flammable liquids having a flash point at or above 100°F (such as gasoline) will not be handled, such locations can be unclassified.

(B) Classified Locations.

(1) Class I Locations. Table 514.3(B)(1) must be used to classify motor fuel dispensing facilities and commercial garages as described in 511.2 where a flammable liquid having a flash point below 100°F [Article 100 Volatile Flammable Liquid] is stored, handled, or dispensed.

A Class I location does not extend beyond an unpierced wall, roof, or any other solid barrier.

Author's Commentary:
If electrical conduit for a diesel dispenser runs through the Class I area around a gasoline dispenser, then the installation must follow the sealing and wiring method requirements of Article 501.

— Michael Hamilton

▶ Figure 514–2

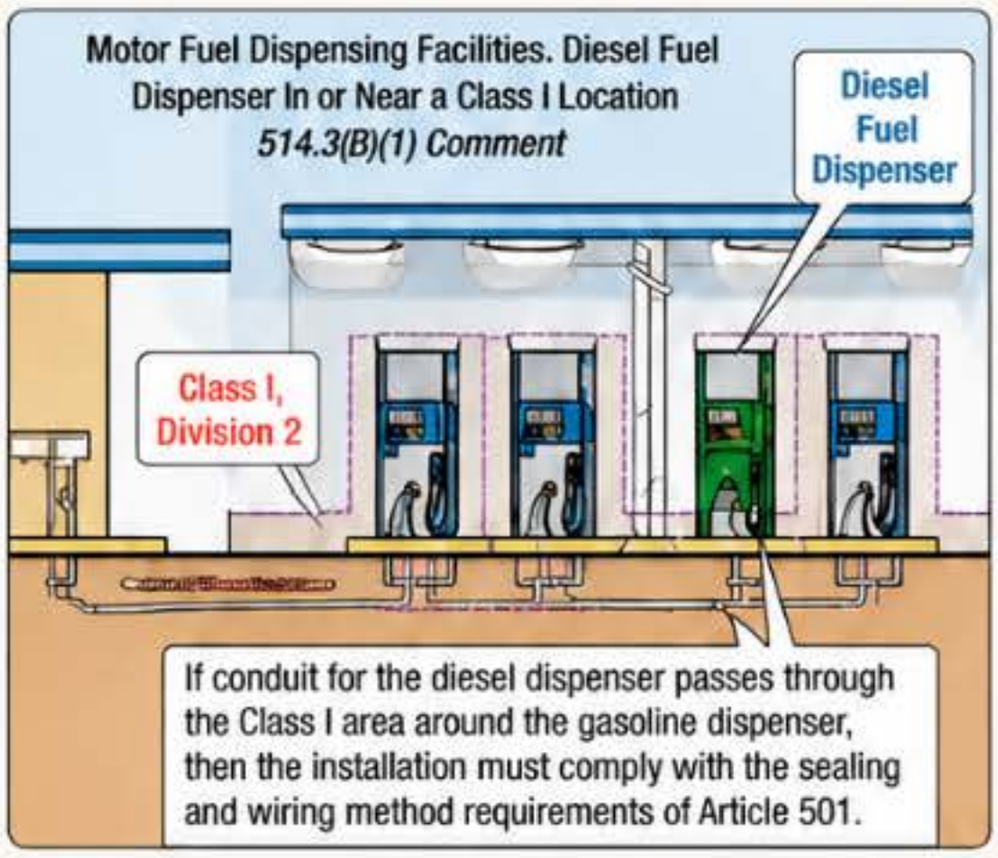


Figure 514–2

(C) Motor Fuel Dispensing Stations in Marinas and Boatyards.

(1) General. Electrical wiring and equipment serving motor fuel dispensing locations must be installed on the side of the wharf, pier, or dock opposite from the fuel piping system. ▸Figure 514–3

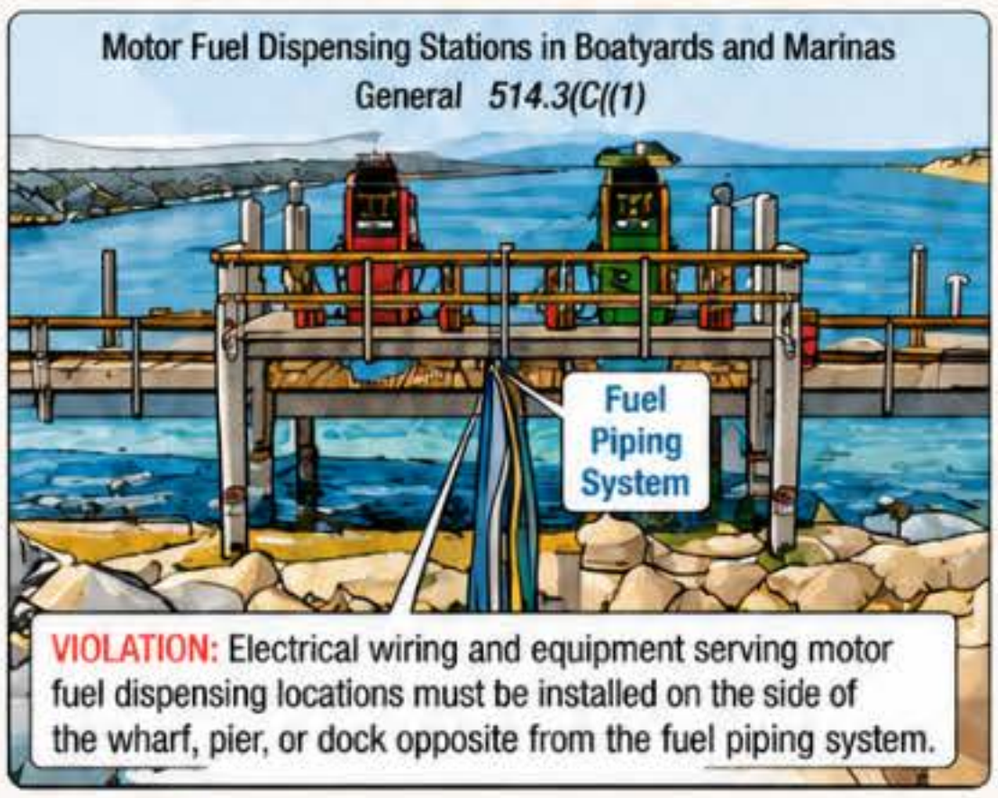


Figure 514–3

Author's Commentary:

- Electrical wiring and equipment for motor fuel dispensing stations covered by Article 514 located in marinas, boatyards, and docking facilities must also comply with Article 555 [555.11].

— Michael Hamilton

(E) Open Construction. Where the construction of piers, wharfs, or docks is open, the following applies:

(1) The area 18 in. above the surface of the dock, pier, or wharf and extending 20 ft horizontally in all directions from the outside edge of the dispenser and down to the water le is considered a Class 1, Division 2 location. ▸Figure 514–4

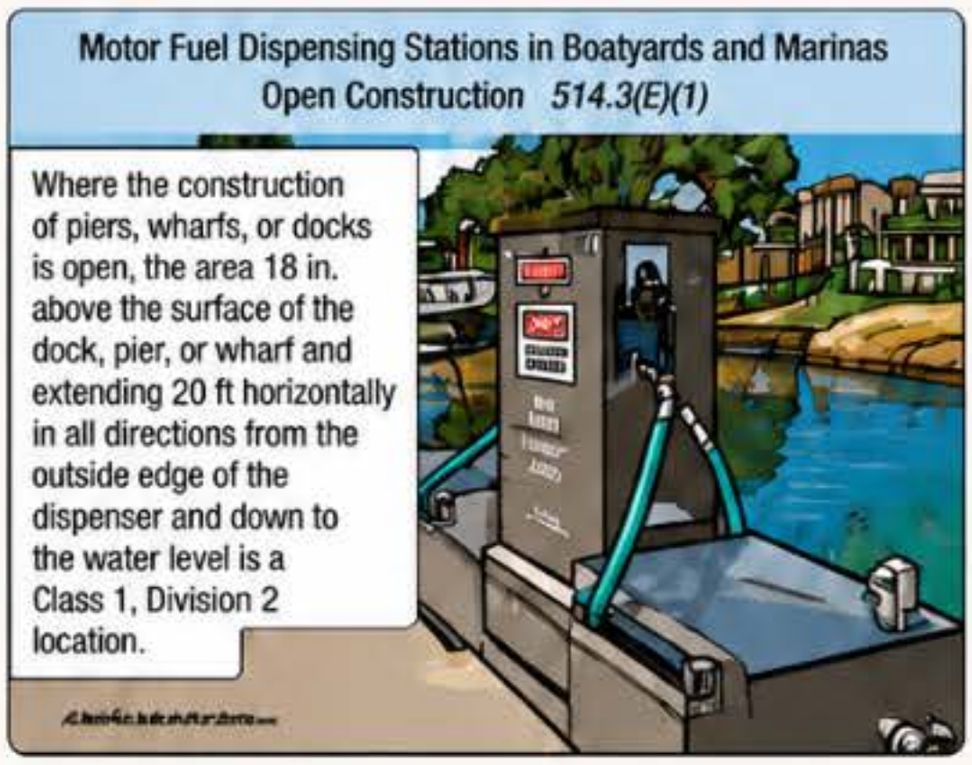


Figure 514–4

514.4 Wiring and Equipment Within Class I Locations

Electrical equipment and wiring within a Class I location, as defined in Table 514.3(B)(1), must comply with Article 501.

Ex: PVC conduit is permitted underground in accordance with 514.8 Ex 2.

514.7 Wiring and Equipment Above Class I Locations

Wiring above a Class I location, as defined in Table 514.3(B)(1), must be installed within a raceway or must be Types AC, MC, MI, PLTC, or TC cable [511.7(A)(1)]. ▸Figure 514–5

514.8 Underground Wiring

Wiring beneath a classified location must be installed in threaded rigid metal conduit or threaded intermediate metal conduit. Electrical conduits located below the surface of a Class I, Division 1 or 2 location, as contained in Table 514.3(B)(1) and Table 514.3(B)(2), must be sealed within 10 ft of the point of emergence above grade. ▸Figure 514–6

Motor Fuel Dispensing Facilities | 514.9

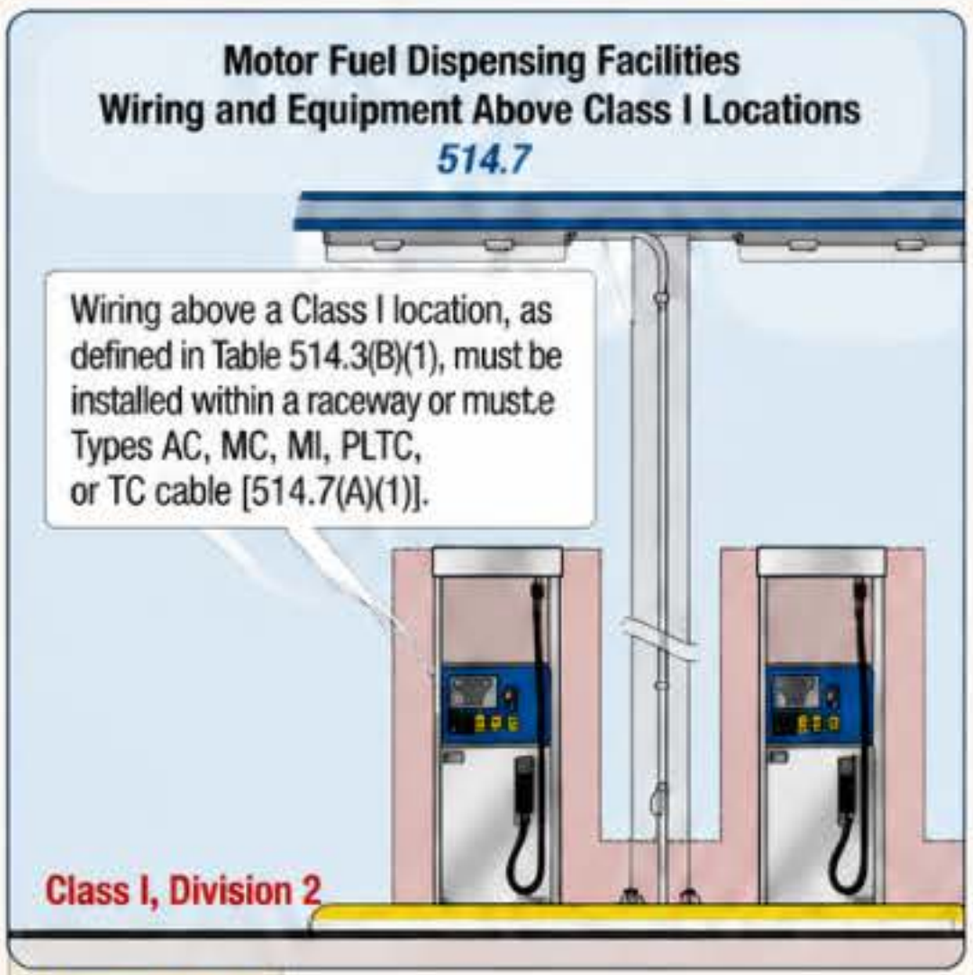


Figure 514–5

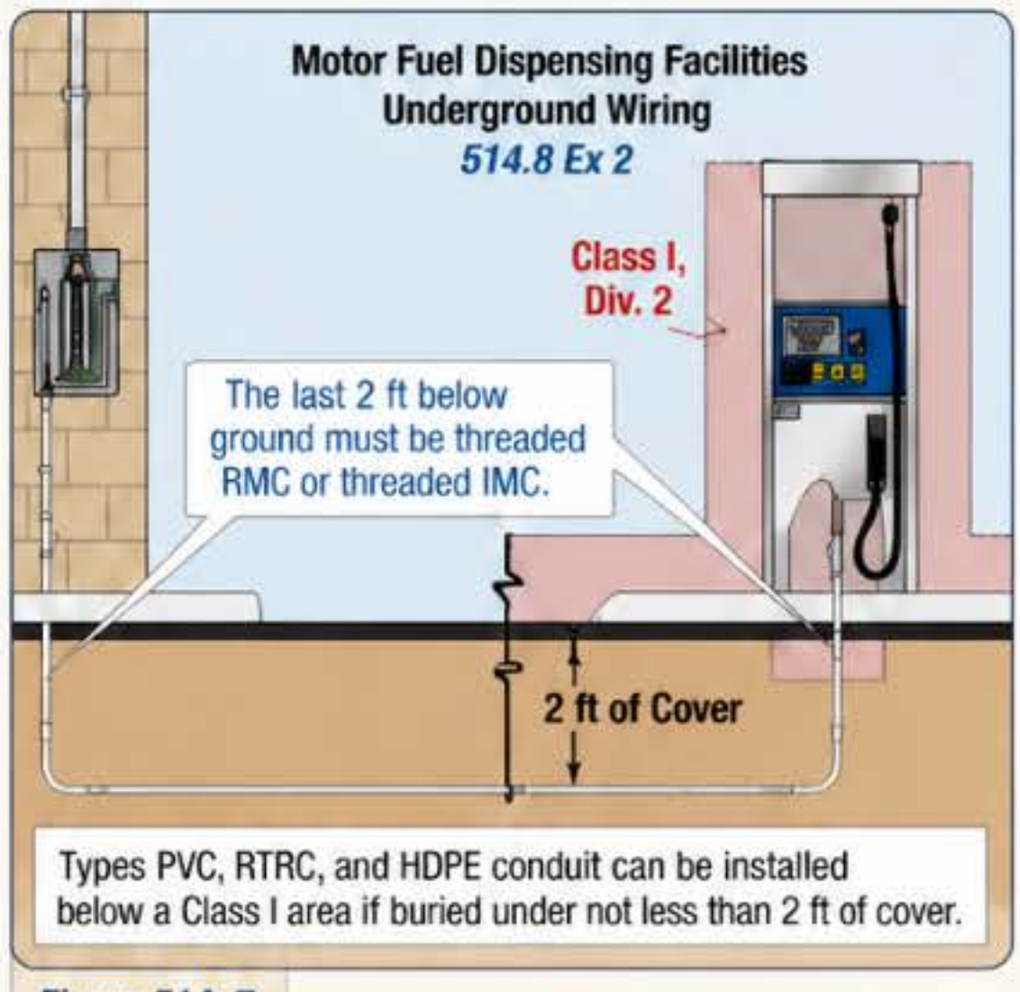


Figure 514–7

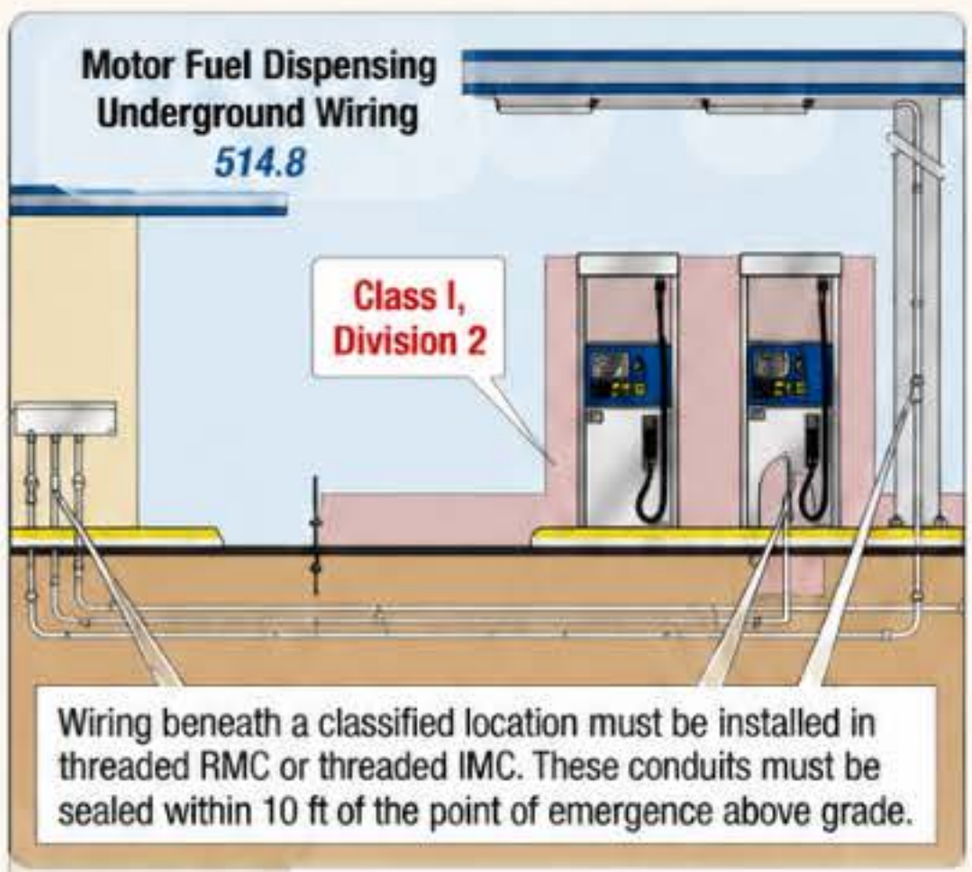


Figure 514–6

Except for listed explosionproof reducers at the conduit seal fitting, there must be no union, coupling, box, or fitting between the conduit seal fitting and the point of emergence above grade.

Ex 2: Type PVC conduit, Type RTRC conduit, and Type HDPE conduit can be installed below a classified location if buried under not less than 2 ft of cover. Threaded rigid metal conduit or threaded intermediate metal conduit must be used for the last 2 ft of the underground run. ▸**Figure 514–7**

Author's Commentary:

The underground space beneath dispensers is not considered a classified location because oxygen levels there are too low to support ignition. However, a small amount of gasoline can be present in the soil. For this reason, the Code includes rules for underground installations, ensuring that you must follow 514.8 even if passing under the area does not actually supply equipment at the classified location.

— *Michael Hamilton*

514.9 Conduit Seal

(A) At Dispenser. A listed conduit seal fitting must be installed in each raceway run that enters or exits a dispenser. The conduit seal fitting or listed explosionproof reducer at the seal must be the first fitting after the raceway emerges from the Earth's surface or concrete. ▸**Figure 514–8**

(B) At Boundary. An additional conduit seal fitting that complies with 501.15(A)(4) and (B)(2) must be installed in each raceway run that leaves a Class I location. ▸**Figure 514–9**

Author's Commentary:

When the boundary is below grade, the sealing fitting may be placed after the raceway comes up out of the soil, but there cannot be any union, coupling, box, or other fitting listed explosionproof between the sealing fitting in the raceway and the spot where the raceway reaches the Earth's surface [501.15(A)(4) Ex 2].

— *Michael Hamilton*

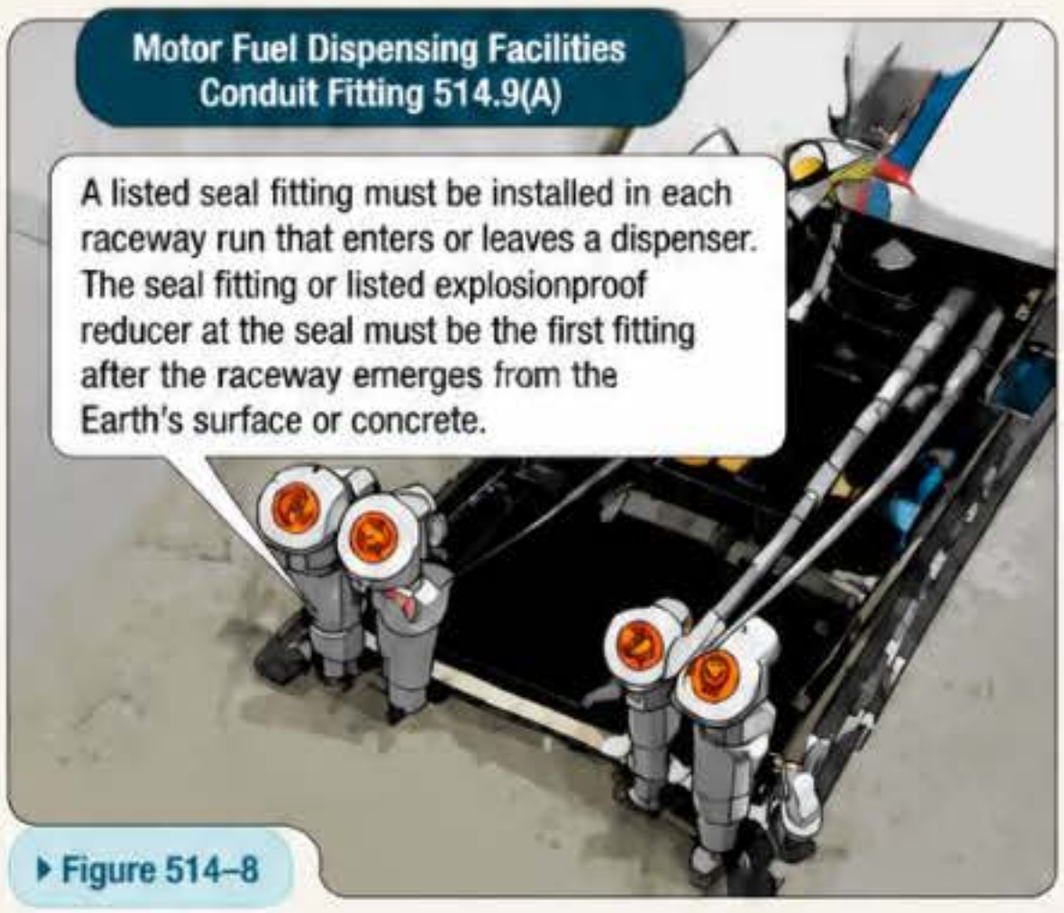


Figure 514–8

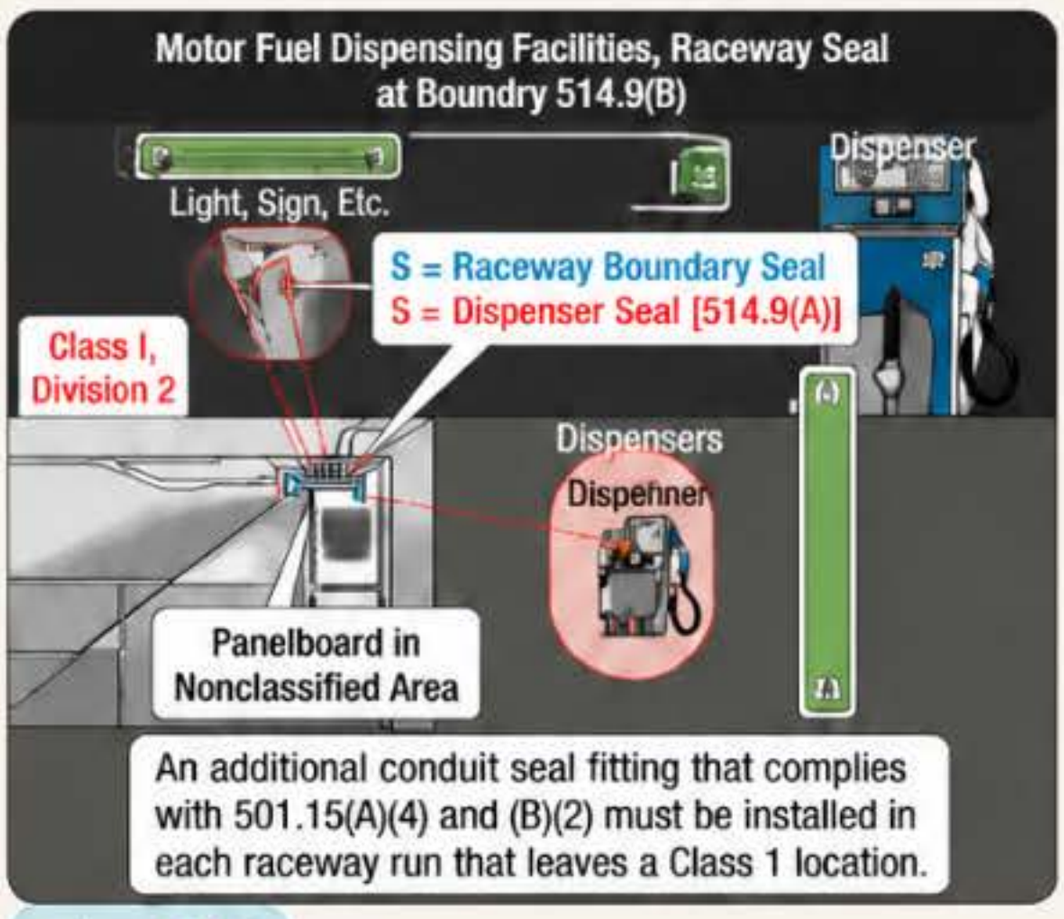


Figure 514–9

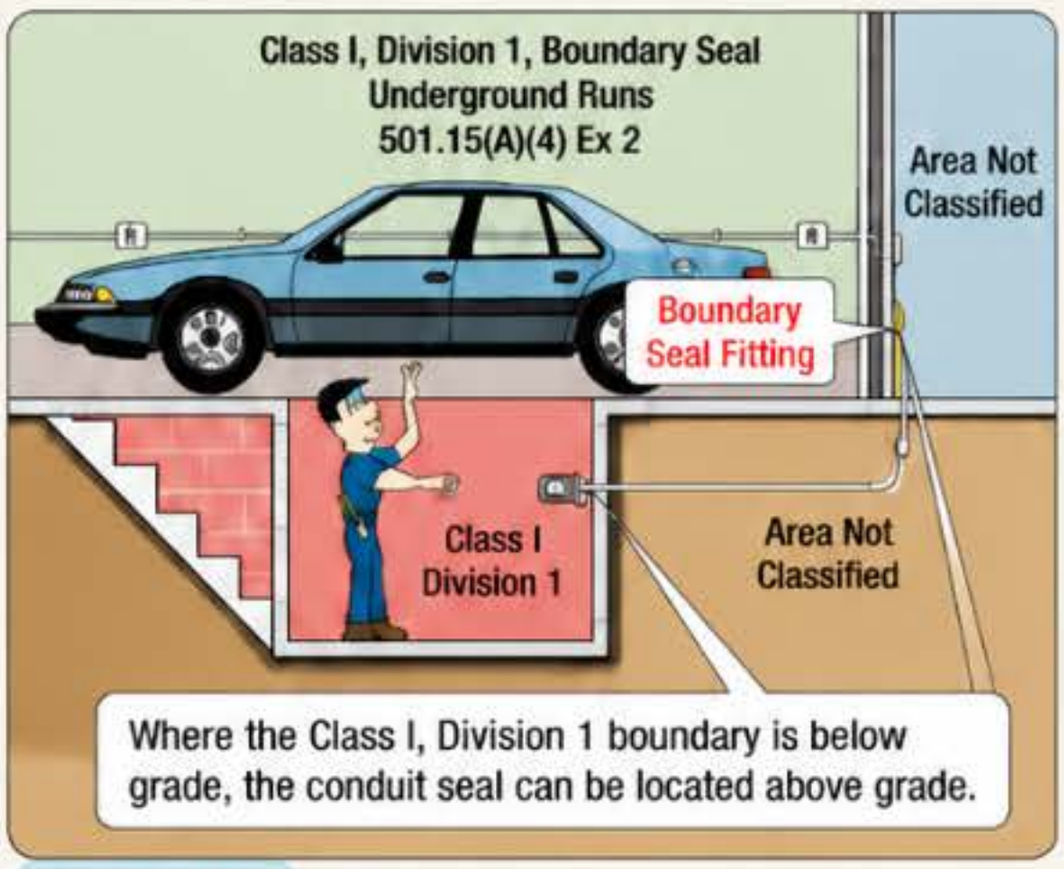


Figure 514–10

514.16 Grounding and Bonding

Because of the explosive conditions associated with electrical installations in hazardous (classified) locations [500.5], electrical continuity of metal parts of equipment and raceways must be ensured by grounding and bonding. Grounding and bonding in Class 1 locations must comply with 501.30.

Figure 514–11

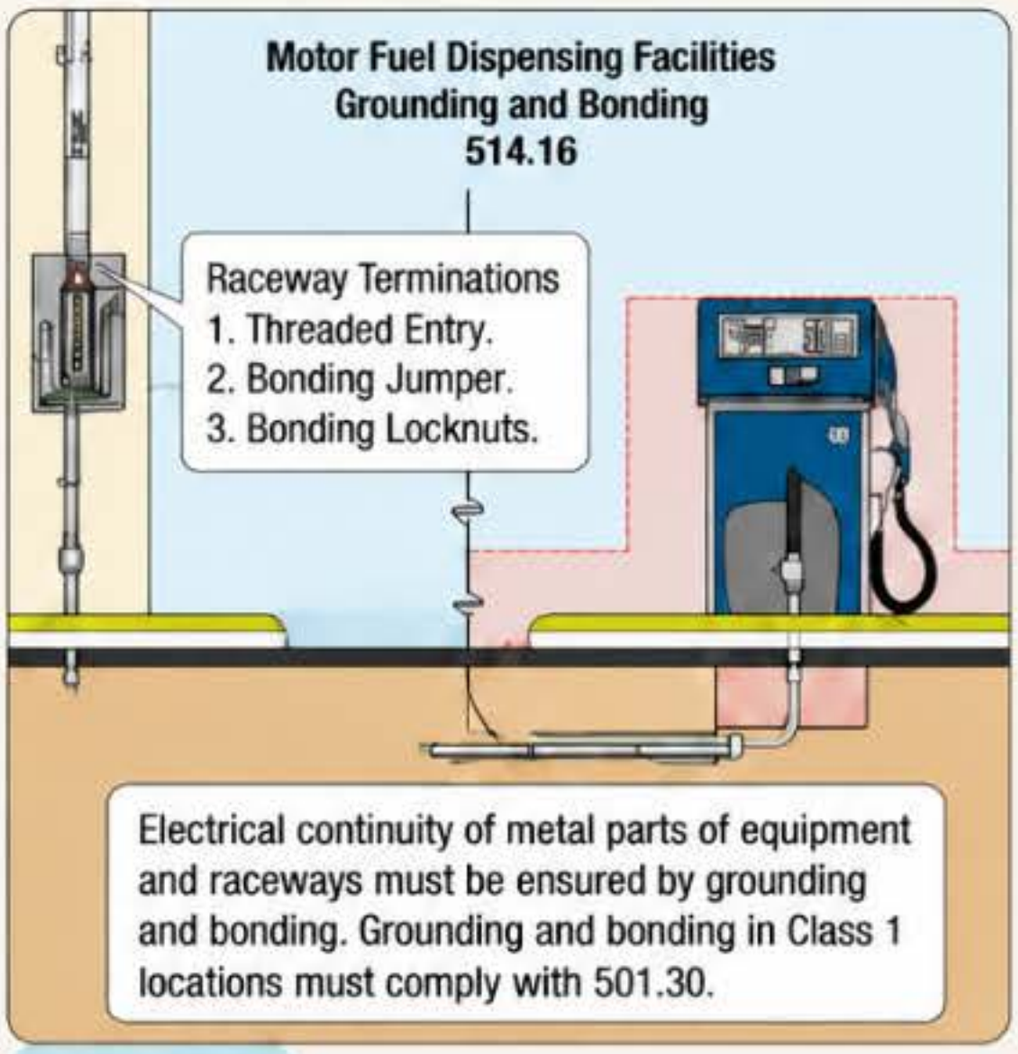


Figure 514–11

Author's Commentary:

- Consult 250.100 for bonding at Class 1 locations as defined in 500.5, and apply the approach described in 250.92(B)(4) to determine whether the equipment grounding conductor of the wire type is installed or not.

— Michael Hamilton

ARTICLE 517 HEALTH CARE FACILITIES

Introduction to Article 517—Health Care Facilities

Health care facilities are built differently from many other types of structures. Article 517 focuses on those portions of health care facilities where patients are evaluated and treated. Whether the facility is fixed in place or can be moved, it must comply with the scope of this article. However, Article 517 wiring and protection requirements do not apply to administrative offices or waiting areas, and they do not extend to animal veterinary buildings.

This article contains many specialized definitions that apply only to health care environments. You do not have to memorize them, but you should understand their meaning. As you study Parts I and III, keep in mind the unique needs of hospitals and why these rules exist. The requirements are highly detailed and not self-evident. Two main objectives are at the heart of Article 517, Parts II and III:

- Safeguard people by requiring metal raceways for wiring.
- Reduce electrical hazards by maintaining a low voltage difference between the patient's body and medical equipment.

Part IV covers gas anesthesia locations. Its central goal is to prevent ignition.

Part V addresses X-ray installations and has two key goals:

- Ensure adequate ampacity and overcurrent protection for branch circuits.
- Control safety issues in high-voltage equipment installations.

Part VI sets out the rules for low-voltage communications systems, such as fire alarms and intercoms. Its main purpose is to prevent interference that could degrade system performance.

Part VII outlines requirements for isolated power systems, with the main goal of keeping them truly isolated.

Remember that the *NEC* is just one of the standards that apply to health care facilities, and other standards or special equipment rules may also be required.

Part I General

517.1 Scope

Article 517 applies to electrical wiring in health care facilities such as hospitals, nursing homes, limited care and supervisory care facilities, clinics, medical and dental offices, and ambulatory care facilities that provide services to human beings.

- Figure 517-1

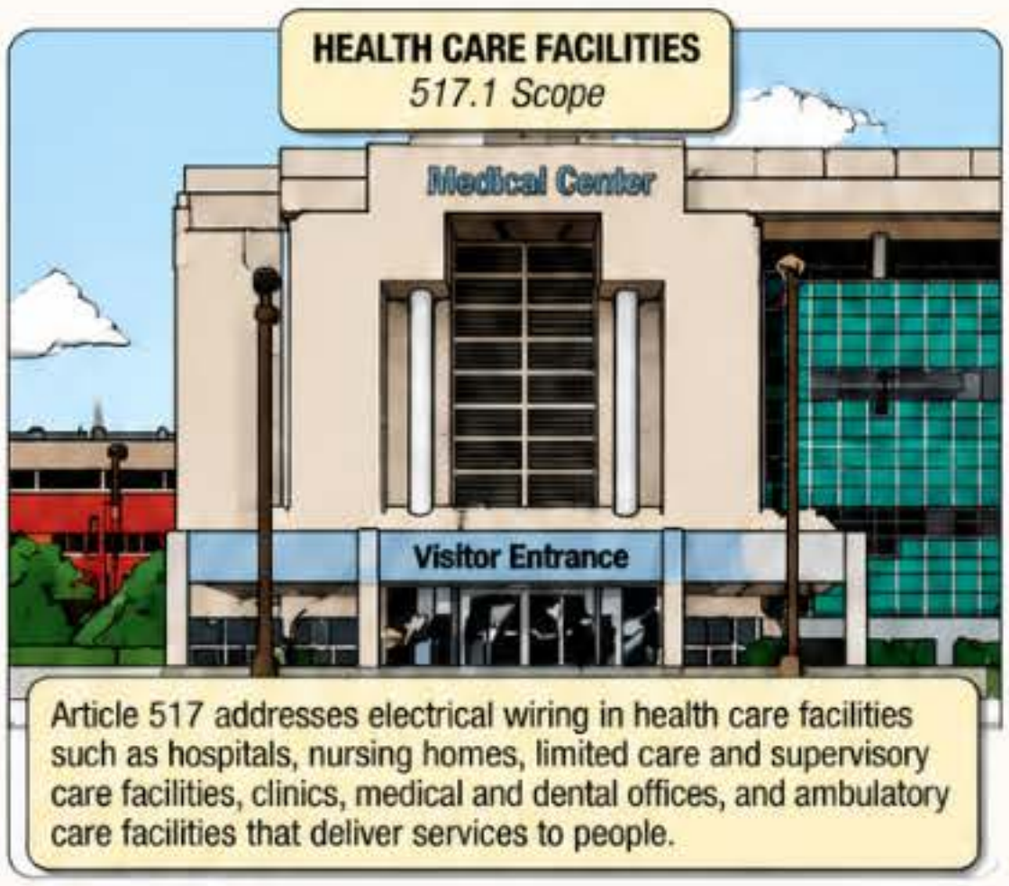
Author's Commentary:
This article does not apply to animal veterinary facilities.
— Michael Hamilton

- Areas of health care facilities not used for the treatment of patients (such as business offices and waiting rooms) are not required to comply with the provisions contained in Article 517.

517.2 Definitions

The definitions in this section apply only within this article.

Dental Office. A building or portion of a building in which the following occur:



▶ Figure 517-1

(1) Examinations and minor treatments/procedures must be performed under the ongoing direction of a dental professional.

(2) Sedation and related procedures are only allowed when they do not compromise the patient's ability to maintain self-preservation during urgent situations.

(3) Overnight stays of any duration or 24-hour surgical services are prohibited.

Health Care Facilities. This term applies to buildings, building areas, or mobile structures used for medical, dental, psychiatric, nursing, obstetrical, or surgical care.

Note: Examples include hospitals, nursing homes, limited care facilities, supervisory care facilities, clinics, medical and dental offices, and ambulatory care facilities.

Health Care Facility's Governing Body. The individual or organization with overall legal accountability for operating a health care facility.

Hospital. A building or designated building area used for delivering medical, psychiatric, obstetrical, or surgical care on a 24-hour basis for four or more inpatients.

Limited Care Facility. A building or area within a building providing housing and care on a 24-hour basis for four or more residents who cannot care for themselves because of physical limitations from accident, illness, intellectual disability, developmental disability, mental illness, or chemical dependency.

Medical Office. A building or portion of a building used for the following:

(1) Examinations and minor treatments/procedures performed under the ongoing supervision of a medical professional;

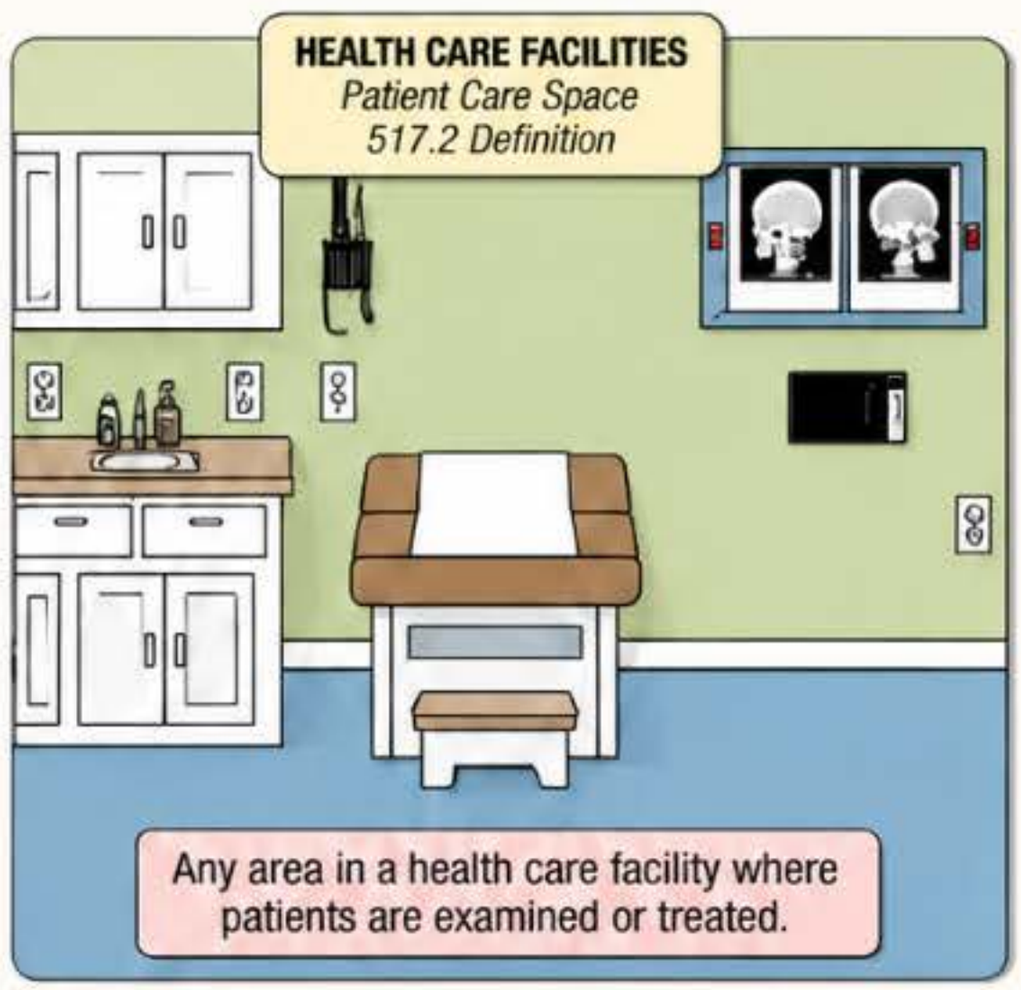
(2) The use of limited to minimal sedation and treatment or procedures that do not make the patient incapable of self-preservation during emergencies; and

(3) No overnight admissions or 24-hour surgical services.

Nursing Home. A building or building area intended for room and board, nursing care, and supervision 24 hours a day for four or more individuals who, due to mental or physical impairment, are unable to provide for their own needs and safety without help.

Patient Bed Location. The position of an inpatient bed.

Patient Care Space. Any area within a health care facility where patients are examined or treated. ▼ Figure 517-2

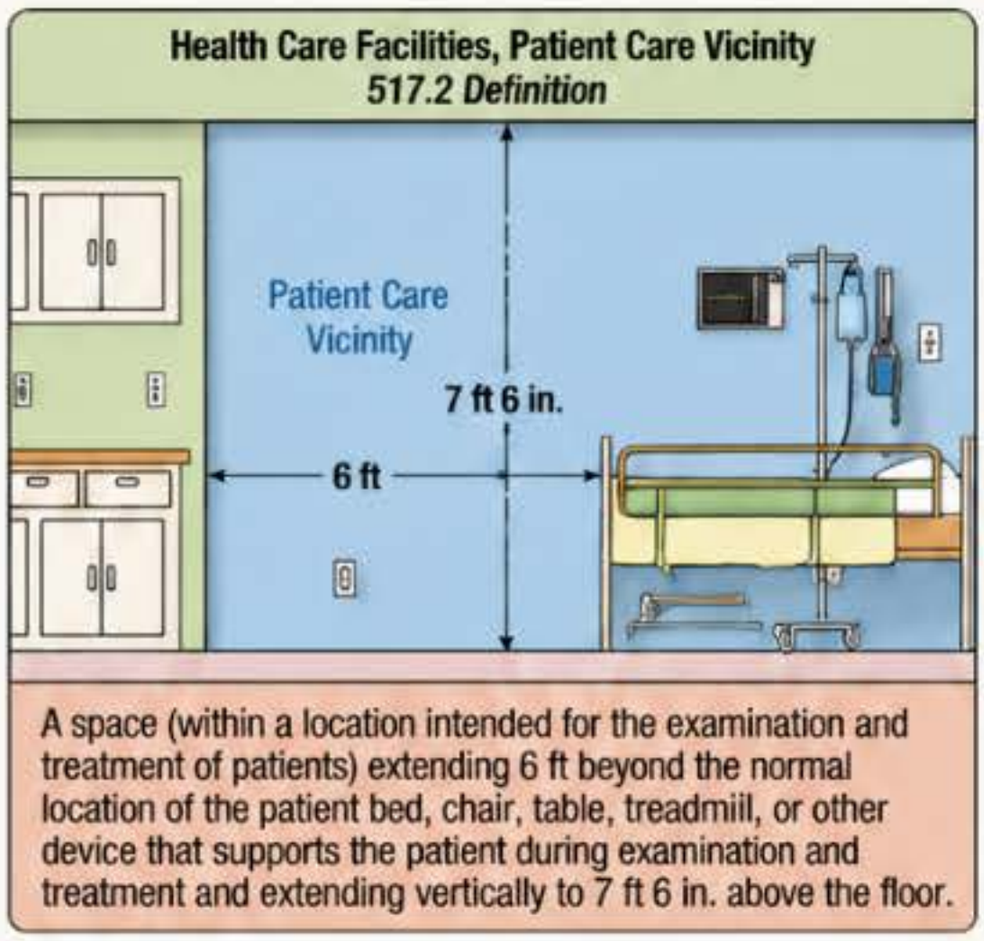


▶ Figure 517-2

Note 2: Business offices, corridors, lounges, day rooms, dining rooms, and similar areas are not considered patient care spaces.

Patient Care Vicinity. An area (inside or outside the patient care space) intended for the examination or treatment of patients, extending horizontally 6 ft beyond the normal bed, chair, table, treadmill, or other equipment that supports the patient during examination and treatment, and extending vertically from 7 ft 6 in above the floor to 7 ft 6 in below it. ▼ Figure 517-3

HEALTH CARE FACILITIES | 517.13



▶ Figure 517–3

Part II. Wiring and Protection

517.10 Applicability

(A) Applicability. This part applies to patient care spaces.

(B) Not Covered. The requirements contained in Part II of Article 517 do not apply to:

(1) Business offices, corridors, waiting rooms, or similar areas in clinics, medical offices, and dental clinics, and outpatient facilities.

(2) Areas of nursing homes and limited care facilities used exclusively for patient sleeping and wired in accordance with Chapters 1 through 4.

(3) Areas used exclusively for any of the following purposes:

a. Intramuscular injections (immunizations)

b. Psychiatry and psychotherapy

c. Alternative medicine

d. Optometry

517.12 Wiring Methods

Wiring methods must comply with the Chapter 1 through 4 provisions except as modified in this article.

517.13 Equipment Grounding Conductor for Receptacles and Fixed Electrical Equipment in Patient Care Spaces

Wiring in patient care spaces must comply with (A) and (B):

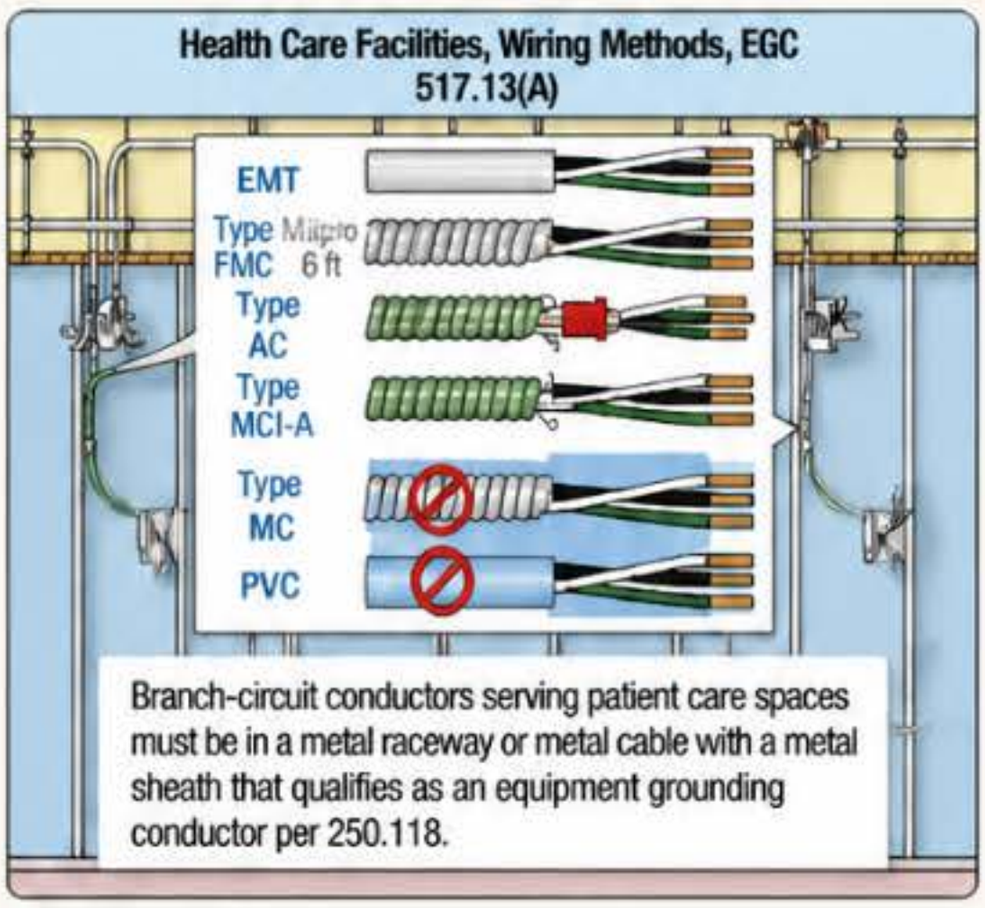
Author's Commentary:

Patient care spaces include only those areas run by the facility administrator that are used for examining patients, providing therapy, offering treatment, and some patient corridors. Offices, lounges, waiting areas, dining areas, day rooms, hallways, and other spaces not classified as patient care spaces are excluded from this scope.

— Michael Hamilton

▶ Because equipment grounding is frequently installed as a backup, spaces classified as patient care must be based on the design of two separate grounding systems. Two types of grounding en conductors are recognized. If an installation violates either either the effective ground-fault current path or the mechanical path for ground faults, the other system continues to provide safety. See Section 517.13(A) for the wiring method using a metal raceway or metal cable sheath that qualifies as the equipment grounding conductor in accordance with 250.118(8) and (10)(b). Section 517.13(B) specifies an insulated copper equipment grounding conductor for the wire type described in 250.118(1).

(A) Wiring Methods. Branch-circuit conductors serving patient care spaces must be installed in a metal raceway or metal cable with a metal sheath that qualifies as the equipment grounding conductor in accordance with 250.118(10)(b). ▶ Figure 517–4



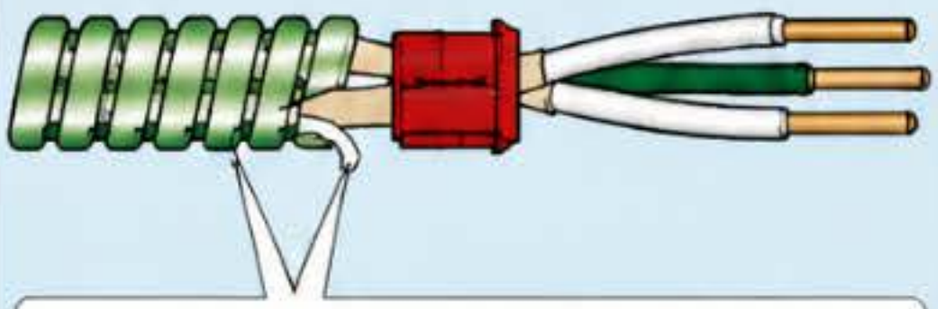
▶ Figure 517–4

Author's Commentary:

The outer covering of Type AC cable qualifies as equipment grounding conductor in 250.118(8) since it has a built-in bonding strip that is in direct electrical contact with the metal sheath of the interlocked cable.

— Michael Hamilton

Health Care Facilities, EGC in Patient Care Spaces
Wiring Methods, Type AC Cable
517.13(A) Comment



The outer covering of Type AC cable qualifies as equipment grounding conductor (EGC) in 250.118(8) since it has a built-in bonding strip that is in direct electrical contact with the metal sheath of the interlocked cable.

▶ **Figure 517-5**

Author's Commentary:

The outer covering of Type MCAP® (metal clad all-purpose) cable qualifies as equipment grounding conductor in 250.118(10)(b) since it has a built-in bonding strip that is in direct electrical contact with the metal sheath of the interlocked cable.

— Michael Hamilton

Health Care Facilities, EGC in Patient Care Spaces
Wiring Methods, Type MCAP® Cable
517.13(A) Comment

The outer covering of Type MCAP® cable (metal clad all-purpose) qualifies as equipment grounding conductor (EGC) in 250.118(10)(b) since it has a built-in bonding strip that is in direct electrical contact with the metal sheath of the interlocked cable.

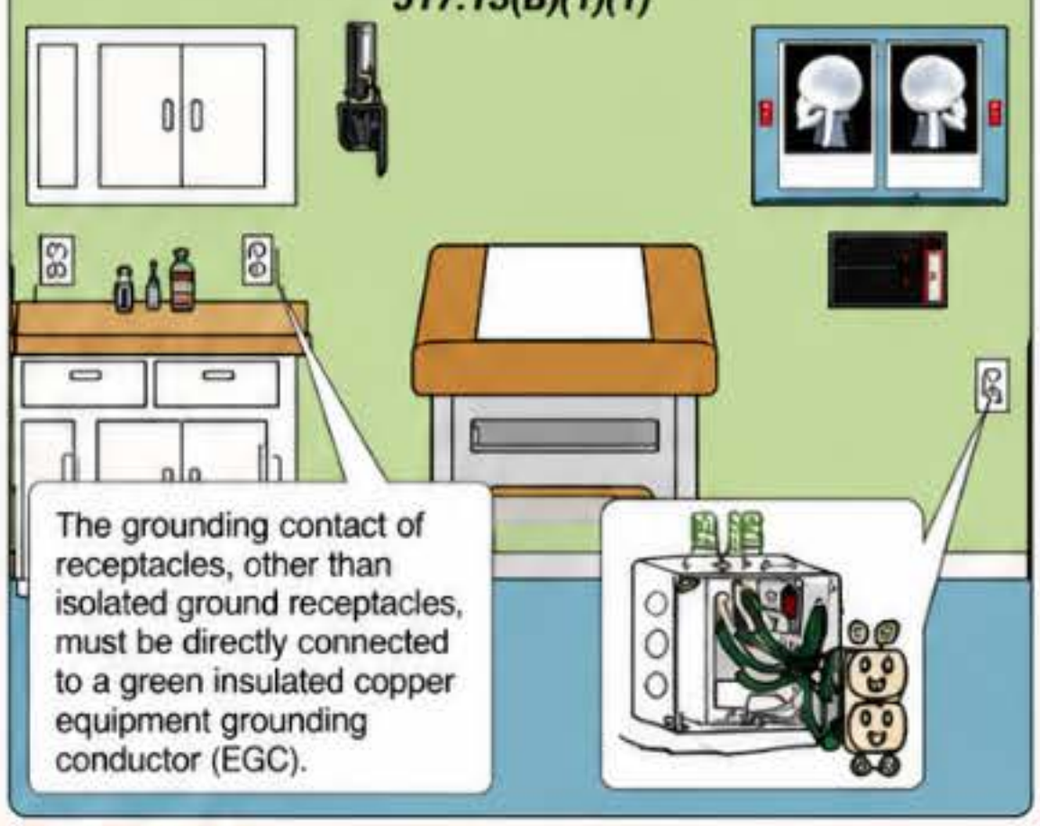
▶ **Figure 517-6**

(B) Insulated Equipment Grounding Conductors.

(1) General. The following equipment must be directly connected to an insulated copper equipment grounding conductor that has green insulation along its entire length. Such conductors must be contained in a suitable wiring method as required in 517.13(A).

(1) The grounding contact of receptacles, other than isolated ground receptacles, must be directly connected to a green insulated copper equipment grounding conductor. ▶**Figure 517-7**

Health Care Facilities, Patient Care Spaces, Insulated C.
ECCs Connection to Receptacles
517.13(B)(1)(1)

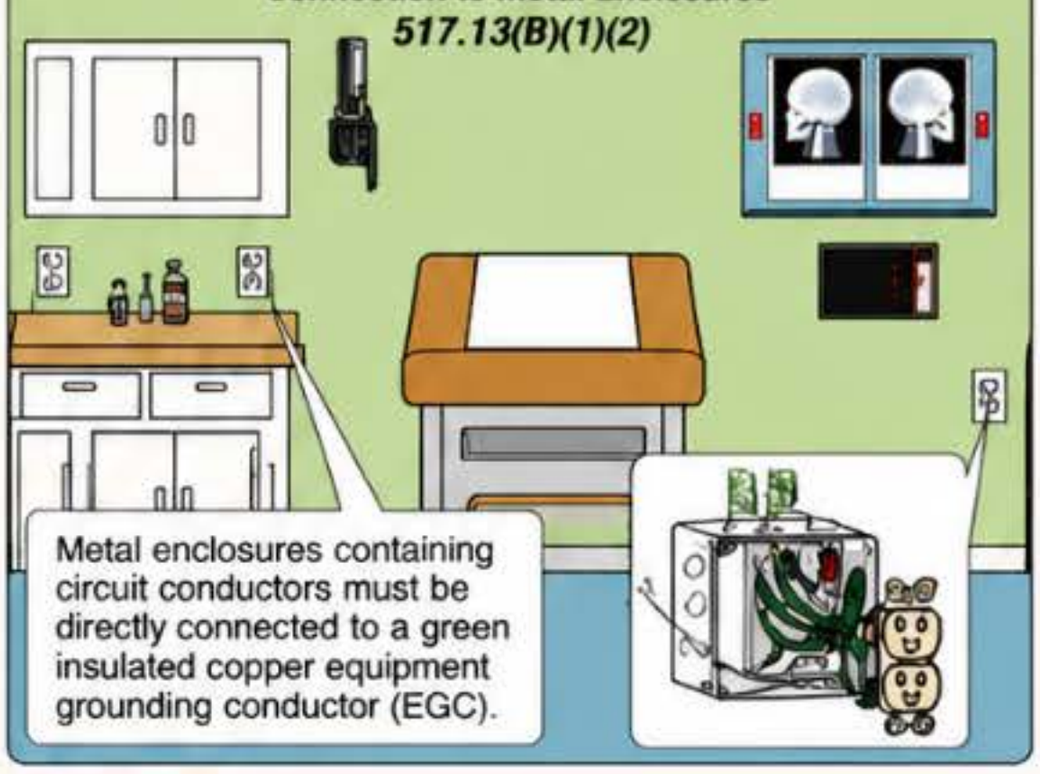


The grounding contact of receptacles, other than isolated ground receptacles, must be directly connected to a green insulated copper equipment grounding conductor (EGC).

▶ **Figure 517-7**

(2) Metal enclosures containing circuit conductors must be directly connected to a green insulated copper equipment grounding conductor. ▶**Figure 517-8**

Health Care Facilities, Patient Care Spaces, Insulated EGCs
Connection to Metal Enclosures
517.13(B)(1)(2)

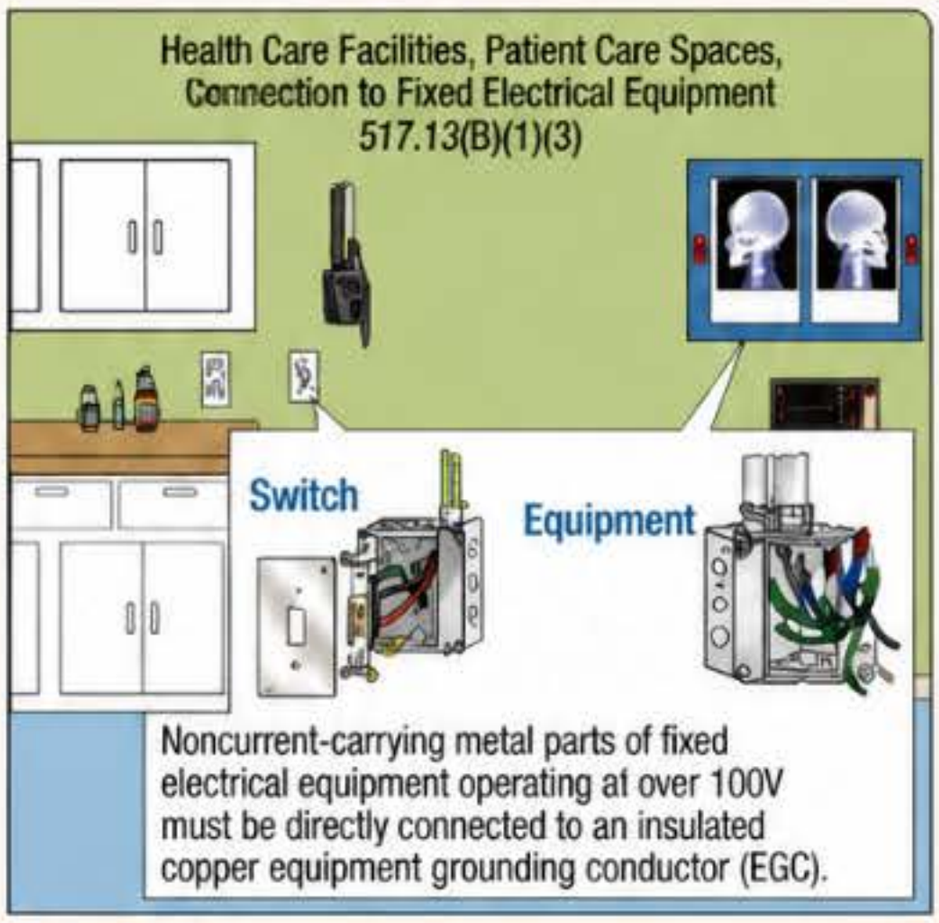


Metal enclosures containing circuit conductors must be directly connected to a green insulated copper equipment grounding conductor (EGC).

▶ **Figure 517-8**

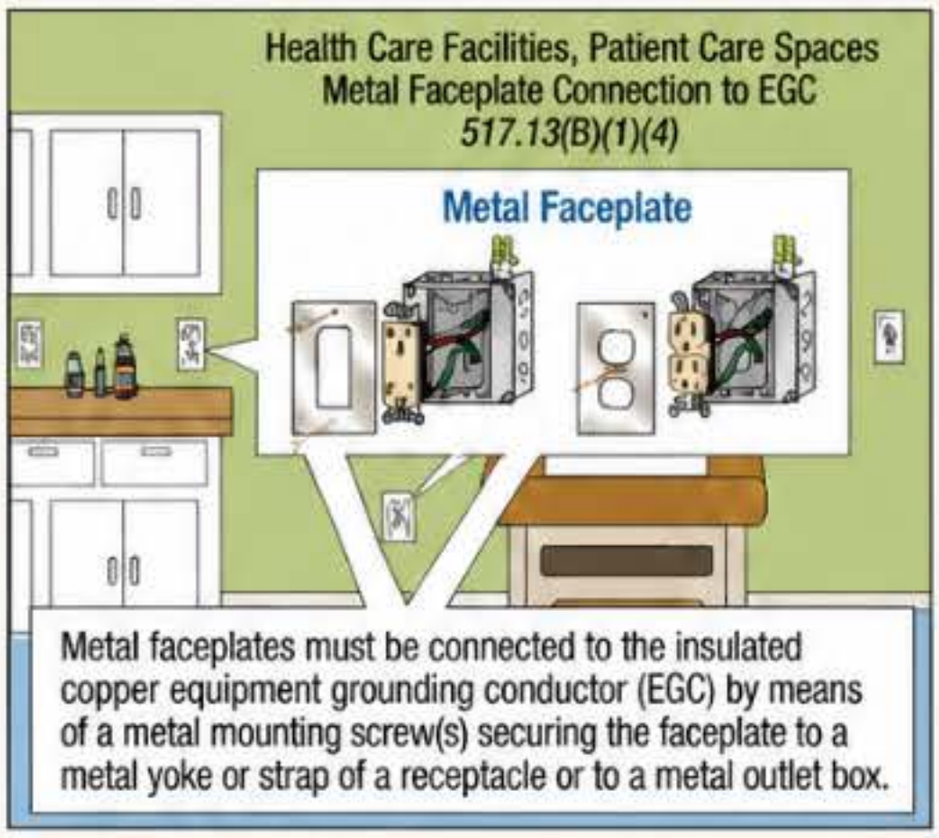
Health Care Facilities | 517.13

(3) Noncurrent-carrying metal parts of fixed electrical equipment operating at over 100V must be connected directly to an insulated copper equipment grounding conductor. ▸Figure 517-9



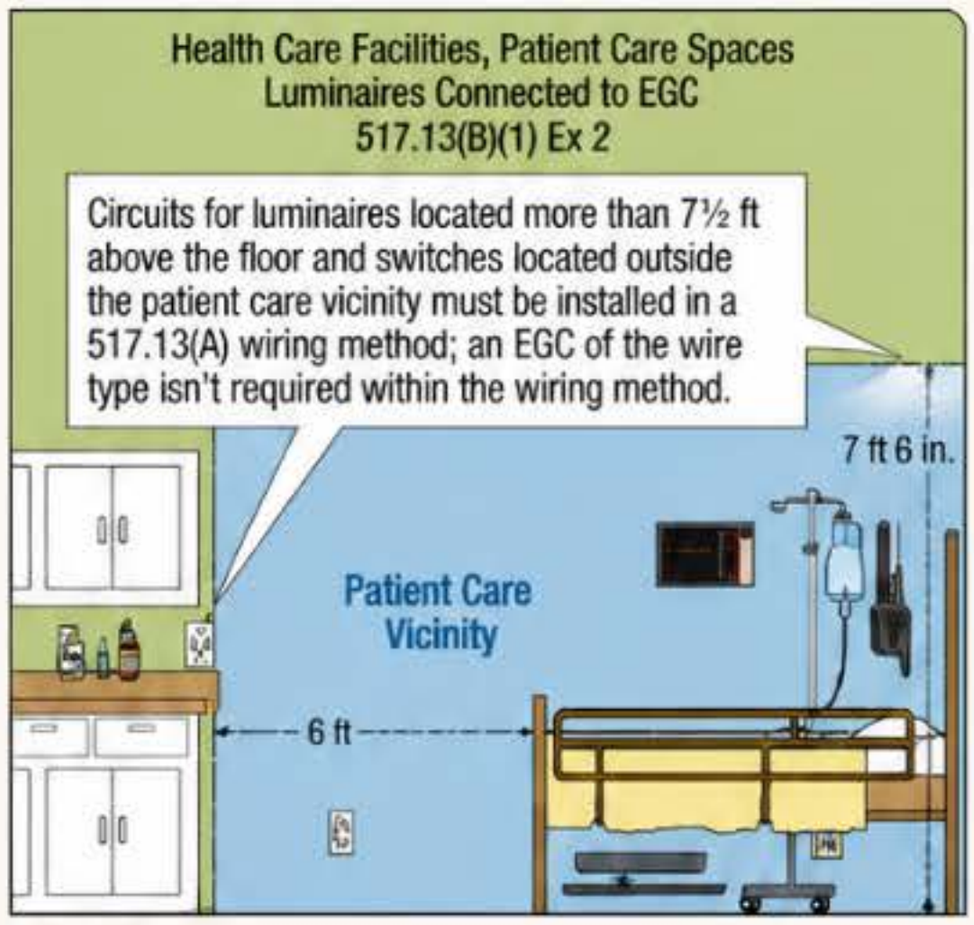
▸Figure 517-9

(4) Metal faceplates must be connected to the insulated copper equipment grounding conductor by means of a metal mounting screw(s) securing the faceplate to a metal yoke or strap of a receptacle, or to a metal outlet box. ▸Figure 517-10



▸Figure 517-10

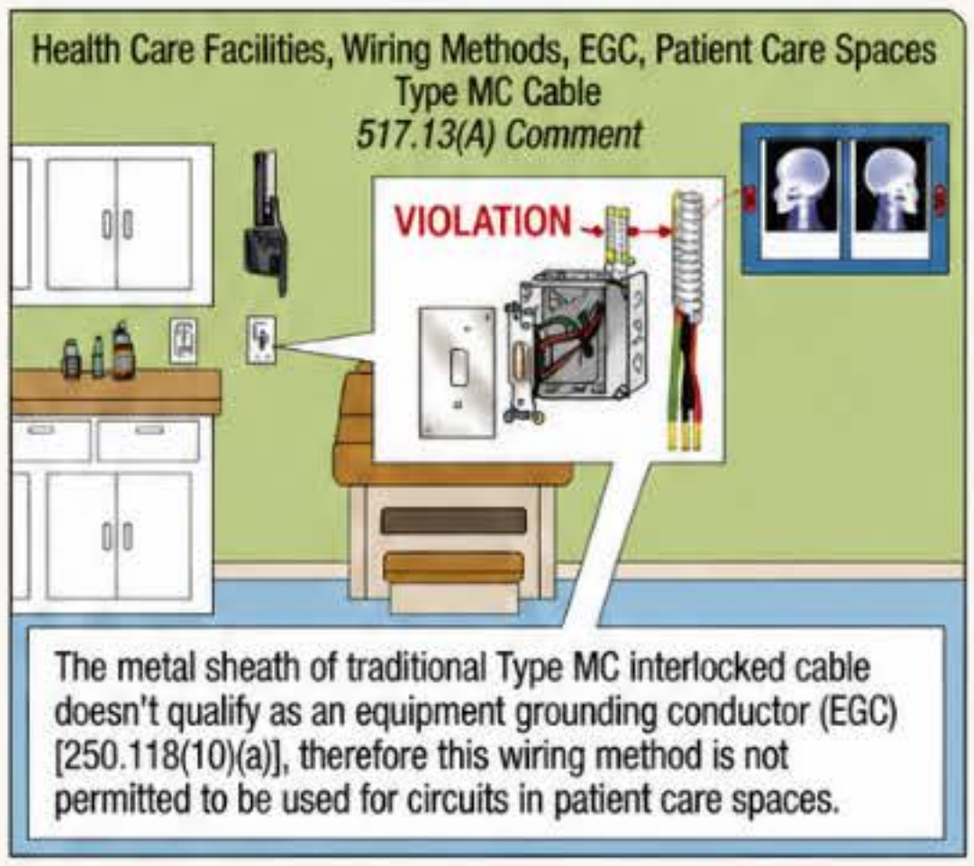
Ex 2: Circuits for luminaires located more than 7½ ft above the floor and switches located outside the patient care vicinity must be installed in a 517.13(A) wiring method; an equipment grounding conductor of the wire type is not required within the wiring method. ▸Figure 517-11



▸Figure 517-11

Author's Commentary:
The metal sheath of traditional Type MC interlocked cable does not qualify as an equipment grounding conductor [250.118(10)(a)], therefore this wiring method is not permitted to be used for circuits in patient care spaces.

— Michael Hamilton



▸Figure 517-12

(2) Sizing. Equipment grounding conductors and equipment jumpers must be sized in accordance with 250.122. ▸Figure 517-13

517.16 | Health Care Facilities

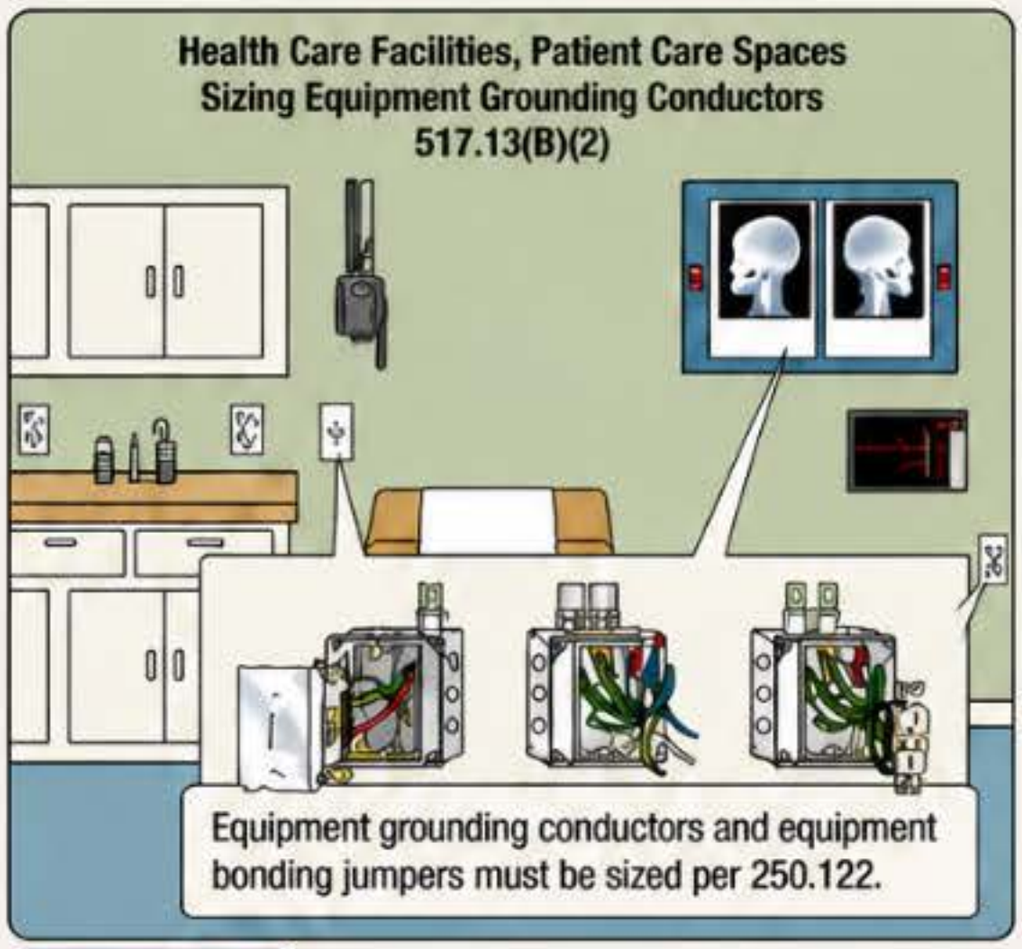


Figure 517–13

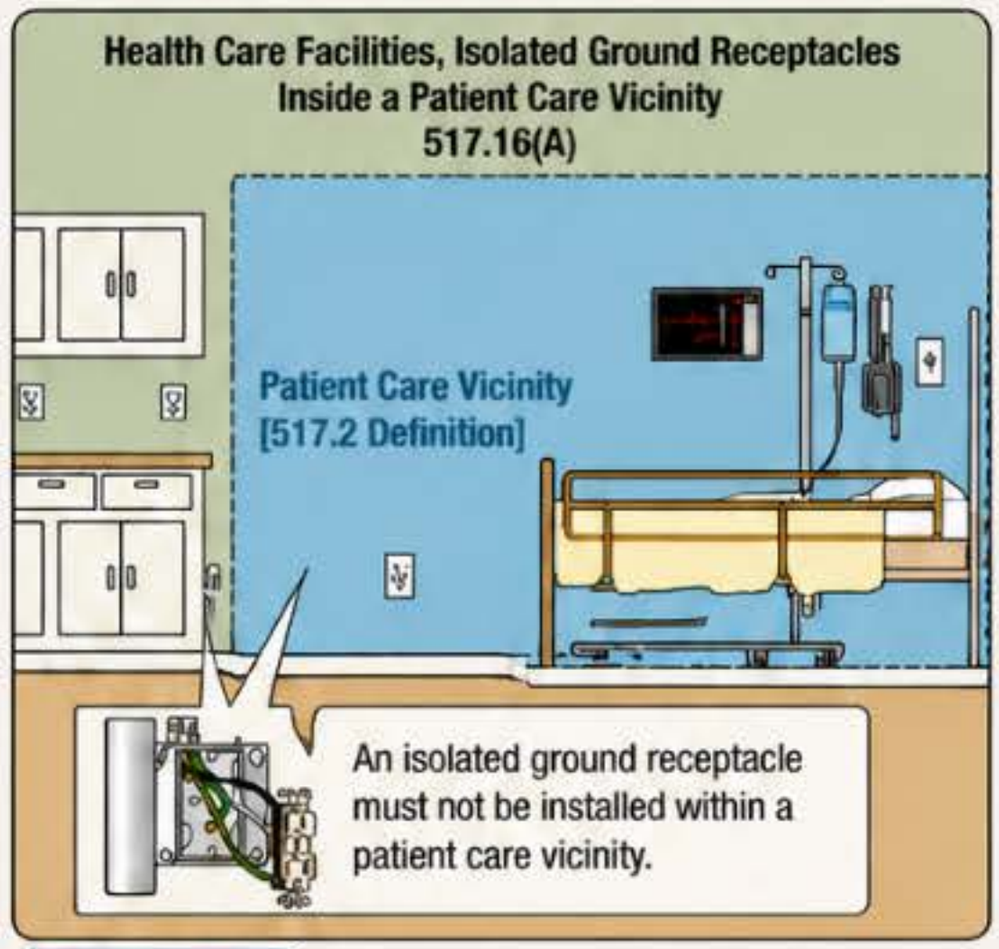


Figure 517–15

517.16 Isolated Ground Receptacles

An isolated ground receptacle, if used, must not defeat the purposes of the safety features of the grounding systems detailed in 517.13.

Figure 517–14

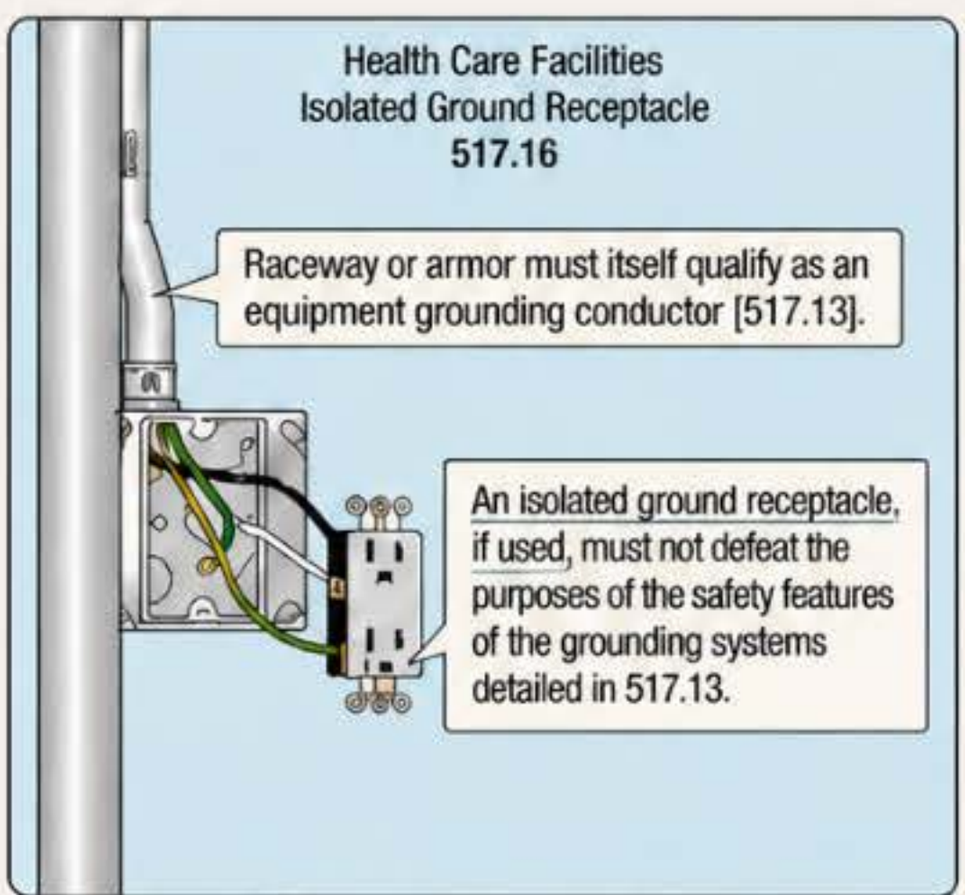


Figure 517–14

(A) Inside Patient Care Vicinity. An isolated ground receptacle must not be installed within a patient care vicinity. ▸Figure 517–15

Author's Commentary:

The patient care vicinity is a zone extending 6 ft beyond the normal location of the patient bed, chair, table, treadmill, or other device that supports the patient during examination and treatment and extends vertically to 7 ft 6 in. above the floor [517.2 Definition].

— Michael Hamilton

(B) Outside Patient Care Vicinity. Isolated ground receptacle(s) within the patient care space (as defined in 517.2) but outside the patient care vicinity must comply with the following:

(1) The equipment grounding terminal of isolated grounding receptacles must be connected to an insulated equipment grounding conductor in accordance with 250.146(D) and installed in a wiring method described in 517.13(A). The equipment grounding conductor connected to the equipment grounding terminals of the isolated grounding receptacle must have green insulation with one or more yellow stripes along its entire length. ▸Figure 517–16

(2) The insulated equipment grounding conductor required by 517.13(B)(1) must be connected to the metal enclosure containing the isolated ground receptacle in accordance with 517.13(B)(1)(2).

Note 2: Care should be taken in specifying a system containing isolated ground receptacles because the impedance of the effective ground-fault current path is dependent on the equipment grounding conductor(s) and does not benefit from any conduit or building structure in parallel with the equipment grounding conductor.

DEFINITIONS | From Michael Hamilton Publications

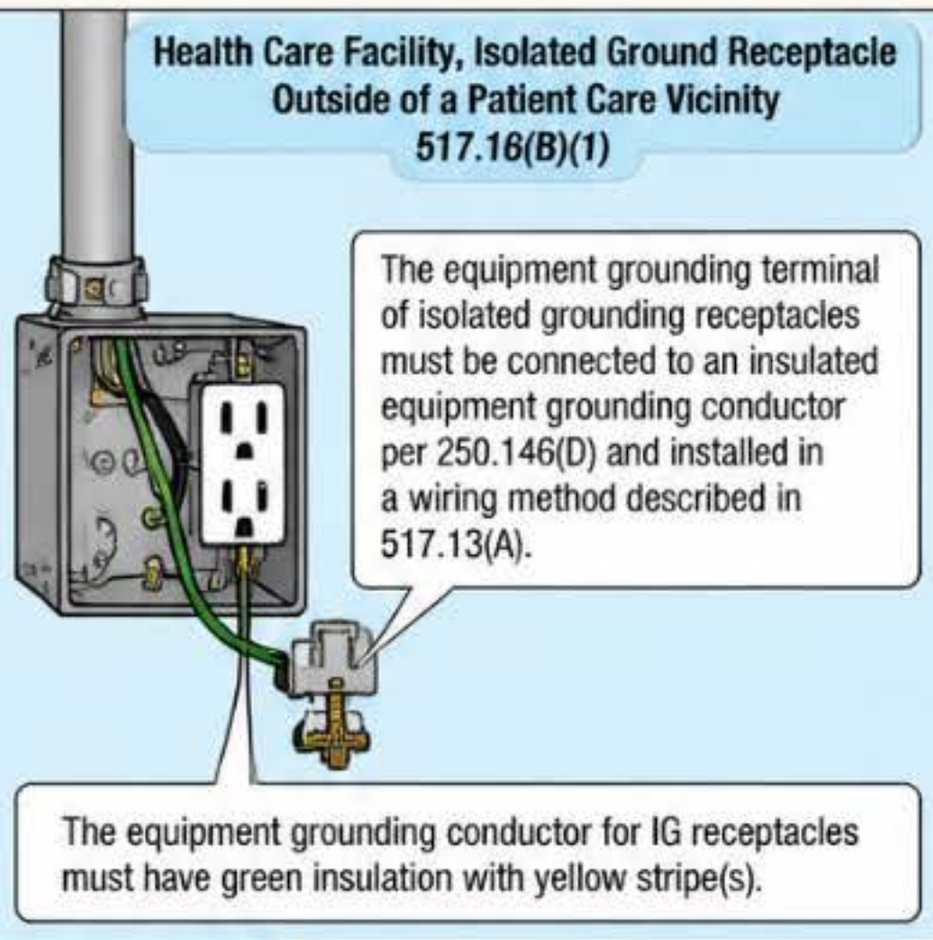


Figure 517–16

Author's Commentary:

- General care areas can include, among other spaces, inpatient bedrooms, dialysis rooms, in vitro fertilization suites, procedure rooms, and comparable rooms [514.2].
- Hospital grade receptacles are necessary only in the location of a patient's bed or procedure table for a critical care space; regular receptacles are allowable in treatment rooms of clinics, medical offices, dental practices, or outpatient facilities.

— Michael Hamilton

Author's Commentary:

- Using equipment grounding conductors alone will not satisfy the requirement for tying the raceway system and the outlet box to an equipment grounding conductor in order to provide a low impedance fault return path back to the supply.

— Michael Hamilton

517.18 General Care Spaces

(B) Patient Bed Location Receptacles. At a location of a patient sleeping bed or the bed or procedure table of a critical care space, a minimum of eight listed and identified hospital grade receptacles must be provided. ▸Figure 517–17

Figure 517–17

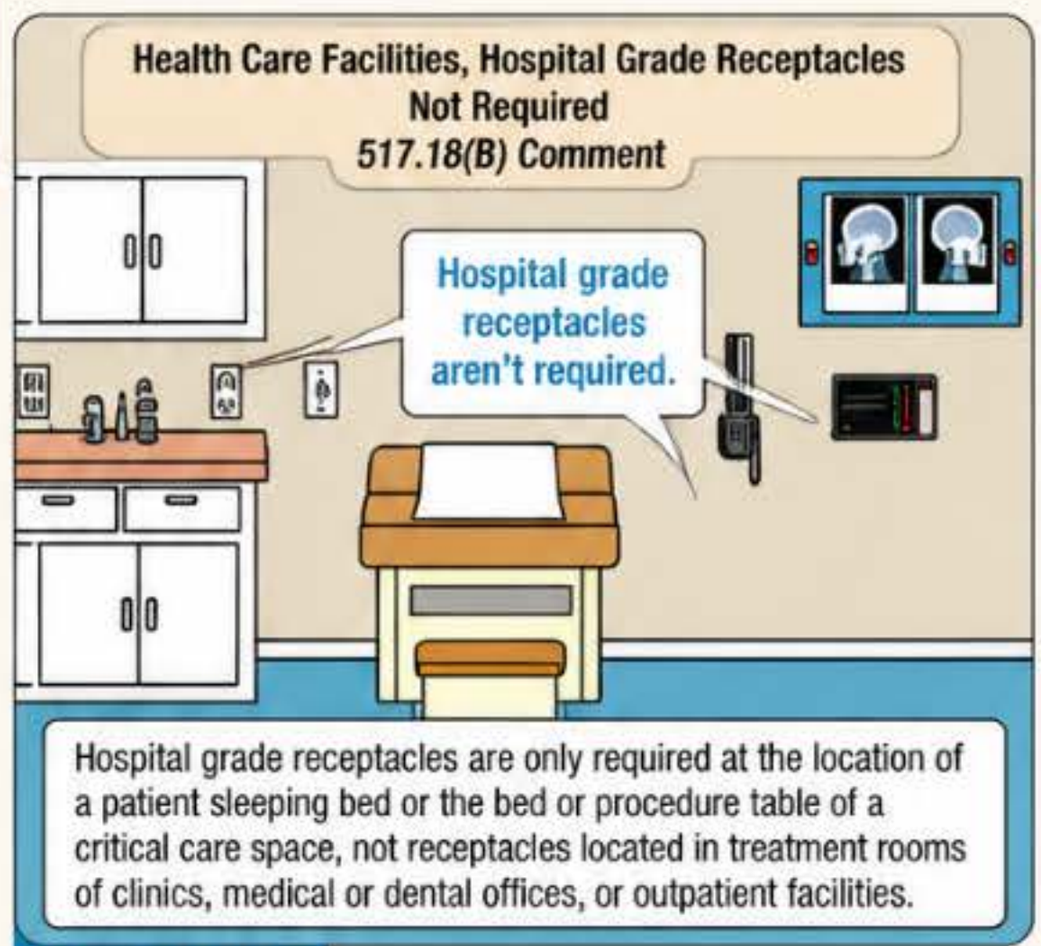


Figure 517–18

Notes

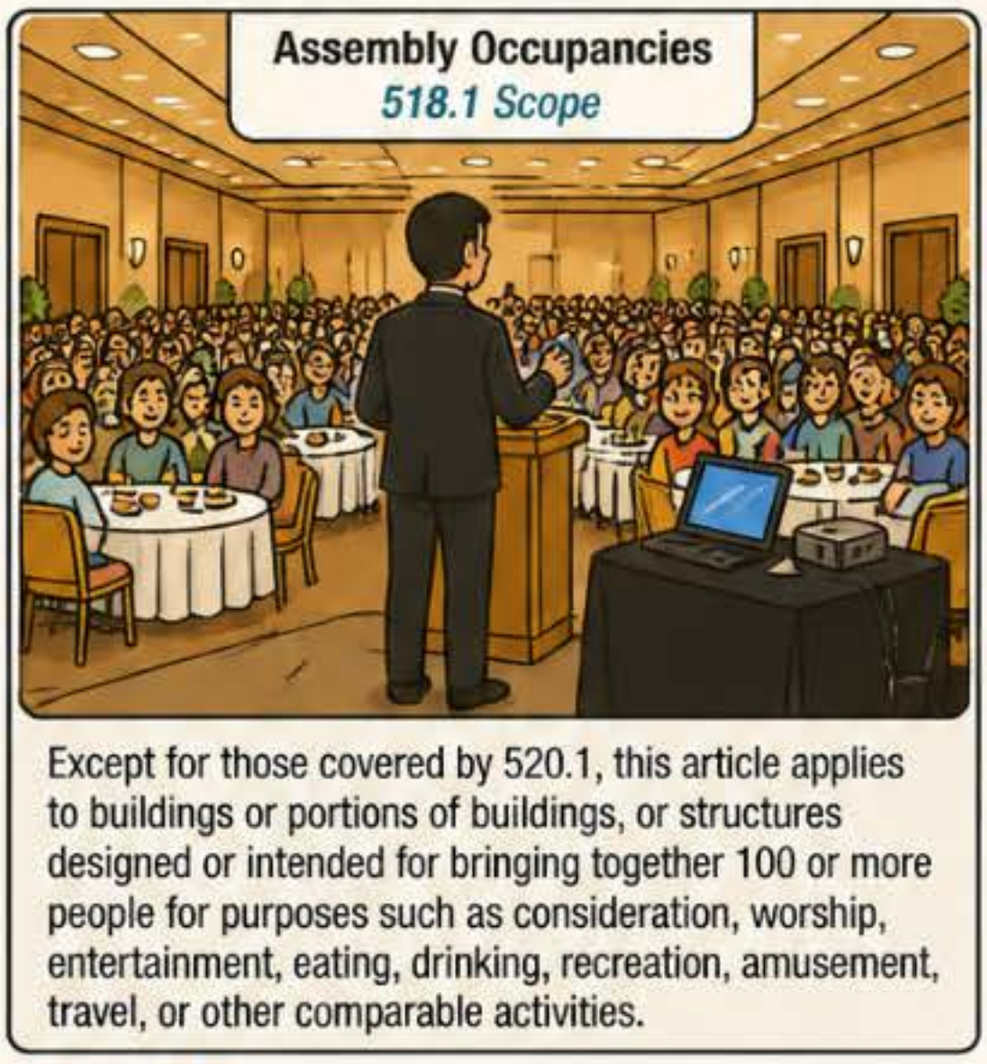
ARTICLE 518 ASSEMBLY OCCUPANCIES

Introduction to Article 518—Assembly Occupancies

Buildings or portions of buildings commonly called "places of occupancy" are specifically planned or intended for the gathering of 100 or more people and must comply with the provisions of Article 518. This article streamlines application of the rules by removing any uncertainty about which occupancies it covers. Refer to 518.2 for the list of occupancies.

518.1 Scope

Except for the assembly occupancies that are already detailed in 520.1, this article applies to buildings or parts of buildings, or structures designed or intended for bringing together 100 or more people for purposes such as consideration, worship, entertainment, eating, drinking, recreation, amusement, travel, or other comparable activities. Figure 518-1



▶ Figure 518-1

Author's Commentary:
Determining how many people a space accommodates is based on NFPA 101, *Life Safety Code*, or the governing building code.

— Michael Hamilton

518.2 General Classifications

(A) Examples. Assembly occupancies include, but are not limited to:

- Armories
- Assembly halls
- Auditoriums
- Bowling lanes
- Club rooms
- Conference rooms
- Courtrooms
- Dance halls
- Dining facilities
- Exhibition halls
- Gymnasiums
- Mortuary chapels
- Multipurpose rooms
- Museums
- Places awaiting transportation
- Pool rooms
- Places of religious worship
- Restaurants
- Skating rinks

(B) Multiple Occupancies. The criteria in Article 518 apply only to those sections of a building that are expressly designed or intended for the assembly of 100 or more individuals.

518.3 Other Articles

(B) Temporary Installations. Display booths set up in exhibit halls may be wired in accordance with Article 590. Approved flexible hard or extra-hard usage cords can be run on the floor when they are protected from contact by the public.

Figure 518–2
Wiring for display booths in exhibit halls can be installed in accordance with Article 590. Approved flexible hard or extra-hard usage cords can be laid on the floor where protected from contact by the public.

GFCI protection must be provided in accordance with 210.8(B) for receptacles where required by *this Code*, except for the temporary wiring requirements of 590.6.

When GFCI protection is supplied by plug-and-cord connection, the GFCI-protected device must deliver a level of protection equivalent to a portable GFCI, whether assembled in the field or at the factory.

518.4 Wiring Methods

(A) General. Fixed wiring methods must be metal raceways, flexible metal raceways, nonmetallic conduits encased in not less than 2 in. of concrete, or Types MI, MC, or AC cable. •

The wiring method used must qualify as an equipment grounding conductor in accordance with 250.118, or it must contain an equipment grounding conductor sized in accordance with Table 250.122.

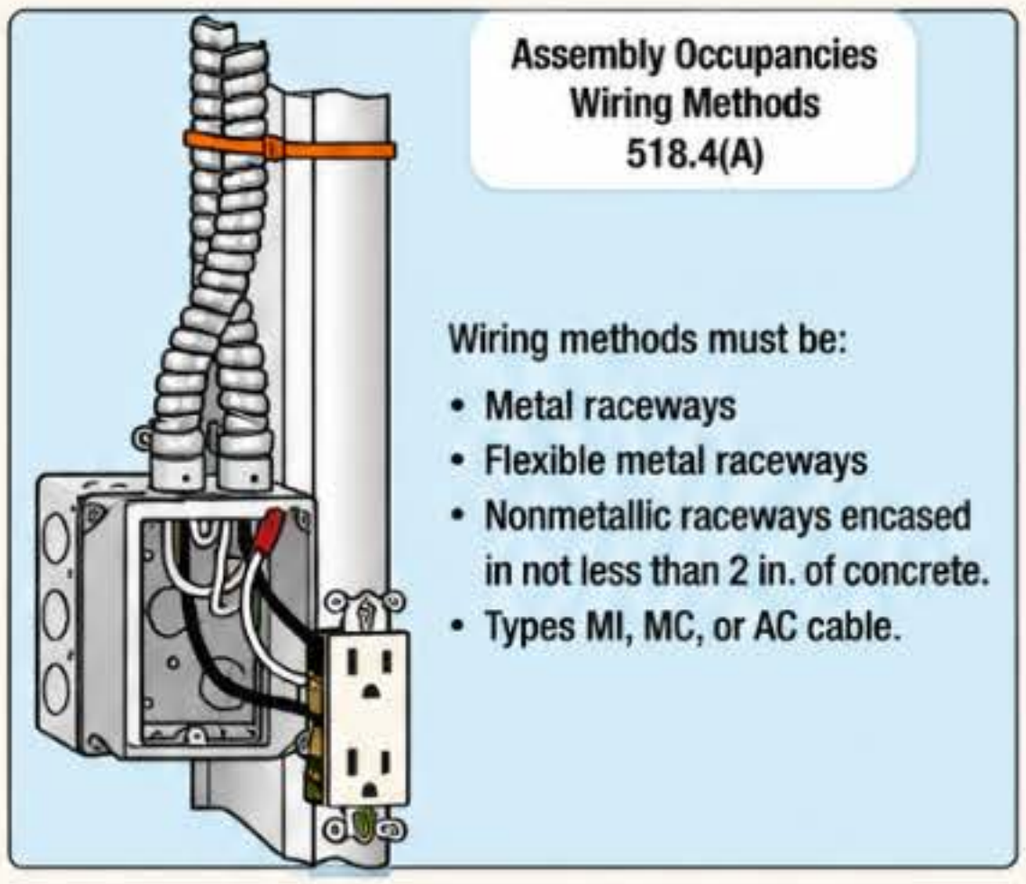
Examples of fixed wiring methods are granted in the following:

(a) Sound Systems—Article 640

(b) Communications Systems—Chapter 8

(c) Class 2 Remote-Control and Signaling Circuits—Article 725

(d) Fire Alarm Circuits—Article 760



(B) Spaces of Nonrated Construction. In addition to the permitted 518.4(A) wiring methods, Type NM cable, electrical nonmetallic tubing, and PVC conduit can be installed in those parts of an assembly occupancy building that are not required to be of fire-rated construction.

Note: Fire-rated construction is the fire-resistive classification used in building codes.

(C) Spaces with Finish Ratings. Electrical nonmetallic tubing and PVC conduit can be installed in club rooms, conference and meeting rooms in hotels or motels, courtrooms, dining facilities, restaurants, mortuary chapels, museums, libraries, and places of religious worship where:

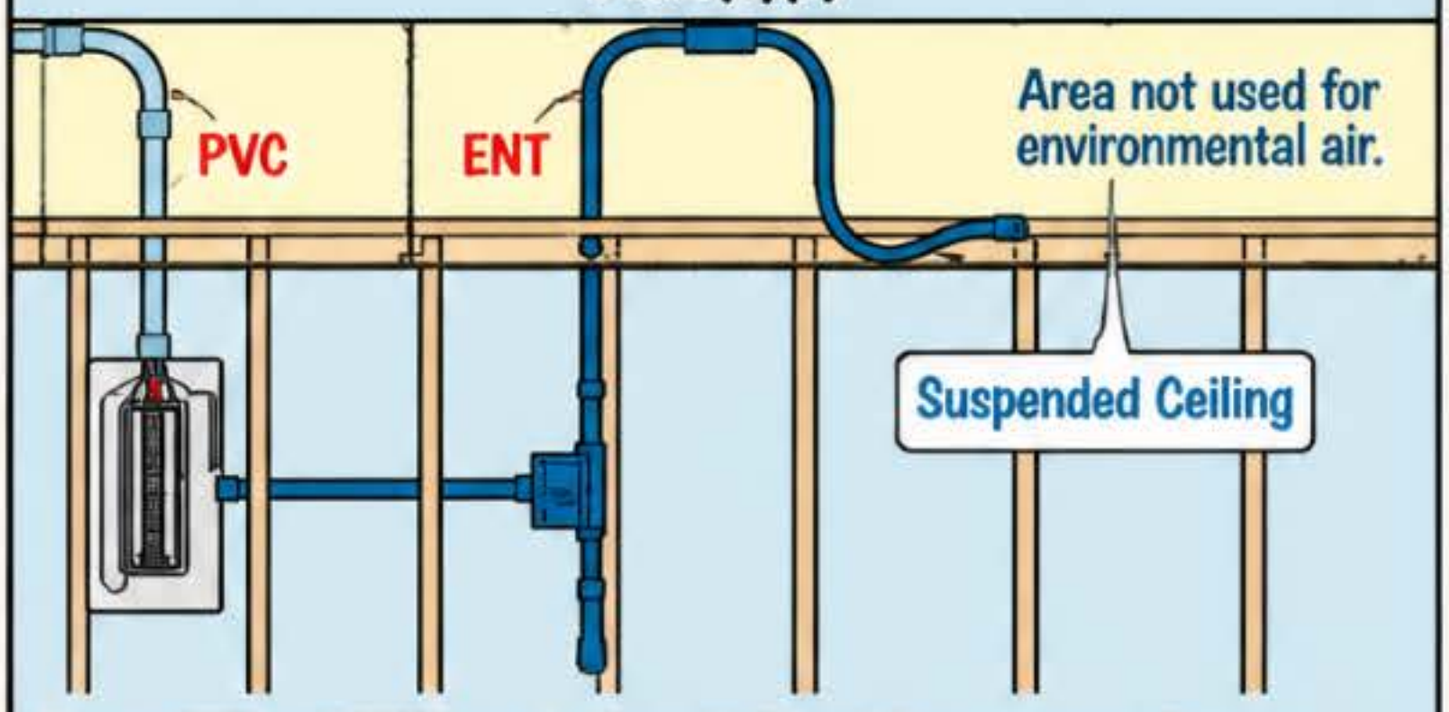
(1) Electrical nonmetallic tubing or Type PVC conduit is installed concealed within walls, floors, and ceilings that provide a thermal barrier with not less than a 15-minute finish rating. • Figure 518-4

(2) Electrical nonmetallic tubing or Type PVC conduit can be installed above nonplenum [300.22(C)] suspended ceilings where the suspended ceilings provide a thermal barrier with not less than a 15-minute finish rating.

518.6 Illumination

Illumination must be provided for all working spaces about fixed service equipment, switchboards, switchgear, panelboards, or motor control centers installed outdoors that serve assembly occupancies. Control by automatic means only is not permitted. Additional lighting outlets are not required where the workspace is illuminated by an adjacent light source. See 110.26(D).

Assembly Occupancies, Nonmetallic Raceways Spaces with Finish Ratings 518.4(C)(1)



Types ENT and PVC can be installed in club rooms, conference and meeting rooms in hotels or motels, courtrooms, dining facilities, restaurants, mortuary chapels, museums, libraries, and places of worship if walls, floors, and ceilings have a 15-minute finish rating.

Figure 518–4

Notes |

ARTICLE 525 CARNIVALS, CIRCUSES, FAIRS, AND SIMILAR EVENTS

Introduction to Article 525—Carnivals, Circuses, Fairs, and Similar Events

This article addresses the setup of temporary electrical wiring and equipment used for carnivals, circuses, exhibitions, fairs, traveling attractions, and comparable activities, including wiring that is in or on structures.

Part I. General Requirements

525.1 Scope

Article 525 establishes the rules for temporary electrical installations and equipment serving carnivals, circuses, exhibitions, fairs, traveling attractions, and similar occasions. ▸Figure 525–1

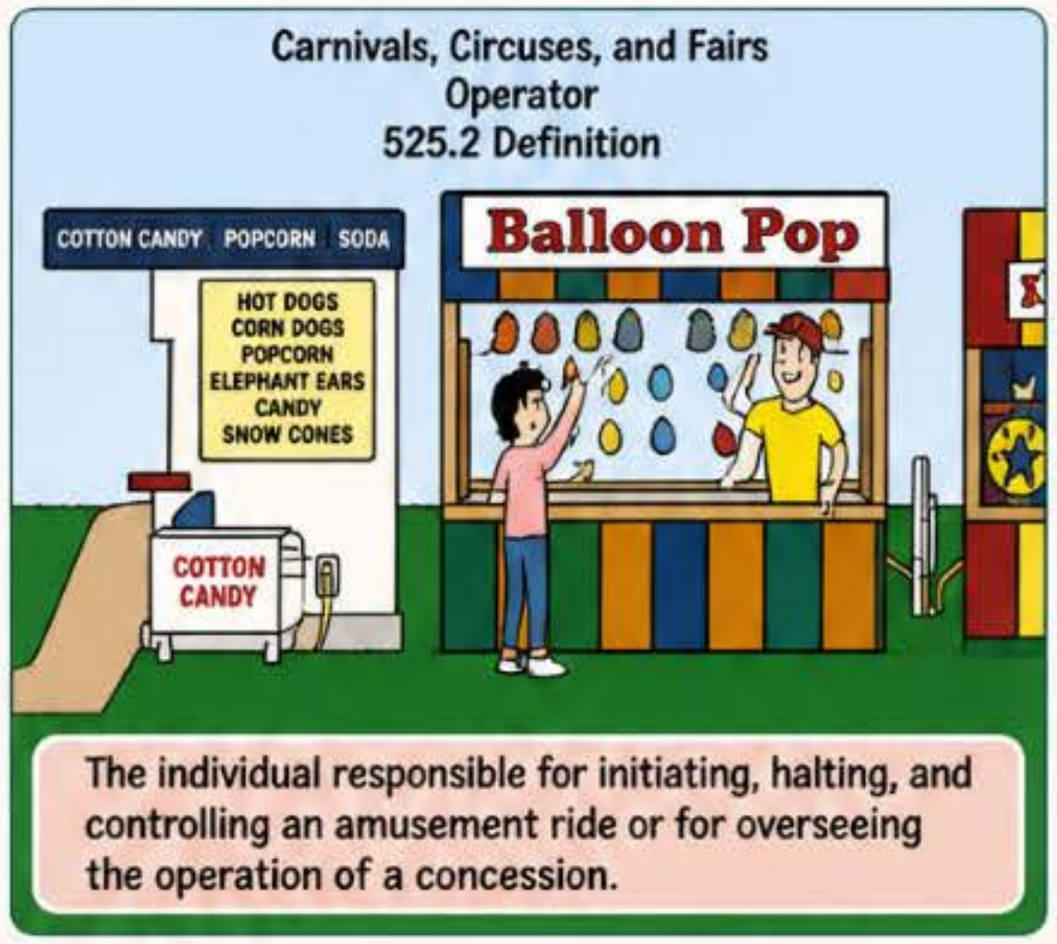
▸Figure 525–1

525.2 Definitions

The terms used in this section apply solely within the scope of this article.

Operator. The person in charge of starting, stopping, and supervising an amusement ride or managing a concession. ▸Figure 525–2

Author's Commentary:
The operator has final authority over the safe operation of the ride or concession.
— Michael Hamilton



▸Figure 525–2

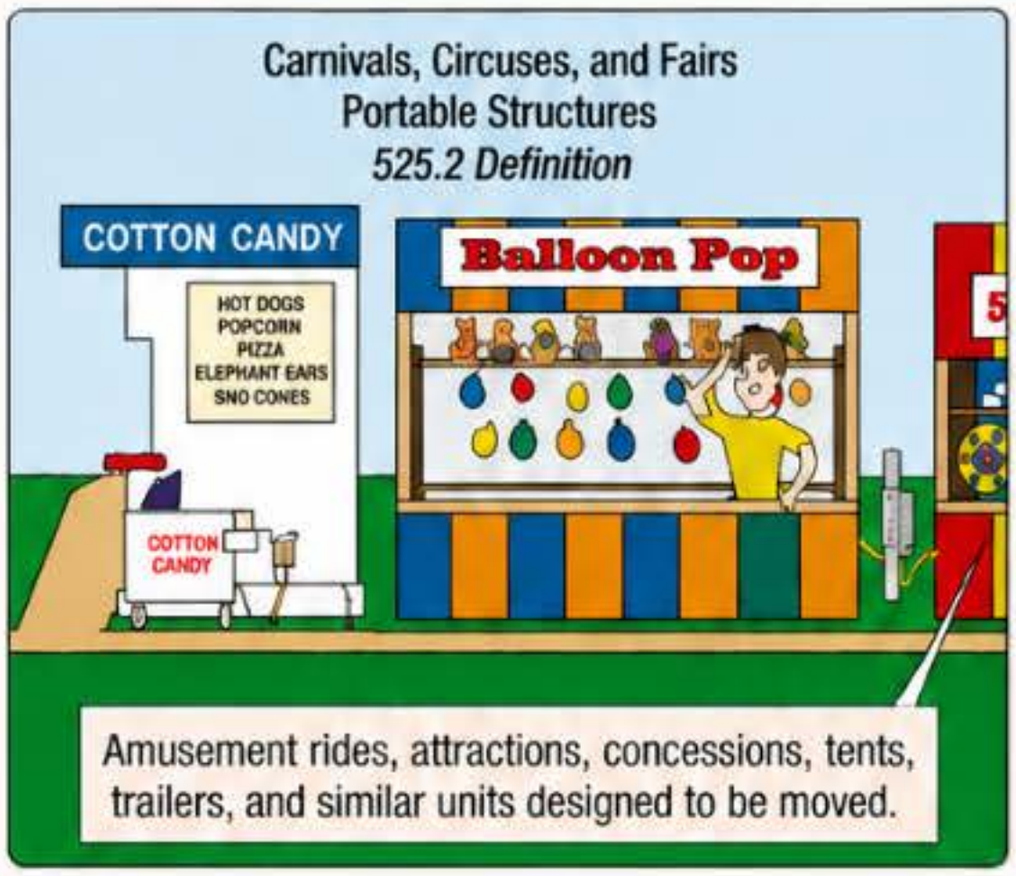
Portable Structures. Amusement rides, attractions, concessions, tents, trailers, and similar units that are intended to be moved. ▸Figure 525–3

525.5 Overhead Conductor Clearances

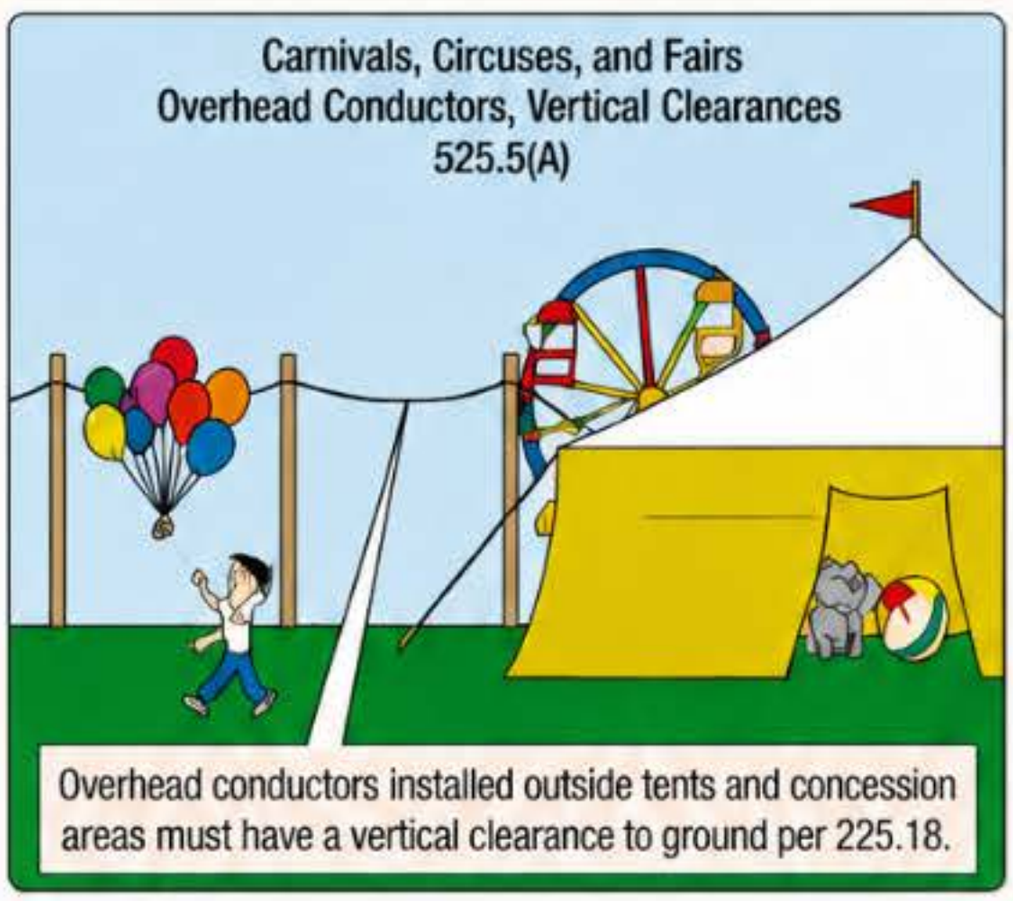
(A) Vertical Clearances. Overhead conductors installed outside of tents and concession areas must have a vertical clearance to the ground in accordance with 225.18. ▸Figure 525–4

Author's Commentary:
Maintaining proper overhead clearance prevents contact between people, equipment, and energized conductors.
— Michael Hamilton

525.6 | Carnivals, Circuses, Fairs, and Similar Events



▸Figure 525–3



▸Figure 525–4

Author's Commentary:

Section 225.18 includes the following requirements:

- 10 ft above finished grade, sidewalks, platforms, or projections from which they might be accessible to pedestrians for 120V, 120/208V, 120/240V, or 240V circuits [225.18(1)].
- 12 ft above residential property and driveways, and those commercial areas not subject to truck traffic for 120V, 120/208V, 120/240V, 240V, 277V, 277/480V, or 480V circuits [225.18(2)].
- 18 ft over public streets, alleys, roads, parking areas subject to truck traffic, driveways on other than residential property, and other areas traversed by vehicles (such as those used for cultivation, grazing, forestry, and orchards) [225.18(4)].

— Michael Hamilton

(B) Clearance to Portable Structures.

(1) Overhead conductors, except for the conductors that supply the amusement ride or attractions, must have a clearance of 15 ft from portable amusement structures.

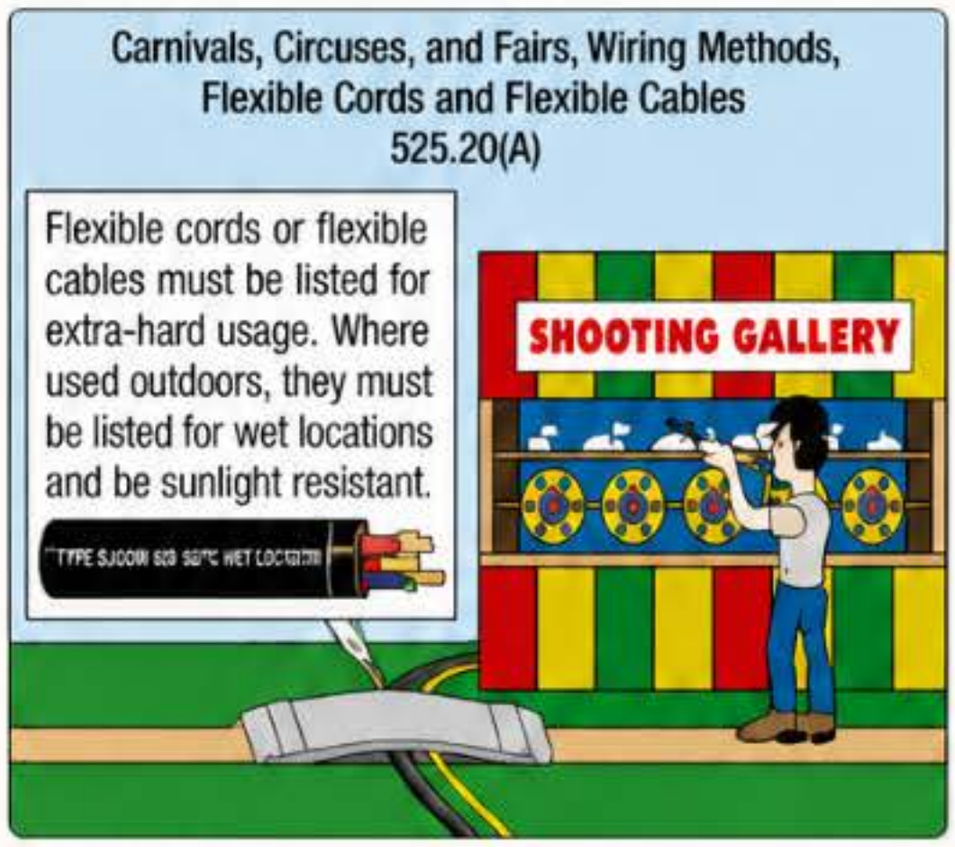
525.6 Protection of Electrical Equipment

Electrical equipment and wiring for portable structures must be provided with mechanical protection where subject to physical damage.

Part III. Wiring Methods

525.20 Wiring Methods

(A) Type. Flexible cords or flexible cables must be listed for extra-hard usage. Where used outdoors flexible cords and flexible cables must be listed for wet locations and be sunlight resistant. ▸Figure 525–5



▸Figure 525–5

(B) Single Conductor. Single-conductor cable is permitted only in sizes 2 AWG and larger.

(C) Open Conductors. Open conductors are permitted as part of a listed assembly or part of festoon lighting installed in accordance with 225.6(B). ▸Figure 525–6

(D) Splices. Flexible cords or flexible cables must be continuous without splice or tap between boxes or fittings.

(E) Cord Connectors. Cord connectors laid on the ground must be listed for wet locations. Connectors and cable connections placed in audience traffic paths or areas accessible to the public must be guarded. ▸Figure 525–7

CARNIVALS, CIRCUSES, FAIRS, AND SIMILAR EVENTS 525.22

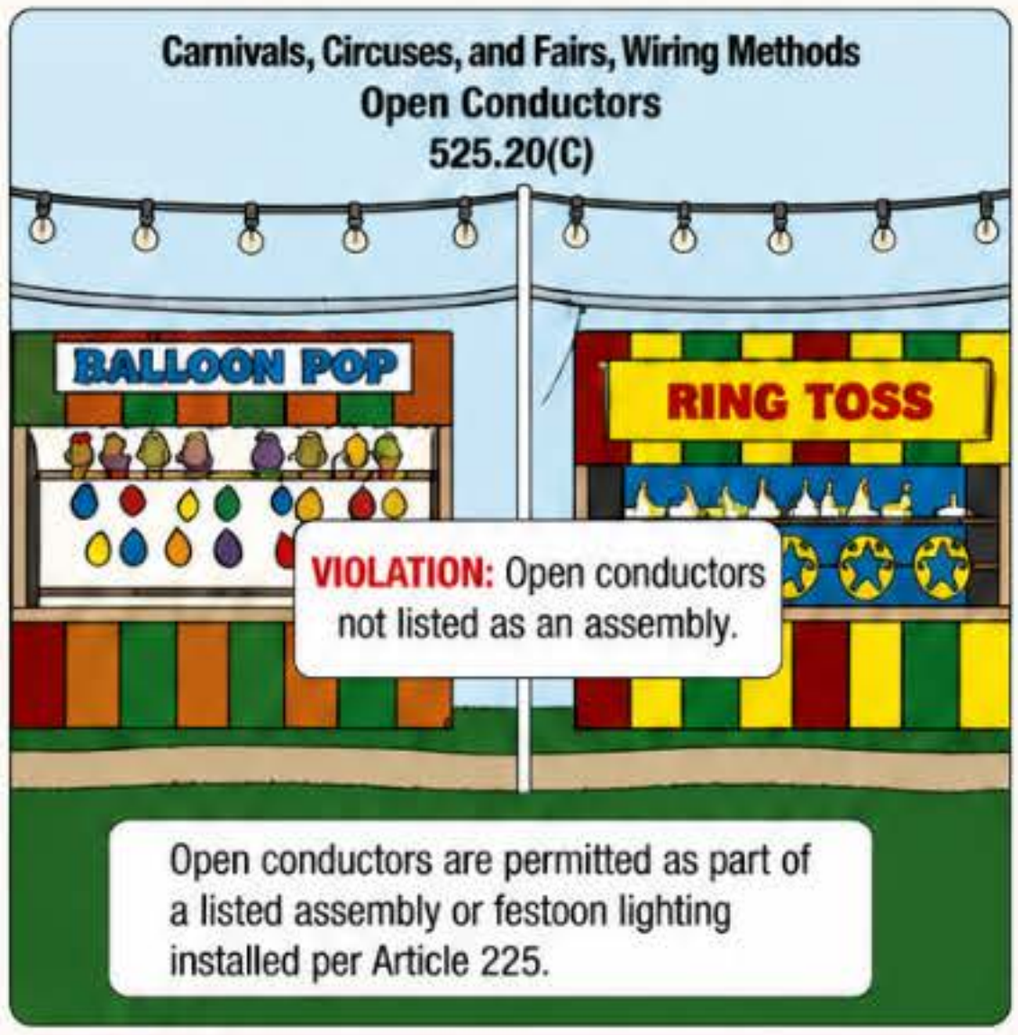


Figure 525–6

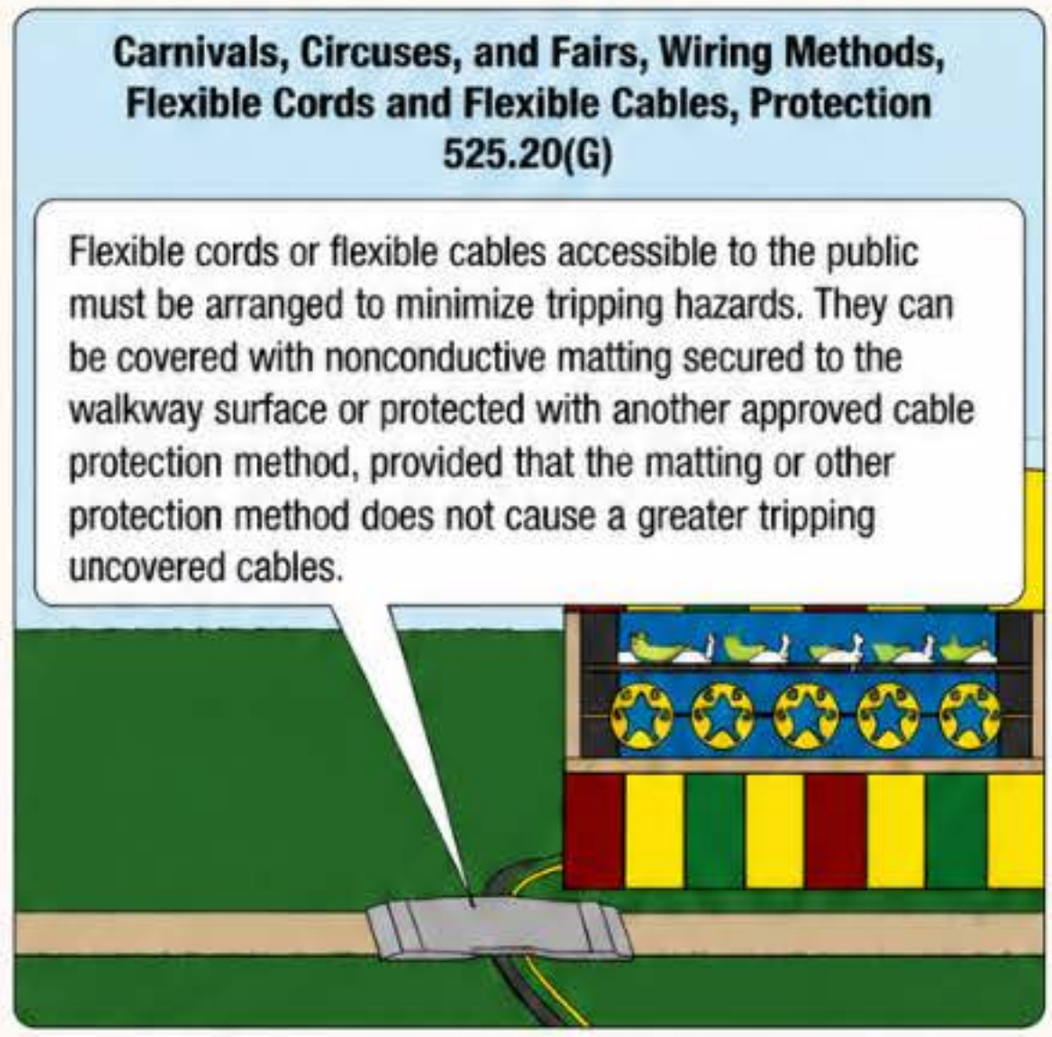


Figure 525–8

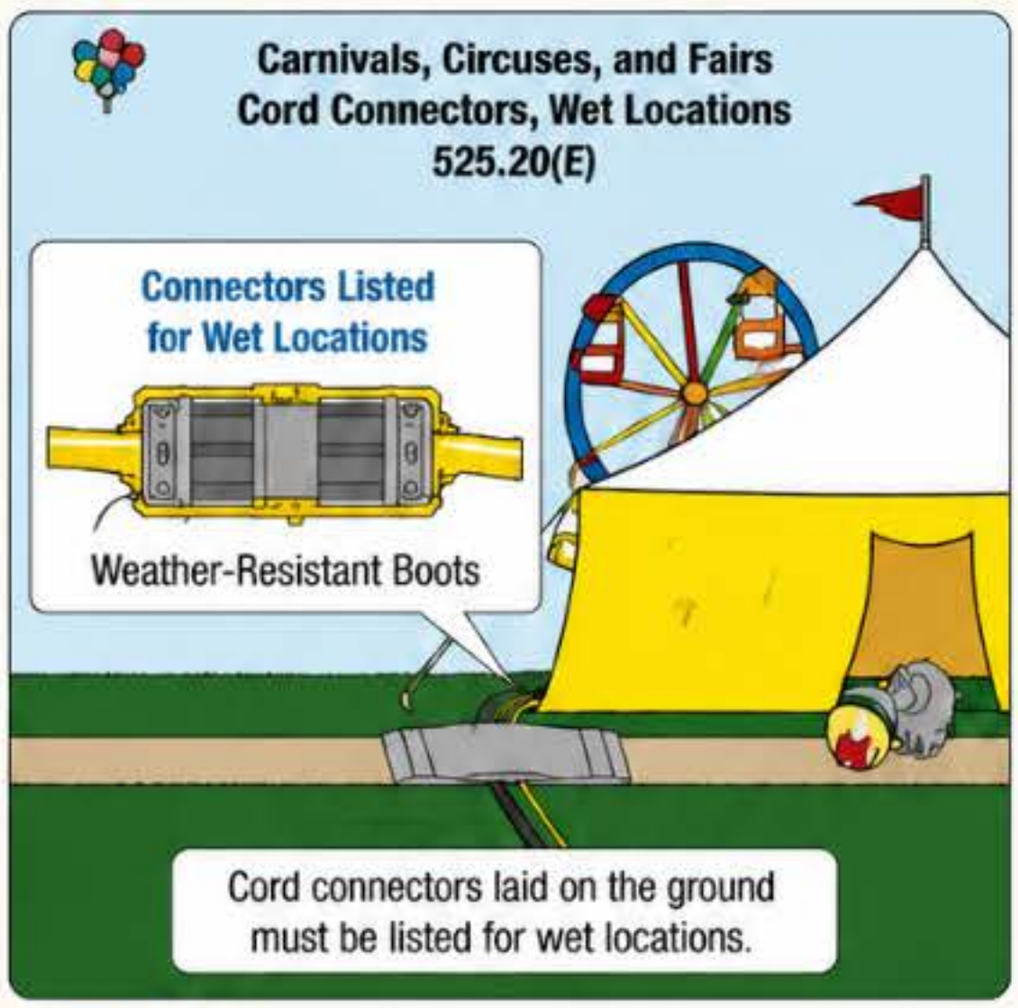


Figure 525–7

(G) Protection. Flexible cords or flexible cables accessible to the public must be arranged to minimize tripping hazard. They can be covered with nonconductive matting secured to the walkway surface or protected with another approved cable protection method, provided that the matting or other protection method does not constitute a greater tripping hazard than the uncovered cables. ▸ Figure 525–8

Burying cables is permitted and the burial depth requirements of 300.5 do not apply.

525.21 Rides, Tents, and Concessions

(A) Disconnecting Means. Each portable structure must have a disconnect that is within sight of, and within 6 ft of, the operator's station and readily accessible to the operator. Where accessible to unqualified persons, the disconnect must be lockable.

Author's Commentary:
The phrase "Within Sight" in Article 100 means that the disconnect is visible and not more than 50 ft from where the equipment is located.
— Michael Hamilton

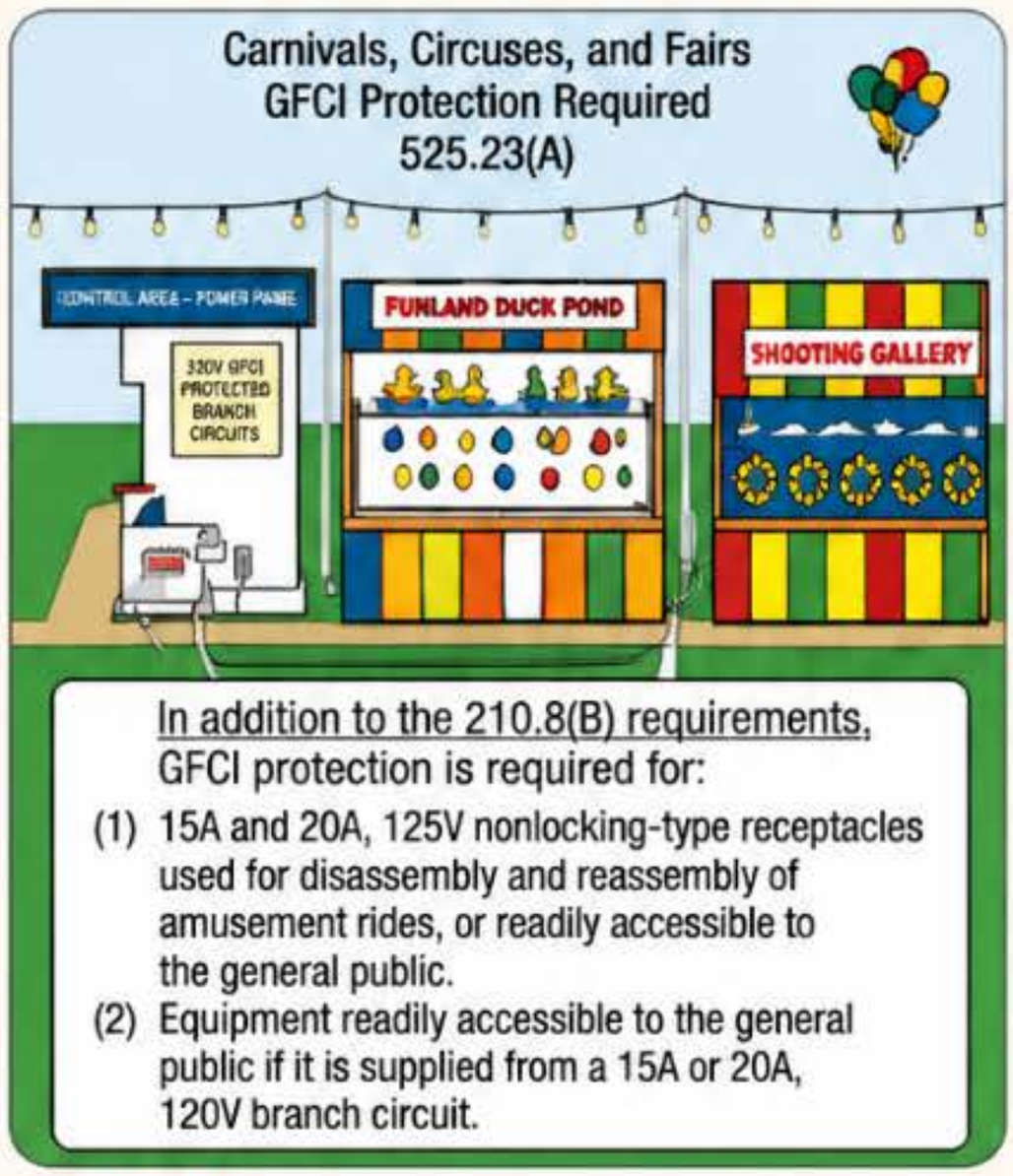
(B) Inside Tents and Concessions. Electrical wiring for lighting inside tents and concession areas must be securely installed. Where subject to physical damage, the wiring must be provided with mechanical protection [300.4] and lamps must be protected from accidental breakage by a suitable luminaire with a guard.

525.22 Outdoor Portable Distribution or Termination Boxes

(A) Terminal Boxes. Portable distribution and/or terminal boxes installed outdoors must be weatherproof, and the bottom of the enclosure must be not less than 6 in. above the ground.

525.23 GFCI-Protected Receptacles and Equipment

(A) GFCI Protection Required. In addition to the requirements of 210.8(B), GFCI protection must be installed for the following: ▸ Figure 525-9



▸ Figure 525-9

(1) 15A and 20A, 125V nonlocking-type receptacles used for disassembly and reassembly of amusement rides and attractions, or readily accessible to the general public.

(2) Equipment readily accessible to the general public if it is supplied from a 15A or 20A, 120V branch circuit.

GFCI protection can be provided by the integral trip mechanism in the attachment plug, by a GFCI device at the power-supply cord's origin, or by a cord set that incorporates GFCI features.

(B) GFCI Protection Not Required. GFCI protection is not required for locking-type receptacles that are not within reach of the general public.

(C) GFCI Protection Not Permitted. GFCI protection is not allowed for egress lighting.

Author's Commentary:

- Keeping exit lighting energized is essential. GFCI protection is not allowed to turn it off or leave areas in the dark.

— Michael Hamilton

Part IV. Grounding and Bonding

525.31 Equipment Grounding

All metal components of electrical equipment must be connected to an equipment grounding conductor of the type specified by 250.118.

525.32 Portable Equipment Grounding Conductor Continuity

Continuity of circuit equipment grounding conductors for portable electrical equipment must be verified each time the equipment is connected.

Author's Commentary:

- Checking equipment grounding conductors helps ensure electrical safety. This rule does not prescribe how to perform the test, what must be checked, or who is required or qualified to carry it out.

— Michael Hamilton

ARTICLE 547 AGRICULTURAL BUILDINGS

Introduction to Article 547—Agricultural Buildings

Three elements—dust, moisture, and the overall corrosive environment—can drastically shorten the service life of agricultural equipment.

Dust infiltrates mechanisms and accelerates wear. When mixed with electricity, dust can add new hazards: ignition and explosions. In barns, grain storage buildings, and fertilizer areas, dust is highly combustible. Combustible substances such as straw and hay also pose a serious fire threat.

Moisture is the second major concern. It promotes corrosion and can lead to damage for many reasons, including simple wash down.

Ammonia from animal waste may release corrosive vapors that attack mechanical equipment and wiring systems, possibly causing electrical failures. Because of these issues, Article 547 sets special requirements for installations where dust, moisture, and corrosive conditions are present.

These rules add to other general requirements. For example, properly installed equipment within concrete floor confinements in livestock facilities that contain metallic parts accessible to animals is expected to operate longer and with better reliability.

Livestock is sensitive to changes in voltage. Even small differences can reduce milk yield and, at times, lead to animal deaths. Therefore, the *NEC* includes specific installation rules for buildings that house livestock.

547.1 Scope

Article 547 covers agricultural buildings and adjacent or related areas of similar nature as described in (A) or (B). Figure 547–1

Article 547 applies to agricultural buildings, or to that part of a building or adjacent areas of similar nature per (A) or (B).

(A) Buildings or areas where excessive dust and/or dust with water may accumulate.

(B) Buildings or areas where a corrosive atmosphere exists.

Figure 547–1

(A) Excessive Dust and Dust with Water. Buildings or areas where large amounts of dust, or dust mixed with water, can accumulate. Examples include locations with poultry, livestock, and confined feeding systems where litter or feed dust builds up.

(B) Corrosive Atmosphere. Buildings or areas where a corrosive atmosphere is present, under any of the following conditions:

(1) Poultry and animal waste.

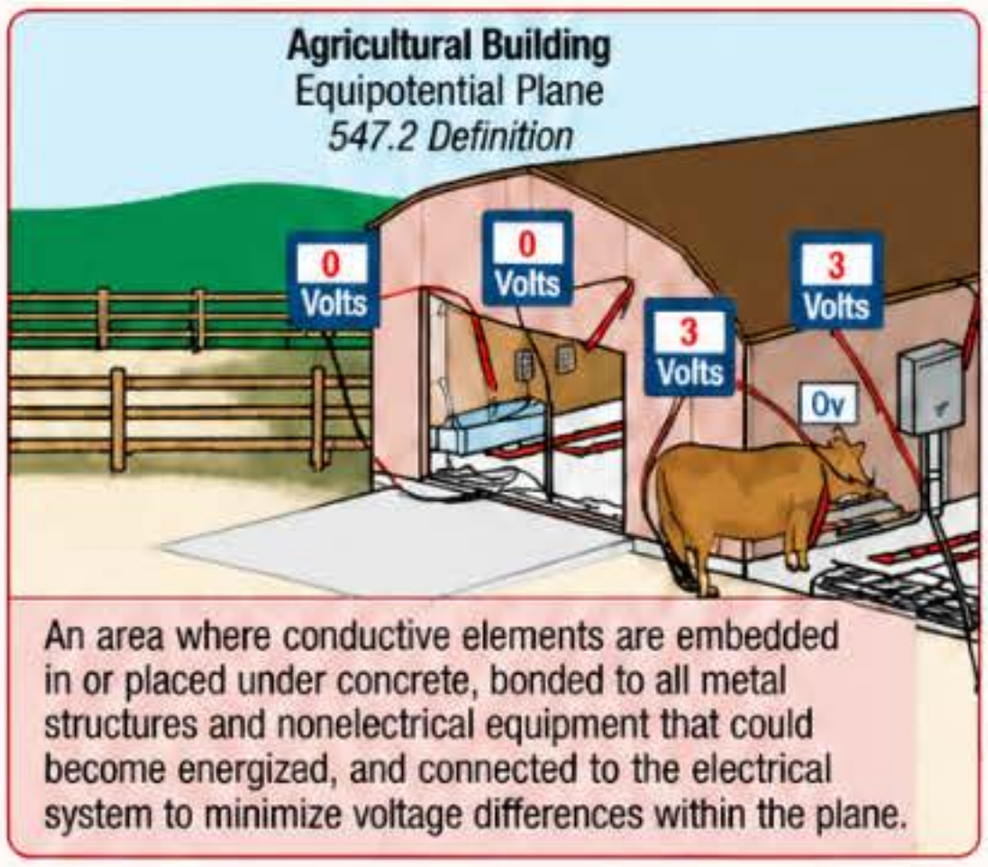
(2) Corrosive particles that may mix with water.

(3) Areas that are damp or are cleaned by periodic washing.

547.2 Definitions

Definitions in this section apply only within this article.

Equipotential Plane (as applied to agricultural buildings). An area where conductive materials are embedded in or placed under concrete, bonded together by metallic means and non-electrical equipment that could become energized, and connected to the electrical system to reduce voltage differences within the plane. Figure 547–2



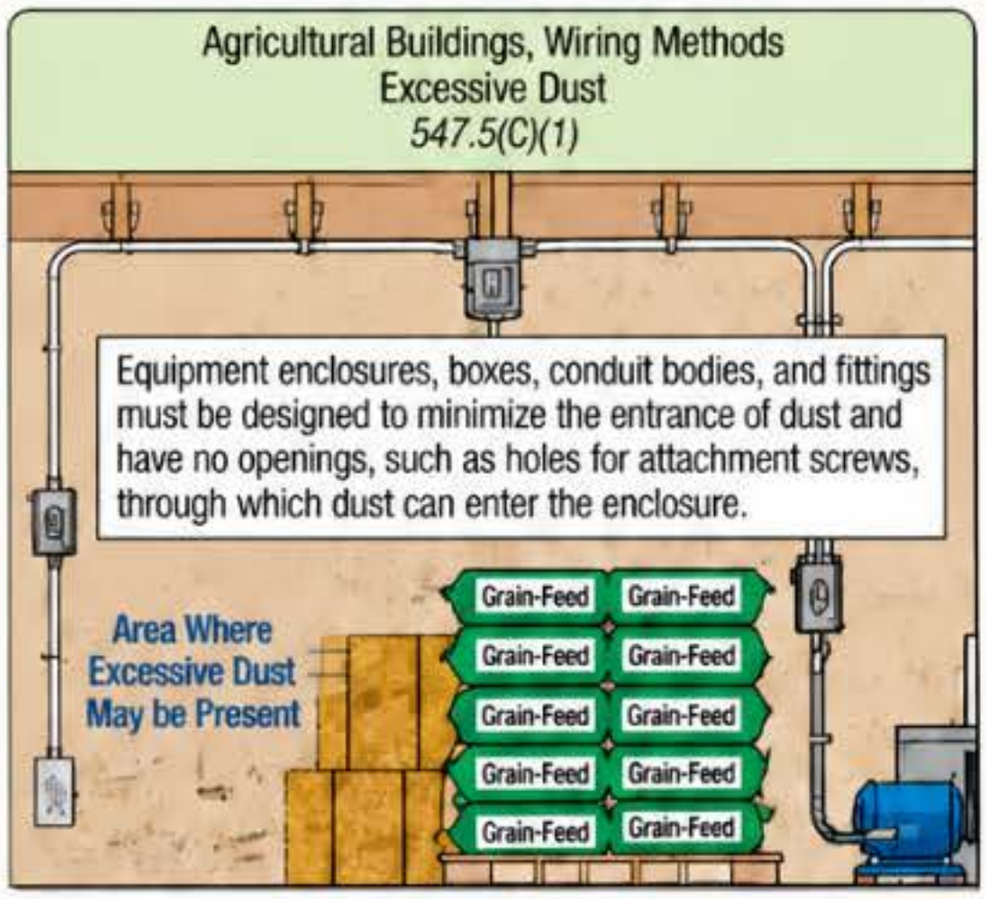
▸ Figure 547-2

547.5 Wiring Methods

(A) Wiring Systems. Types UF, NMC, and SE cables that use copper conductors, jacketed Type MC cable, PVC conduit, or liquidtight flexible nonmetallic conduit may be installed in agricultural buildings.

(C) Equipment Enclosures, Boxes, Conduit Bodies, and Fittings.

(1) Excessive Dust. In locations within agricultural buildings where heavy dust may be present, enclosures, boxes, conduit bodies, and fittings must be designed to reduce the entry of dust. They may not have any openings, such as holes for attachment screws, through which dust can enter. ▸ Figure 547-3



▸ Figure 547-3

Author's Commentary:

- Weatherproof boxes and covers can be used to satisfy this requirement.

— Michael Hamilton

(2) Damp or Wet Locations. In damp or wet areas of agricultural buildings, equipment enclosures, boxes, conduit bodies, and fittings must be kept dry by preventing moisture intrusion or accumulation. Boxes, conduit bodies, and fittings installed in wet areas must be suitable for wet locations and the enclosures must be **weather-resistant.**

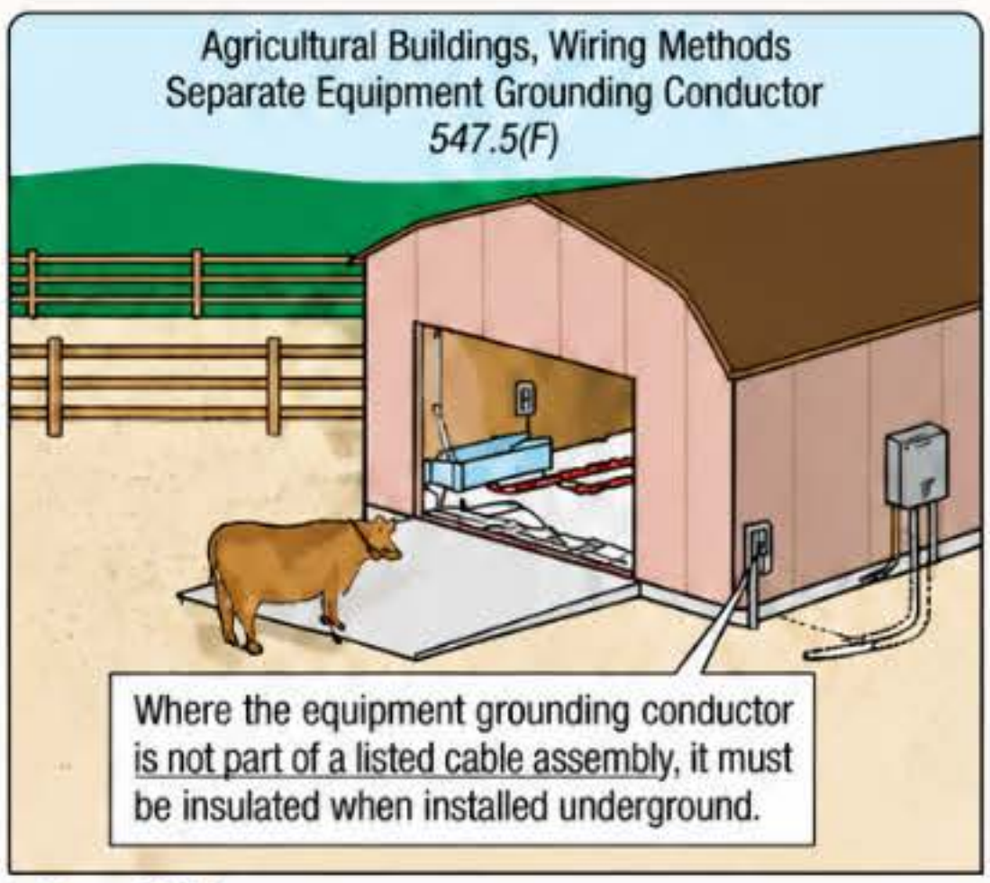
(3) Corrosive Atmosphere. Where moisture, dust, corrosive vapors, or other corrosive conditions may be present inside agricultural buildings, equipment enclosures, boxes, conduit bodies, and fittings must be made of corrosion-resistant materials that are appropriate for the environment.

Note 1: See Table 110.28 for appropriate enclosures for the location.

(D) Flexible Connections. Use flexible connectors, liquidtight flexible connectors, liquidtight flexible metal conduit, liquidtight flexible nonmetallic conduit, or flexible cord listed for hard usage when flexible connections are necessary.

(E) Physical Protection. Electrical wiring and equipment must be installed in a manner that protects them from physical damage. See 300.4.

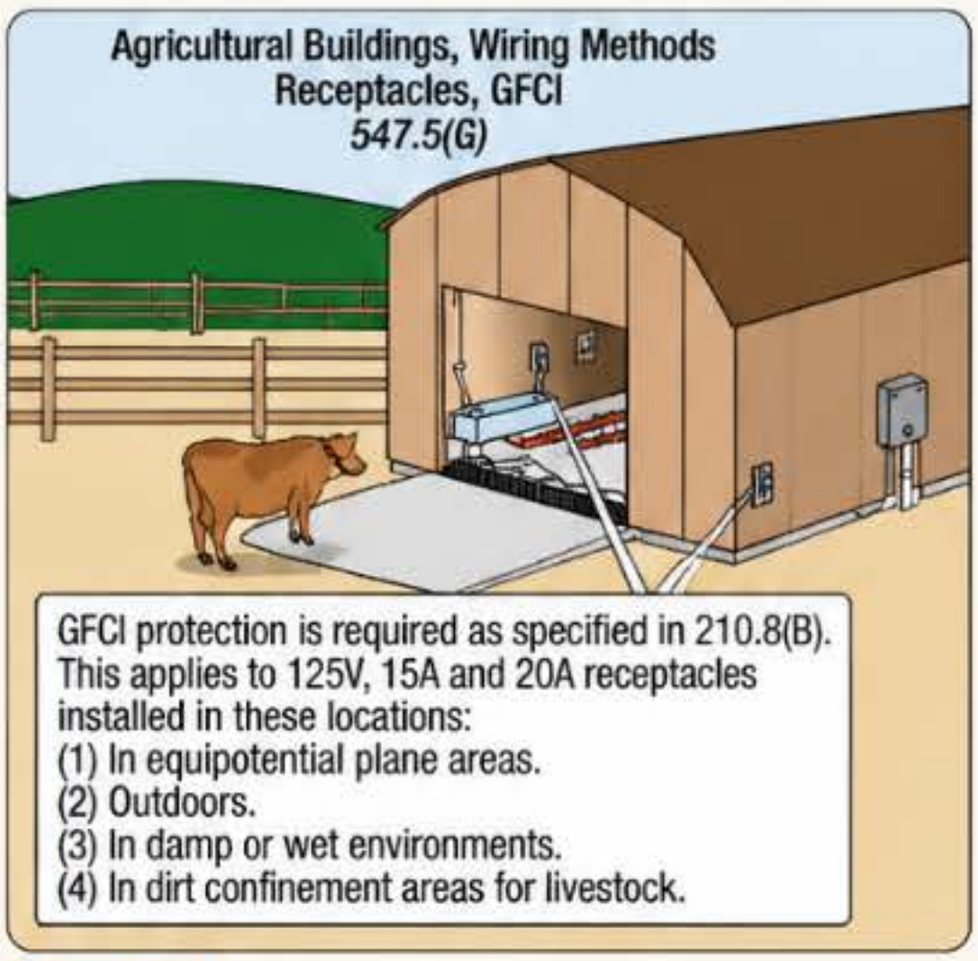
(F) Separate Equipment Grounding Conductor. If the equipment grounding conductor is not included as part of a listed cable assembly, it must be insulated when installed underground. ▸ Figure 547-4



▸ Figure 547-4

Agricutural Buildings | 547.10

(G) GFCI Protection of Receptacles. All receptacles defined in 210.8(B) need GFCI protection. This applies not only to 125V, 15A and 20A receptacles, but also to those installed within the following areas: ▸Figure 547–5



▸Figure 547–5

(1) Zones that have an equipotential plane as outlined in 547.10(A).

(2) Outdoors.

(3) Damp or wet environments.

(4) Dirt confinement areas for livestock.

Author's Commentary:

Refer to 210.8(B) for GFCI protection of 250V, 30A and 50A receptacles installed in accessory structures located on or beside agricultural sites used to store or service farm equipment and supplies.

— Michael Hamilton

547.8 Luminaires

Luminaires must comply with the following guidelines:

(A) Reduce Dust Entry. Install luminaires to limit the entry of dust, foreign matter, moisture, and corrosive substances.

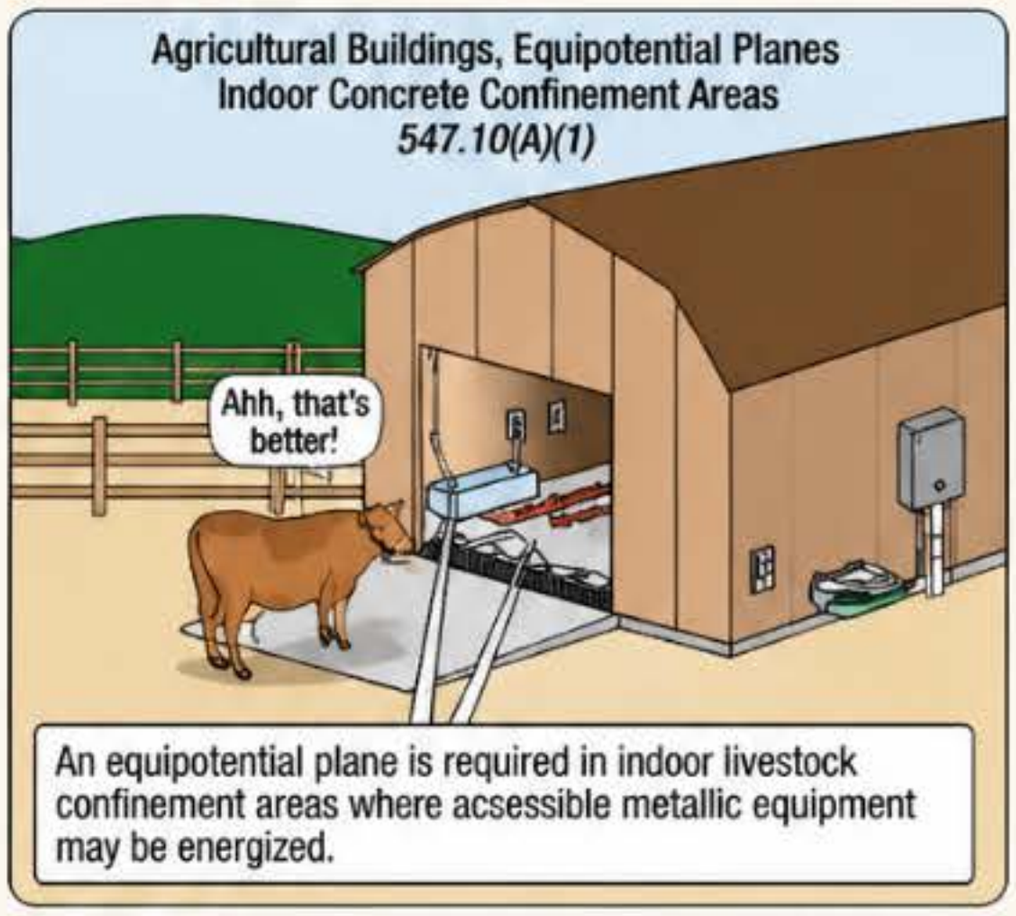
(B) Guard Against Impact. Protect luminaires from physical harm by using an adequate guard.

(C) Wet Location Use. Luminaires intended for use in wet locations must be identified accordingly.

547.10 Equipotential Planes

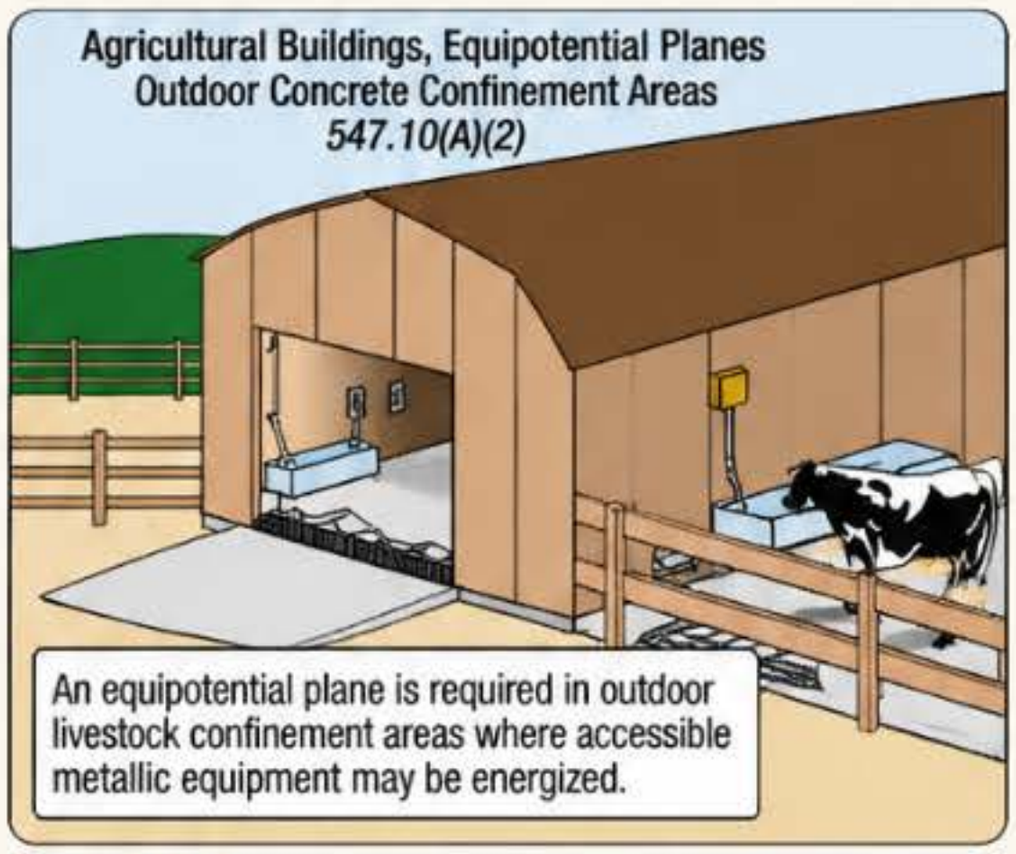
(A) Where Required. Equipotential planes must be installed in accordance with the following requirements:

(1) Indoor Concrete Confinement Areas. An equipotential plane is required in indoor livestock confinement areas where metallic equipment that livestock can reach may become energized. ▸Figure 547–6



▸Figure 547–6

(2) Outdoor Concrete Confinement Areas. An equipotential plane is required in outdoor livestock confinement areas where metallic equipment that livestock can reach may become energized. ▸Figure 547–7



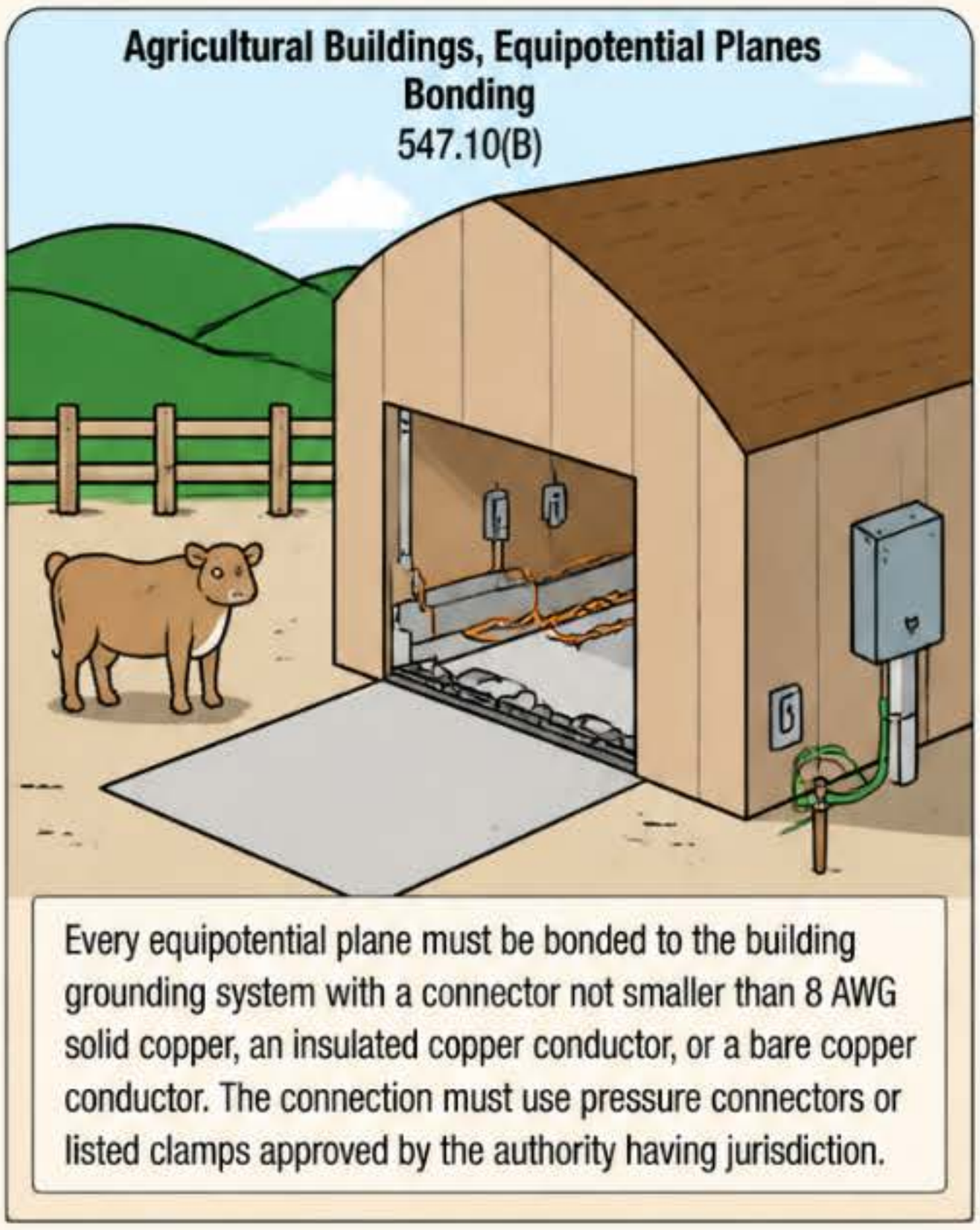
▸Figure 547–7

547.10 | Agricultural Buildings

(B) Bonding. All equipotential planes must be tied to the building's electrical grounding system using a bonding conductor that is not smaller than an 8 AWG solid copper wire, an insulated copper conductor, or a bare copper conductor. The connection must be made with pressure connectors or listed clamps approved for the purpose by the authority having jurisdiction. ▸ **Figure 547–8**

Note 1: ASABE Standard EP473.2, *Equipotential Planes in Animal Containment Areas*, offers guidance on establishing a voltage gradient ramp at the entrances to agricultural buildings.

Note 2: See the American Society of Agricultural and Biological Engineers (ASABE) EP342.2, *Safety for Electrically Heated Livestock Waterers.*



Every equipotential plane must be bonded to the building grounding system with a connector not smaller than 8 AWG solid copper, an insulated copper conductor, or a bare copper conductor. The connection must use pressure connectors or listed clamps approved by the authority having jurisdiction.

▸ **Figure 547–8**

Author's Commentary:

- The bonding rules in Article 547 are different from other locations because livestock are very sensitive to even small voltage differences, especially in wet or damp confined spaces.
- Typically, the voltage difference between metal parts and the earth is so low that it does not create a shock risk for people. However, if livestock touches the metal, the impact of these differences can be serious to milk production. Although the stock can tolerate up to about 0.50 volts RMS, anything higher may harm milk yield.

— Michael Hamilton

ARTICLE 550

MOBILE HOMES, MANUFACTURED HOMES, AND MOBILE HOME PARKS

Introduction to Article 550—Mobile Homes, Manufactured Homes, and Mobile Home Parks

Different kinds of dwellings experience the greatest number of fires. Article 550 addresses certain factors that contribute to these fires and outlines ways to reduce them. It covers both mobile homes and manufactured homes used as living quarters, along with the mobile home parks in which people live. It also includes structures such as construction trailers or clinics [550.4(A)].

Mobile homes and manufactured homes are not dealt with using the same building rules that apply to site-built houses. Instead, HUD standards are used. According to HUD, both terms refer to the same type of dwelling, and the phrase "mobile home" may have been used for many decades. Confusion between the *NEC* and industry practices can occur, so consult the *Code* carefully when applying this article.

Part I. General

550.1 Scope

Article 550 covers electrical conductors and equipment installed within or on mobile and manufactured homes, conductors that connect mobile and manufactured homes to the electric supply, and the installation of electrical wiring, luminaires, and electrical equipment within mobile home parks. ***Figure 550-1***

Figure 550-1

In addition, this article applies to electrical equipment related to the mobile home feeder/service-entrance conductors and service disconnects as covered by Part III of this article.

550.2 Definitions

These definitions apply wherever this article is used throughout the *Code*.

Manufactured Home. A structure, in the travel mode, that is at least 8 ft wide and 40 ft long, constructed on a chassis and intended for use as a dwelling unit with or without a permanent foundation. ***Figure 550-2***

Author's Commentary:

▸ See Article 100 for the definition of "Dwelling Unit."

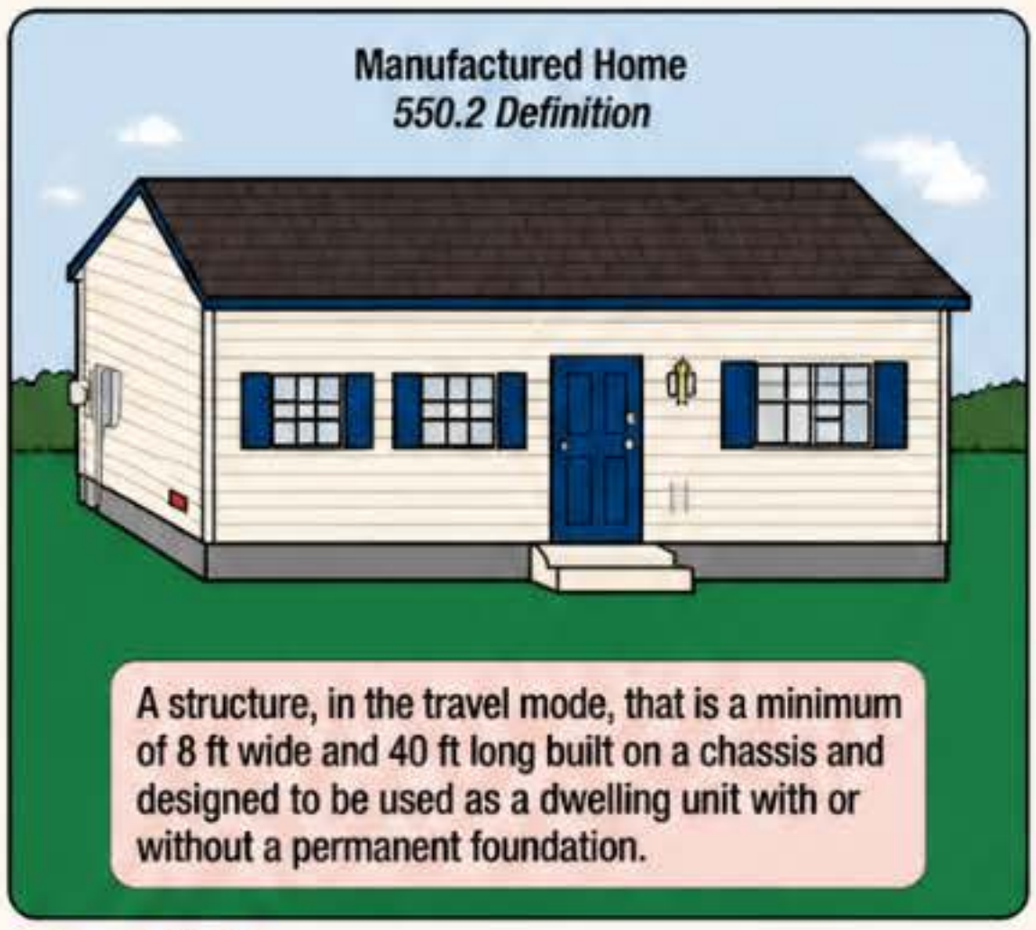
— Michael Hamilton

These definitions apply wherever this article is used throughout the *Code*.

Mobile Home. A transportable structure built on a permanent chassis and designed to be used as a dwelling unit without a permanent foundation. In this article and unless otherwise indicated, the term "mobile home" includes manufactured homes.

These definitions apply *only* within this article.

550.4 | Mobile Homes, Manufactured Homes, and Mobile Home Parks



▶ Figure 550–2

Mobile Home Accessory Building or Structure. Any awning, cabana, ramada, storage cabinet, carport, fence, windbreak, or porch established for the use of the occupant of the mobile home on a mobile home lot.

550.4 General Requirements

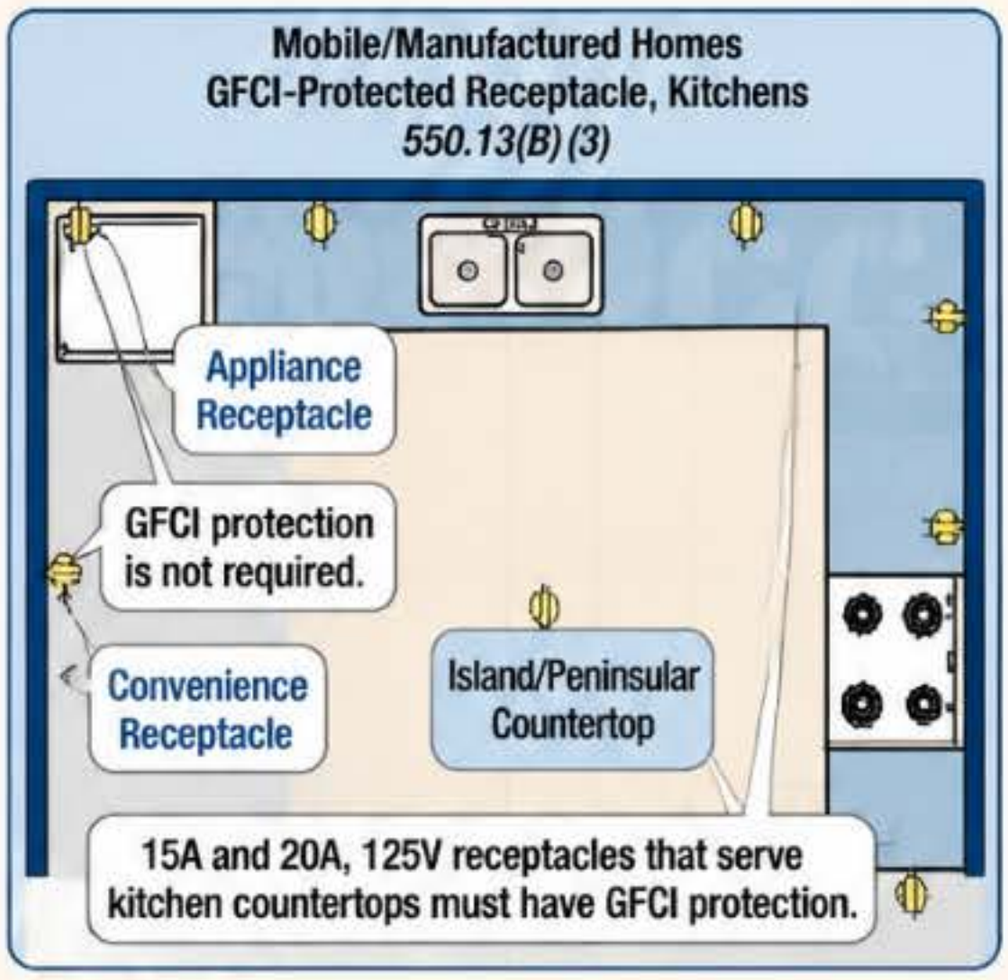
(B) Wiring System. Mobile homes must be connected to a 120/240V, nominal, grounded system.

Part II. Mobile and Manufactured Homes

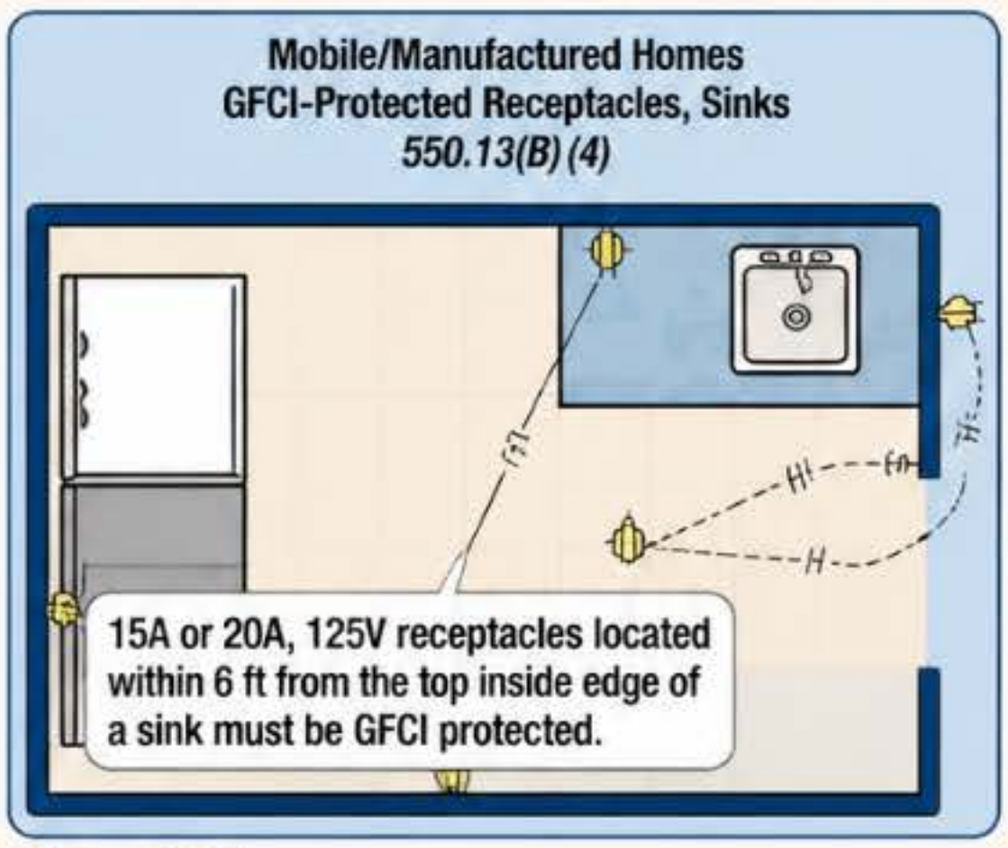
550.13 Receptacle Outlets

(B) GFCI-Protected Receptacles. Ground-fault circuit-interrupter protection must be provided as required in 210.8(A). GFCI protection is not required for other than 125V, 15A and 20A receptacles installed within a mobile or manufactured home in the following areas:

1. Compartments accessible from the outdoors.
2. Bathroom areas.
3. Kitchens, where receptacles are installed to serve countertop surfaces. ▶Figure 550–3
4. Sinks, where within 6 ft from the top inside edge of the sink. ▶Figure 550–4
5. Dishwashers. See 422.5(A)(7).



▶ Figure 550–3



▶ Figure 550–4

Author's Commentary:

See 210.8(A)(10) for mobile or manufactured homes with laundry areas; in addition to the washing machine, GFCI protection is required for the dryer receptacle.

— Michael Hamilton

550.15 Wiring Methods and Materials

(H) Under Chassis. Under-chassis line-voltage wiring (120V) must be installed in a raceway identified for wet locations.

550.33 Mobile Homes, Manufactured Homes, and Mobile Home Parks

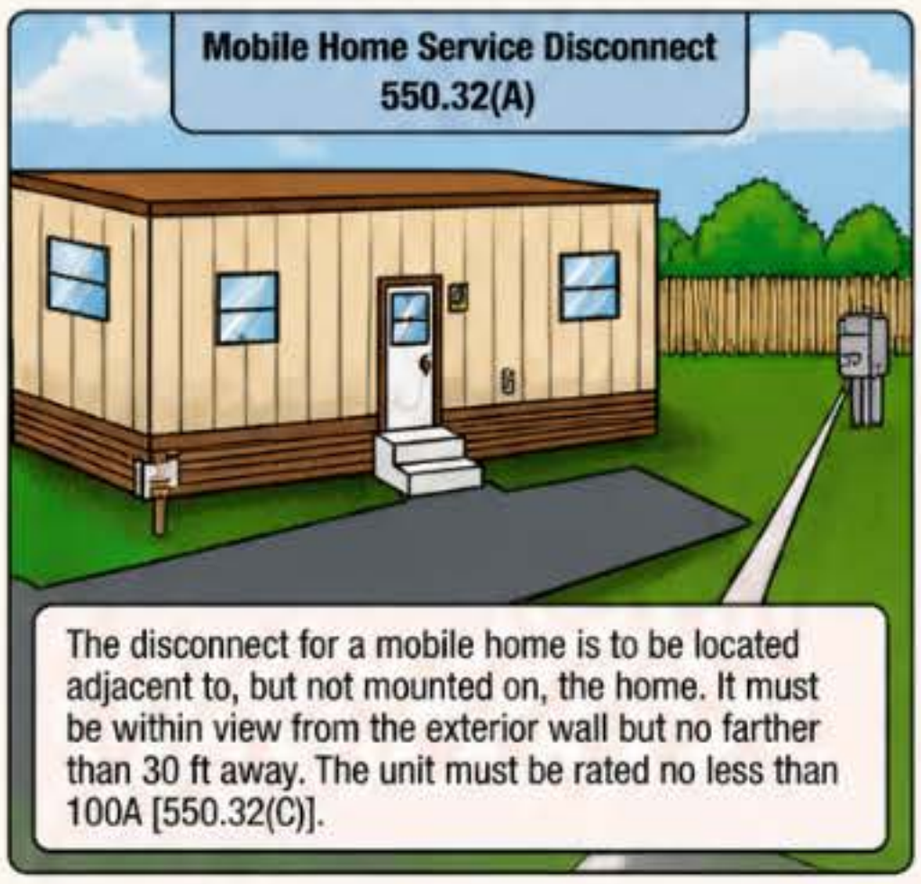
550.25 AFCI Protection

(B) Requirements. If a branch circuit is rated 15A or 20A, 120V, single-phase, the outlets or devices it serves that are installed by someone other than the manufacturer must have AFCI protection in accordance with 210.12.

Part III. Services and Feeders

550.32 Mobile and Manufactured Home Service Disconnect

(A) Mobile Home Disconnect. Install the service disconnect for a mobile home next to, but not on, the mobile home. It must be within sight from, but no more than 30 ft from, the outside wall of the home. The disconnect must be rated at not less than 100A [550.32(C)]. ▶ **Figure 550–5**



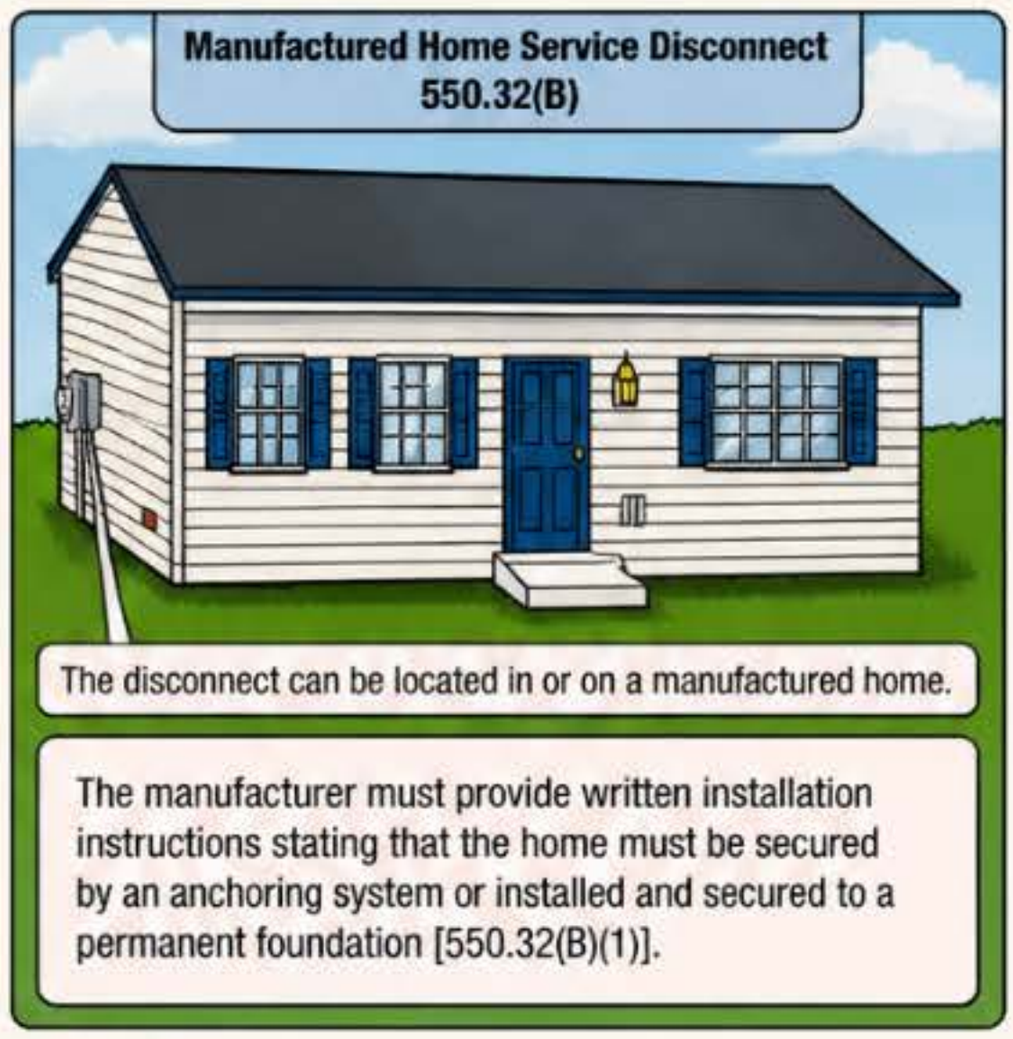
▶ **Figure 550–5**

Author's Commentary:

Article 100, **"Within Sight"** means the equipment is visible and located no more **than 50 ft from** where it is situated. However, for this section, one must meet the stricter 30-ft limit.

— Michael Hamilton

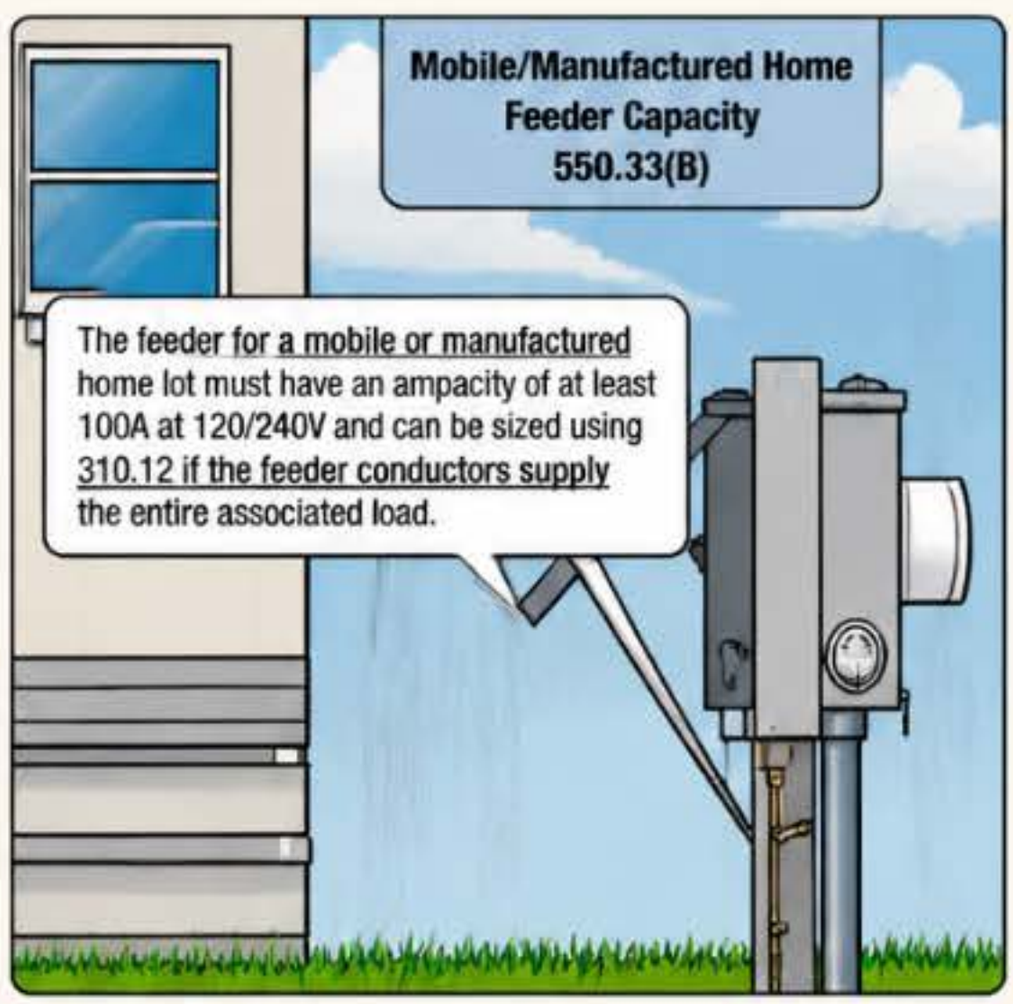
(B) Manufactured Home Disconnect. For a manufactured home, place the service disconnect on or near the home. Follow the manufacturer's installation instructions, which typically require the home to be secured by an anchoring system or installed and permanently fastened to a permanent foundation [550.32(B)(1)]. ▶ **Figure 550–6**



▶ **Figure 550–6**

550.33 Feeder

(B) Feeder Capacity. A feeder supplying a mobile or manufactured home must have an ampacity of at least 100A at 120/240V and may be sized using 310.12 if the feeder conductors supply the entire associated load. ▶ **Figure 550–7**



▶ **Figure 550–7**

Mobile Homes, Manufactured Homes, and Mobile Home Parks | 550.33

550.25 AFCI Protection

(B) Requirements. For 15A or 20A, 120V, single-phase branch-circuit outlets or devices installed by someone other than the manufacturer, the circuit must be AFCI protected in accordance with 210.12.

Part III. Services and Feeders

550.32 Mobile and Manufactured Home Service Disconnect

(A) Mobile Home Disconnect. The service disconnect for a mobile home must be positioned adjacent to—but not mounted on or within—the mobile home. It must be placed within sight from, but not more than 30 ft from, the exterior wall of the mobile home and must be rated at not less than 100A [550.32(C)]. ▶ Figure 550–5

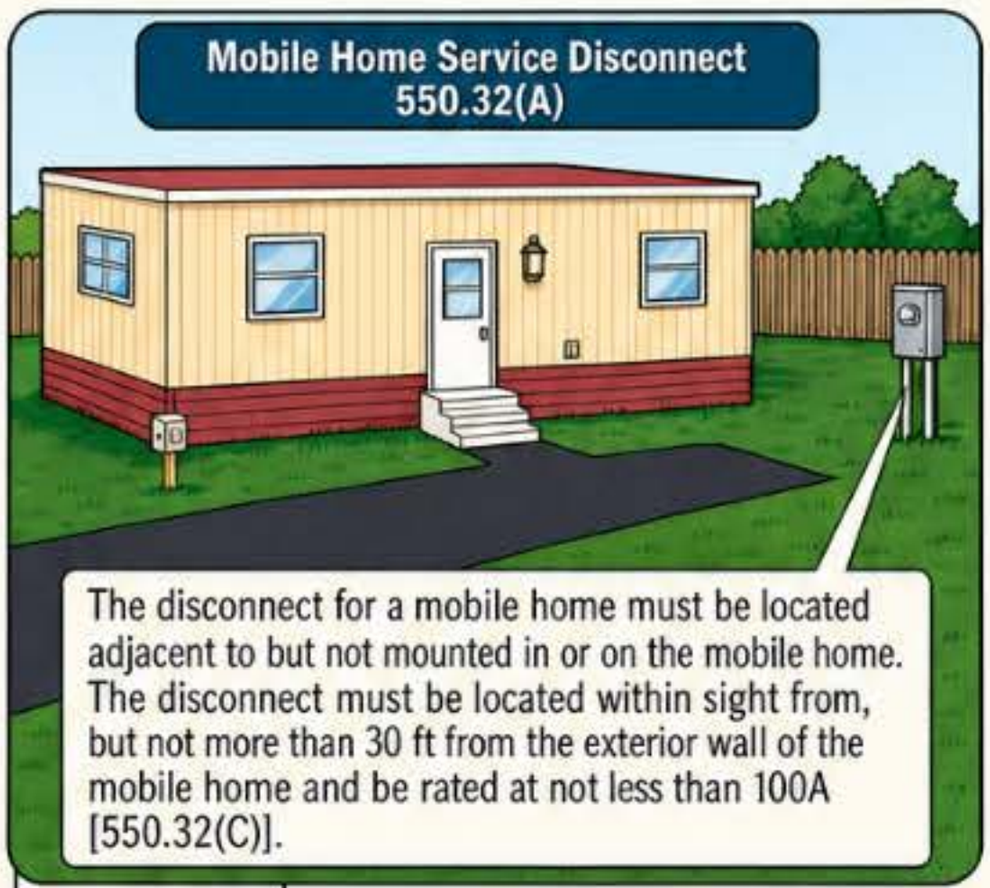


Figure 550–5

Author's Commentary:

▶ *Article 100 defines "Within Sight" as a location that is visible and no more than 50 ft from the equipment. In this situation, installations must comply with the maximum 30-ft limitation of this section.*

— Michael Hamilton

(B) Manufactured Home Disconnect. The service disconnect can be located in or on a manufactured home. The manufacturer must include written installation instructions indicating that the home must be secured by an anchoring system or installed and secured to a permanent foundation [550.32(B)(1)]. ▶ Figure 550–6

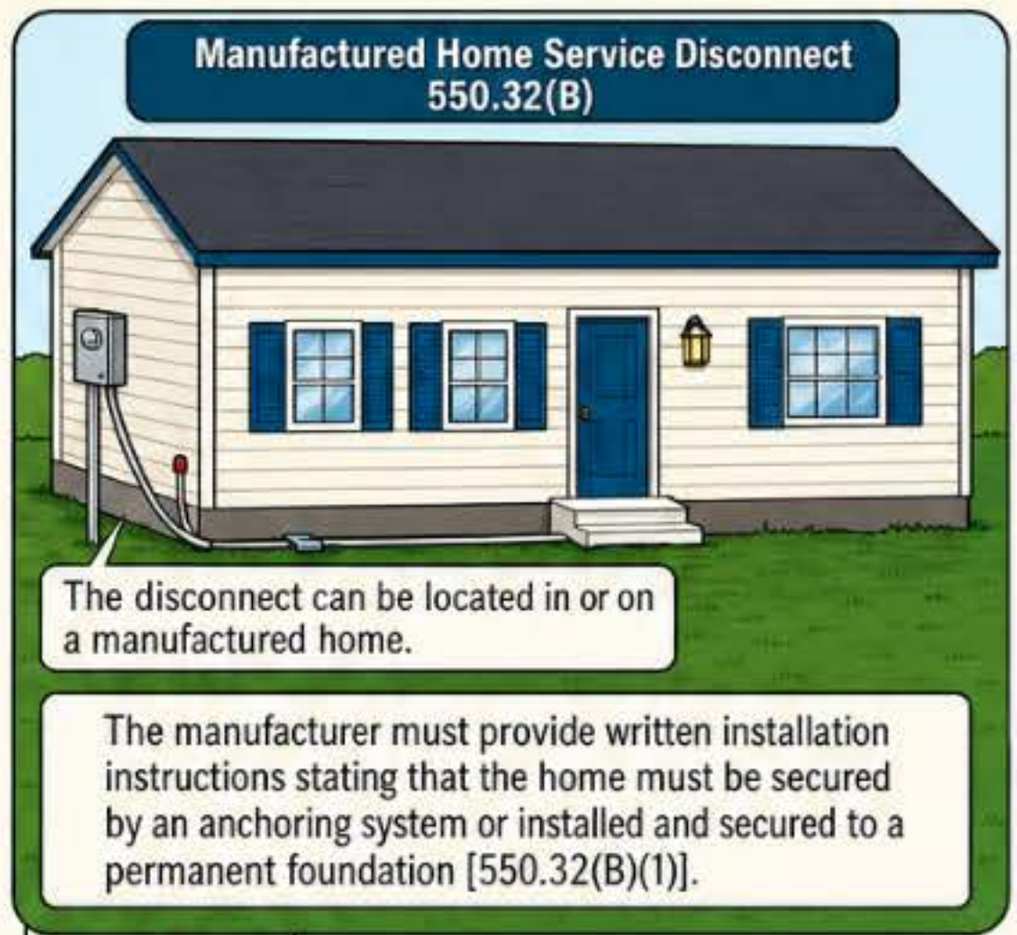


Figure 550–6

550.33 Feeder

(B) Feeder Capacity. The feeder for a mobile or manufactured home lot must have an ampacity of at least 100A at 120/240V and can be sized using 310.12 if feeder conductors supply the entire associated load. ▶ Figure 550–7

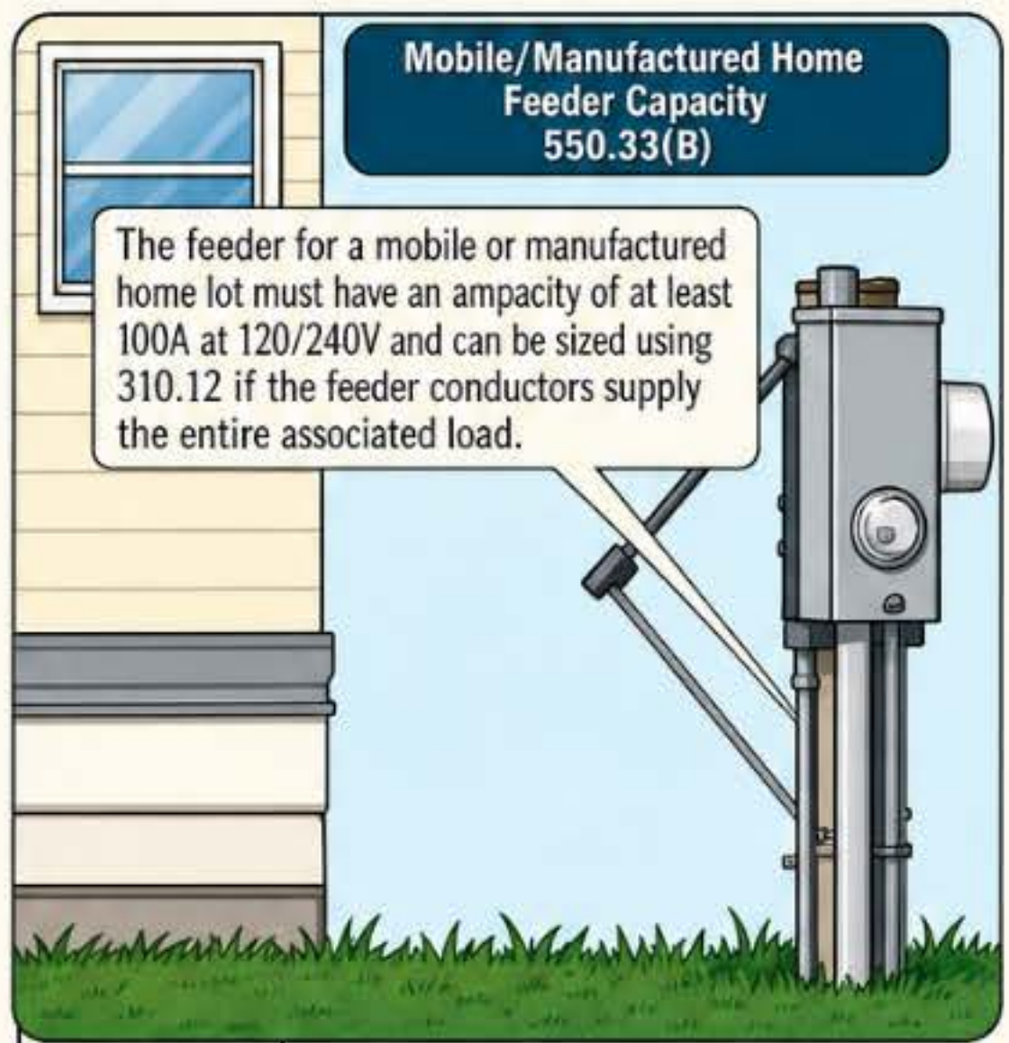


Figure 550–7

DEFINITIONS | From Michael Hamilton Publications

ARTICLE 555

MARINAS, BOATYARDS, AND DOCKING FACILITIES

Introduction to Article 555—Marinas, Boatyards, and Docking Facilities

Water levels constantly change. Ocean tides rise and fall, while lakes and rivers also shift in depth with rainfall. To supply electricity to a marina, boatyard, or docking facility, you must account for these changing water levels between the point of use and the power source. Article 555 addresses this requirement.

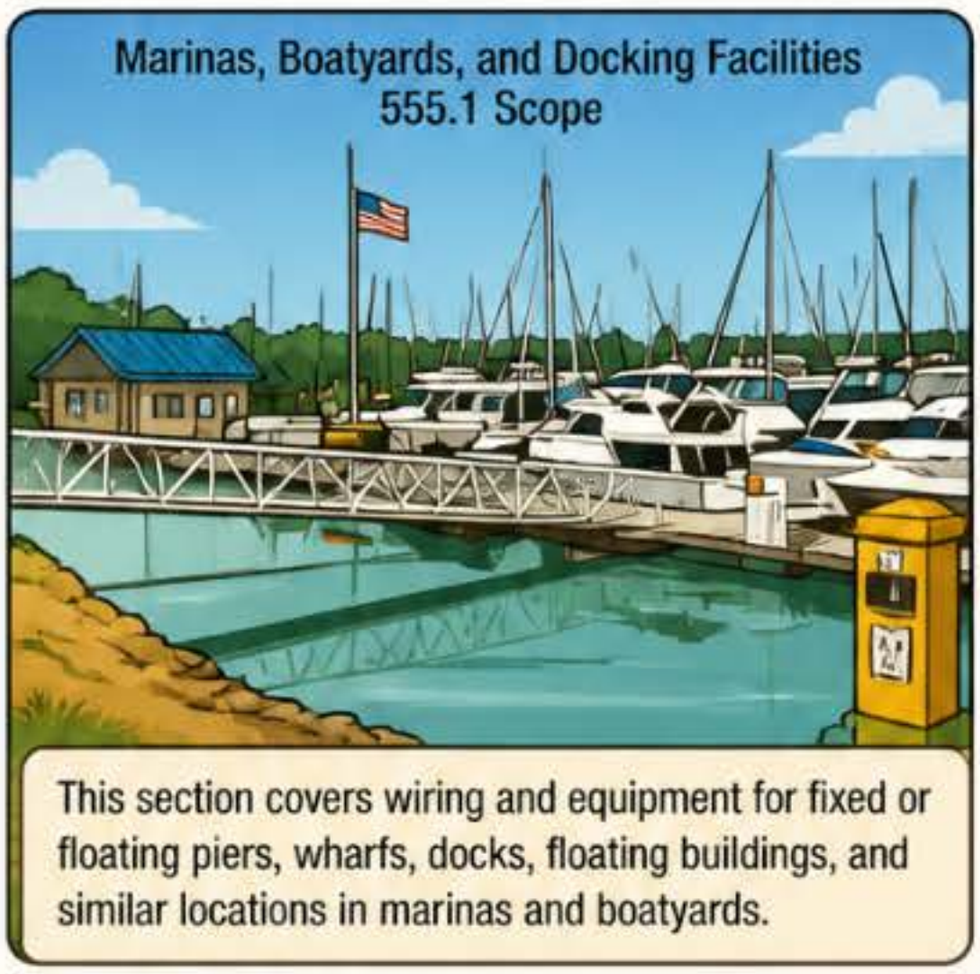
This article begins with the idea of the electrical datum plane. You can think of it as the edge of a "de-energized" zone" for electrical equipment. Or imagine it as the boundary of a "no man's land" where electrical equipment is not permitted. Once you identify where this plane is, do not place transformers, connections, or receptacles below that line.

Because of past electrocution incidents, power systems in marinas and boatyards now require increased electrical safety. Modern installations include ground-fault protection, leakage-detection devices, and visible warning signs to alert people about the presence of dangerous voltages and currents in the water.

Part I. General

555.1 Scope

Article 555 applies to electrical installations in residences and commercial locations that use fixed or floating piers, wharfs, docks, floating buildings, and other waterfront areas in marinas and boatyards. ▸Figure 555–1



▸Figure 555–1

555.2 Definitions

Author's Commentary:
Several terms used in this section also appear in Article 100 of the *NEC*® (2023 Edition). They are repeated here and include notes for clarity and example purposes.

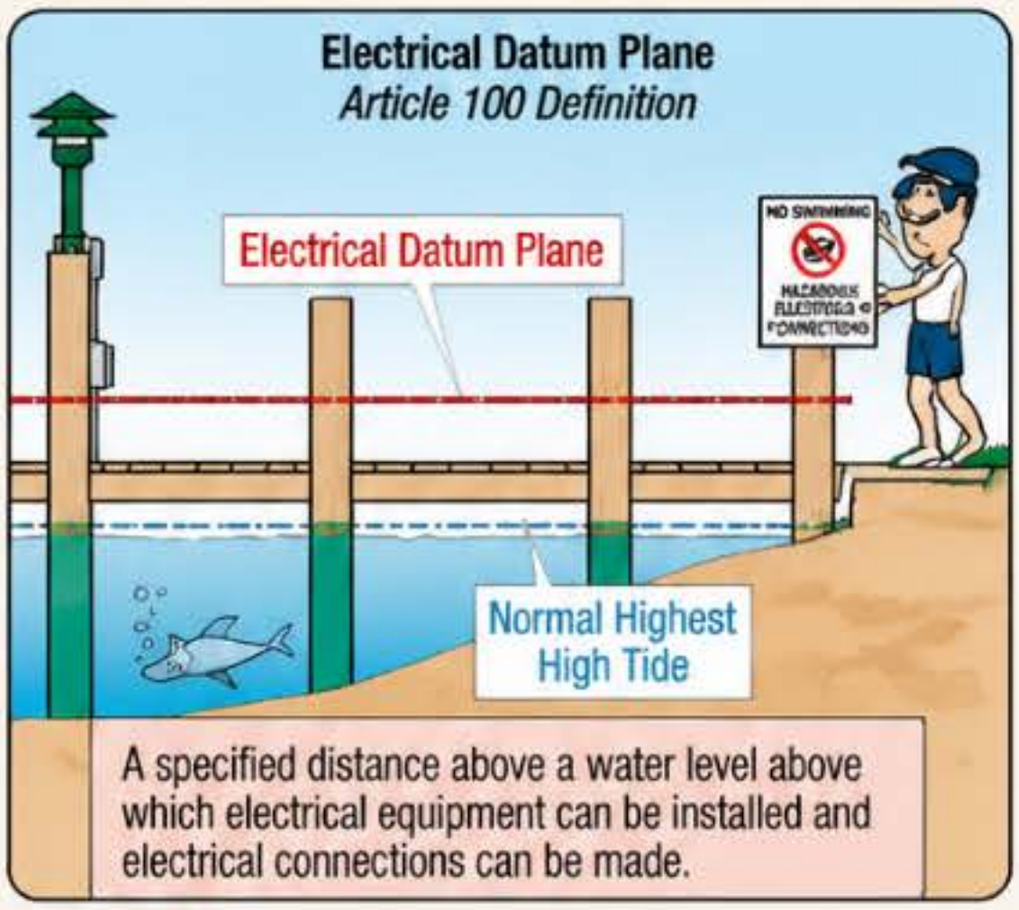
— Michael Hamilton

Docking Facility. A covered or open structure, fixed or floating, that provides a secured area for boats to be tied up.

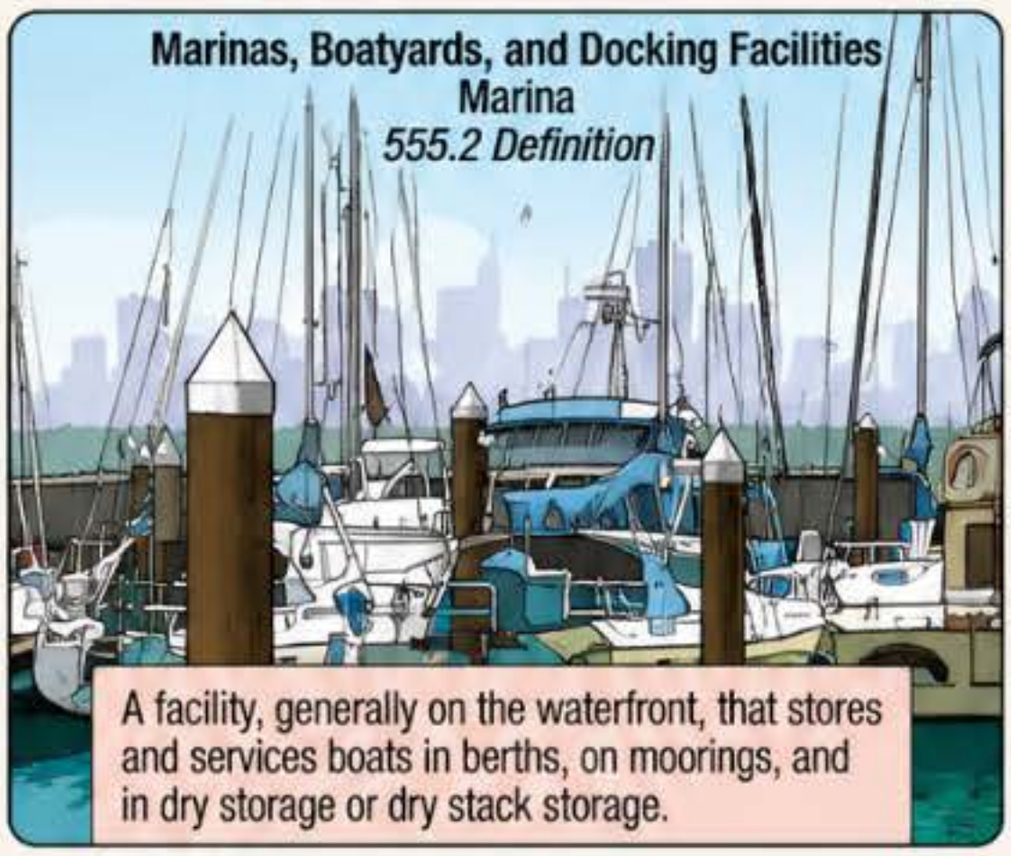
Electrical Datum Plane. A designated elevation above a water level (which may change due to tides or other variances) above which electrical equipment can be installed and electrical connections can be made. ▸Figure 555–2

Marina. A location—most often on the water—where boats are kept in berths or on moorings and where services are available, including dry storage or dry stack storage. ▸Figure 555–3

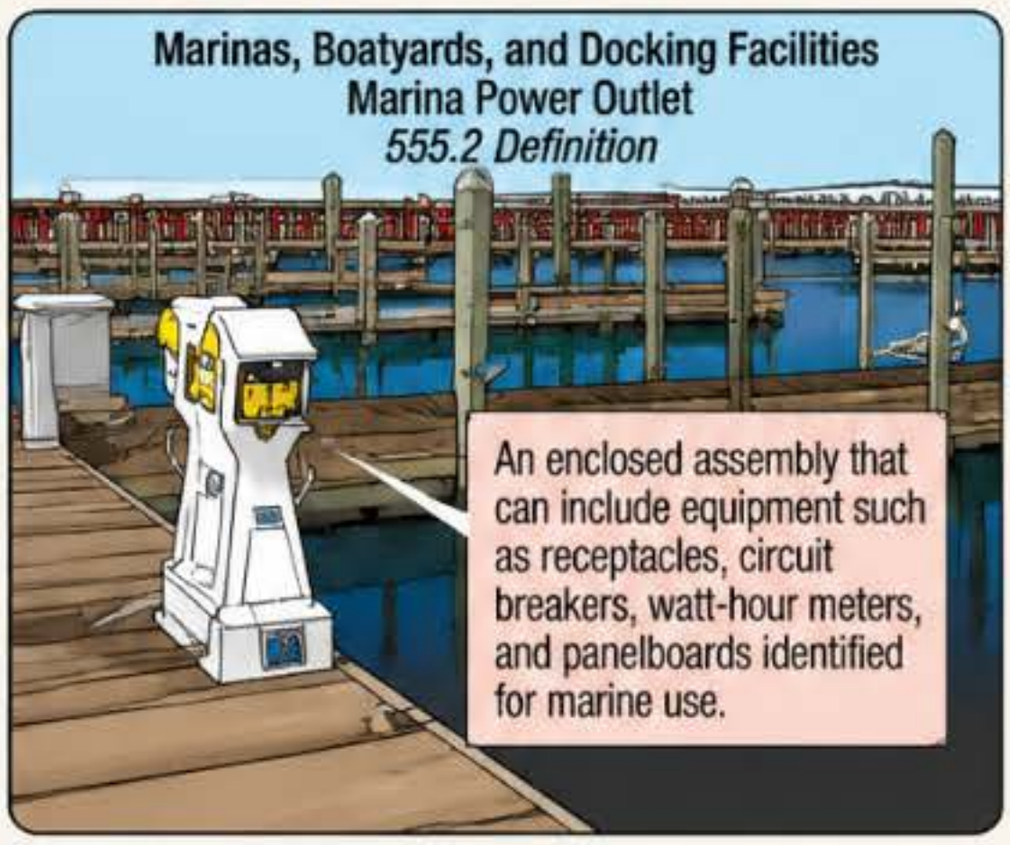
Marine Power Outlet. An enclosed assembly that may include equipment such as receptacles, circuit breakers, watt-hour meters, and panelboards approved for marine use. ▸Figure 555–4



▸Figure 555-2

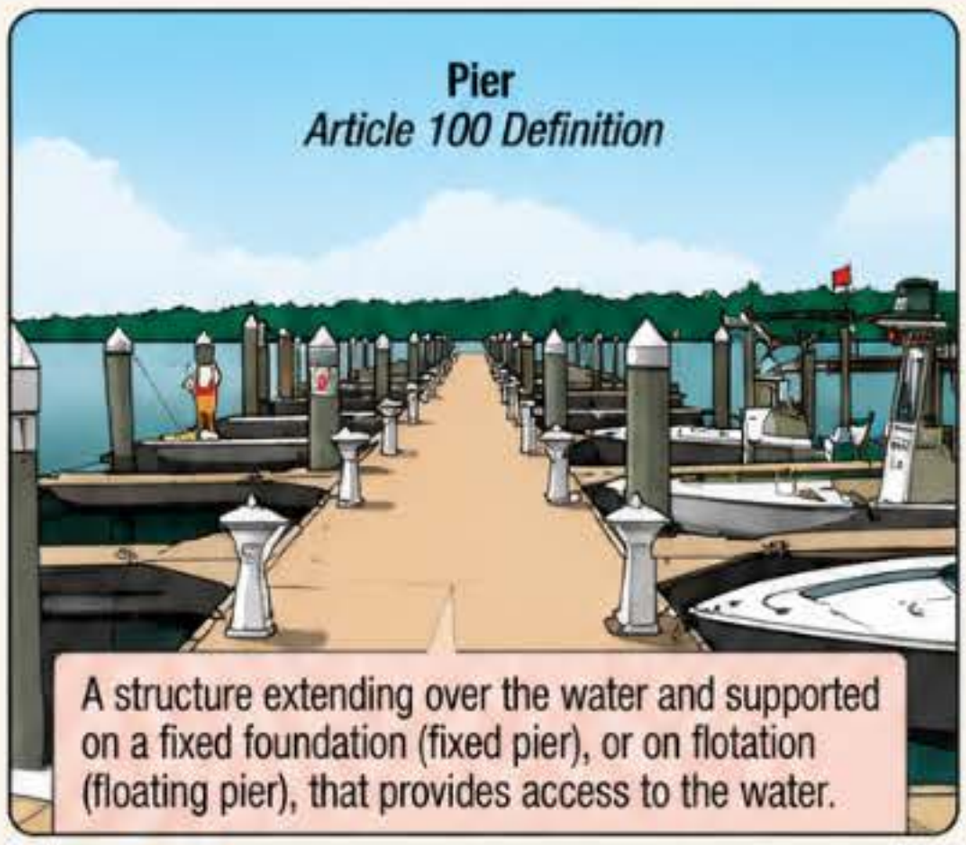


▸Figure 555-3



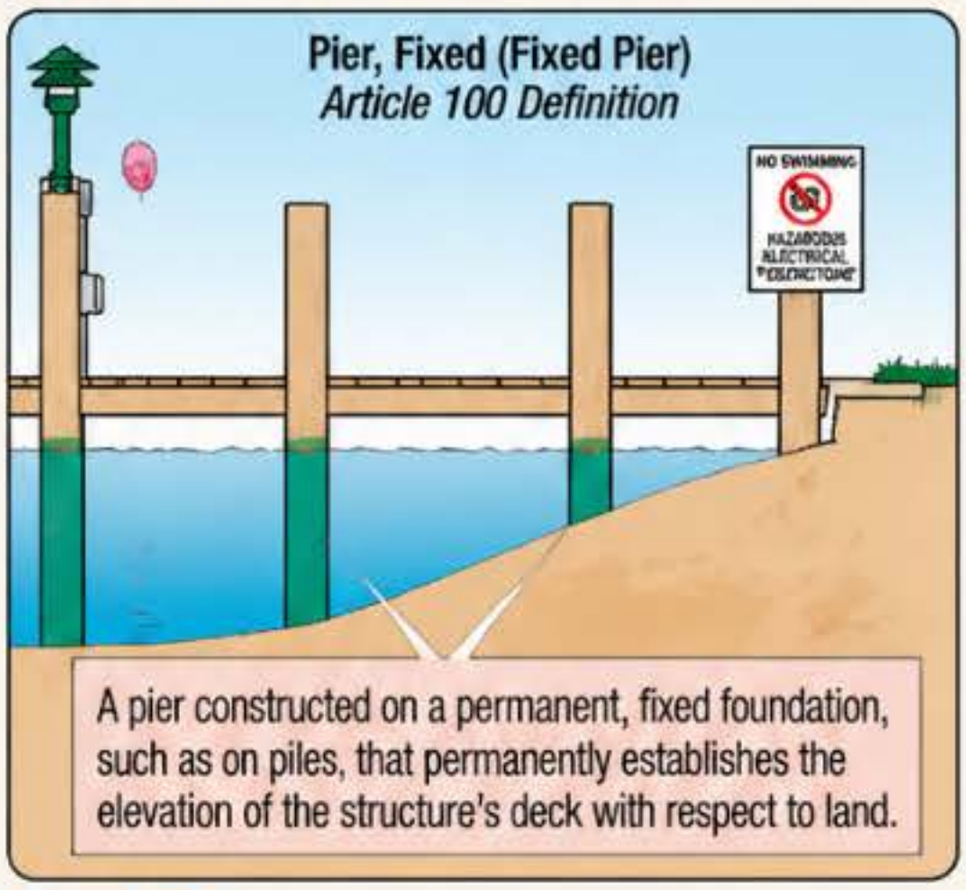
▸Figure 555-4

Pier. A structure extending over the water and supported on a fixed foundation (fixed pier), or on flotation (floating pier), that provides access to the water. ▸Figure 555-5



▸Figure 555-5

Pier, Fixed (Fixed Pier). A pier constructed on a permanent, fixed foundation (such as on piles) that permanently establishes the elevation of the structure's deck with respect to land. ▸Figure 555-6

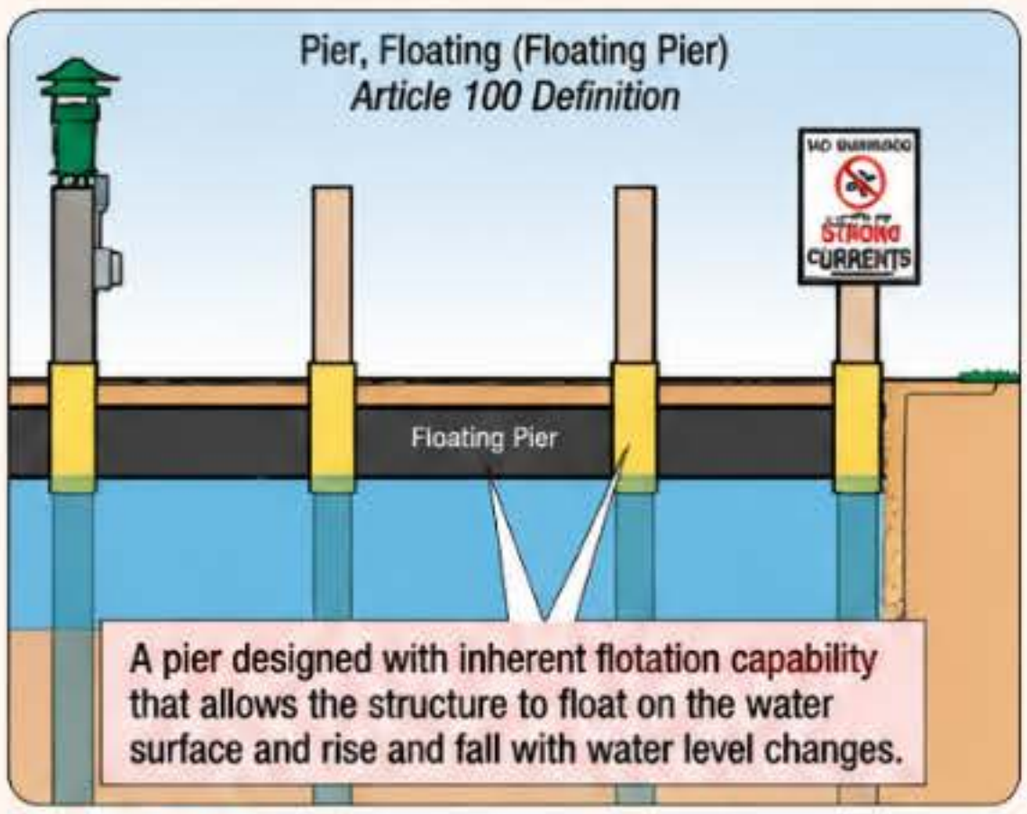


▸Figure 555-6

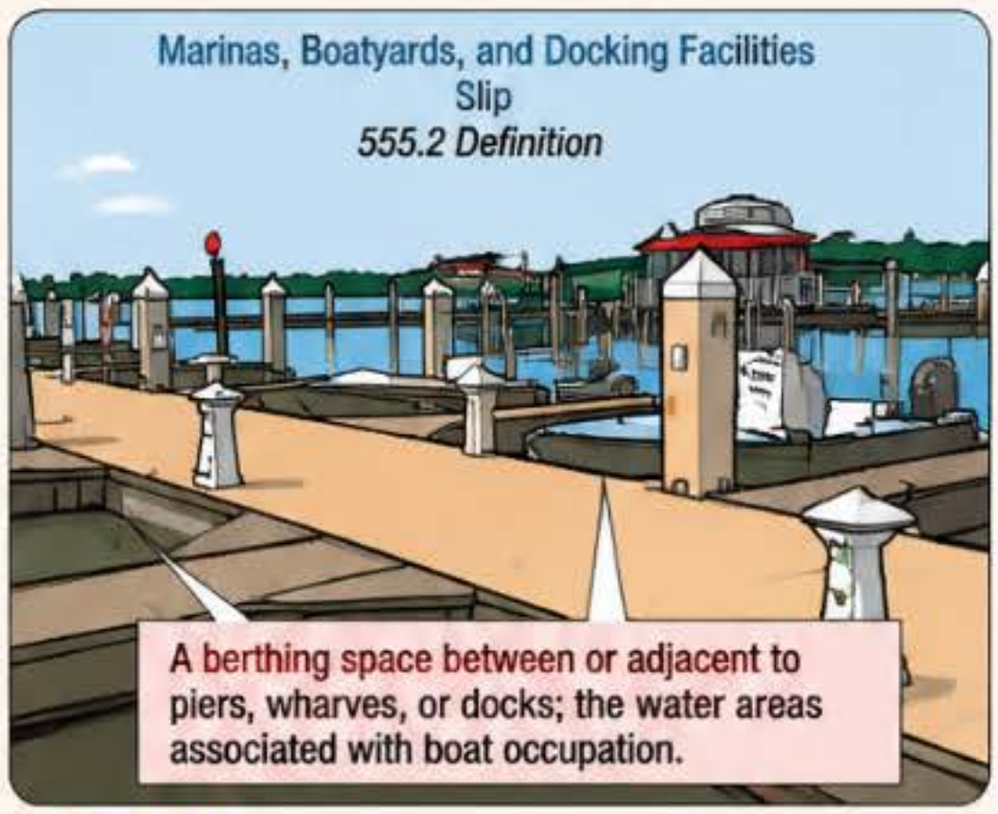
Pier, Floating (Floating Pier). A pier designed with inherent fotation capability that allows the structure to float on the water surface and rise and fall with water level changes. ▸Figure 555-7

Shore Power. The electrical equipment required to power a floating vessel including, but not limited to, the receptacle and cords. ▸Figure 555-8

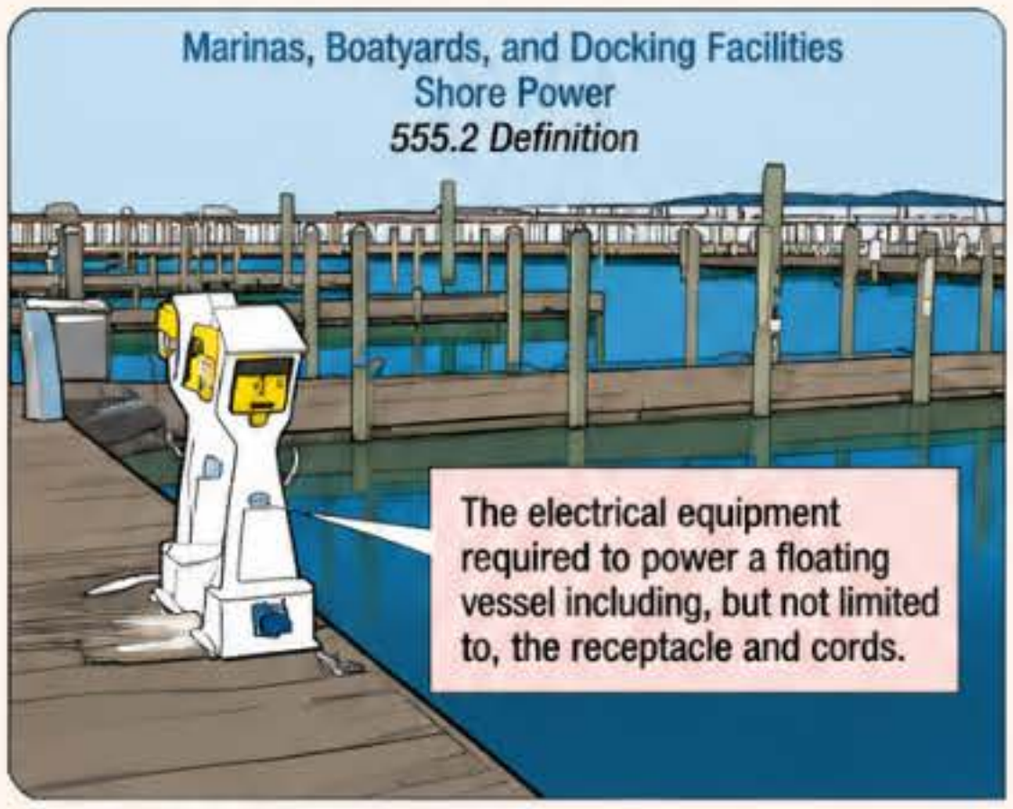
Marinas, Boatyards, and Docking Facilities 555.3



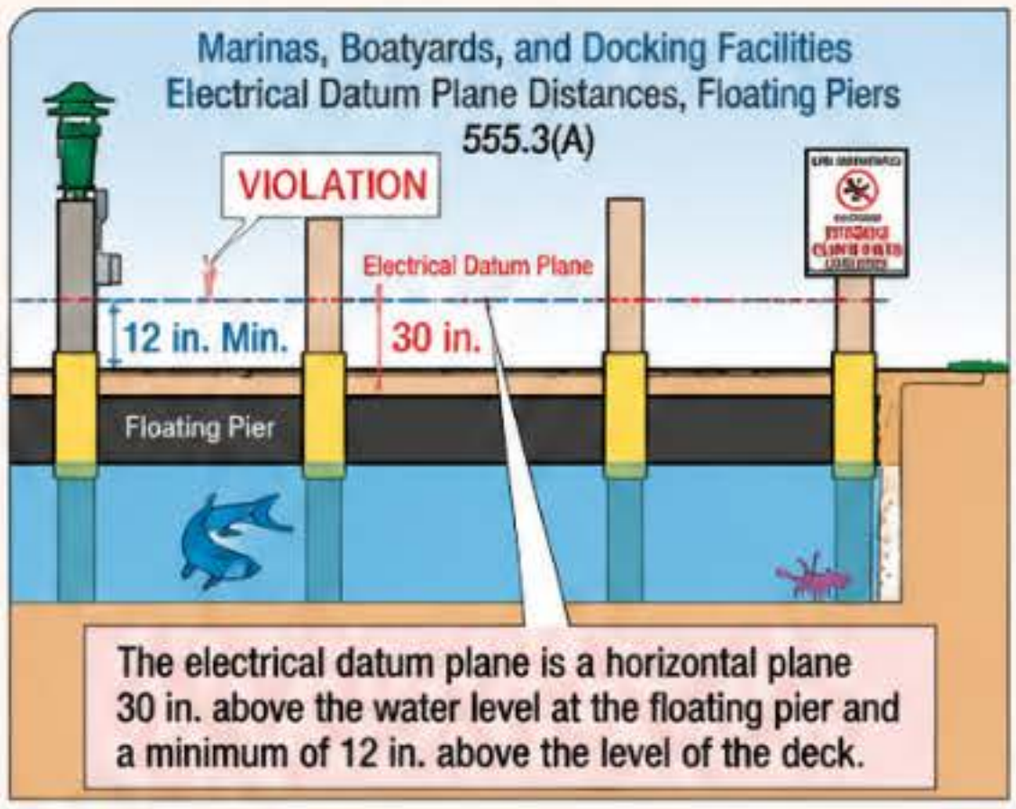
▸Figure 555–7



▸Figure 555–9



▸Figure 555–8



▸Figure 555–10

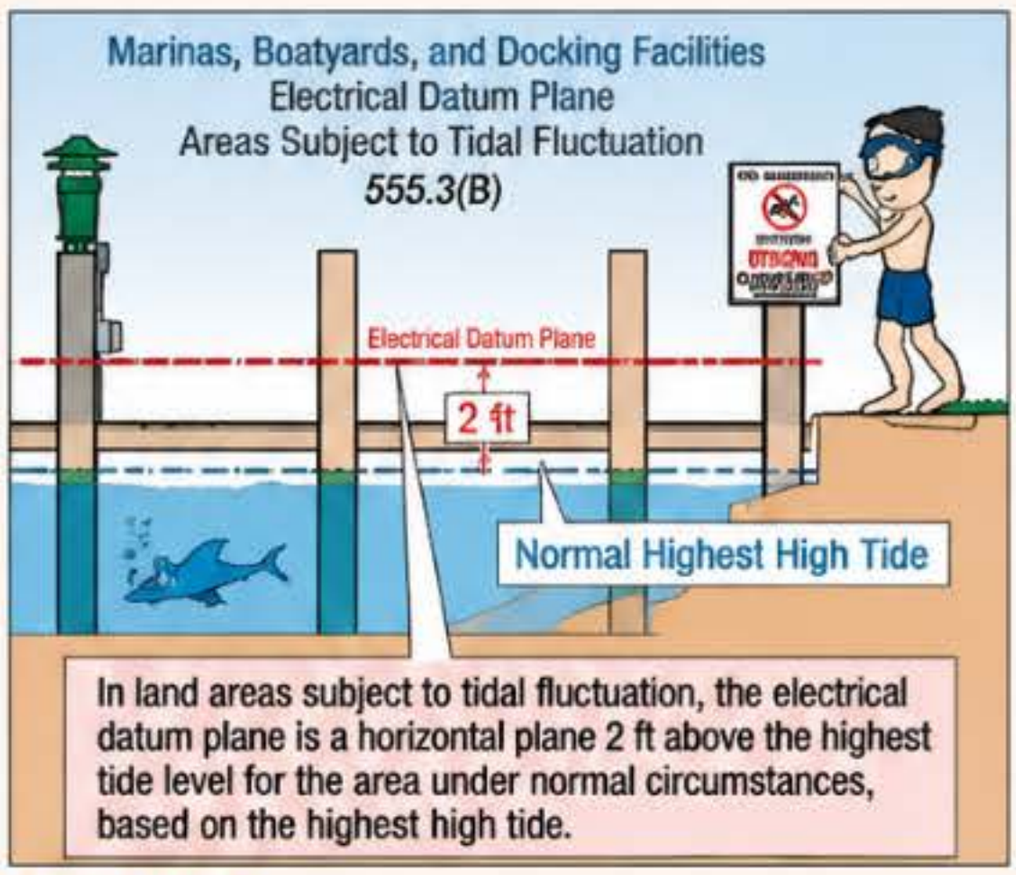
Slip. A berthing space between or adjacent to piers, wharves, or docks; the water areas associated with boat occupation. ▸Figure 555–9

555.3 Electrical Datum Plane Distances

(A) Floating Piers. The electrical datum plane for floating piers and boat landing stages is a horizontal plane 30 in. above the water level at the floating pier and a minimum of 12 in. above the level of the deck. ▸Figure 555–10

(B) Areas Subject to Tidal Fluctuations. In land areas subject to tidal fluctuation, the electrical datum plane is a horizontal plane 2 ft above the highest tide level for the area occurring under normal circumstances, based on the highest high tide. ▸Figure 555–11

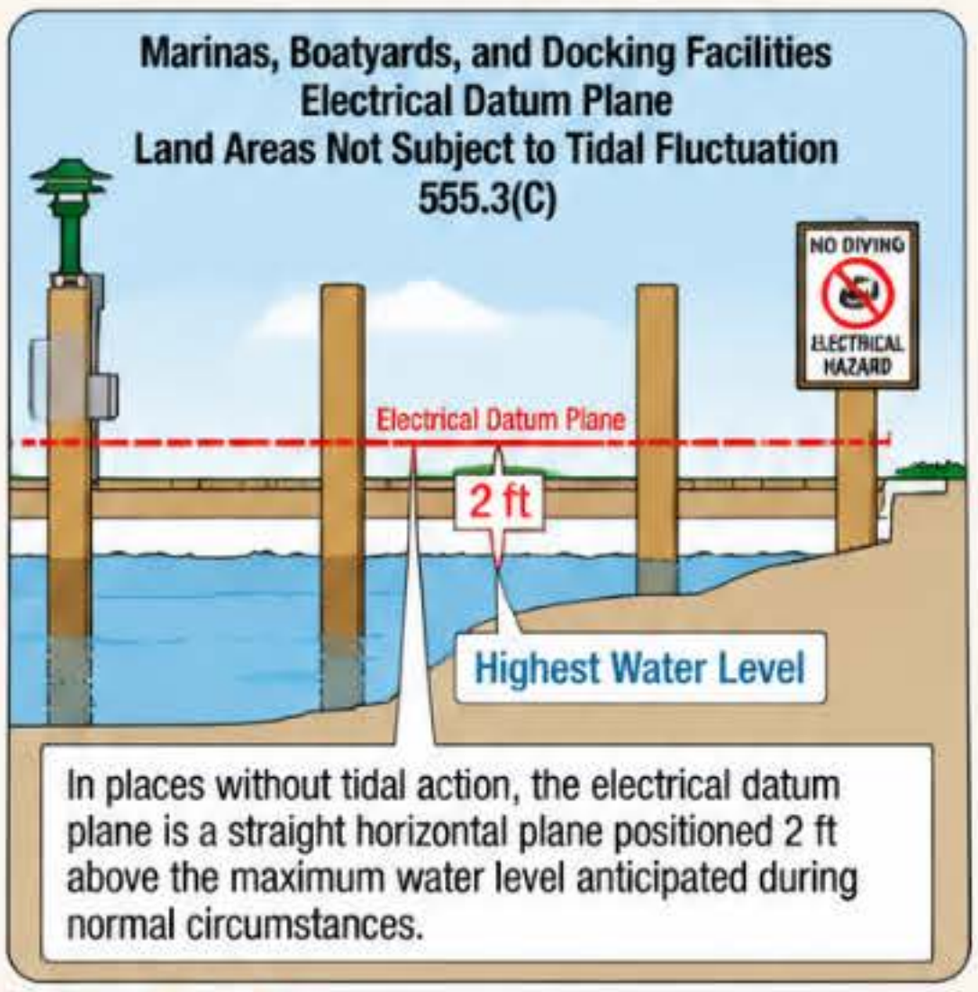
Author's Commentary:
Always verify local tide records and use the highest predicted tide level under normal conditions when establishing the datum plane.
— Michael Hamilton



▸Figure 555–11

555.4 | Marinas, Boatyards, and Docking Facilities

(C) Areas Not Subject to Tidal Fluctuations. In locations where tidal movement does not occur, the electrical datum plane is defined as a horizontal line set 2 ft above the highest water elevation expected under normal conditions. ▶ Figure 555-12



▶ Figure 555-12

555.4 Location of Service Equipment

The service equipment for a floating building, dock, or marina must be installed on land adjacent to the structure it serves, not on or in the structure itself.

555.5 Maximum Voltage

Pier power distribution systems must not exceed 250V phase to phase. Systems where qualified personnel service the equipment under engineering supervision may be permitted to exceed 250V, but in no case may they exceed 600V.

555.6 Load Calculations for Service and Feeder Conductors

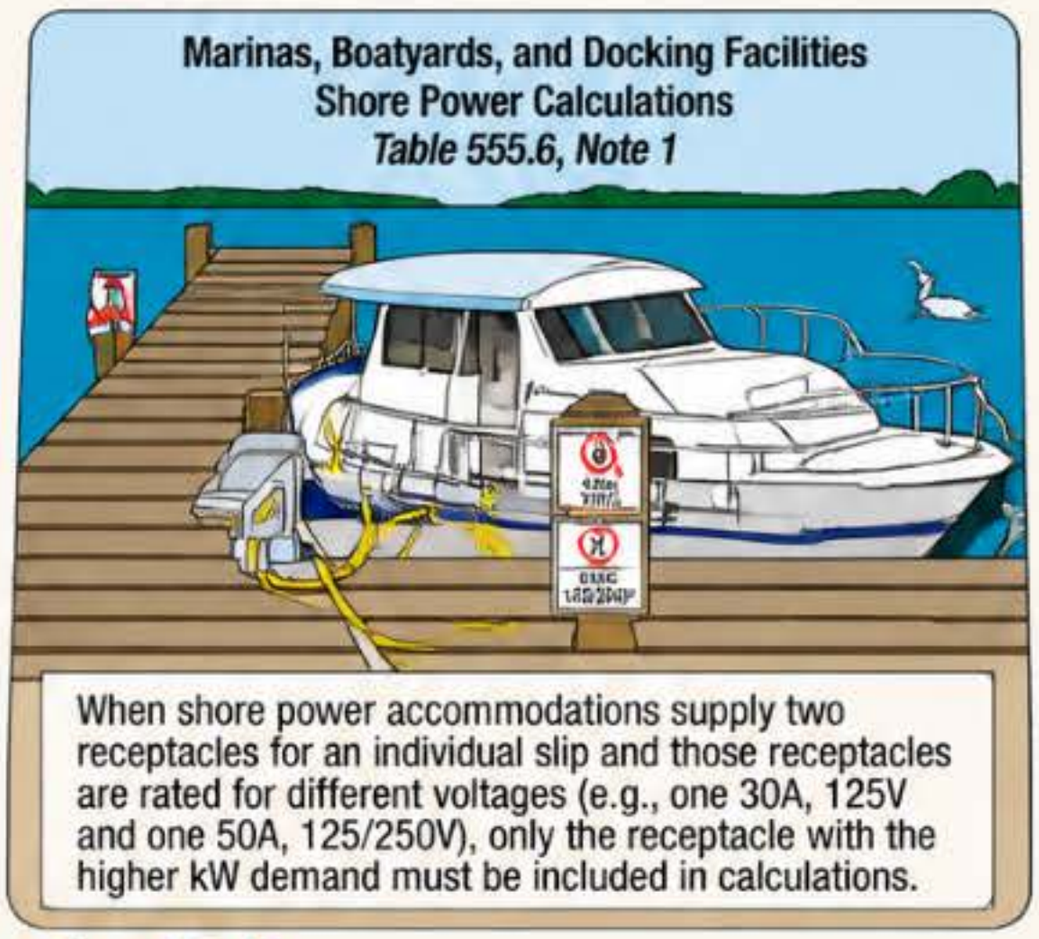
To determine the required capacity of service and/or feeder conductors, the demand factors listed in Table 555.6 should be used.

> **Author's Commentary:** Using demand factors helps prevent oversizing of electrical systems while ensuring adequate capacity for actual usage. This approach balances safety, reliability, and cost-effectiveness in marina power installations.
>
> *— Michael Hamilton*

Table 555.6 Demand Factors

Number of Shore Power Receptacles	Sum of the Rating of the Receptacles %
1–4	100
5–8	90
9–14	80
15–30	70
31–40	60
41–50	50
51–70	40
71 and Over	30

Note 1: Where shore power accommodations provide two receptacles specifically for an individual boat slip and these receptacles have different voltages (for example, one 30A, 125V and one 50A, 125/250V), only the receptacle with the larger kilowatt demand is required to be calculated. ▶ Figure 555-13

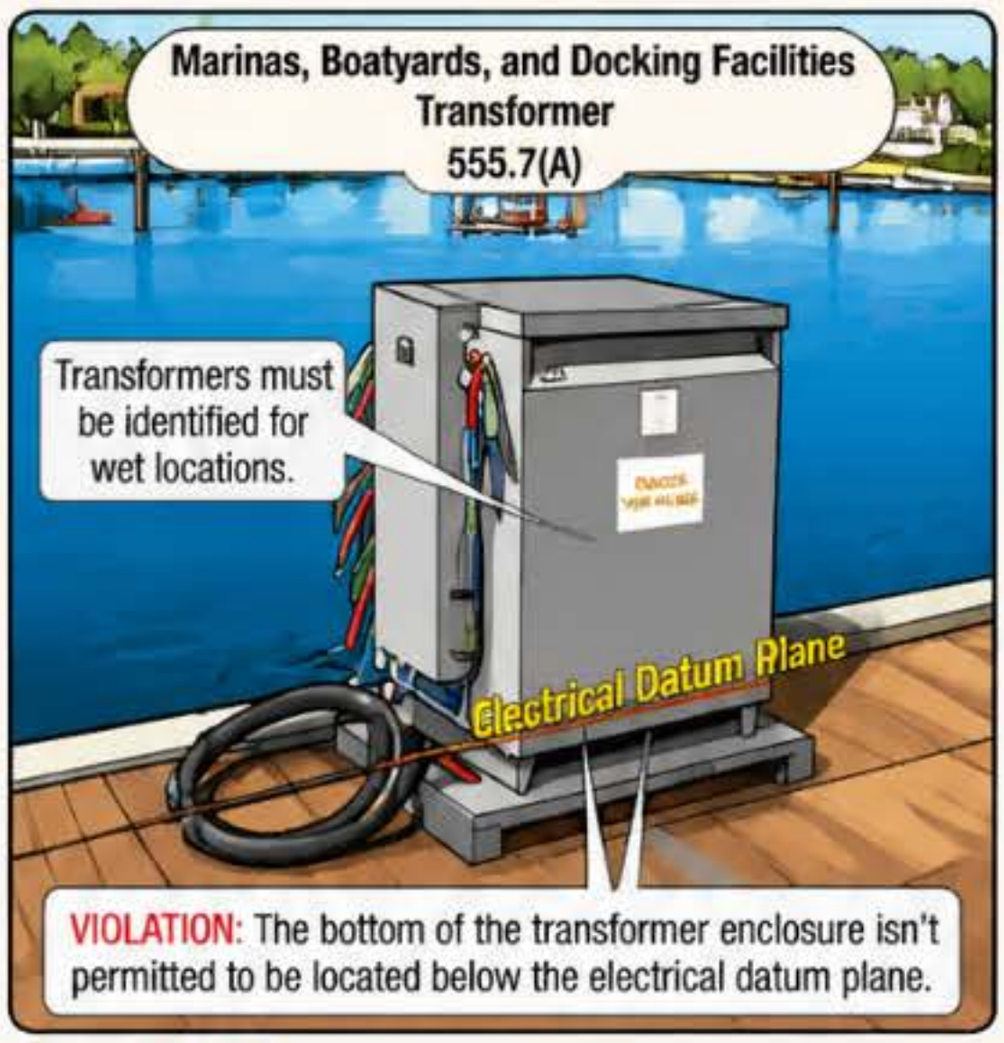


▶ Figure 555-13

555.7 Transformers

(A) General. Transformers and their enclosures must be **marked for wet locations.** The bottom of the transformer enclosure is not allowed to be below the electrical datum plane shown above. ▶ Figure 555-14

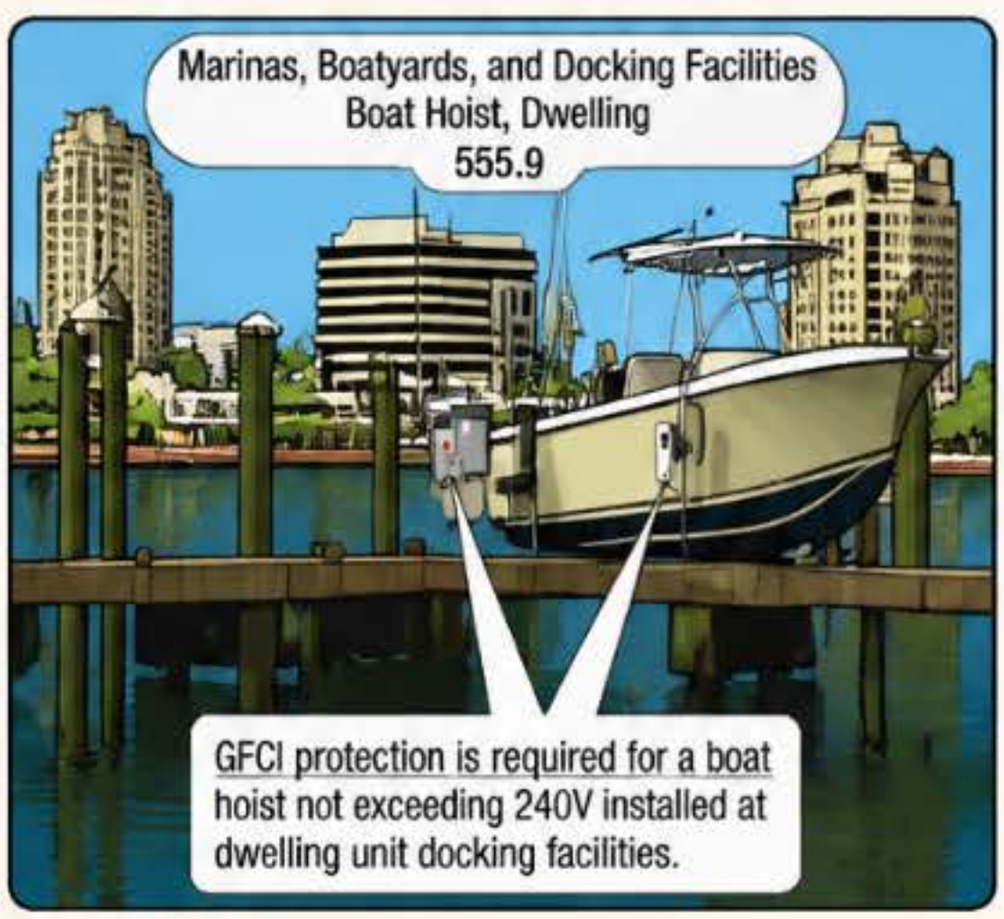
> **Author's Commentary:** Keeping transformers above the electrical datum plane reduces the risk of water contact and potential electrical hazards.
>
> *— Michael Hamilton*



▸ Figure 555–14

555.9 Boat Hoists

GFCI protection is required for a boat hoist not exceeding 240V installed at dwelling unit docking facilities. ▸ Figure 555–15



▸ Figure 555–15

Author's Commentary:

▸ This section was previously covered in 210.8(C) but is now in Article 555 due to its scope now covering dwelling unit docking facilities.

— Michael Hamilton

555.10 Electric Shock Hazard Signage

A permanent safety sign is required to give notice of electrical shock hazard risks to persons using or swimming near a docking facility, boatyard, or marina. The safety sign must meet all of the following requirements: ▸ Figure 555–16

▸ Figure 555–16

(1) The sign must warn of the hazards using effective words, colors, or symbols (or a combination) in accordance with 110.21(B)(1) and be of sufficient durability to withstand the environment.

(2) The signs must be clearly visible from all approaches to a marina or boatyard facility.

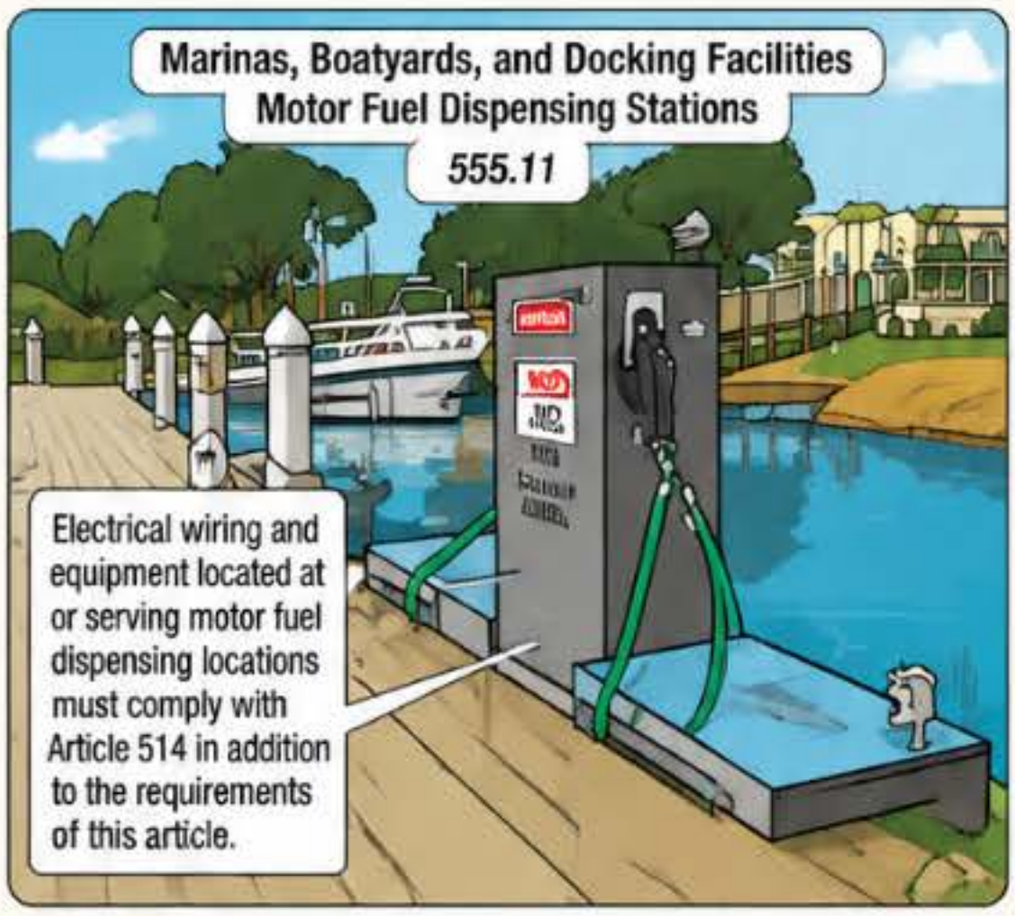
(3) The signs must state:

WARNING—POTENTIAL SHOCK HAZARD—ELECTRICAL CURRENTS MAY BE PRESENT IN THE WATER.

555.11 Motor Fuel Dispensing Stations—Hazardous (Classified) Locations

Electrical wiring and equipment located at or serving motor fuel dispensing locations must comply with Article 514 in addition to the requirements of this article. ▸ Figure 555–17

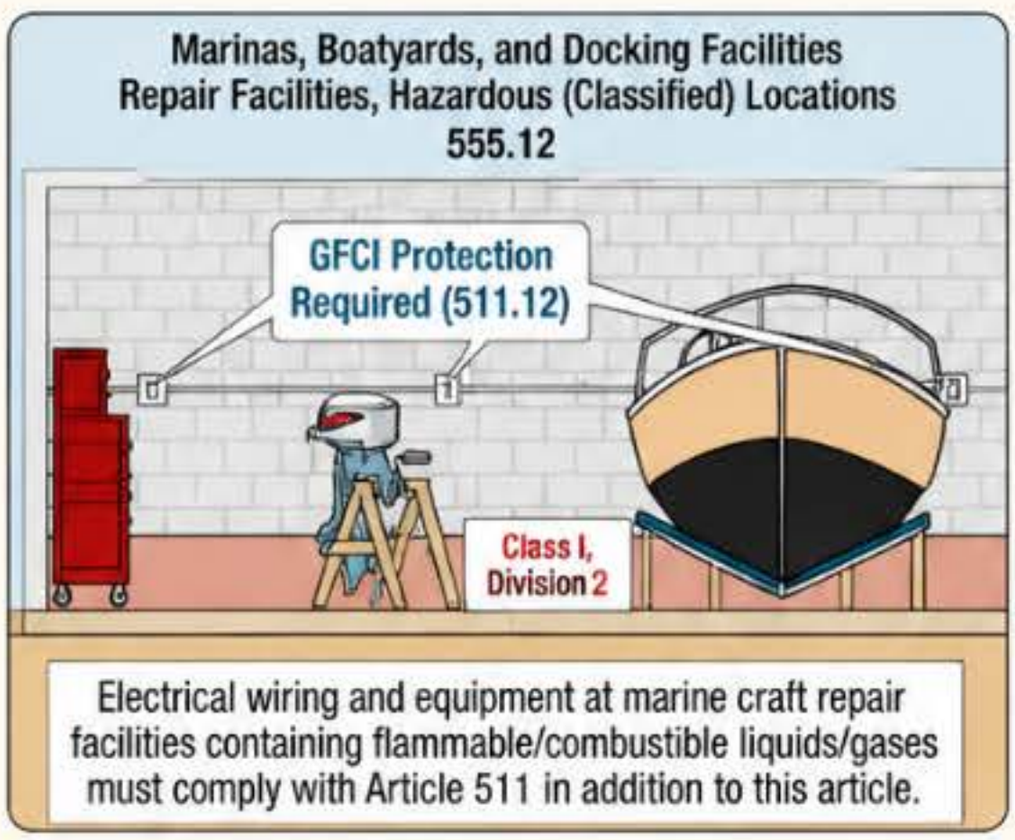
555.12 | Marinas, Boatyards, and Docking Facilities



▸Figure 555–17

555.12 Repair Facilities—Hazardous (Classified) Locations

Electrical wiring and equipment at marine craft repair facilities containing flammable or combustible liquids or gases must comply with Article 511 in addition to the requirements of this article. ▸Figure 555–18



▸Figure 555–18

Author's Commentary:

Important rules in Article 511 to consider include:

- 511.3—Classification of Hazardous Areas
- 511.4—Wiring and Equipment in Hazardous (Classified) Locations
- 511.7—Wiring and Equipment Above Hazardous (Classified) Locations
- 511.9—Explosionproof Seals
- 511.12—GFCI-Protected Receptacles

— Michael Hamilton

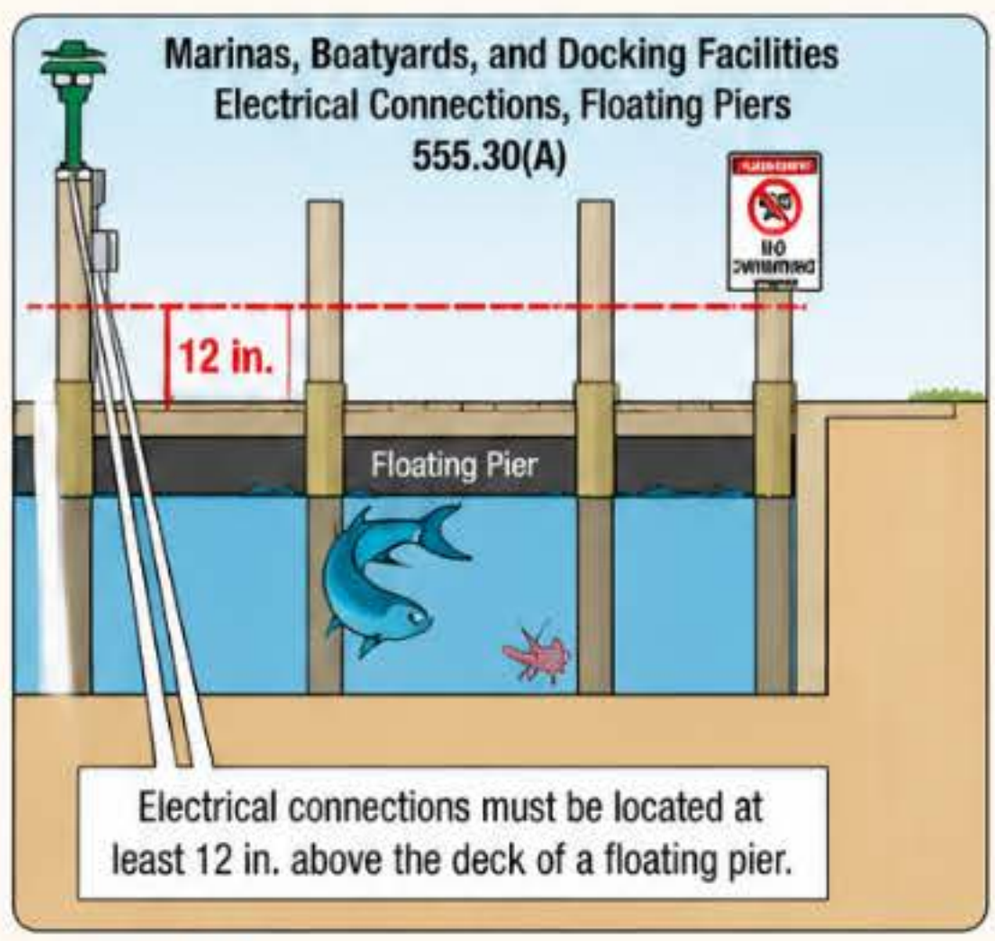
555.13 Bonding of Noncurrent-Carrying Metal Parts

Metal parts in contact with the water, metal piping, and noncurrent-carrying metal parts likely to become energized must be connected to the grounding bus in the panelboard using a solid copper conductor that is insulated, covered, or bare and not smaller than 8 AWG. Connections must be made in accordance with 250.8.

Part II. Marinas, Boatyards, and Docking Facilities

555.30 Electrical Connections

(A) Floating Piers. Electrical connections must be located at least 12 in. above the deck of a floating pier. ▸Figure 555–19



▸Figure 555–19

(B) Fixed Piers. Electrical connections must be located at least 12 in. above the deck of a fixed pier and not below the electrical datum plane. ▸Figure 555–20 and ▸Figure 555–21

Marinas, Boatyards, and Docking Facilities

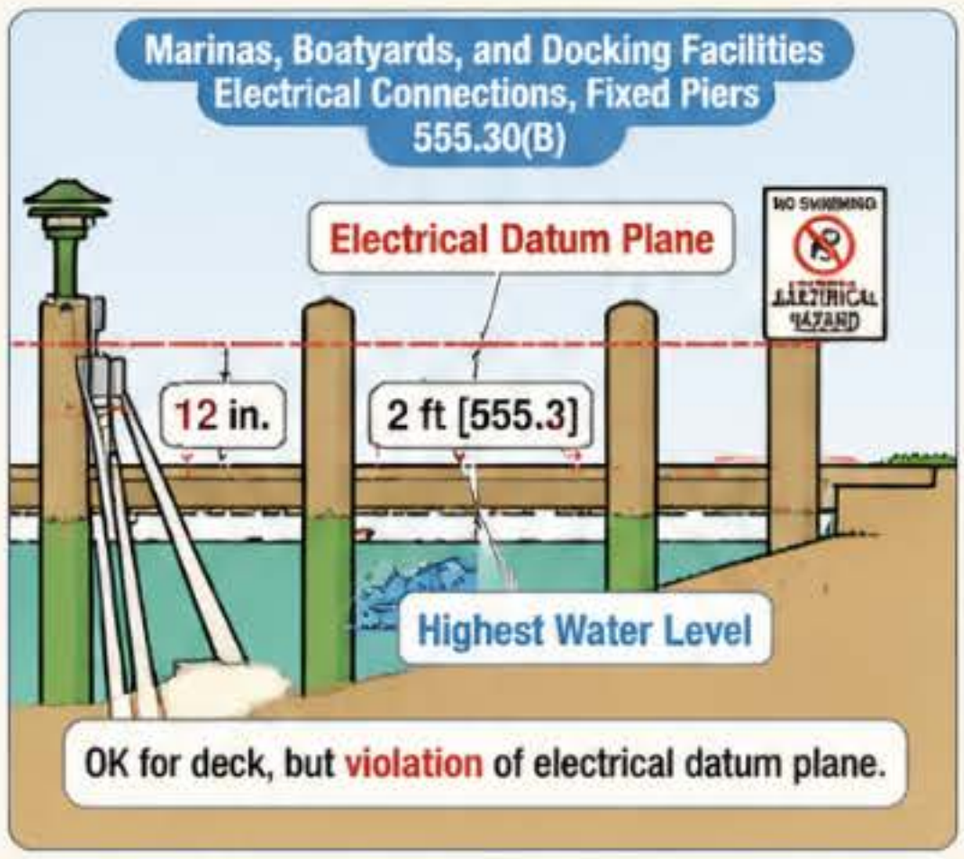


Figure 555–20

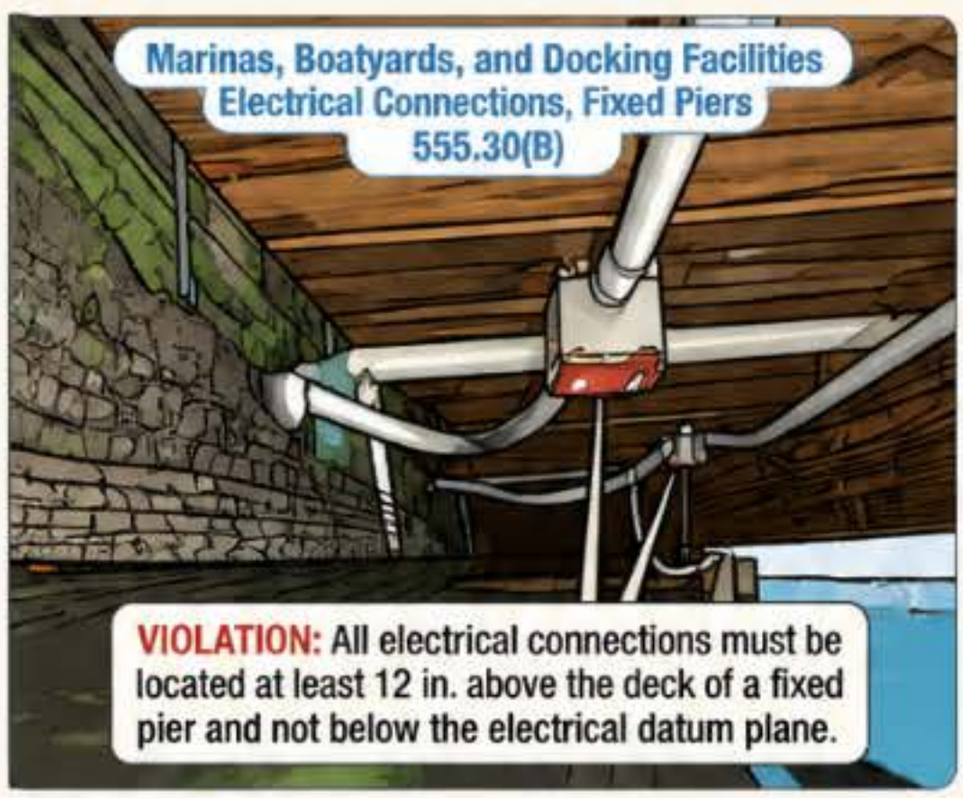


Figure 555–21

(C) Replacements. Replacement electrical connections for a floating pier must be located at least 12 in. above its deck. Conductor splices where positioned above the waterline but below the electrical datum plane for floating piers are required to be within junction boxes identified for wet locations, utilizing sealed wire connector systems listed and identified for submersion.

555.33 Receptacles

Receptacles must be mounted not less than 12 in. above the deck surface, and not below the electrical datum plane on a fixed pier. Figure 555–22

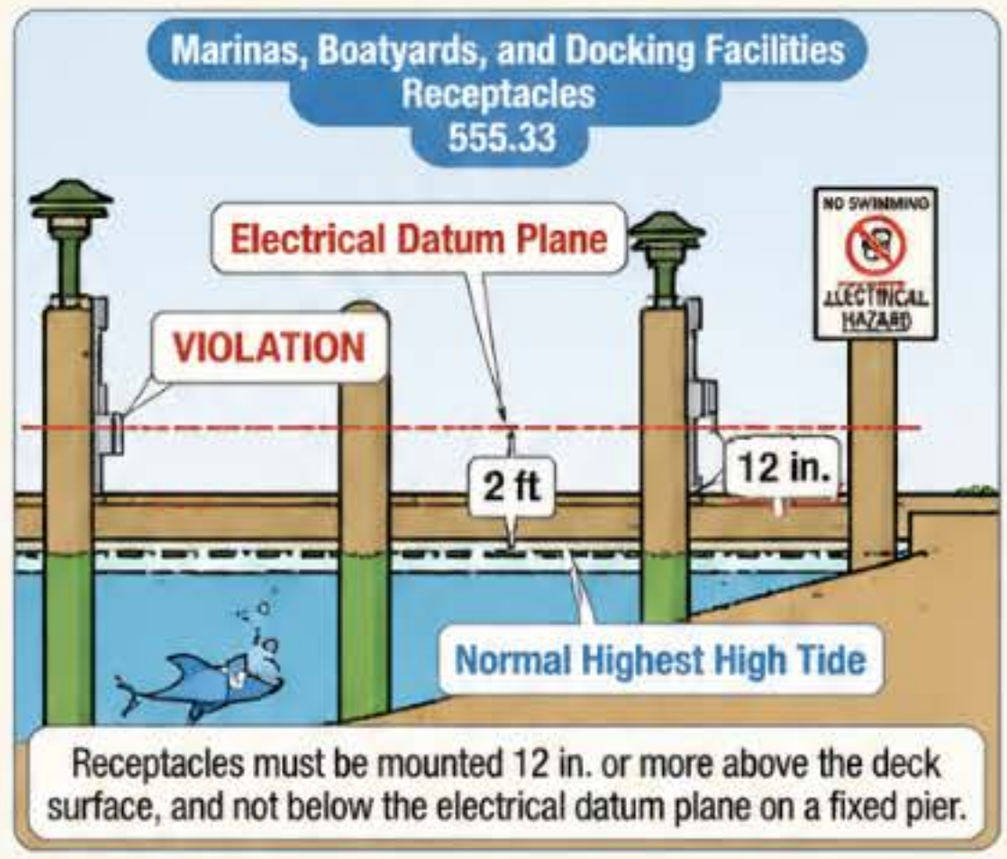


Figure 555–22

(A) Shore Power Receptacles.

(1) Enclosures. Receptacles intended to supply shore power to boats must be part of a listed marina power outlet enclosure and be installed in listed enclosures protected from the weather or in listed weatherproof enclosures.

(4) Ratings. Receptacles that provide shore power for boats must be rated at least 30A and must be of the pin and sleeve type if rated 60A or higher.

> ***Author's Commentary:***
> The elevation of the shore power receptacle is not dependent on the tide level. The *Code* simply establishes a minimum of 30A and leaves the rest to the designer and/or owner so the receptacles are positioned based on the projected usage of the slips.
>
> ***— Michael Hamilton***

(B) Other Than Shore Power.

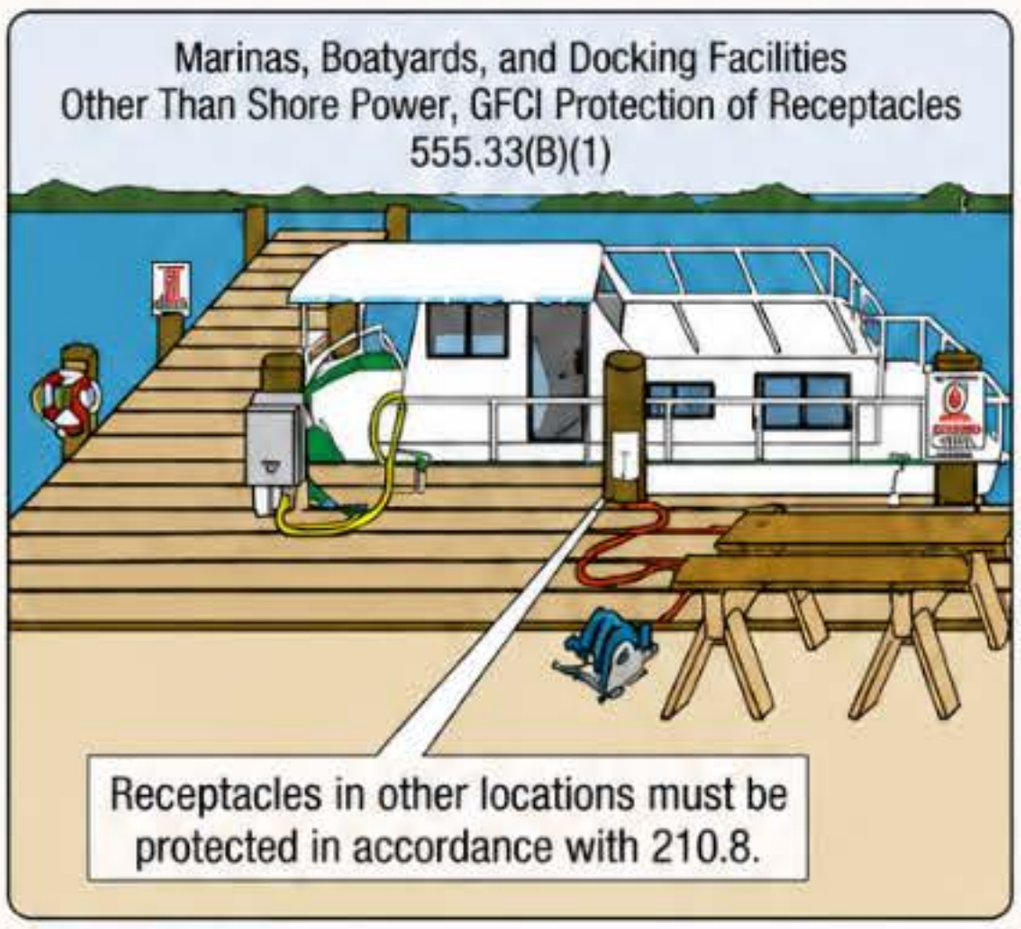
(1) GFCI Protection of Receptacles. Receptacles in other locations must be protected in accordance with 210.8. Figure 555–23

(C) Replacement Receptacles. Replacement receptacles must comply with 555.33.

555.34 Wiring Methods and Installation

(A) Wiring Methods.

(1) General. Any Chapter 3 wiring method identified for wet locations is permitted.



▶ Figure 555–23

(2) Portable Power Cables. Sunlight resistant, extra-hard usage portable power cables listed for wet locations having an outer jacket resistant to temperature extremes (not less than 167°F), oil, gasoline, ozone, abrasion, acids, and chemicals are permitted as follows:

(1) As permanent wiring on the underside of piers (floating or fixed).

(2) Where flexibility is necessary as on piers composed of floating sections.

(3) Temporary Wiring. Temporary wiring, except as permitted by Article 590, must not be used to supply power to boats.

(B) Installation.

(2) Outdoor Branch Circuits and Feeders. Multiple feeders and branch circuits are permitted and clearances for overhead branch-circuit and feeder wiring in locations of the boatyard other than those described in 555.34(B)(1) must be not less than 18 ft above grade. Only Part I of Article 225 applies to marina installations.

(3) Portable Power Cables.

(a) Portable power cables permitted by 555.33(A)(2) must be:

(1) Properly supported.

(2) Located on the underside of the pier.

(3) Securely fastened by nonmetallic clips to structural members other than the deck planking.

(4) Not be subject to physical damage.

(5) Protected against chafing by a permanently installed oversized sleeve of nonmetallic material when cables pass through structural members.

(b) Where portable power cables are used, there must be a junction box of corrosion-resistant construction with permanently installed terminal blocks on each pier section to which the feeders are connected. A listed marina power outlet employing terminal blocks/bars is permitted in lieu of a junction box. Metal junction boxes and covers, and metal screws and parts that are exposed externally to the boxes, must be of corrosion-resistant materials or protected by material resistant to corrosion.

(4) Protection. Rigid metal conduit, reinforced thermosetting resin conduit (RTRC) listed for aboveground use, or rigid polyvinyl chloride (PVC) conduit suitable for the location must be used to protect wiring above the decks of piers and landing stages.

555.35 Ground-Fault Protection of Equipment (GFPE) and Ground-Fault Circuit-Interrupter (GFCI) Protection

(A) Ground-Fault Protection. For other than floating buildings, ground-fault protection for docking facilities must be provided in accordance with the following:

(1) GFPE Protection. Receptacles installed in accordance with 555.33(A) can have individual GFPEs set to open at currents not exceeding 30 mA.

(2) GFCI Protection. All 15A and 20A, 125V receptacles for other than shore power must be protected in accordance with 555.33(B)(1) and (B)(2).

(3) Feeder and Branch-Circuit Conductors with GFPE. Feeder and branch-circuit conductors that are installed on docking facilities must be provided with GFPEs set to open at currents not exceeding 100 mA. Coordination with the feeder GFPE overcurrent protective device is permitted.

Ex to (3): Transformer secondary conductors of a seperately derived system that do not exceed 10 ft and are installed in a raceway are permitted to be installed without ground-fault protection. This exception also applies to the supply terminals of the equipment supplied by the transformer secondary conductors.

(B) Leakage Current Measurement Device. Where more than three receptacles supply shore power to boats, a leakage current measurement device must be available and be used to determine leakage current from each boat that will utilize shore power.

Note 1: Leakage current measurement will provide the capability to determine when an individual boat has defective wiring or other problems contributing to hazardous voltage and current. The use of this test device will allow the facility operator to identify a boat that is introducing excessive leakage current.

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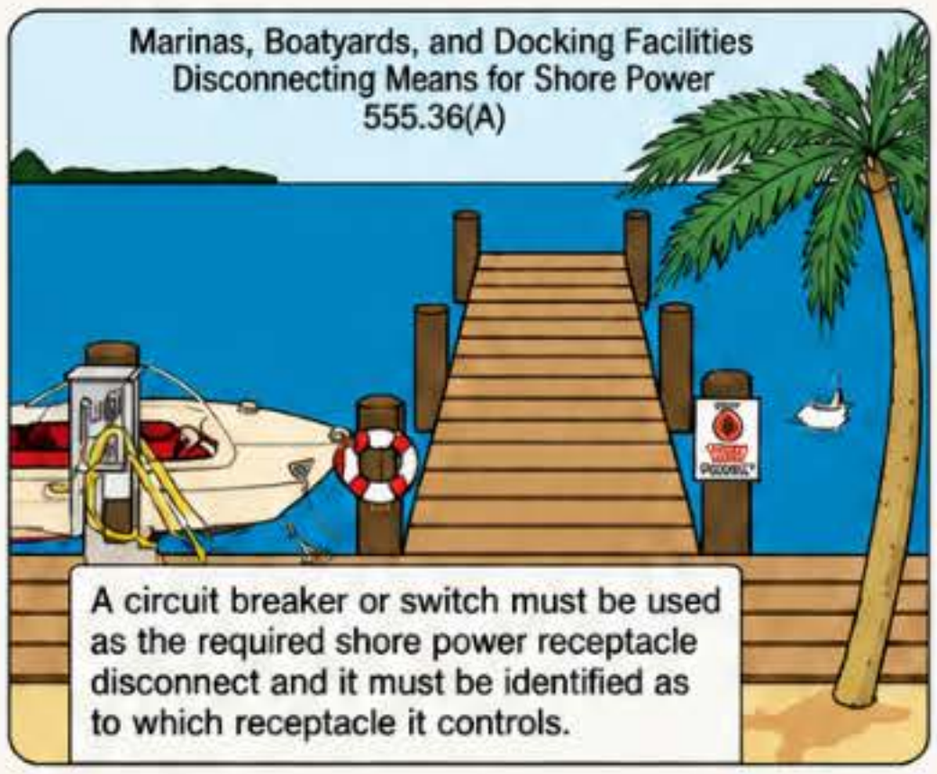
An electrical hazard can arise in certain situations where a single boat may cause an upstream GFCI device that safeguards a feeder to trip, even though several boats are powered from that same feeder. Using this device helps the facility operator prevent a specific boat from adding hazardous voltage and current into the marina environment.

Note 2: A manual test of each boat with respect to leakage current measurement is an important first step in determining if the boat has faulty wiring that could be contributing to dangerous voltage and current. Where a leakage current measurement device shows that a boat might be adding hazardous voltage and current, repairs should be made to the boat before it is allowed to use shore power.

555.36 Boat Receptacle Disconnecting Means

A disconnect must electrically separate each boat from its shore power receptacle.

(A) Type of Disconnecting Means. A circuit breaker or switch is required as the shore power receptacle disconnect, and it must be clearly identified as the control for that receptacle. • Figure 555–24



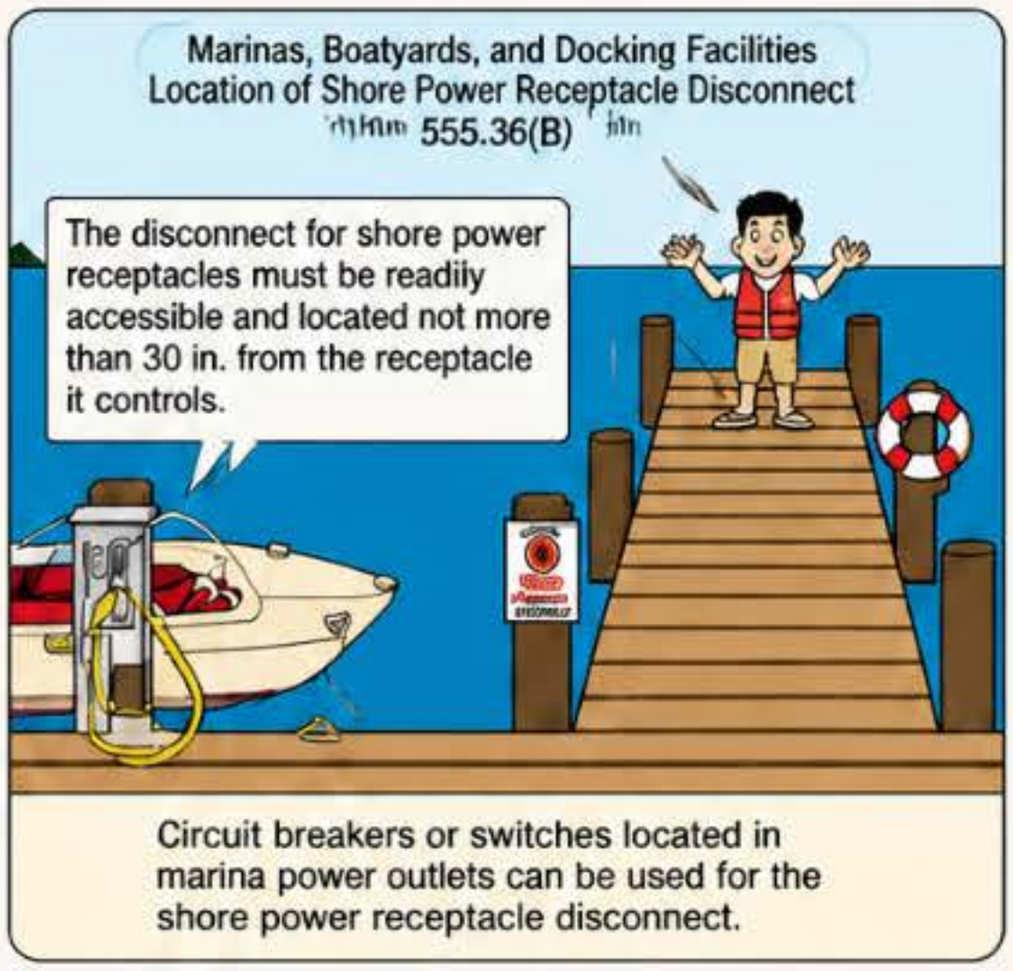
▶Figure 555–24

(B) Location. The disconnect for shore power receptacles must be readily accessible and located not more than 30 in. from the receptacle it controls. Circuit breakers or switches located in marina power outlets can be used for the shore power receptacle disconnect. • Figure 555–25

Author's Commentary:

This shore power receptacle disconnect is intended to eliminate the hazard of someone engaging or disengaging the boat's shore power attachment plug with wet, slippery hands, and possibly contacting energized blades.

— Michael Hamilton



▶Figure 555–25

555.37 Equipment Grounding Conductor

(A) Equipment to be Connected to the Equipment Grounding Conductor. The following items must be linked to an equipment grounding conductor that is installed with the circuit conductors inside the same raceway, cable, or trench:

(1) Metal boxes, metal cabinets, and any other metal enclosures.

(2) Metal frames of utilization equipment.

(3) Grounding terminals of grounding-type receptacles.

(B) Type of Equipment Grounding Conductor. The equipment grounding conductor must be an insulated conductor with a continuous outer jacket that is either green, green with one or more yellow stripes, or solid yellow.

(C) Size of Equipment Grounding Conductor. The insulated equipment grounding conductor must be sized per 250.122, but not smaller than 12 AWG.

(D) Branch-Circuit Equipment Grounding Conductor. The insulated equipment grounding conductor for branch circuits must end at a grounding terminal in a remote panelboard or at the grounding terminal of the main service equipment.

(E) Feeder Equipment Grounding Conductor. If a feeder delivers power to a remote panelboard, an insulated equipment grounding conductor must run from the main grounding terminal in the service equipment to a grounding terminal in the remote panelboard.

Notes |

ARTICLE

590 TEMPORARY INSTALLATIONS

Introduction to Article 590—Temporary Installations

It is widely believed that temporary wiring involves a lower level of quality than permanent wiring. In reality, it follows a distinct set of standards. While fundamental rules for workmanship, amperage capacity, and overcurrent protection still apply, temporary setups are governed by additional provisions.

So, what truly distinguishes a temporary installation? Once the work or event is finished and the temporary system is no longer needed, it must be taken down. If the installation is for a celebration, it cannot remain in place beyond 90 days.

Article 590 tackles the real-world application and practical challenges unique to temporary installations, streamlining the process so you spend less time setting them up.

590.1 Scope

The rules in Article 590 cover temporary power and lighting systems and their removal. This includes power used for construction, remodeling, upkeep, repairs, demolition, and also decorative lighting.

▶ Figure 590-1

Article 590 applies to temporary power and lighting installations and their removal, including power for construction, remodeling, maintenance, repair, demolition, and decorative lighting.

This article also applies when temporary installations are necessary during emergencies or for tests and experiments [590.3(C)].

Author's Commentary:

- Temporary wiring is intended only for short-term activities such as construction, remodeling, repair, demolition, and building work, as well as for structures, equipment, or similar uses during emergencies, tests, experiments, or research projects. Once the job is complete, all temporary wiring must be removed.
- Events like carnivals, circuses, trade fairs, and similar gatherings are covered under Article 525, not Article 590.

— Michael Hamilton

590.2 All Wiring Installations

(A) Other Articles. *All NEC* rules apply to temporary installations unless this article specifically changes them.

▶ Figure 590-2

(B) Approval. Temporary wiring methods are acceptable only when the authority having jurisdiction approves them based on the conditions of use and any special requirements of the temporary installation.

590.3 Time Constraints

(A) Construction Period. You may install temporary electrical power and lighting systems during the construction, remodeling, maintenance, repair, or demolition phases of buildings, structures, equipment, or similar operations.

590.4 | Temporary Installations

Figure 590–2

(B) Decorative Lighting. Temporary electrical power for decorative holiday lighting and similar purposes is permitted for a period of up to 90 days. Figure 590–3

Figure 590–3

Author's Commentary:

- Decorative lighting used for holiday displays and comparably seasonal purposes must be listed as specified in [590.5].

— Michael Hamilton

(C) Emergencies and Tests. Temporary electrical power and lighting installations are permitted for the duration necessary for emergencies or for tests and experiments.

(D) Removal. Temporary installations must be removed immediately upon the completion of the purpose for which they were installed. Figure 590–4

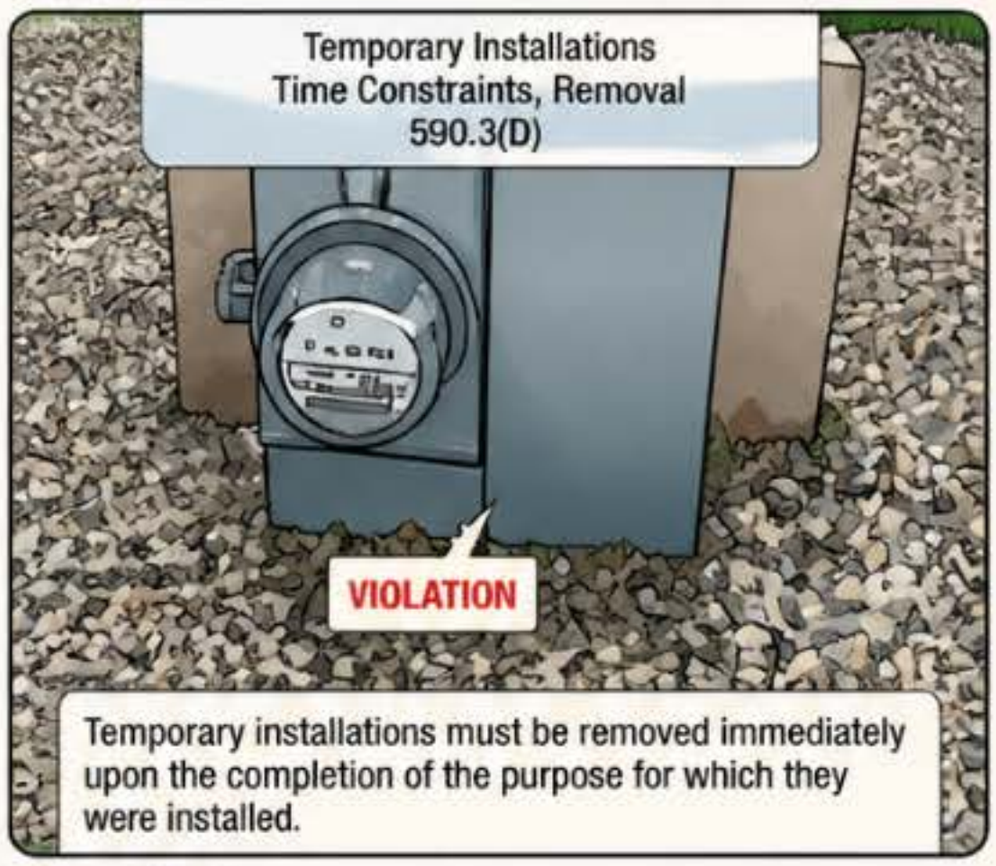


Figure 590–4

590.4 General

(A) Services. Services must be installed in accordance with Parts I through VIII of Article 230 as applicable.

(B) Feeders. Overcurrent protection must be provided in accordance with 240.4 and 240.5. The following wiring methods are permitted:

(1) Type NM cable, Type SE cable, and flexible cords are permitted to be used in a building without height limitations or the type of construction. Figure 590–5

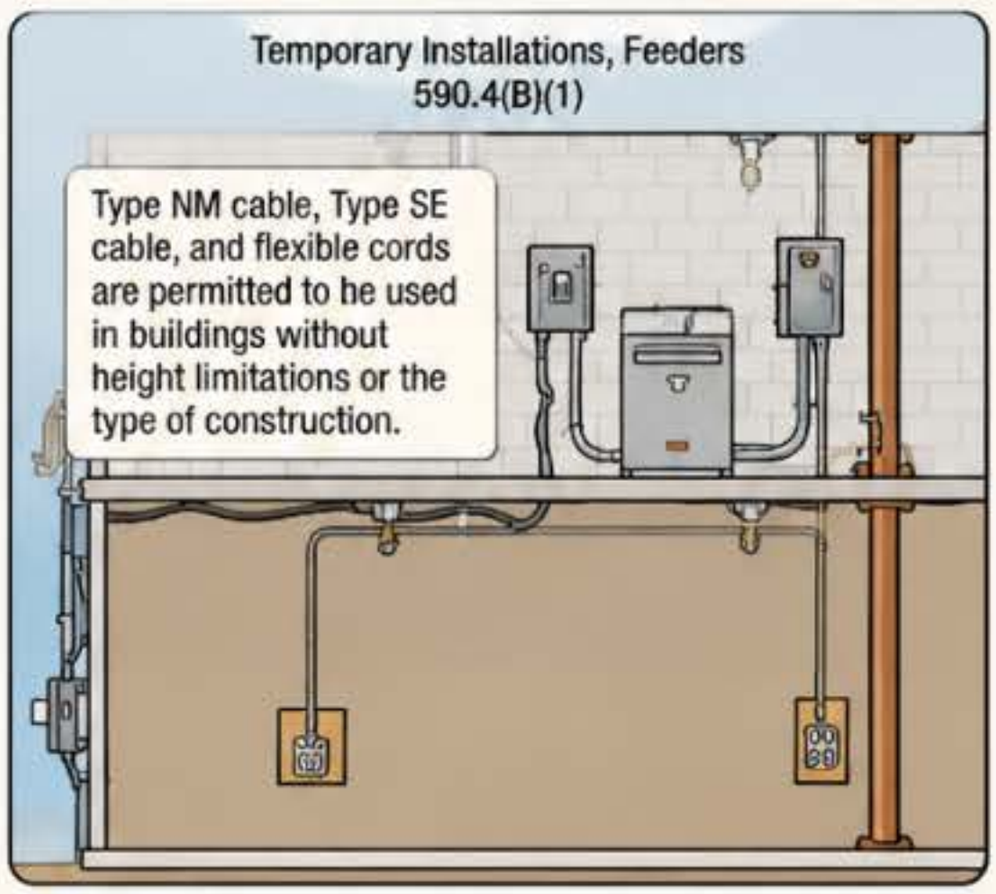


Figure 590–5

(2) Type SE cable may be installed in a raceway underground.

(C) Branch Circuits. Each branch circuit must have overcurrent protection in accordance with 240.4 and 240.5. The following wiring methods are allowed:

(1) Type NM cable, Type SE cable, and flexible cords are approved for use in buildings that are not subject to height limits or specific construction-type restrictions. ▸ Figure 590–6

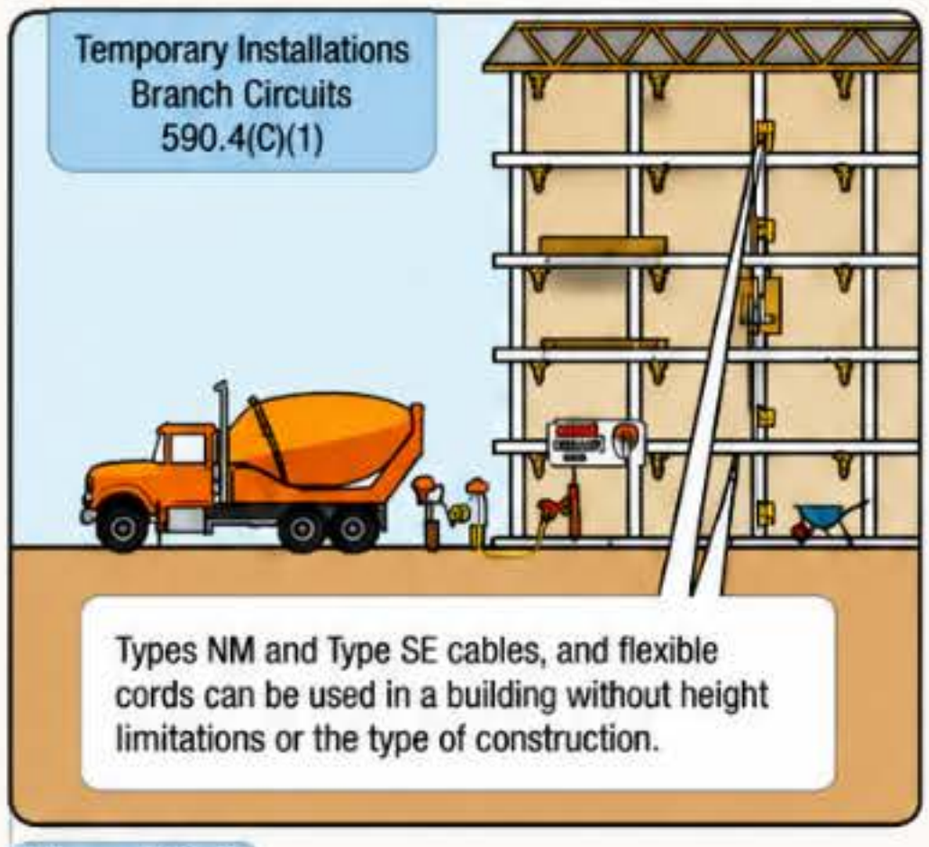


Figure 590–6

(2) Type SE cable may be installed in a raceway underground.

(D) Receptacles.

(1) Receptacles Not on Lighting Circuit. On a construction site, receptacles are prohibited on any branch circuit that supplies temporary lighting. ▸ Figure 590–7

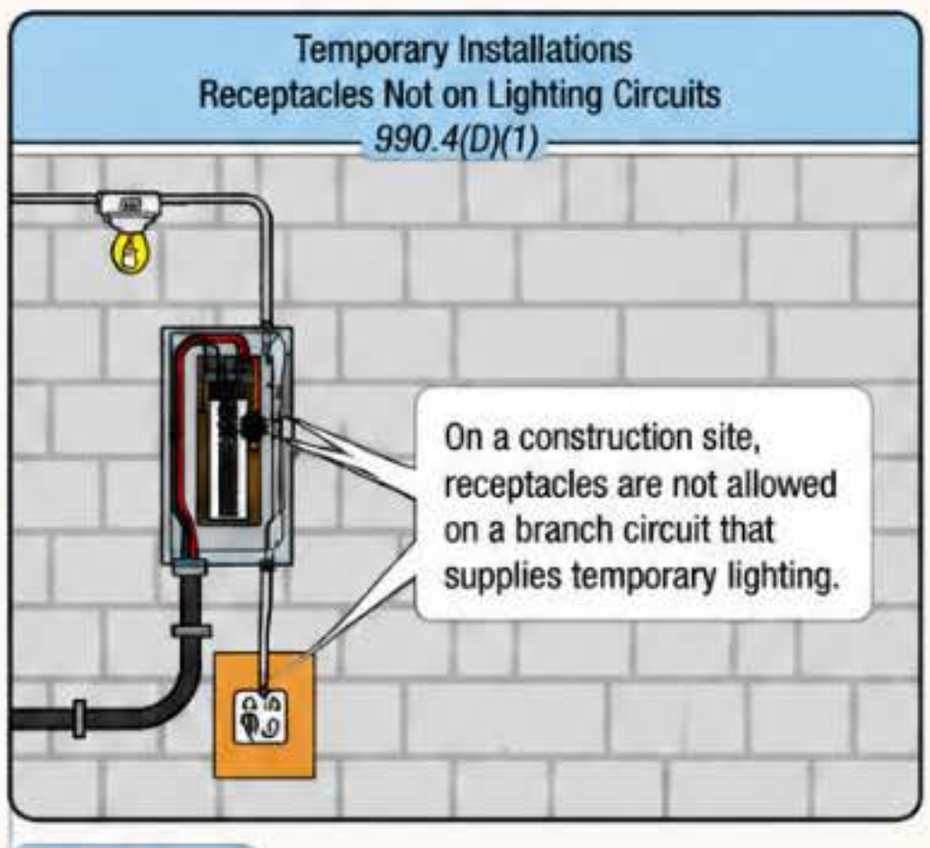


Figure 590–7

Author's Commentary:
This requirement ensures that adequate illumination is maintained, even when the receptacle's GFCI-protective device opens [590.6].

— Michael Hamilton

(2) Receptacles in Wet Locations. 15A and 20A receptacles installed in a wet location must be placed in an enclosure that is weatherproof whenever an attachment plug is inserted. ▸ Figure 590–8

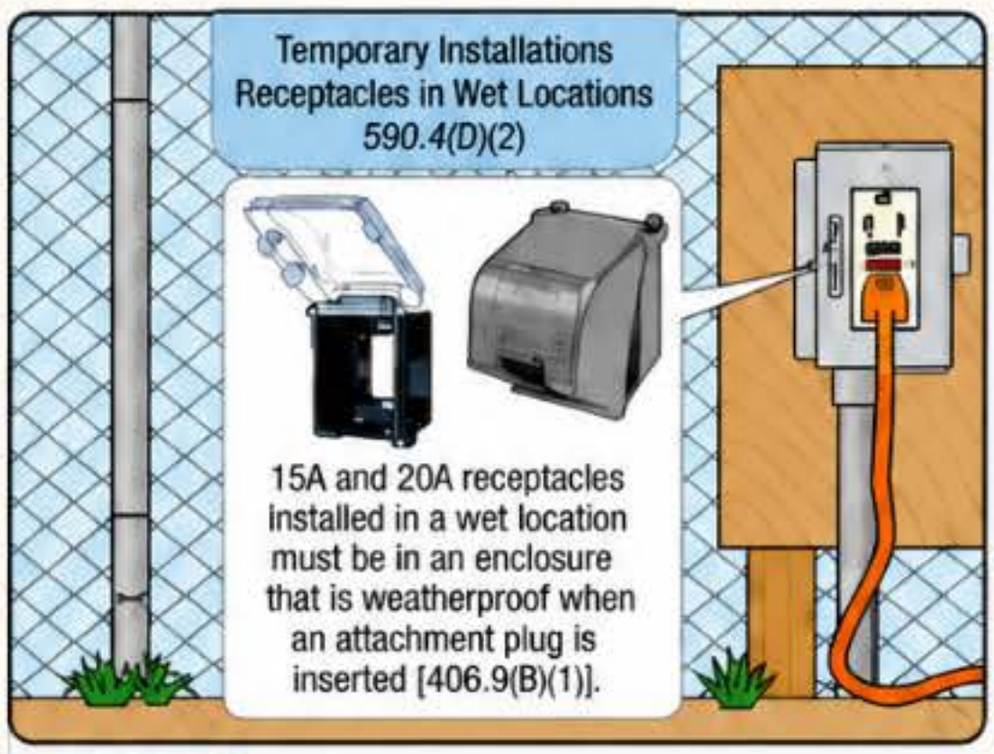


Figure 590–8

The outlet box hood must be listed for extra-duty use, and luminaires in a wet location must be listed as weather resistant [406.9(B)(1)].

(F) Lamp Protection. Lamps (bulbs)must be safeguarded against accidental contact by a suitable luminaire or lampholder with a guard. ▸ Figure 590–9

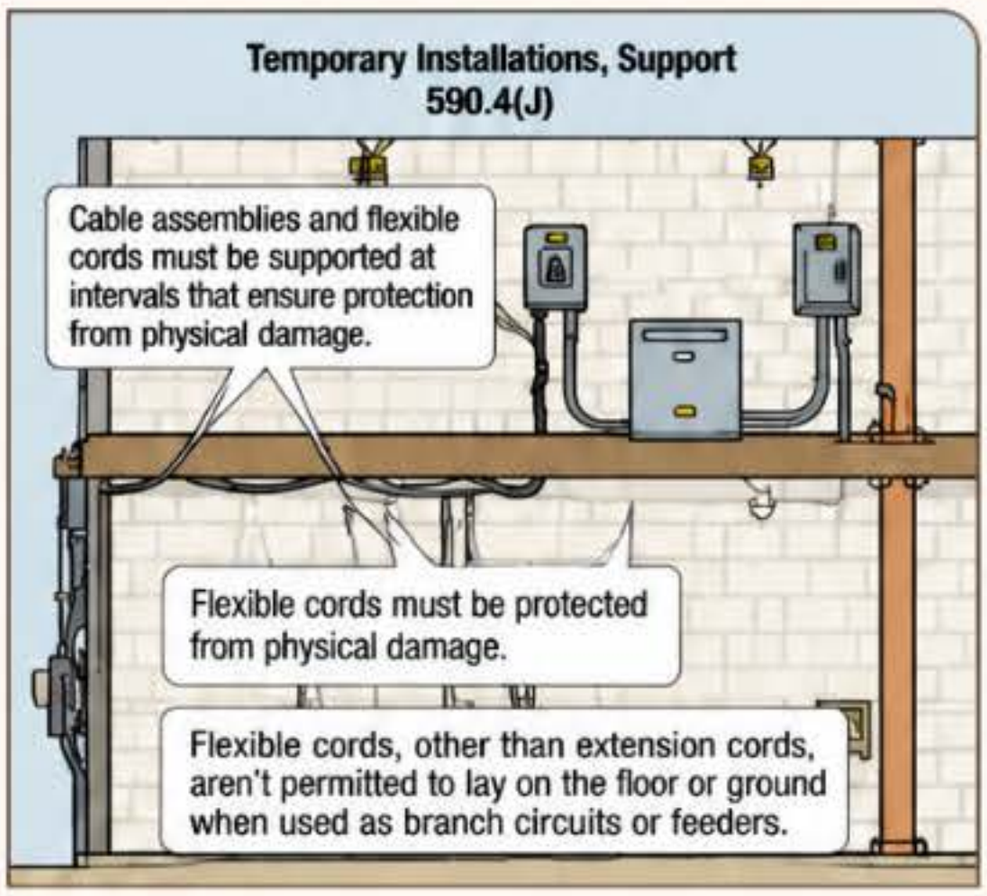
(G) Splices. A box, conduit body, or other enclosure (with a cover installed) is required for all splices.

Example 1: On construction projects, a box is not required if the conductors are being spliced in the long length of nonmetallic sheathed cable or cord, or in the extended run of metal-sheathed cable assemblies that remain continuous without a splice box.

(1) The circuit conductors being spliced may be from nonmetallic multiconductor cord or cable assemblies. provided the equipment grounding conductor is maintained with or without the box.

(2) The circuit conductors being spliced may be from metal-sheathed cable assemblies that terminate in listed fittings which mechanically secure the cable sheath to preserve effective electrical continuity.

▸ Figure 590–9



▸ Figure 590–10

Ex 2: On construction sites a box is not required for GFCI-protected branch circuits that are permanently installed in framed walls and ceilings and are used to supply temporary power or lighting.

(1) A box cover is not required for splices installed completely inside of junction boxes with plaster rings.

(2) Listed pigtail-type lampholders can be installed in ceiling-mounted junction boxes with plaster rings.

(3) Finger safe devices are permitted for supplying and connecting devices.

(H) Protection from Accidental Damage. Cables and flexible cords must be protected from physical harm, sharp corners or projections, and areas where cables and flexible cords could pass through doorways or or other pinch points.

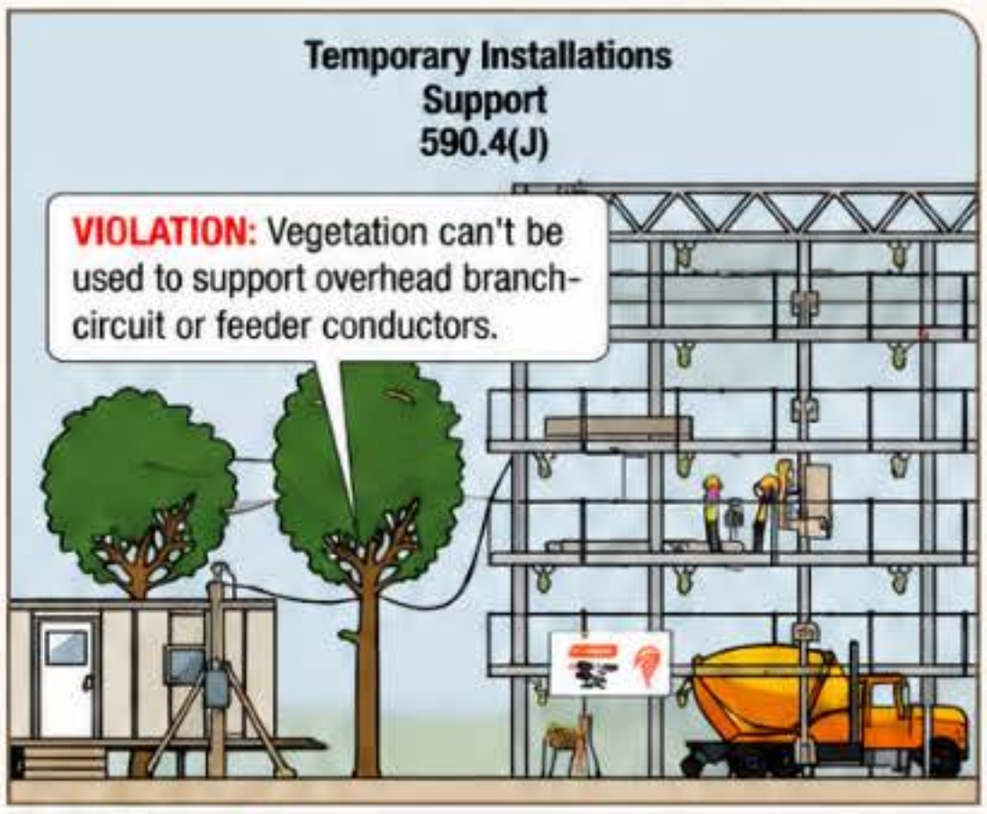
(J) Support. Cable assemblies and flexible cords must be supported at intervals that prevent physical damage. Use suitable supports such as staples, cable ties, straps, or other similar devices designed not to damage the cable or flexible cord assembly. Flexible cords, other than extension cords, are not allowed to rest on the floor or on the ground when used as branch circuits or feeders. ▸ Figure 590–10

Author's Commentary:

- The support requirement for temporary cables is determined by the authority having jurisdiction based on the jobsite conditions [590.2(B)].

Vegetation is not permitted to be used for the support of overhead branch-circuit or feeder conductors.

— Michael Hamilton



▸ Figure 590–11

590.5 Listing of Decorative Lighting

Decorative lighting used during holidays and for similar purposes [590.3(B)] must be listed and labeled on the product.

590.6 GFCI Protection for Personnel

(A) Receptacle Outlets. GFCI protection is required for receptacles used for construction, remodeling, maintenance, repair, or demolition of buildings, structures, or equipment.

(1) Receptacles Not Part of Permanent Wiring. GFCI protection is required for 15A, 20A, and 30A receptacles that are not part of the permanent wiring of the building. ▸ Figure 590–12

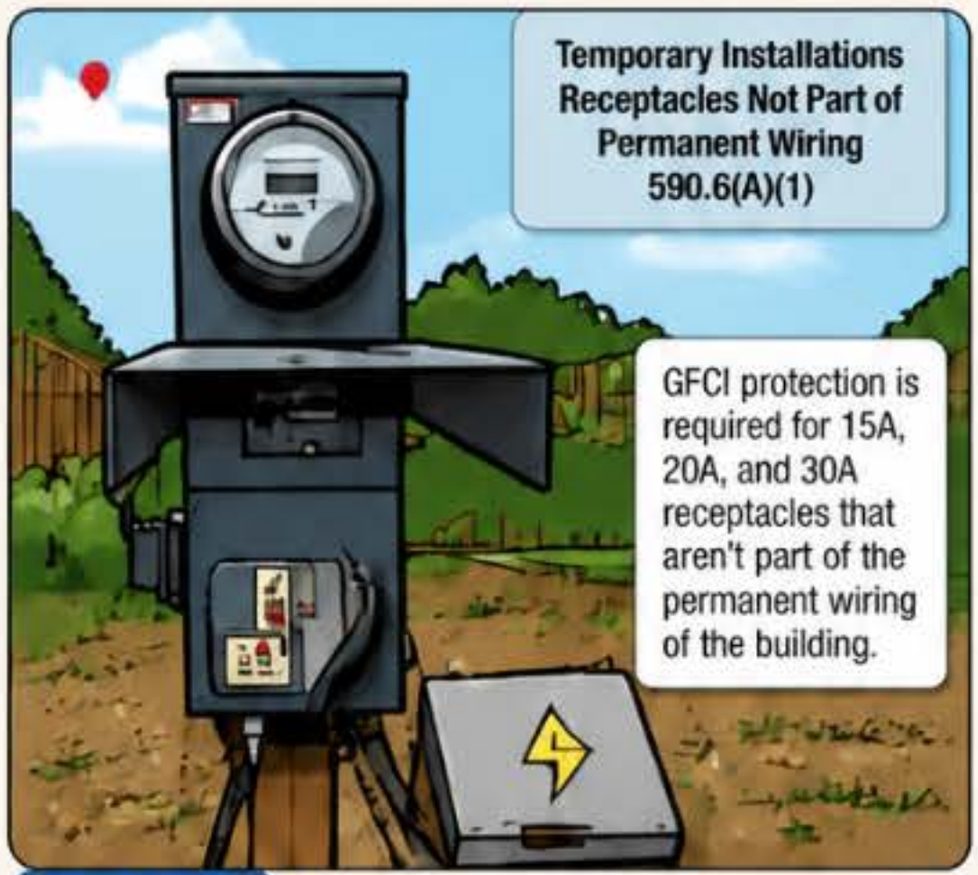


Figure 590–12

Author's Commentary:

Section 590.6(A) requires 125V and 125/250V, 15A, 20A, and 30A receptacles to have GFCI protection. Section 590.6(B) requires all other receptacles used on temporary installations to be GFCI protected. This simply means all 125V and 125/250V receptacles used for temporary power require GFCI protection.

— Michael Hamilton

(2) Receptacle Outlets Existing or Installed as Permanent Wiring. GFCI protection is required for 15A, 20A, and 30A receptacles that are being used as temporary power but are part of the permanent wiring of the building. Listed flexible cord sets or devices that incorporate listed GFCI protection can be used in addition to the required GFCI receptacles. ▶ Figure 590–13

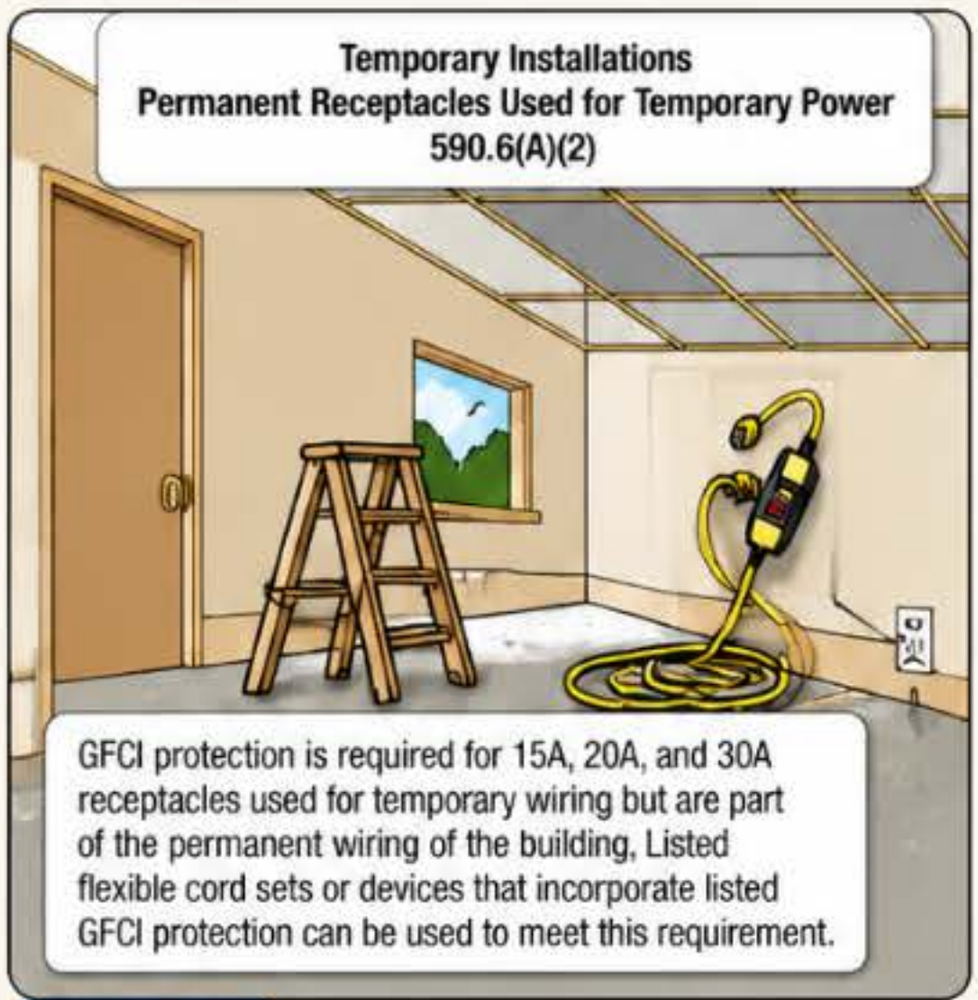


Figure 590–13

Temporary Installations | 590.8

(3) Portable Generators 15 kW or Less. GFCI protection is required for 125V and 125/250V, 15A, 20A, and 30A receptacles that are part of a portable generator rated not greater than 15 kW. ▶ Figure 590–14

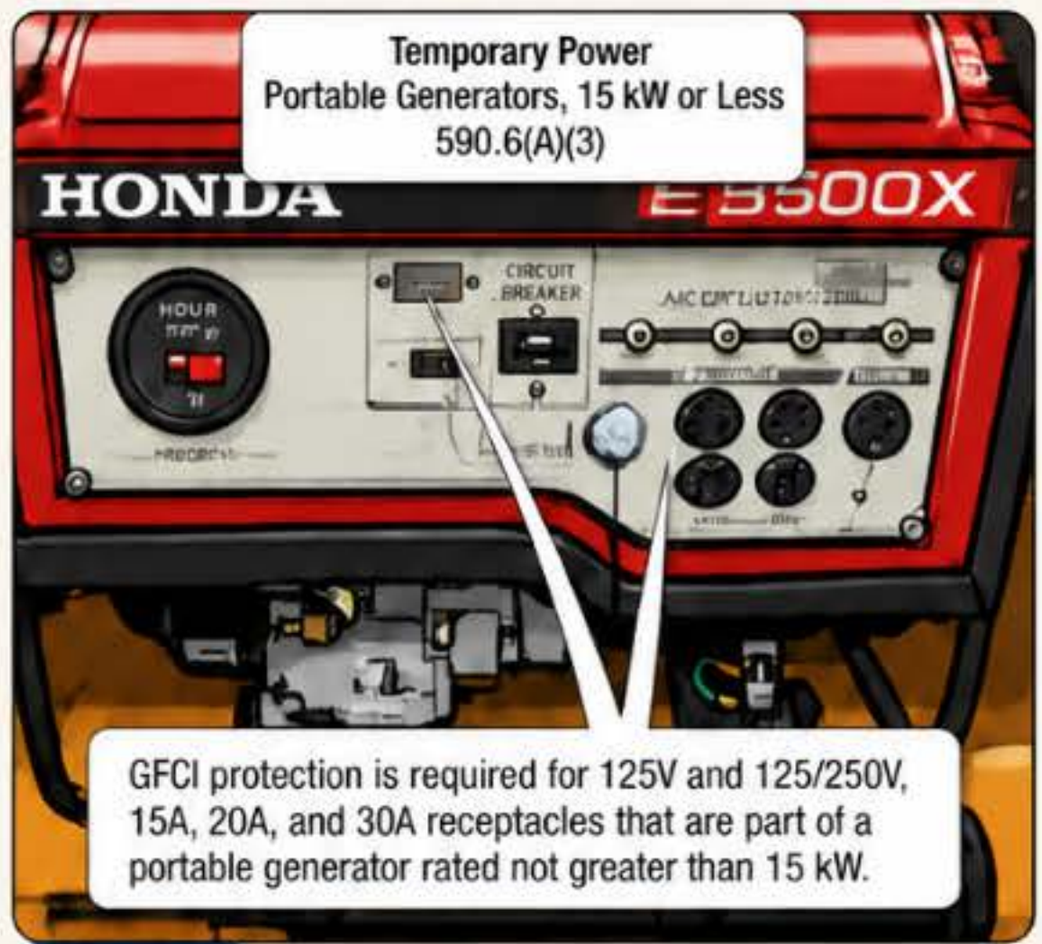


Figure 590–14

(B) Other Receptacle Outlets. Receptacles other than those covered by 590.6(A)(1) through (A)(3) that supply temporary power used by personnel during construction, remodeling, maintenance, repair, or demolition of buildings, structures, equipment, or similar activities must be GFCI protected.

590.8 Overcurrent Protective Devices

(A) Where Reused. Where overcurrent protective devices that have been previously used are installed in a temporary installation, they must be examined [110.3(A)] to ensure the devices have been properly installed, properly maintained, and there is no evidence of impending failure.

Note: The phrase "evidence of impending failure" means that there is evidence such as arcing, overheating, loose parts, burned equipment parts, visible damage, or deterioration. The phrase "properly maintained" means that the equipment has been maintained in accordance with the manufacturers' recommendations and applicable industry codes and standards.

DEFINITIONS | From Michael Hamilton Publications

References for manufacturers' recommendations and applicable industry codes and standards include but are not limited to NEMA AB 4, *Guidelines for Inspection and Preventative Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications*; NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*; NEMA GD, *Evaluating Water-Damaged Electrical Equipment*; and IEEE 1458, *IEEE Recommended Practice for the Selection, Field Testing, and Life Expectancy of Molded-Case Circuit Breakers for Industrial Applications.*

(B) Service Overcurrent Protective Devices. Overcurrent protective devices for 277/480V services must be of the current-limiting type.

CHAPTER 5 PRACTICE QUESTIONS

Please use the 2023 *Code* book to answer the following questions.

CHAPTER 5—SPECIAL OCCUPANCIES

Article 500—Hazardous (Classified) Locations

1. All areas designated as hazardous (classified) locations shall be properly _____ and shall be available to those authorized to design, install, inspect, maintain, or operate electrical equipment at these locations.

(a) cleaned
(b) documented
(c) maintained
(d) all of these

2. Hazardous (classified) locations shall be classified depending on the properties of the _____ that could be present, and the likelihood that a flammable or combustible concentration or quantity is present.

(a) flammable liquid-produced vapors
(b) flammable gases
(c) combustible dusts
(d) all of these

3. It is frequently possible to locate much of the equipment in less hazardous or unclassified locations and thus reduce the amount of special equipment required.

(a) True
(b) False

4. Class I, Division 1 locations are those in which ignitable concentrations of _____ can exist under normal operating conditions.

(a) combustible dust
(b) easily ignitable fibers or flyings
(c) flammable gases or flammable liquid-produced vapors
(d) pyrotechnics

5. An area that is adjacent to a Class I, Division 1 location, and to which ignitable concentrations of flammable gases, flammable liquid-produced vapors, or combustible liquid-produced vapors above their flash points might occasionally be communicated is a _____ location.

(a) Class I, Division 1
(b) Class II, Division 1
(c) Class I, Division 2
(d) Class II, Division 2

6. When determining a Class I, Division 2 location, the _____ is a factor that should be considered in determining the classification and extent of the location.

(a) quantity of flammable material that might escape in case of an accident
(b) adequacy of ventilating equipment
(c) record of the industry or business with respect to explosions or fires
(d) all of these

7. Class II locations are those that are hazardous because of the presence of _____.

(a) combustible dust
(b) easily ignitable fibers/flyings
(c) flammable gases or vapors
(d) flammable liquids or gases

8. Locations in which combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitable mixtures are classified as _____.

(a) Class I, Division 2
(b) Class II, Division 1
(c) Class II, Division 2
(d) Class III, Division 1

9. A Class II, Division 2 location is a location _____.

(a) in which combustible dust due to abnormal operations may be present in the air in quantities sufficient to produce explosive or ignitable mixtures
(b) where combustible dust accumulations are present but are normally insufficient to interfere with the normal operation of electrical equipment, but could as a result of infrequent malfunctioning of handling or processing equipment become suspended in the air
(c) in which combustible dust accumulations on, in, or in the vicinity of the electrical equipment could be sufficient to interfere with the safe dissipation of heat from electrical equipment
(d) all of these

10. Class III locations are those that are hazardous because of the presence of _____.

(a) combustible dust
(b) easily ignitable fibers or materials producing combustible flyings
(c) flammable gases or vapors
(d) flammable liquids or gases

11. Class III, Division _____ locations include areas where easily ignitable fibers/flyings are handled, manufactured, or used.

(a) 1
(b) 2
(c) 3
(d) all of these

12. A Class III, Division _____ location is where easily ignitable fibers/flyings are stored or handled but not manufactured.

(a) 1
(b) 2
(c) 3
(d) all of these

13. Electrical and electronic equipment in hazardous (classified) locations shall be protected by a(an) _____ technique.

(a) explosionproof
(b) dust-ignitionproof
(c) dusttight
(d) any of these

14. Dusttight protection techniques shall be permitted for equipment in Class I, Division 2 locations.

(a) True
(b) False

15. Suitability of identified equipment for use in a hazardous (classified) location shall be determined by _____.

(a) equipment listing or labeling
(b) evidence of equipment evaluation from a qualified testing laboratory or inspection agency concerned with product evaluation
(c) evidence acceptable to the authority having jurisdiction, such as a manufacturer's self-evaluation or an owner's engineering judgment
(d) any of these

16. Equipment shall be identified not only for the class of hazardous (classified) location, but also for the explosive, combustible, or ignitable properties of the specific _____ present.

(a) gas or vapor
(b) dust
(c) fibers/flyings
(d) any of these

17. Threaded conduits or fittings installed in hazardous (classified) locations shall be made wrenchtight to _____.

(a) prevent sparking when fault current flows through the conduit system
(b) prevent seepage of gases or fumes
(c) prevent sag in the conduit runs
(d) maintain a workmanship like installation

Practice Questions | Article 501

Article 501—Class I Hazardous (Classified) Locations

1. Article 501 establishes the rules for electrical and electronic equipment and wiring at all voltages in Class I, Division 1 and 2 locations where fire or explosion hazards may be present because of flammable _____.

   (a) gases
   (b) vapors
   (c) liquids
   (d) any of these

2. Wiring methods and materials permitted in Class I, Division 1 locations include _____.

   (a) threaded rigid metal conduit or threaded steel IMC
   (b) flexible fittings listed for Class I, Division 1 locations
   (c) boxes approved for Class I, Division 1 locations
   (d) all of these

3. Type PVC conduit, Type RTRC conduit, and Type HDPE conduit shall be permitted in Class I, Division 1 underground locations where encased in a concrete envelope a minimum of _____ in. thick and provided with not less than _____ in. of cover measured from the top of the condiut to grade.

   (a) 2, 12
   (b) 2, 24
   (c) 12, 2
   (d) 24, 2

4. MI cable terminated with fittings listed for the location is allowed in Class I, Division 1 locations.

   (a) True
   (b) False

5. In industrial facilities with restricted public access where only qualified persons will service the installation, MC-HL cable is permitted for use in a Class I, Division 1 location if it is installed and terminated with fittings listed for the application. Such cable shall comply with Part II of Article 330.

   (a) is listed for use in Class I, Zone 1, or Division 1 locations
   (b) has a gas/vaportight continuous corrugated metallic sheath and an overall jacket of suitable polymeric material
   (c) has a separate equipment grounding conductor(s) in accordance with 250.122
   (d) all of these

6. In industrial establishments with restricted public access, where the conditions of maintenance and supervision ensure that only qualified persons service the installation, Type ITC-HL cable is allowed to be used in a Class I, Division 1 location if it _____ and installed in accordance with the provisions of Article 727.

   (a) is listed for use in Class I, Zone 1, or Division 1 locations
   (b) has a gas/vaportight continuous corrugated metallic sheath and an overall jacket of suitable polymeric material
   (c) is terminated with fittings listed for the application
   (d) all of these

7. When necessary to employ flexible connections in a Class I, Division 1 location, such as at motor terminals, flexible fittings listed for the location are permitted, or flexible cord in accordance with 501.140 is permitted if terminated with cord connectors listed for the location.

   (a) True
   (b) False

8. When necessary to employ flexible connections in a Class I, Division 1 location, such as at motor terminals, _____ shall be permitted.

   (a) flexible fittings listed for the location
   (b) flexible cord in accordance with the provisions of 501.140, terminated with cord connectors listed for the location
   (c) listed Type TC-ER-HL in industrial establishments with restricted public access, where the conditions of maintenance and supervision ensure that only qualified persons service the installation, and installed in accordance with 336.10
   (d) any of these

9. Wiring methods permitted in Class I, Division 1 locations are permitted in Class I, Division 2 locations.

   (a) True
   (b) False

Article 501 | Practice Questions

10. _____ is(are) among the wiring methods permitted within a Class I, Division 2 location.

(a) Type MC, MV, TC, or TC-ER cable, including installation in cable tray systems and terminated with listed fittings
(b) Optical fiber cable Types OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN, and OFC installed in cable trays or any other raceway in accordance with 501.10(B) and sealed in accordance with 501.15
(c) Cablebus
(d) all of these

11. In Class I, Division 2 locations, where metallic conduit does not provide sufficient corrosion resistance, reinforced thermosetting resin conduit (RTRC), factory elbow, and associated fittings all marked with the suffix "-XW" shall be permitted.

(a) True
(b) False

12. In Class 1, Division 2 locations, Schedule 80 PVC conduit shall be permitted _____.

(a) where metal conduit does not provide sufficient corrosion resistance
(b) where the conditions of maintenance and supervision ensure that only qualified persons service the installation
(c) in industrial establishments with restricted public access
(d) all of these

13. In a Class I, Division 2 location, if flexibility is necessary, _____ fittings are some of the wiring methods that are permitted.

(a) listed flexible metal
(b) flexible metal conduit, liquidtight flexible metal conduit, and liquidtight nonmetallic conduit, all with listed
(c) interlocked armor Type MC cable with listed
(d) all of these

14. When provisions for flexibility are necessary in Class I, Division 2 locations, FMC with listed fittings can be used.

(a) True
(b) False

15. In a Class I, Division 2 location, switches and circuit breakers shall be installed in explosionproof enclosures meeting the requirements for Class I, Division 1 locations.

(a) True
(b) False

16. General-purpose enclosures and fittings are permitted in Class I, Division 2 locations unless the enclosure contains make-and-break contacts for _____ as required by 501.105(B)(1), 501.115(B)(1), and 501.150(B)(1).

(a) meters, instruments, and relays
(b) circuit breakers or motor controllers
(c) signaling, alarm, remote-control, and communications systems
(d) all of these

17. In Class I hazardous (classified) locations, sealing compound shall be used in Type MI cable termination fittings to _____.

(a) prevent the passage of gases or vapors
(b) exclude moisture and other fluids from the cable insulation
(c) limit a possible explosion
(d) prevent the escape of powder

18. In Class I, Division 1 locations, seals shall not be required for conduit entering an enclosure if the switch, circuit breaker, fuse, relay, or resistor is _____.

(a) enclosed within a chamber hermetically sealed against the entrance of gases or vapors
(b) immersed in oil in accordance with 501.115(B)(1)(2)
(c) enclosed within an enclosure, identified for the location, and marked "Leads Factory Sealed," or "Factory Sealed," "Seal not Required," or equivalent
(d) any of these

19. Class I, Division 1 conduit seals shall be installed within in. of the enclosure in each conduit entry into a pressurized enclosure where the conduit is not pressurized as part of the protection system.

(a) 6
(b) 12
(c) 18
(d) 24

20. In Class I, Division 1 locations, conduit seals entering pressurized enclosures, shall be installed within _____ in from the enclosure or as required by the enclosure marking.

(a) 12
(b) 18
(c) 20
(d) 24

Author's Commentary:

These practice questions are designed to help you reinforce key requirements for Class I, Division 2 locations. Take time to review each item carefully and compare your answers with the NEC® to build confidence for exams and real-world applications.

— Michael Hamilton

21. Where two or more explosionproof enclosures that require conduit seals are connected by nipples or runs of conduit not more than _____ in. long, a single conduit seal in each such nipple connection or run of conduit shall be considered sufficient if the seal is located not more than 18 in. from either enclosure.

(a) 12
(b) 18
(c) 24
(d) 36

22. A conduit run between a conduit seal and the point at which the conduit leaves a Class I, Division 1 location shall contain no union, coupling, box, or other fitting except for a listed _____ reducer installed at the conduit seal.

(a) explosionproof
(b) fireproof
(c) vaportight
(d) dusttight

23. A sealing fitting shall be permitted to be installed within _____ ft of either side of the boundary where a conduit leaves a Class I, Division 1 location.

(a) 5
(b) 6
(c) 8
(d) 10

24. Where the Class I, Division 1 location boundary is below grade, a sealing fitting shall be permitted to be installed _____ and there shall not be any unions, couplings, boxes, or fittings between the sealing fitting and the grade, other than listed explosion-proof reducers.

(a) after the conduit emerges from grade
(b) before the conduit emerges from grade
(c) within 10 ft of where the conduit emerges from grade
(d) if the raceway type is RMC or PVC conduit

25. A conduit seal shall be required in each conduit run leaving a Class I, Division 2 location. The conduit sealing fitting shall be installed on either side of the boundary within _____ ft of the boundary.

(a) 1
(b) 3
(c) 5
(d) 10

26. A sealing fitting shall not be required if a metal conduit passes completely through a Class I, Division 2 location if the termination points of the unbroken conduit are located in unclassified locations and it has no fittings less than _____ in. of either side of the boundary of the hazardous (classified) location.

(a) 6
(b) 12
(c) 18
(d) 24

27. When sealing fittings are required for Class I locations, they shall comply with which of the following rule(s)?

(a) They shall be listed for Class I locations and shall be accessible.
(b) The minimum thickness of the sealing compound shall not be less than the trade size of the sealing fitting and, in no case, shall the thickness of the compound be less than ½ in.
(c) Splices and taps shall not be made in the conduit seal.
(d) all of these

28. The minimum thickness of sealing compound in Class I locations shall not be less than the trade size of the conduit or sealing fitting and, in no case, shall the thickness of the compound be less than _____ in.

(a) ½
(b) ¼
(c) ⅜
(d) ⅜

29. In Class I, Division and 1 and Division 2 locations, the cross-sectional area of the conductors or optical fiber tubes (metallic or nonmetallic) permitted in a seal shall not exceed _____ percent of the cross-sectional area of a RMC of the same trade size unless the seal is specifically identified for a higher percentage of fill.

(a) 25
(b) 50
(c) 100
(d) 125

Article 501 | Practice Questions

30. In Class I, Division 1 locations, seals for cables at all terminations must be installed within _____ in. of the enclosure or as required by the enclosure marking.

(a) 6
(b) 12
(c) 18
(d) 20

31. In Class I, Division 1 locations, only threaded couplings, or explosionproof fittings such as unions, reducers, elbows, and capped elbows that are not larger than the _____ of the conduit are allowed between the sealing fitting and the enclosure.

(a) cross-sectional area
(b) trade size
(c) volume
(d) any of these

32. When installing shield cables and twisted-pair cables in conduit in a Class I, Division 1 hazardous (classified) location, the removal of shielding material or the separation of the twisted pairs of shielded cables and twisted pair cables is not required within the conduit seal fitting.

(a) True
(b) False

33. Each multiconductor cable installed in conduit in a Class I, Division 1 location shall be considered as a single conductor if the cable is incapable of transmitting _____ through the cable core.

(a) gases or vapors
(b) dust
(c) flyings
(d) any of these

34. The removal of shielding material or the separation of the twisted pairs of shielded cables and twisted pair cables is not required within the conduit seal fitting in a Class I, Division 2 hazardous (classified) location provided the termination is by an approved means to minimize the entrance of gases or vapors and prevent flame propagation.

(a) True
(b) False

35. In Class I locations, the locknut-bushing and double-locknut types of contacts shall not be depended on for bonding purposes.

(a) True
(b) False

36. When FMC or LFMC is used as permitted in Class I, Division 2 locations, it shall include an equipment bonding jumper of the wire type in compliance with 250.102.

(a) True
(b) False

37. Circuit breakers in Class I, Division 2 locations that are not hermetically sealed or oil-immersed shall be installed in a Class I, Division 1 enclosure.

(a) True
(b) False

38. Motors, generators, or other rotating electrical machinery identified for Class I, Division 2 locations can be used in Class I, Division 1 locations.

(a) True
(b) False

39. Totally enclosed motors of the types specified in 501.125(A)(2) or (A)(3) shall have a device to detect and automatically de-energize the motor or provide an adequate alarm if there is any increase in temperature of the motor beyond designed limits when operating in Class I, Division 1 locations.

(a) True
(b) False

40. Luminaires installed in Class I, Division 1 locations shall be identified as a complete assembly for the Class I, Division 1 location and shall be clearly marked to indicate the _____ for which it is identified.

(a) maximum wattage of lamps
(b) minimum conductor size
(c) maximum overcurrent protection permitted
(d) all of these

41. Luminaires installed in Class I, Division 1 locations shall be protected from physical damage by a suitable _____.

(a) warning label
(b) pendant
(c) guard or by location
(d) all of these

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42. Pendant luminaires in a Class I, Division 1 location shall be suspended by and supplied through threaded rigid metal conduit stems or threaded steel intermediate conduit stems, and threaded joints shall be provided with ____ or other effective means to prevent loosening.

(a) set-screws
(b) welded joints
(c) expansion joints
(d) explosionproof flex

43. Boxes, box assemblies, or fittings used to support luminaires in Class I, Division 1 locations shall be identified for Class I locations.

(a) True
(b) False

44. Luminaires installed in Class I, Division 2 locations shall be protected from physical damage by a suitable ____.

(a) warning label
(b) pendant
(c) guard or by location
(d) all of these

45. In Class I, Division 1 locations, all utilization equipment shall be ____ for use in a Class I, Division 1 location.

(a) identified
(b) approved
(c) marked
(d) listed

46. Flexible cords are not permitted in Class I locations.

(a) True
(b) False

47. Flexible cords in Class I hazardous (classified) locations shall ____.

(a) be listed as extra-hard usage
(b) contain an equipment grounding conductor
(c) be supported by clamps or other suitable means to avoid tension on the terminals
(d) all of these

48. In Class I, Division 1 or Division 2 locations where the boxes, fittings, or enclosures are required to be explosionproof, if a flexible cord is used it shall terminate with a cord connector or attachment plug listed for the location, or a listed cord connector installed with a seal that is listed for the location. In Division 2 locations where explosionproof equipment is not required, the cord shall terminate ____.

(a) with irreversible connections
(b) with a listed receptacle
(c) in a splice of any manner
(d) with a listed cord connector or listed attachment plug

49. For Class I locations where 501.140(A)(5) is applied, flexible cords shall be ____ from the power source to the temporary portable assembly and from the temporary portable assembly to the utilization equipment.

(a) permitted to be spliced
(b) of continuous length
(c) installed in a metal raceway
(d) spliced only using listed splicing kits

50. In Class I locations, attachment plugs shall be of the type providing for ____ a permitted flexible cord and shall be identified for the location.

(a) sealing compound around
(b) quick connection to
(c) connection to the equipment grounding conductor of
(d) interlocking

51. In Class I, Division 1 locations, all apparatus and equipment of signaling, alarm, remote-control, and communications systems shall be identified for Class I, Division 1 locations.

(a) over 50V
(b) over 100 volts-to-ground
(c) regardless of voltage
(d) except those operating at less than 24V

Article 502—Class II Hazardous (Classified) Locations

1. Article 502 covers the requirements for electrical and electronic equipment and wiring in Class II, Division 1 and 2 locations where fire or explosion hazards may exist due to ____.

(a) gases or vapors
(b) fibers/flyings
(c) combustible dust
(d) all of these

Article 502 | Practice Questions

2. Raceways permitted as a wiring method in Class II, Division 1 locations include _____.

(a) threaded RMC and steel IMC
(b) PVC conduit
(c) electrical metallic tubing
(d) any of these

3. Where flexibility is required, _____ are permitted in a Class II, Division 1 location.

(a) dusttight flexible connectors
(b) liquidtight flexible metal conduit with listed fittings
(c) flexible cords listed for extra-hard usage with listed dust-tight cord connectors
(d) any of these

4. Boxes and fittings used for taps, joints, or terminal connections shall be _____ where installed in Class II, Division 1 locations.

(a) explosionproof
(b) identified for Class II locations
(c) dusttight
(d) weatherproof

5. Rigid metal conduit and IMC shall not be required to be threaded when used in Class II, Division 2 locations.

(a) True
(b) False

6. In Class II, Division 2 locations, where provision must be made for flexibility, _____ shall apply.

(a) 502.10(A)(2)
(b) 502.10(A)(3)
(c) 502.10(B)(1)
(d) 502.10(B)(4)

7. In Class II locations, dust shall be prevented from entering the required dust-ignitionproof enclosure through a raceway by which of the following method(s)?

(a) a permanent and effective seal
(b) a horizontal raceway not less than 10 ft long
(c) a vertical raceway that extends downward for not less than 5 ft
(d) any of these

8. Seals in Class II hazardous (classified) locations shall be explosionproof.

(a) True
(b) False

9. In Class II locations, a permitted method of bonding is the use of bonding jumpers with proper fittings.

(a) True
(b) False

10. Where LFMC is used in a Class II, Division 1 location, it shall _____ in compliance with 250.102.

(a) not be unsupported
(b) not exceed 6 ft in length
(c) include an equipment bonding jumper of the wire type
(d) be listed for use in Class I locations

11. In Class II, Division 1 locations, switches, circuit breakers, motor controllers, and fuses, including pushbuttons, relays, and similar devices shall be provided with enclosures that are _____.

(a) explosionproof
(b) identified for the location
(c) dusttight
(d) weatherproof

12. In Class II, Division 2 locations, enclosures for fuses, switches, circuit breakers, and motor controllers, including pushbuttons, relays, and similar devices shall be _____.

(a) dusttight or otherwise identified for the location
(b) raintight
(c) rated as Class I, Division 1 explosionproof
(d) general duty

13. In Class II, Division 1 locations, motors, generators, and other rotating electrical machinery shall be _____.

(a) listed for the environment
(b) explosionproof
(c) general duty
(d) identified for the location or totally enclosed pipe-ventilated

14. In Class II, Division 2 locations, motors, generators, and other rotating electrical equipment shall be _____.

(a) totally enclosed nonventilated or pipe-ventilated
(b) totally enclosed water-air-cooled or fan-cooled
(c) dust-ignitionproof
(d) any of these

15. Luminaires placed in Class II, Division 1 areas must be labeled for their location and the markings shall clearly show the following:

(a) the highest wattage and lamp style for which it was made
(b) the smallest conductor size allowed
(c) the greatest overcurrent protection permitted
(d) all the above

16. Fixtures used in Class II, Division 1 locations must be shielded from physical damage by a proper means. The protection shall be provided by a suitable:

(a) warning sign
(b) pendant
(c) guard or by the location
(d) all of the above

17. Pendant luminaires in Class II, Division 1 locations have to be hung from threaded RMC or IMC conduit stems, chain with approved hardware, or other accepted supports. Stems must be fitted with _____ or similar supporting devices to stop loosening.

(a) set-screws
(b) welded joints
(c) expansion joints
(d) explosionproof flexible fittings

18. Lighting fixtures for fixed use in Class II, Division 2 areas shall be enclosed in housings that are _____ or otherwise recognized for the intended location.

(a) dust-ignitionproof
(b) dusttight
(c) dustproof
(d) explosionproof

19. Fixed lighting luminaires in Class II, Division 2 locations must be protected from physical damage by a suitable:

(a) warning sign
(b) pendant
(c) guard or by the location
(d) all of the above

20. In Class II, Division 2 areas, a flexible cord can be used to support a pendant luminaire.

(a) True
(b) False

21. Flexible cords used in Class II, Division 1 or 2 locations shall _____.

(a) be listed for heavy-duty service
(b) be listed for extra-hard usage
(c) not be allowed
(d) be Type SJTO or SJOWT

22. Signaling, alarm, remote-control, and communication system wiring with contact devices in Class II, Division 2 areas shall be installed in enclosures that are _____ or otherwise identified for the location.

(a) dust-ignitionproof
(b) dusttight
(c) dustproof
(d) explosionproof

Article 503—Class III Hazardous (Classified) Locations

1. Article 503 specifies the rules for electrical and electronic equipment and wiring in Class III locations where fire or explosion hazards may be present because of ignitable _____.

(a) gases or vapors
(b) fibers/flyings
(c) dust
(d) all of these

2. Raceways allowed in a Class III, Division 1 location include _____.

(a) RMC and IMC
(b) Type MC cable with listed termination fittings
(c) electrical metallic tubing
(d) any of these

3. Boxes and fittings shall be _____ where installed in a Class III location.

(a) explosionproof
(b) dust-ignitionproof
(c) dusttight
(d) weatherproof

4. In Class III locations, locknut-bushing and double-locknut types of fittings may be depended on for bonding purposes.

(a) True
(b) False

Article 511 Practice Questions

5. Where LFMC is used in a Class III location, it shall ____.
   (a) not be unsupported
   (b) not exceed 6 ft in length
   (c) include an equipment bonding jumper of the wire type in compliance with 250.102
   (d) be listed for use in a Class I hazardous (classified) location

6. In Class II locations, switches, circuit breakers, motor controllers, and fuses, including pushbuttons, relays, and similar devices, shall be provided with ____.
   (a) Class I enclosures
   (b) general duty enclosures
   (c) dusttight enclosures
   (d) seals at each enclosure

7. In Class III locations, motors, generators, and other rotating machinery shall be totally enclosed ____.
   (a) nonventilated
   (b) pipe ventilated
   (c) fan cooled
   (d) any of these

8. Luminaires for fixed lighting in Class III locations shall have enclosures for lamps and lampholders that are designed to prevent the escape of ____.
   (a) sparks
   (b) burning material
   (c) hot metal
   (d) all of these

9. Luminaires in Class III locations exposed to physical damage shall be protected by a(an) ____ guard.
   (a) plastic
   (b) metal
   (c) suitable
   (d) explosionproof

10. In a Class III location, pendant luminaires suspended by stems longer than ____ in. shall be provided with a fitting or flexible connector identified for the location or shall be provided with effective bracing.
   (a) 12
   (b) 18
   (c) 24
   (d) 30

11. In Class III locations, portable lighting equipment shall be equipped with handles and protected with substantial guards. Lampholders shall be of the unswitched type with no provision for ____.
   (a) receiving attachment plugs
   (b) grounding connections
   (c) lamp installation
   (d) hooks or hangers

12. In Class III locations, flexible cords shall ____.
   (a) be listed as extra-hard usage
   (b) contain an equipment grounding conductor
   (c) terminate with a listed dusttight cord connector
   (d) all of these

13. In Class III locations, receptacles and attachment plugs shall be of the grounding type, shall be designed so as to minimize the accumulation or the entry of ____, and shall prevent the escape of sparks or molten particles.
   (a) gases or vapors
   (b) particles of combustion
   (c) fibers/flyings
   (d) flammable liquids

Article 511—Commercial Garages, Repair and Storage

1. Article ____ contains the wiring requirements for service and repair operations in connection with self-propelled vehicles in which volatile flammable liquids or flammable gases are used for fuel or power.
   (a) 500
   (b) 501
   (c) 511
   (d) 514

2. Parking garages used for parking or storage shall be permitted to be unclassified locations.
   (a) True
   (b) False

Author's Commentary:

Practice questions are a powerful way to test your understanding of code requirements. Review each option carefully, then check the NEC to confirm the correct answer and reinforce your knowledge.

— Michael Hamilton

3. In major and minor repair garages, where vehicles using Class _____ liquids or heavier-than-air gaseous fuels (such as LPG) are repaired, hazardous area classification guidance is found in Table 511.3(C).

(a) I
(b) II
(c) III
(d) all of these

4. In major repair garages where ventilation is not provided, any pit or depression below floor level shall be a Class I, Division _____ location.

(a) 1
(b) 2
(c) 1 or Division 2
(d) 1 and Division 2

5. For each floor area inside a major repair garage where ventilation is not provided and Class I liquids or gaseous fuels are not transferred or dispensed, the entire area up to a level of _____ in. above the floor is considered to be a Class I, Division 2 location.

(a) 6
(b) 12
(c) 18
(d) 24

6. Any pit for which ventilation is not provided below a minor repair garage floor level of a lubrication or service room is considered to be a Class I, Division _____ location.

(a) 1
(b) 2
(c) 1 or Division 2
(d) 1 and Division 2

7. Where Class I liquids or gaseous fuels will not be transferred in a minor repair garage, such location is considered to be a(an) _____ location, provided the entire floor area has mechanical ventilation providing a minimum of four air changes per hour or one cubic foot per minute of exchanged air for each square foot of floor area.

(a) Class I, Division 1
(b) Class I, Division 2
(c) Class II, Division 1
(d) unclassified

8. In major repair garages where vehicles using lighter-than-air gaseous fuels (such as hydrogen and natural gas) are repaired, hazardous area classification guidance is found in Table 511.3(D).

(a) salvaged for parts
(b) assembled
(c) sold to the public
(d) repaired or stored

9. In major repair garages where lighter-than-air gaseous fueled vehicles, such as vehicles fueled by natural gas or hydrogen, are repaired or stored, the area within _____ in. of the ceiling is classified as Class I, Division 2 unless otherwise indicated in the Table footnotes.

(a) 6
(b) 12
(c) 18
(d) 24

10. The area used for _____ of alcohol-based windshield washer fluid in repair garages shall be unclassified.

(a) storage
(b) handling
(c) dispensing into motor vehicles
(d) any of these

11. Type NM cable can be installed above a Class I location in a commercial garage.

(a) True
(b) False

12. Fixed electrical equipment installed in spaces above a Class I location in a commercial garage shall be _____.

(a) well ventilated
(b) GFPE protected
(c) GFCI protected
(d) located above the level of any defined Class I location or identified for the location

13. A permanently mounted luminaire in a commercial garage, located over lanes on which vehicles are commonly driven, shall be located not less than _____ ft above floor level.

(a) 10
(b) 12
(c) 14
(d) 16

Article 514 | Practice Questions

14. Underground wiring below Class I locations in a commercial garage shall be installed in ____.

(a) threaded rigid or intermediate metal conduit
(b) Schedule 40 PVC conduit
(c) Schedule 80 PVC conduit
(d) coated EMT

15. In commercial garages, Type PVC conduit, Type RTRC conduit, and Type HDPE conduit shall be permitted where buried under not less than ____ ft of cover.

(a) 1
(b) 2
(c) 2½
(d) 3

16. Battery chargers and the batteries being charged can be located in any area of a commercial garage.

(a) True
(b) False

17. In commercial garages, GFCI protection for personnel shall be provided as required in 210.8(B).

(a) True
(b) False

Article 514—Motor Fuel Dispensing Facilities

1. Article 514 applies to motor fuel dispensing facilities, marine/motor fuel dispensing facilities, motor fuel dispensing facilities located inside buildings, and ____ vehicle motor fuel dispensing facillities.

(a) commercial
(b) hybrid
(c) military
(d) fleet

2. In motor fuel dispensing facilities, where the authority having jurisdiction can satisfactorily determine that flammable liquids having a flash point ____, such as gasoline, will not be handled such location shall not be required to be classified.

(a) above 100°F
(b) below 100°F
(c) below 86°F
(d) above 86°F

3. Underground wiring to motor fuel dispensers shall be installed (or shall be permitted to be installed) in ____.

(a) threaded rigid metal conduit
(b) threaded steel IMC
(c) PVC conduit, Type RTRC conduit, and HDPE conduit when buried under not less than 2 ft of cover
(d) any of these

4. A listed seal for motor fuel dispensers shall be provided in each conduit run ____.

(a) adjacent to a dispenser
(b) within 36 in. of a dispenser
(c) inside the dispenser equipment
(d) entering or leaving a dispenser

5. The sealing fitting or listed explosionproof reducer at the seal for motor fuel dispensers shall be the ____ fitting after the conduit emerges from the earth or concrete.

(a) first
(b) second
(c) third
(d) fourth

6. In motor fuel dispensing facilities, all metal raceways, the metal armor or metallic sheath on cables, and all noncurrent-carrying metal parts of fixed and portable electrical equipment ____ shall be grounded and bonded.

(a) operating at under 600V
(b) regardless of voltage
(c) over 300V
(d) under 50V

Article 517—Health Care Facilities

1. Article 517 applies to electrical construction and installation criteria in health care facilities that provide services to ____.

(a) human beings
(b) animals
(c) children only
(d) intellectually challenged persons

2. A "Dental Office" is a building or part thereof in which ____ occur.
   (a) examinations and minor treatments or procedures are performed under the continuous supervision of a dental professional
   (b) use of limited to minimal sedation and treatment or procedures that do not render the patient incapable of self-preservation under emergency conditions
   (c) there are no overnight stays for patients or 24-hour operations
   (d) all of these

3. "Health care facilities" are defined as buildings or portions of buildings, or mobile enclosures in which human medical, dental, ____, or surgical care are provided.
   (a) psychiatric
   (b) nursing
   (c) obstetrical
   (d) any of these

4. The person or persons who have the overall responsibility for the operation of a health care facility is known as the "governing body."
   (a) financial
   (b) legal
   (c) moral
   (d) all of these

5. A "hospital" is a building or portion thereof used for the medical, psychiatric, obstetrical, or surgical care, on a 24-hour basis, of ____ or more inpatients.
   (a) two
   (b) three
   (c) four
   (d) five

6. A "limited care facility" is defined as a building or portion thereof used on a(an) ____ basis for the housing of four or more persons who are incapable of self-preservation because of age; physical limitation due to accident or illness; or limitations such as intellectual disability/developmental disability, mental illness, or chemical dependency.
   (a) occasional
   (b) 10-hour or less per day
   (c) 24-hour
   (d) temporary

7. A "nursing home" is a building or portion of a building used for the housing and nursing care, on a 24-hour basis, of ____ or more persons who, because of mental or physical incapacity, might be unable to provide for their own needs and safety without the assistance of another person.
   (a) two
   (b) three
   (c) four
   (d) five

8. A "patient ____" is the location of an inpatient sleeping bed, or the bed or procedure table of a Category 1 (critical care) space.
   (a) bed location
   (b) care area
   (c) observation area
   (d) sterile area

9. The "patient care space" is any space within a health care facility where patients are intended to be ____.
   (a) admitted
   (b) evaluated
   (c) registered
   (d) examined or treated

10. Wiring methods in healthcare facilities shall comply with Chapters 1 through 4 of the *NEC* except as modified in Article ____.
    (a) 511
    (b) 516
    (c) 517
    (d) 518

11. In health care facilities, the ____ for branch circuits serving patient care spaces, shall itself qualify as an equipment grounding conductor in accordance with 250.118.
    (a) metal raceway system
    (b) metallic cable armor
    (c) sheath assembly
    (d) all of these

Article 517 | Practice Questions

12. In patient care spaces, an insulated equipment bonding jumper that directly connects to the equipment grounding conductor is permitted to connect the box and receptacle(s) to the equipment grounding conductor for other than ____ receptacles.

(a) AFCI-protected
(b) GFCI-protected
(c) isolated ground
(d) all of these

13. In patient care spaces, luminaires more than _____ ft above the floor and switches located outside of the patient care vicinity shall be permitted to be connected to an equipment grounding return path complying with 517.13(A) or (B).

(a) 7
(b) 7½
(c) 7¾
(d) 8

14. In patient care spaces, metal faceplates shall be directly connected to an insulated copper equipment grounding conductor by means of _____ securing the faceplate to a metal yoke or strap of a receptacle or to a metal outlet box.

(a) ground clips
(b) rivets
(c) metal mounting screws
(d) a spot weld

15. In health care facilities, isolated ground receptacles shall be installed in a patient care vicinity.

(a) True
(b) False

16. In health care facilities, _____ ground receptacle(s) installed in patient care spaces outside of a patient care vicinity(s) shall comply with 517.16(B)(1) and (B)(2).

(a) AFCI-protected
(b) GFCI-protected
(c) isolated
(d) all of these

17. Outside of patient care vicinities, the equipment grounding terminals of isolated ground receptacles installed in branch circuits for patient care _____ shall be connected to an insulated equipment grounding conductor in accordance with 250.146(D) installed in a wiring method described in 517.13(A).

(a) vicinities
(b) spaces
(c) bathrooms
(d) vicinities or spaces

18. Outside of patient care vicinities, the equipment grounding conductor connected to the equipment grounding terminals of isolated ground receptacles in patient care spaces, shall be clearly ____ along the equipment grounding conductor's entire length by green insulation with one or more yellow stripes.

(a) listed
(b) labeled
(c) identified
(d) approved

19. Outside of patient care vicinities, the insulated equipment grounding conductor required in 517.13(B)(1) shall be clearly ____ along its entire length by green insulation, with no yellow stripes, and shall not be connected to the grounding terminals of isolated equipment ground receptacles but shall be connected to the box or enclosure indicated in 517.13(B)(1)(2) and to noncurrent-carrying conductive surfaces of fixed electrical equipment indicated in 517.13(B)(1)(3).

(a) listed
(b) labeled
(c) identified
(d) approved

20. Outside of patient care vicinities, care should be taken in specifying a system containing isolated ground receptacles, because the ____ of the effective ground-fault current path is dependent upon the equipment grounding conductor(s) and does not benefit from any conduit or building structure in parallel with the equipment grounding conductor.

(a) ampacity
(b) resistance
(c) effectiveness
(d) impedance

Article 518—Assembly Occupancies

1. With the exception of assembly occupancies that are specifically addressed in 520.1, Article 518 addresses any buildings or portions of buildings or structures that are either intended or designed to bring together _____ or more individuals.

   (a) 16 (b) 50
   (c) 100 (d) 125

2. Illustrations of assembly occupancies include _____.

   (a) restaurants
   (b) conference rooms
   (c) pool rooms
   (d) all of these

3. Temporary wiring installed for exhibit booths in assembly occupancies is allowed to be used in accordance with Article 590, except _____.

   (a) GFCI requirements of 590.6 do not apply
   (b) Flexible cords and cables approved for extra-hard usage must be used on floors where protected from contact with the general public
   (c) GFCI protection must be provided where required by the *NEC*, excluding 590.6 requirements
   (d) all of these

4. Plug-and-cord-connected ground-fault circuit interrupter protection for personnel, at a minimum, for both branch-circuit and feeder supplies must be listed as _____ ground-fault circuit interrupter protection.

   (a) suitable
   (b) acceptable
   (c) accessible
   (d) portable

5. Which of the following wiring methods are permitted in an assembly occupancy?

   (a) Metal raceways
   (b) Type MC cable
   (c) Type AC cable
   (d) all of these

6. Nonmetallic raceways encased in not less than _____ in. of concrete shall be permitted in assembly occupancies.

   (a) 1
   (b) 2
   (c) 3
   (d) 4

7. In assembly occupancies, Type NM cable, ENT, and PVC conduit may be installed in those portions of buildings not required to be of _____ construction by the applicable building code.

   (a) Class I, Division 1
   (b) fire-rated
   (c) occupancy-rated
   (d) aboveground

Article 525—Carnivals, Circuses, Fairs, and Similar Events

1. Article(s) _____ covers the installation of portable wiring and equipment for carnivals, circuses, fairs, and similar functions.

   (a) 518
   (b) 525
   (c) 590
   (d) all of these

2. The individual responsible for starting, stopping, and controlling an amusement ride or supervising a concession is known as the _____.

   (a) operator
   (b) director
   (c) manager
   (d) facilitator

3. Overhead wiring outside of tents and concession areas of carnivals and circuses that are accessible to pedestrians must maintain a vertical clearance of _____. ft above finished grade, sidewalks, platforms, projections, or surfaces from which the wiring might be reached.

   (a) 3
   (b) 6
   (c) 8
   (d) 10

Article 525 | Practice Questions

4. Portable carnival or circus structures must be kept at least _____ ft in all directions away from overhead conductors that operate at 600V or less.

(a) 7½
(b) 10
(c) 12½
(d) 15

5. Electrical equipment and wiring techniques used on or in portable setups for carnivals, circuses, fairs, and similar occasions are required to include mechanical safeguards whenever exposed to _____.

(a) public access
(b) physical damage
(c) exposure to the weather
(d) operator access

6. When doors are installed in enclosures at carnivals, circuses, or fairs, the flexible cords and cables inside must be approved for wet locations and also resist sunlight.

(a) True
(b) False

7. At carnivals, circuses, and fairs, cord connectors are allowed to be used on the ground only when they are _____ for a wet location.

(a) listed
(b) labeled
(c) approved
(d) identified

8. Flexible cords and cables that the public can reach in carnivals or circuses may be buried, provided they meet the requirements of 300.5.

(a) True
(b) False

9. Every portable building at a carnival, circus, or fair must have a way to disconnect it from any ungrounded conductors that are visible and within _____ ft of the operator's station.

(a) 3
(b) 6
(c) 8
(d) 10

10. Wiring for illumination inside tents and for concession spaces at carnivals, circuses, and fairs—where there is a risk of physical harm—must be supplied with mechanical protection.

(a) True
(b) False

11. Portable distribution and termination boxes located outside at carnivals, circuses, or fairs must be weather-resistant and raised off the ground so the bottom of the enclosure is no less than _____ in. above grade.

(a) 6
(b) 8
(c) 10
(d) 12

12. GFCI protection for personnel is required at carnivals, circuses, and fairs for all 15A and 20A, 125V nonlocking-type receptacles that are readily accessible to the general public.

(a) True
(b) False

13. At carnivals and fairs, locking-type receptacles that are not easily reached by the public and are only used for rapid disconnection and reconnection of equipment do not have to include GFCI protection.

(a) True
(d) False

14. GFCI protection is not allowed at carnivals, circuses, and fairs for _____.

(a) portable structures
(b) egress lighting
(c) nighttime operation lighting
(d) amusement lighting

15. In circuses and carnivals, all equipment grounding must be connected to a(n) _____ conductor of a type listed in 250.118.

(a) equipment grounding conductor
(b) grounded
(c) grounding electrode
(d) ungrounded

16. To ensure reliable operation, equipment grounding conductors used at carnivals, circuses, fairs, and similar gatherings must be checked for continuity at the time the portable electrical equipment is connected.

(a) True
(b) False

Article 547—Agricultural Buildings

1. Agricultural buildings where excessive dust and dust with water may collect, including all spaces of _____ confinement systems where litter dust or feed dust may build up, must comply with Article 547.

(a) poultry
(b) livestock
(c) fish
(d) all of these

2. Agricuttural buildings where corrosive atmospheres exist must include areas where _____ conditions exist(s).

(a) poultry and animal excrement
(b) corrosive particles which may combine with water
(c) areas of periodic washing with water and cleansing agents
(d) all of these

3. An "equipotential plane" is an area where wire mesh or other conductive elements are embedded in or placed under concrete and bonded to _____.

(a) all metal structures
(b) fixed nonelectrical equipment that could become energized
(c) the electrical grounding system
(d) all of these

4. Type NM cable shall be permitted in agricultural buildings.

(a) True
(b) False

5. Enclosures and fittings installed in areas of agricultural buildings where excessive dust may be present shall be designed to minimize the entrance of dust and shall have no openings through which dust can enter the enclosure.

(a) True
(d) False

6. In damp or wet locations of agricultural buildings, equipment enclosures and fittings shall be located or equipped to prevent moisture from _____ within the enclosure, box, conduit body, or fitting.

(a) entering and accumulating
(b) draining from
(c) creating a short-circuit
(d) causing damage

7. Where _____ may be present in an agricultural building, enclosures and fittings shall have corrosion-resistance properties suitable for the conditions.

(a) wet dust or excessive moisture
(b) corrosive gases or vapors
(c) other corrosive conditions
(d) any of these

8. Where an equipment grounding conductor is installed underground within an agricultural building, it shall be _____.

(a) insulated
(b) copper
(c) bare
(d) covered

9. All 15A and 20A, 125V, single-phase receptacles installed _____ of agricultural buildings shall be GFCI protected.

(a) in areas having an equipotential plane
(b) outdoors
(c) in dirt confinement areas for livestock
(d) any of these

10. Luminaires used in agricultural buildings shall _____.

(a) minimize the entrance of dust, foreign matter, moisture, and corrosive material
(b) be protected by a suitable guard if exposed to physical damage
(c) be listed for use in wet locations when exposed to water
(d) all of these

11. An equipotential plane shall be installed in all concrete floor confinement areas of livestock buildings, and all outdoor confinement areas with a concrete slab that contains metallic equipment accessible to livestock and that may become energized.

(a) True
(d) False

Article 550 Practice Questions

12. The equipotential plane in an agricultural building must be connected to the electrical grounding system with a solid copper, insulated, covered, or bare conductor that is not smaller than _____ AWG.

    (a) 10
    (b) 8
    (c) 6
    (d) 4

Article 550—Mobile Homes, Manufactured Homes, and Mobile Home Parks

1. Article _____ addresses the electrical conductors and equipment installed within or on mobile and manufactured homes and the conductors that connect mobile and manufactured homes to a source of electricity.

    (a) 550
    (b) 551
    (c) 555
    (d) 590

2. A "_____" is a structure that can be moved in one or more sections and was built on a permanent chassis. It is designed for use as a dwelling, with or without a permanent foundation, whether or not it is connected to utilities, and includes plumbing, heating, air conditioning, and electrical systems that are contained within it.

    (a) manufactured home
    (b) mobile home
    (c) dwelling unit
    (d) manufactured or mobile home

3. The term "mobile home" refers to manufactured homes, unless otherwise stated.

    (a) True
    (b) False

4. GFCI protection in a mobile home shall be provided for _____.

    (a) receptacle outlets installed outdoors and in compartments accessible from outside
    (b) receptacles within 6 ft of a wet bar sink, dishwasher outlets, and where installed to serve countertop surfaces
    (c) all receptacles in bathrooms including receptacles in luminaires
    (d) all of these

Author's Commentary: *Practice is how we turn code knowledge into confident, correct application. Keep working these questions until the answers become second nature.*

— Michael Hamilton

5. Where outdoor or under-chassis line-voltage (120V, nominal, or higher) mobile home wiring is exposed, it must be protected by a conduit or raceway approved for such use in wet locations. The conductors shall be listed for use in _____ locations.

    (a) hazardous
    (b) damp
    (c) wet
    (d) corrosive

6. In mobile and manufactured homes, all 120V branch circuits that supply 15A and 20A outlets must have _____ protection in accordance with 210.12.

    (a) AFCI
    (b) GFCI
    (c) AFCI and GFCI
    (d) adequate

7. Mobile home service equipment must be located adjacent to the mobile home and no more than _____ ft from the exterior wall of the mobile home it serves.

    (a) 15
    (b) 20
    (c) 30
    (d) 40

8. Mobile home and manufactured home feeder circuit conductors shall have a capacity not less than the loads supplied and have an ampacity of not less than _____.

    (a) 50A
    (b) 60A
    (c) 100A
    (d) 200A

9. Mobile home and manufactured home feeder circuit conductors shall have a capacity not less than the loads supplied, shall have an ampacity of not less than 100A, and shall be permitted to be sized in accordance with 310.12.

    (a) True
    (b) False

Article 555—Marinas, Boatyards, and Docking Facilities

1. Article 555 addresses marinas, boatyards, docking facilities but not floating buildings.

    (a) True
    (b) False

DEFINITIONS | From Michael Hamilton Publications

2. Article 555 governs the installation of wiring and equipment in locations such as _____ and other locations in marinas and boatyards.

(a) fixed or floating piers
(b) floating buildings
(c) wharves and docks
(d) all of these

3. A "marine _____" is a contained assembly that may house receptacles, circuit breakers, fused switches, fuses, watthour meter(s), panelboards, and monitoring equipment used for marina service.

(a) power receptacle
(b) source outlet
(c) power outlet
(d) any of these

4. The electrical system needed to supply power to a floating vessel, excluding the receptacle and cords, is called a "_____."

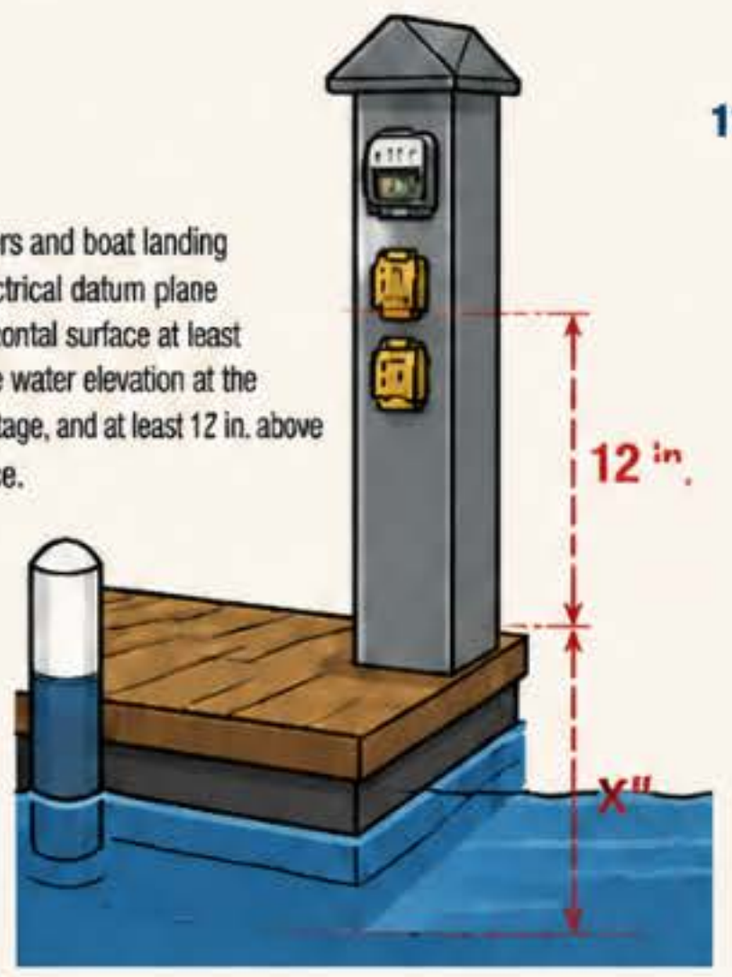
(a) a marina service
(b) dock power
(c) shore power
(d) ship power

5. For floating piers and boat landing stages, the electrical datum plane must be a flat surface 30 in. above the water elevation at the pier or landing stage, and at least _____ in. above the deck surface.

(a) 12
(b) 18
(c) 24
(d) 30

6. For floating piers and boat landing stages, the electrical datum plane must be a horizontal surface at least 30 in. above the water elevation at the pier or landing stage, and at least 12 in. above the deck surface.

(a) 12
(b) 18
(c) 24
(d) 30



7. In land areas that may be affected by tidal changes, the electrical datum plane must be a horizontal surface _____ ft above the greatest tide level expected under normal conditions, based on the highest high tide.

(a) 1
(b) 1½
(c) 2
(d) 2½

8. In land areas not affected by tidal changes, the electrical datum plane must be a horizontal surface _____ ft above the greatest tide level expected under normal conditions, based on the highest high tide.

(a) 1
(b) 1½
(c) 2
(d) 2½

9. Service equipment for floating docks or marinas must be installed _____ the floating structure.

(a) on land adjacent to
(b) on
(c) in
(d) any of these

10. For marina load calculations, the demand factor for 45 shore power receptacles is _____ percent.

(a) 40
(b) 50
(c) 60
(d) 70

11. For shore power at an individual boat slip, when the receptacles have different voltages, only the receptacle with the _____ must be used in the calculation.

(a) smaller kW demand
(b) larger kW demand
(c) higher voltage
(d) nominal voltage

Article 555 | Practice Questions

12. In marinas, boatyards, and commercial and noncommercial docking facilities, the bottom of enclosures for transformers shall not be located below ____.

(a) 2 ft above the dock
(b) 18 in. above the electrical datum plane
(c) the electrical datum plane
(d) a dock

13. Permanent safety signs shall be installed to give notice of electrical shock hazard risks to persons using or swimming near a boat dock or marina and shall ____.

(a) comply with 110.21(B)(1) and be of sufficient durability to withstand the environment
(b) be clearly visible from all approaches to a marina, docking facility, or boatyard facility
(c) state "WARNING—POTENTIAL SHOCK HAZARD—ELECTRICAL CURRENTS MAY BE PRESENT IN THE WATER"
(d) all of these

14. In marinas, boatyards, and commercial and noncommercial docking facilities, all metal parts in contact with the water, all metal piping, and all noncurrent-carrying metal parts shall be connected to the grounding bus in the panelboard using solid copper conductors; insulated, covered, or bare; not smaller than ____ AWG.

(a) 12
(b) 10
(c) 8
(d) 6

15. Electrical connections shall be located at least ____ in. above the deck of a floating pier.

(a) 12
(b) 18
(c) 24
(d) 30

16. Conductor splices, within junction boxes identified for wet locations, utilizing sealed wire connector systems listed and identified for submersion shall be required for floating piers where located above the electrical datum plane for floating piers.

(a) True
(d) False

17. Electrical connections in marinas, boatyards, and commercial and noncommercial docking facitilies shall be located [above the deck of a floating or fixed] pier unless the conductor splices for floating piers are contained within sealed wire connector systems listed and identified for submersion.

(a) at least 12 in. above the deck of a floating pier
(b) at least 12 in. above the deck of a fixed pier
(c) not below the electrical datum plane of a fixed pier
(d) all of these

18. All electrical connections shall be located at least ____ in. above the deck of a fixed pier but shall not be located below the electrical datum plane.

(a) 12
(b) 18
(c) 24
(d) 30

19. Replacement electrical connections shall be located at least ____ in. above the deck of a floating pier.

(a) 12
(b) 18
(c) 24
(d) 30

20. Receptacles that provide shore power for boats shall be rated not less than ____.

(a) 15A
(b) 20A
(c) 30A
(d) 60A

21. All receptacles installed for other than shore power shall be protected in accordance with ____.

(a) 110.11
(b) 200.3
(c) 210.8
(d) 250.62

22. Shore power receptacles installed in accordance with 555.33(A) shall have individual GFCIs set to open at currents not exceeding ____ milliamperes.

(a) 6
(b) 30
(c) 75
(d) 100

23. All ____ , 15A and 20A receptacles for other than shore power shall be protected in accordance with 555.33(B)(1) and (B)(2).

(a) 125V, single-phase
(b) 250V, single-phase
(c) single or three-phase
(d) 125V, single-phase or 250V, single-phase

24. Feeder and branch-circuit conductors that are installed on docking facilities shall be provided with GFPE set to open at currents not exceeding ____ milliamperes.

(a) 6
(b) 30
(c) 75
(d) 100

25. Where more than ____ receptacles supply shore power to boats, a leakage current measurement device shall be available and be used to determine leakage current from eah boat boat that will uiilize shore power.

(a) two
(b) three
(c) four
(d) six

26. Leakage current measurement devices will provide the capability to determine when an individual boat has defective wiring or other problems contributing to hazardous voltage and current and will help the facility operator prevent a particular boat from contributing to hazardous voltage and current in the marina area.

(a) True
(b) False

27. A(m) ____ test of each boat with the leakage current measurement device is a prudent step toward determining if a boat has defective wiring that may be contributing hazardous voltage and current in the marina area.

(a) monthly
(b) quarterly
(c) bi-annual
(d) annual

Author's Commentary:
Shore power systems in marinas are unique environments where electrical safety is critical. Ground-fault protection, proper isolation, and leakage monitoring all work together to protect people, boats, and equipment from the hazards of electrical faults in or near the water.

— Michael Hamilton

28. Disconnecting means shall be provided to ____ each boat from its supply connection(s).

(a) isolate
(b) separate
(c) guard
(d) control

29. A ____ shall be used to serve as the required shore power receptacle disconnecting means, and it shall be identified as to which receptacle it controls.

(a) circuit breaker
(b) switch
(c) circuit breaker or fused knife switch
(d) circuit breaker, switch, or both

30. In marinas, boatyards, and commercial and noncommercial docking facilities, the disconnecting means shall be ____ , located not more than 30 in. from the receptacle it controls, and shall be located in the supply circuit ahead of the receptacle.

(a) accessible
(b) readily accessible
(c) remote
(d) any of these

31. The disconnecting means for a shore power connection shall be not more than ____ in. from the receptacle it controls.

(a) 12
(b) 24
(c) 30
(d) 36

32. Marina or dock items shall be connected to an equipment grounding conductor run with the circuit conductors in the same raceway, cable, or trench. These items include metal boxes, metal cabinets, and all other metal enclosures; metal frames of utilization equipment; and ____.

(a) metal fencing
(b) wood rails of piers and docks
(c) metal rails of piers and docks
(d) grounding terminals of grounding-type receptacles

33. The equipment grounding conductor at a marina is required to be an insulated conductor for all circuits.

(a) True
(b) False

Article 590 | Practice Questions

34. Where a shore power feeder supplies a remote panelboard, an insulated _____ shall extend from a grounding terminal in the service equipment to a grounding terminal in the remote panelboard.

(a) bonding jumper
(b) equipment grounding conductor
(c) grounding electrode conductor
(d) copper conductor

Article 590—Temporary Installations

1. The provisions of Article _____ apply to temporary electric power and lighting installations.

(a) 480
(b) 555
(c) 590
(d) 600

2. Temporary wiring methods shall be acceptable only if based on the conditions of use and any special requirements of the temporary installation.

(a) listed
(b) identified
(c) approved
(d) any of these

3. Temporary electrical power and lighting installations shall be permitted for a period not to exceed 90 days for _____ decorative lighting and similar purposes.

(a) Christmas
(b) New Year's
(c) July 4th
(d) holiday

4. Temporary electrical power and lighting shall be permitted during emergencies and for _____.

(a) tests
(b) experiments
(c) developmental work
(d) all of these

5. Temporary wiring shall be _____ immediately upon the completion of construction or purpose for which the wiring was installed.

(a) disconnected
(b) removed
(c) de-energized
(d) any of these

6. Types NM, NMC, and SE cables can be used for feeder temporary installations without height limitation and without concealment.

(a) True
(b) False

7. Type _____ cable shall be permitted to be installed in a feeder raceway in a temporary underground installation.

(a) NM
(b) NMC
(c) SE
(d) any of these

8. Types NM, NMC, and SE cables can be used for branch circuits for temporary installations without height limitation and without concealment.

(a) True
(b) False

9. Type _____ cable shall be permitted to be installed in a branch-circuit raceway in a temporary underground installation.

(a) NM
(b) NMC
(c) SE
(d) any of these

10. Receptacles on construction sites shall not be installed on _____ that supplies temporary lighting.

(a) any branch circuit
(b) the same feeder
(c) any branch circuit or the same feeder
(d) a cord or cable

11. For temporary installations, lamps for general illumination shall be protected from accidental contact or breakage by a suitable _____ or by the use of a lampholder with a guard.

(a) globe
(b) luminaire
(c) fitting
(d) porcelain fitting

PRACTICE QUESTIONS | Article 590

12. For temporary installations, a box, conduit body, or other enclosure, with a cover installed, must be provided for all splices except where the circuit conductors being spliced are all from nonmetallic multiconductor cable assemblies, provided the equipment grounding continuity is maintained with or without the box.

(a) listed
(b) identified
(c) cord or cable
(d) feeder and service conductor

13. Flexible cords and flexible cables used for temporary wiring shall ____.

(a) be protected from accidental damage
(b) be protected where passing through doorways
(c) avoid sharp corners and projections
(d) all of these

14. For temporary installations, cable assemblies, flexible cords, and flexible cables shall be supported by ____ or similar fittings so as not to damage the wiring.

(a) staples
(b) cable ties
(c) straps
(d) any of these

15. Vegetation shall not be used to support overhead conductor spans of ____ for temporary installations.

(a) luminaires
(b) receptacles
(c) branch circuits or feeders
(d) lighting conductors

16. Ground-fault protection for personnel is required for all temporary wiring used for construction, remodeling, maintenance, repair, or demolition of buildings, structures, or equipment, from power derived from a(an) ____ or from an on-site-generated power source.

(a) electric utility company
(b) cable or cord
(c) feeder
(d) separately derived system

17. All ____ 125V receptacle outlets that are not part of the permanent wiring of the building or structure and are used by personnel for temporary power shall be GFCI protected.

(a) 15A
(b) 20A
(c) 30A
(d) all of these

18. GFCI protection is required for 15A, 20A, and 30A, 125V receptacle outlets that are installed or existing as part of the permanent wiring of the building/structure when used during construction or remodeling. Listed cord sets or adapters that incorporate listed GFCI protection for portable use can be used to meet this requirement.

(a) True
(b) False

19. For temporary power outlets existing or installed as permanent wiring, GFCI protection can be incorporated into a listed ____.

(a) circuit breaker
(b) receptacle
(c) cord set
(d) any of these

20. GFCI protection is required for 15A, 20A, and 30A, 125V and 125/250V receptacles that are part of a portable generator used for temporary wiring rated not greater than ____.

(a) 5 kW
(b) 7.50 kW
(c) 10 kW
(d) 15 kW

21. Receptacles rated other than 125V, single-phase, 15A, 20A, and 30A for temporary installations shall be protected by ____.

(a) GFCI protection for personnel
(b) GFCI protection for personnel
(c) GFPE protection for equipment
(d) a surge protective device (SPD)

Article 590 Practice Questions

22. Where overcurrent protective devices that have been previously used are installed in a temporary installation, these overcurrent protective devices shall be examined to ensure these devices _____.

    (a) have been properly installed
    (b) have been properly maintained
    (c) show no evidence of impending failure
    (d) all of these

23. Where overcurrent protective devices that have been previously used are installed in a temporary installation, the phrase "evidence of impending failure" means that there is evidence such as _____.

    (a) arcing or overheating
    (b) loose or bound equipment parts
    (c) visible damage or deterioration
    (d) any of these

24. Where overcurrent protective devices that have been previously used are installed in a temporary installation, the phrase "properly maintained" means that the equipment has been maintained in accordance with the _____.

    (a) product listing
    (b) manufacturer's recommendations and applicable industry codes and standards
    (c) field evaluator's recommendations
    (d) any of these

CHAPTER 6 SPECIAL EQUIPMENT

Introduction to Chapter 6—Special Equipment

The first four chapters of the *Code* establish the groundwork for each of the next four chapters. Chapter 6, which addresses special equipment, is the second of the four *NEC* chapters that cover dedicated topics. Chapters 5 and 7 discuss specialized locations and conditions, while Chapter 8 addresses communication systems.

Special Equipment, as defined here, refers to equipment whose use, construction, or distinctive nature creates a requirement for additional safeguards. The goal is to protect people and property in alignment with the *NEC*'s "safeguarding of persons and property" mission stated in Article 90. The *Code* organizes this chapter into logical groups as you would expect.

- **Article 600—Electric Signs and Outline Lighting.** This article covers wiring, equipment, and installation requirements for electric signs and outline lighting as described in Article 100. It includes all products and installations that use neon tubing for signs, decorative accents, skeleton tubing, or art forms.
- **Article 604—Manufactured Wiring Systems.** Article 604 addresses field-installed manufactured wiring systems for branch circuits, remote-control circuits, signaling circuits, and communication circuits in accessible locations. Components of a listed manufactured wiring system are assembled at the site.
- **Article 620—Elevators, Escalators, and Moving Walks.** This article covers electrical equipment and wiring used with elevators, dumbwaiters, escalators, moving walks, wheelchlair lifts, and stairway chair lifts.
- **Article 625—Electric Vehicle Power Transfer System.** An electrically powered vehicle requires a dedicated charging circuit, which Article 625 provides. It outlines the electrical needs for charging automotive-type electric and hybrid vehicles such as cars, bikes, and buses.
- **Article 630—Electric Welders.** Welding equipment can operate by producing an electric arc between two surfaces or by using heat from a current-carrying rod that melts due to overcurrent. These methods both create a momentary current flow. Welding machines exist in many designs and sizes. This article covers electric arc welding and resistance welding equipment supplied from an electric source.
- **Article 640—Audio Signal Amplification and Reproduction Equipment.** This article covers equipment and wiring for audio systems, including recording, processing, amplification, and reproduction; distribution of sound, public address, speech-input devices, temporary audio setups, and electric musical instruments such as electronic organs, electric guitars, and electronic drums/percussion.
- **Article 645—Information Technology Equipment.** This article addresses equipment, power-supply wiring, equipment interconnecting wiring, and grounding of information technology equipment and systems, including terminal units in an information technology equipment room.

Chapter 6 Special Equipment

- **Article 680—Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations.**

  This article addresses the installation of bonding and grounding components for these installations, along with the wiring and equipment that feed swimming pools, wading areas, therapeutic and decorative water features, hot tubs, spas, hydromassage bathubs, and equipment that can be permanently installed or removed.

- **Article 690—Solar Photovoltaic (PV) Systems.**

  This article focuses on minimizing the electrical hazards that can occur when installing or operating a solar PV system, to the point where the system is considered safe for property and people. The requirements in *NEC* Chapters 1 through 4 are also applicable to these installations, except where specifically revised.

- **Article 691—Large-Scale Solar Photovoltaic (PV) Electric Supply Stations.**

  Article 691 covers large photovoltaic electric supply stations with a generating capacity of 5,000 kW or greater and that are not under the exclusive control of a utility.

- **Article 695—Fire Pumps.**

  This article covers the electrical power sources and interconnection circuits for electric motor-driven fire pumps. It also addresses switching and control equipment dedicated to fire pump drivers. Article 685 does not apply to sprinkler system pumps in one- and two-family dwellings or to pressure maintenance (jockey) pumps.

ARTICLE 600 ELECTRIC SIGNS AND OUTLINE LIGHTING

Introduction to Article 600—Electric Signs and Outline Lighting

When you walk into a strip mall, you will typically see a sign for every business. Because every commercial space requires identification, the NEC® sets rules for how those signs are powered. Article 600.5 requires a sign outlet at each tenant entrance. Rule 600.6 requires a disconnect visible from the sign unless it can be locked in the open position.

Author's Commentary:

Article 100 describes an electric sign as any "fixed, stationary, or portable self-contained, electrically illuminated utilization equipment with words or symbols designed to convey information or attract attention."

— Michael Hamilton

Signs that are not attached to a building, such as those in a parking lot, must be positioned at least 14 ft above any vehicle area unless they are protected from physical damage [600.9(A)].

Neon and other decorative lighting elements are subsets of electric signs and outline lighting. If these items are installed independently and not fastened to an enclosure or sign body, they are treated as skeleton tubing used to apply Article 600 requirements. However, if neon tubing is mounted to an enclosure or sign structure—possibly on a support frame—it is considered a sign or outline lighting. Therefore, the sign and outline lighting rules in 600.3 apply to those installations that must be listed.

Part I. General

600.1 Scope

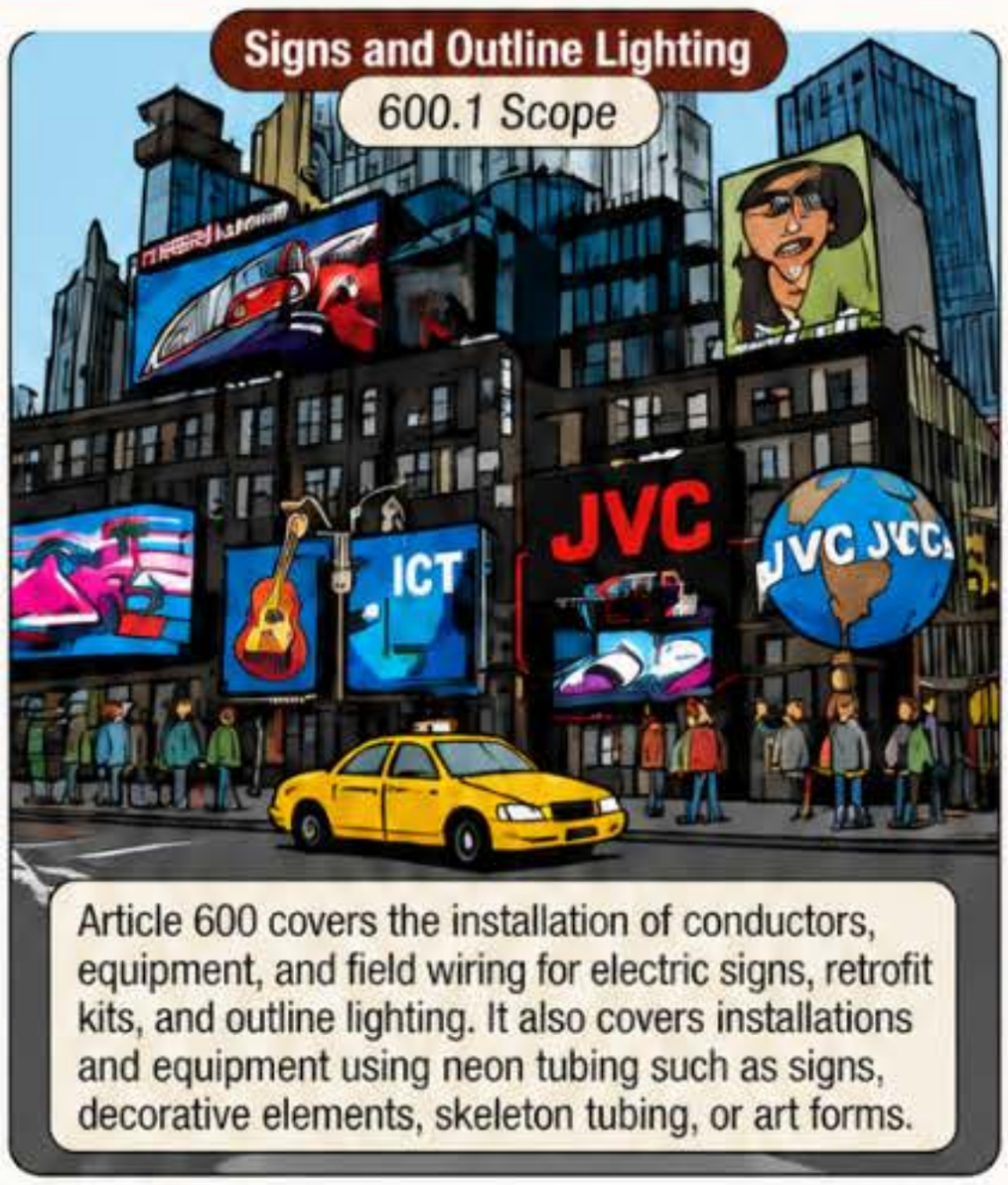
Article 600 addresses the installation of conductors, equipment, and field wiring for electric signs, retrofit kits, and outline lighting. It also includes requirements for their installations and related equipment using neon tubing for signs, decorative elements, skeleton tubing, or art forms.

Author's Commentary:

- Outline lighting features arrangements of incandescent or electric-discharge lamps used to outline buildings or to draw attention to specific details—such as the shape of a structure, its ornamentation, or a window.

— Michael Hamilton

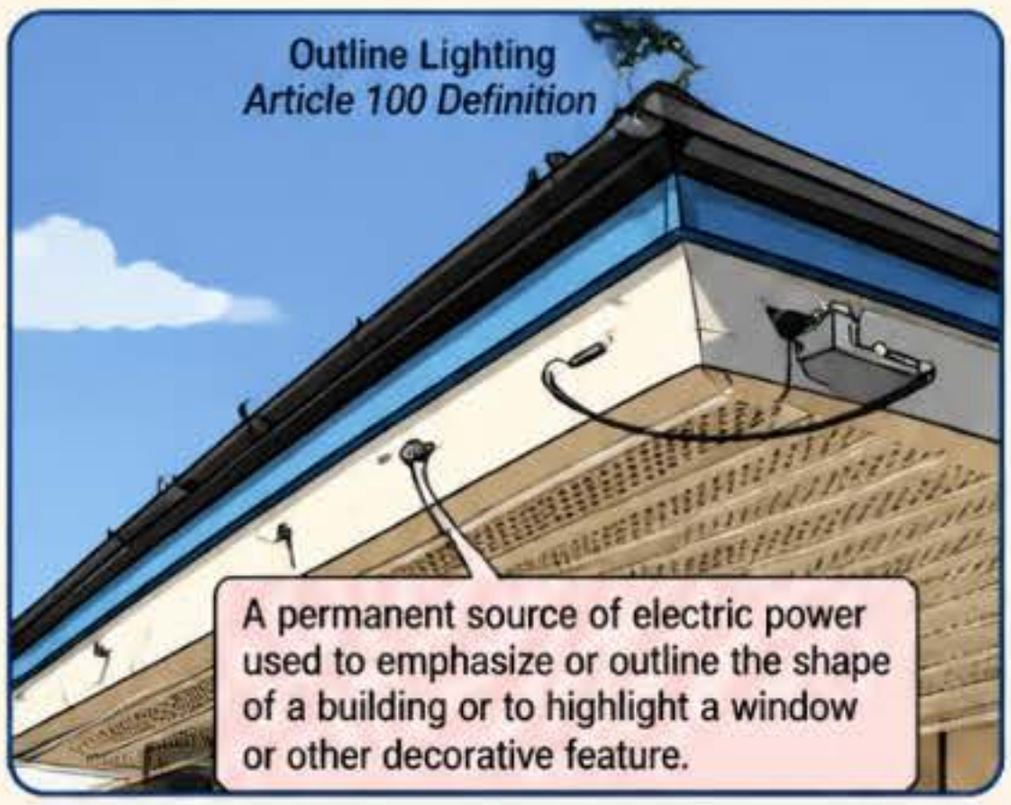
Note: Sign and outline lighting systems can use cold cathode neon tubing, high-intensity discharge lamps (HID), fluorescent or incandescent lamps, light-emitting diodes (LEDs), and electroluminescent as well as inductive lighting.



Article 600 covers the installation of conductors, equipment, and field wiring for electric signs, retrofit kits, and outline lighting. It also covers installations and equipment using neon tubing such as signs, decorative elements, skeleton tubing, or art forms.

▶ Figure 600–1

600.2 Electric Signs and Outline Lighting



▲ Figure 600-2

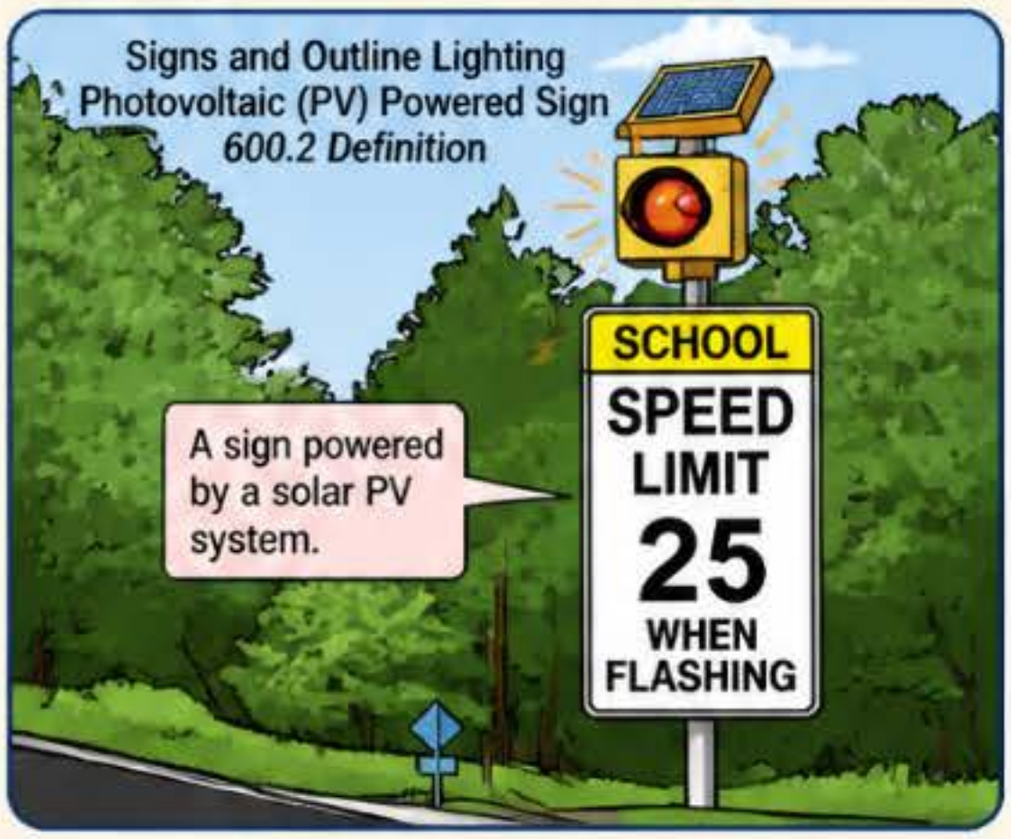
600.2 Definitions

The definitions in this section apply only to this article.

Neon Tubing. Glass tubing that emits light when an electric discharge passes through the enclosed gas. This category includes cold cathode neon and similar tubing used in illuminated signs, letters, skeleton tubing, outline lighting, and other decorative pieces. It can also describe tubing containing different inert gases.

Photovoltaic (PV) Powered Sign. A sign that operates using power generated by a solar PV system.

▼ Figure 600-3



▲ Figure 600-3

Host Sign. A sign or outline lighting system that is already in place at the site. It is used to convert the existing illumination system with a retrofit kit.

Retrofit Kit, General Use. This kit contains the main components required for converting a subassembly that was not originally part of the system. It also does not include a list of extra parts or installation instructions for finishing the subassembly in the field.

Retrofit Kit, Sign Specific. This kit supplies all the parts and mounting hardware necessary for field installation in a host sign. It is based on the included installation guide.

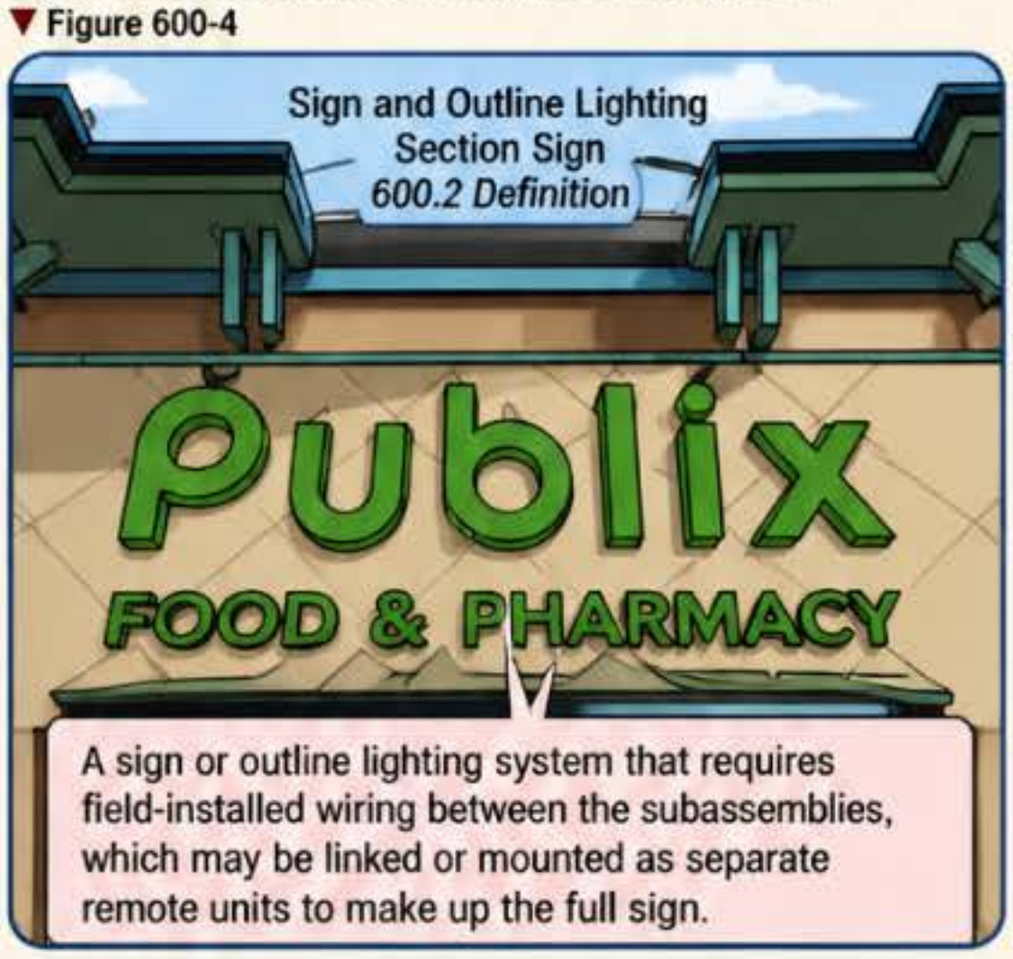
Author's Commentary:

- Because there are only two retrofit kit types, the general-use version is the one most often encountered in practice.

— ***Michael Hamilton***

Section Sign. A sign or outline lighting system that requires field-installed wiring between its subassemblies. These subassemblies may be joined or mounted as separate remote parts forming the entire system.

▼ Figure 600-4



▲ Figure 600-4

Skeleton Tubing. Neon tubing that serves as a sign or outline lighting system when it is not enclosed in a cabinet or sign body.

▼ Figure 600-5

Subassembly. A specific component or segment of a sign, retrofit kit, or outline lighting system. When assembled, these parts create a complete unit or finished product.

600.3 Listing

Fixed, mobile, or portable electric signs, section signs, outline lighting, PV powered signs, and retrofit kits must be listed and labeled. They also need to be installed in accordance with their instructions.

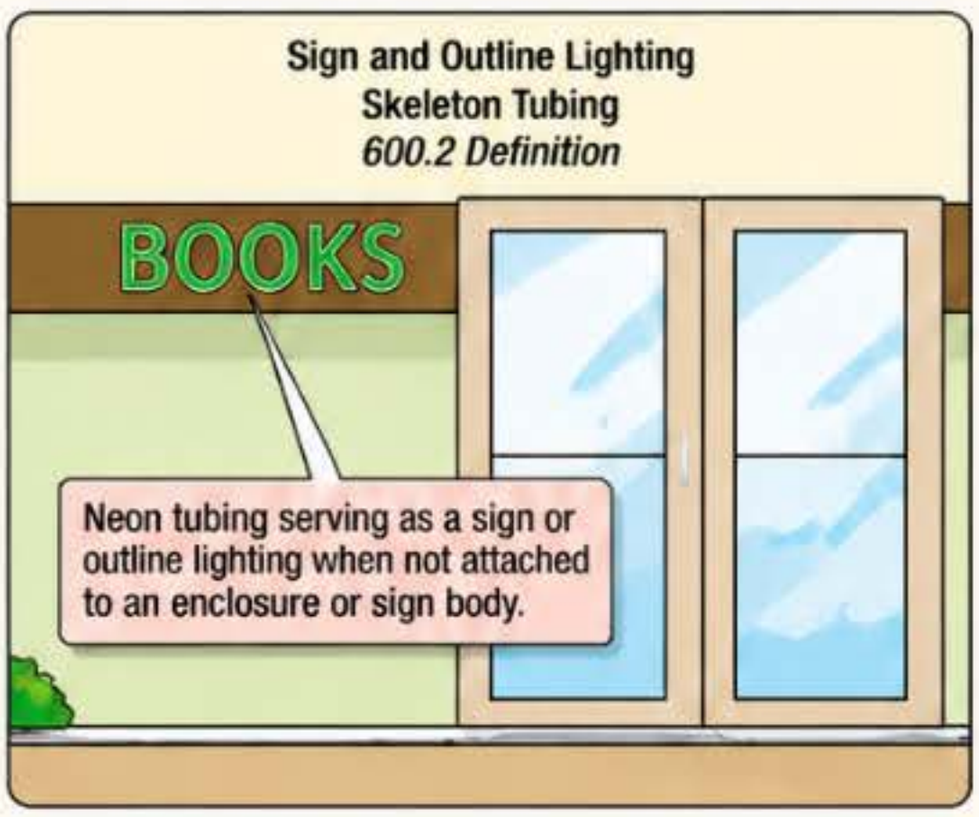


Figure 600–5

(A) Field-Installed Skeleton Tubing. Skeleton tubing for signs installed in the field is not considered to be listed.

(B) Outline Lighting. Field-installed outline lighting is not required to be listed when it consists of listed luminaires that are wired in accordance with Chapter 3.

600.4 Markings

(A) Signs and Outline Lighting Systems. Signs and outline lighting systems must carry labels or markings that show the manufacturer's name, trademark, voltage and current ratings, or other means of identification.

(B) Signs with a Retrofitted Illumination System. Signs that have been retrofitted with an illumination system must include the following:

(1) A clear marking indicating that the illumination system has been replaced.

(2) The marking must include the kit provider's and installer's name, logo, or a unique identifier.

(3) Signs that use tubular light-emitting diode (LED) lamps powered by existing sign sockets must have an additional warning label to alert service personnel that the sign has been modified and that fluorescent lamps are not to be used.

(D) Marking Visibility. Required labels in 600.4(A) and these additional labels must be visible after installation and remain attached in a conspicuous location for servicing. The marking is allowed to be installed in a place not generally visible to the public.

(E) Durability. Markings must be permanent, durable, and resistant to the weather when located in wet spaces.

600.5 Branch Circuits

(A) Required Branch Circuit. Every commercial building or occupancy area where pedestrians must walk must have at least one readily accessible outlet at the entrance of each tenant space, supplied by a dedicated branch circuit rated at least 20A. **Figure 600–6**

Figure 600–6

A sign or outline lighting outlet is not required at entrances for deliveries, service corridors, or service hallways that are intended to be used only by service personnel or employees. **Figure 600–7**

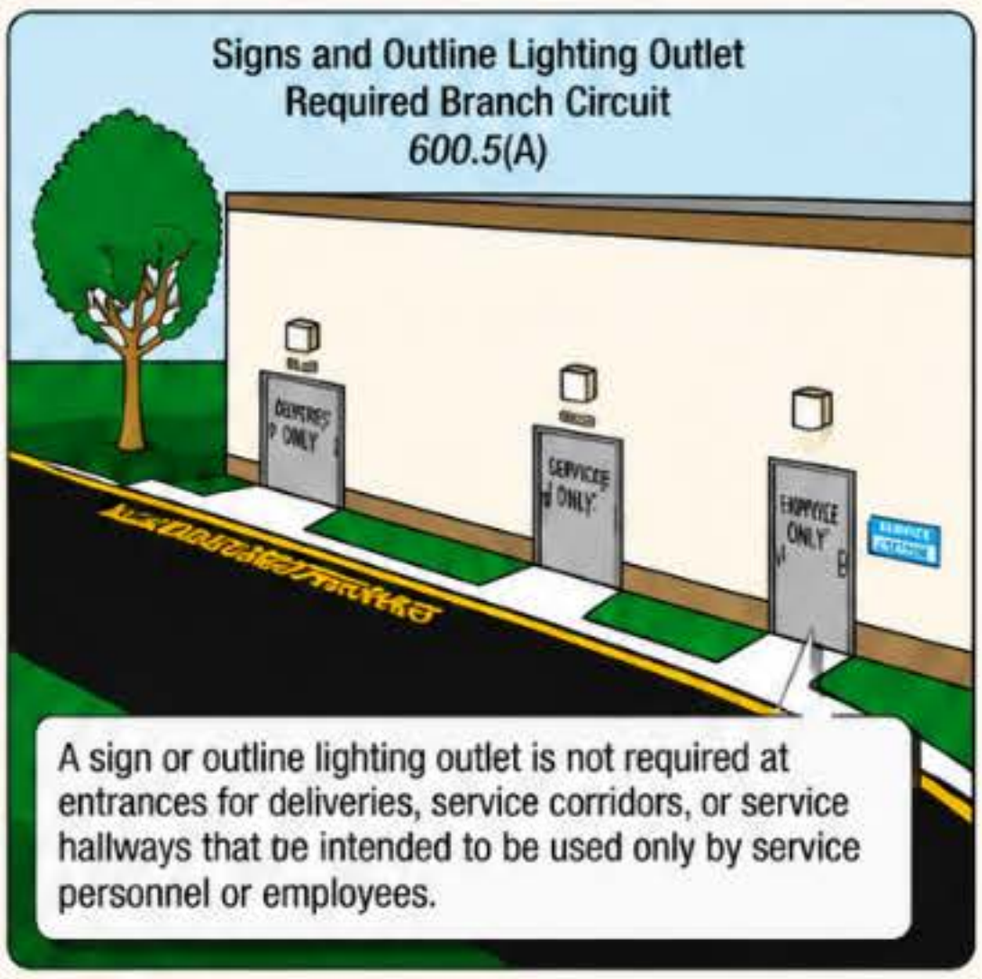


Figure 600–7

600.6 | Electric Signs and Outline Lighting

Author's Commentary:

- In short, this means every business location that can be reached by people needs at least one 20A branch circuit for its sign outlet. This rule applies whether a sign will actually be installed or not. If the circuit feeds a neon sign [600.5(C)(1)], then that circuit can be 30A.

— Michael Hamilton

(B) Marking. Every disconnecting means for a sign, outline lighting system, or controller must be clearly labeled so the purpose is immediately evident—i.e., "SIGN," "OUTLINE LIGHTING SYSTEM," or "CONTROLLER."

Example: *If a disconnect is mounted to the sign structure, the sign box, the sign pole, or the controller itself, it isn't necessary to put any additional identification on the sign, outline lighting system, or controller.*

(C) Rating. Branch circuits that feed signs are considered continuous loads. ▸ Figure 600–8

▸ Figure 600–8

(D) Wiring Methods. Wiring techniques used to supply signs and outline lighting systems must comply with 600.5(D)(1), (D)(2), and (D)(3).

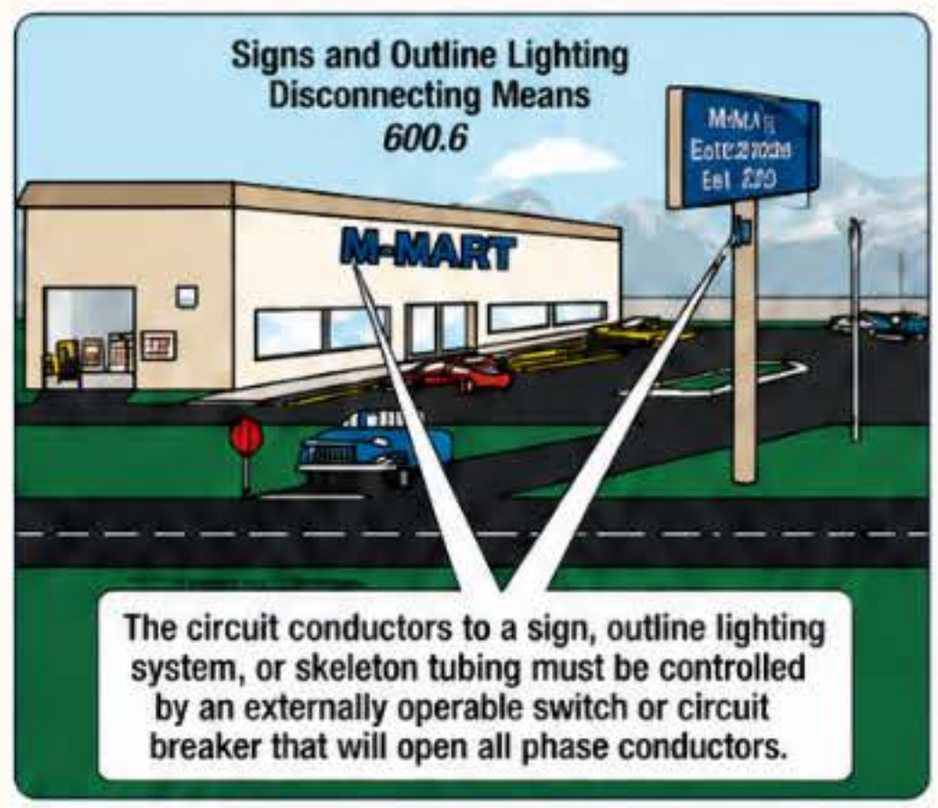
(1) Supply. The wiring method for these systems must end within a suitable outlet, junction box, conduit body, or panelboard.

(2) Enclosures as Pull Boxes. Transformer housings are allowed as pull or junction boxes for the conductors feeding other signs, outline lighting systems, or floodlights that are part of a sign, and may be used to contain both branch- and secondary-circuit conductors, provided the sign disconnecting means de-energizes all current-carrying conductors in those enclosures.

(3) Metal or Nonmetallic Poles. Poles used to support signs—whether metal or nonmetallic—may be used to enclose supply conductors, as long as the poles and conductors are installed in accordance with 410.30(B).

600.6 Disconnecting Means

The conductors serving a sign, outline lighting system, or skeletal tubing must be controlled by a remote-operable switch or circuit breaker that opens all ungrounded conductors. ▸ Figure



▸ Figure 600–9

Note: The disconnect's location is intended to allow service or maintenance personnel and first responders to complete and control the disconnection.

Author's Commentary:

- The sign disconnect may be positioned right beside the sign [404.8(A) Ex 2]. In many cases, the disconnect is an integral component of the sign or is mounted so it's easy to access and secure on the outside of the sign.

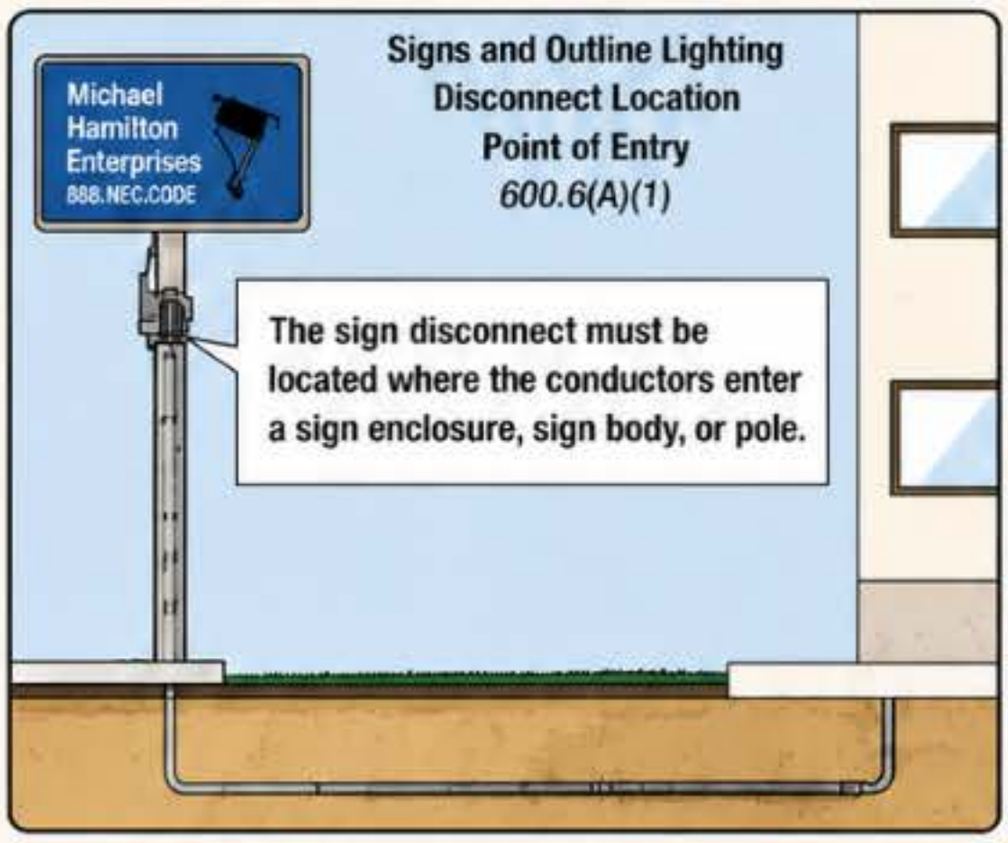
— Michael Hamilton

(A) Disconnect Location. The sign disconnect must be installed in one of the following locations:

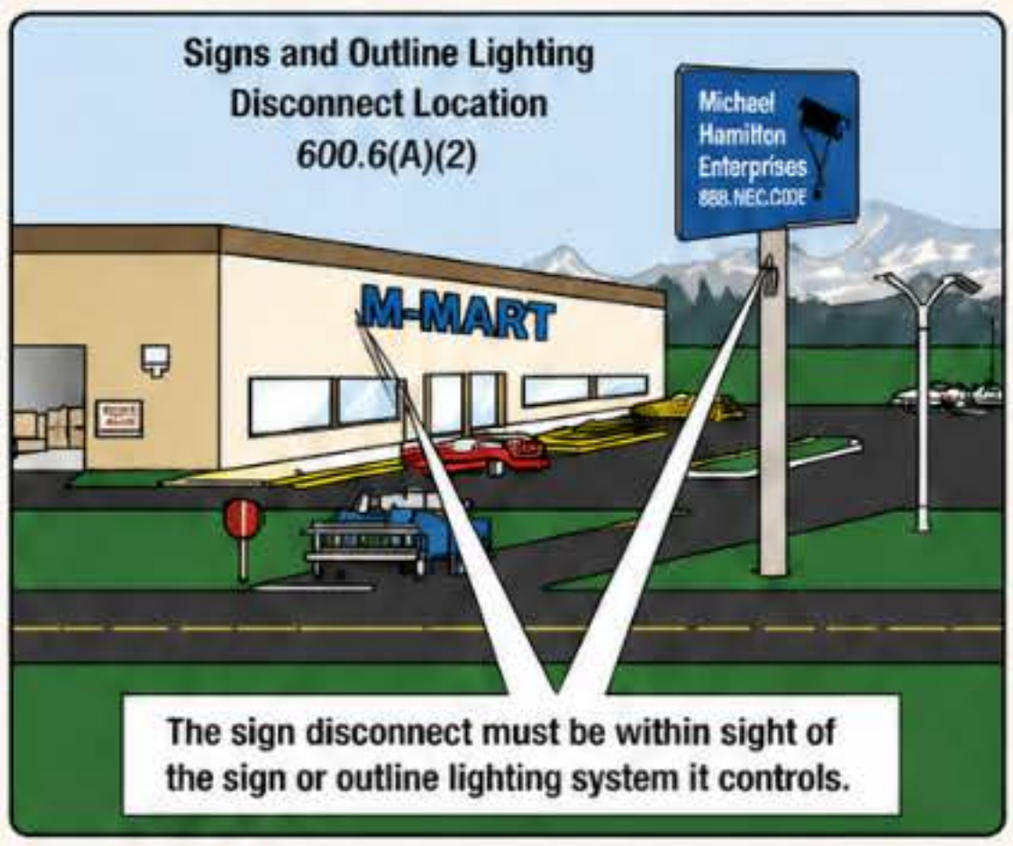
(1) At the Point of Entry to a Sign. The disconnect must be positioned where the conductors enter the sign enclosure, sign body, or pole. ▸ Figure 600–10

Ex 1: *It is not required to place a sign disconnect at the point where the conductors enter a sign enclosure or sign body for conductors that route through a sign where the sign enclosure is not readily accessible and is enclosed in a Chapter 3 raceway or metal-jacketed cable.*

Electric Signs and Outline Lighting 600.6



▸ Figure 600–10



▸ Figure 600–11

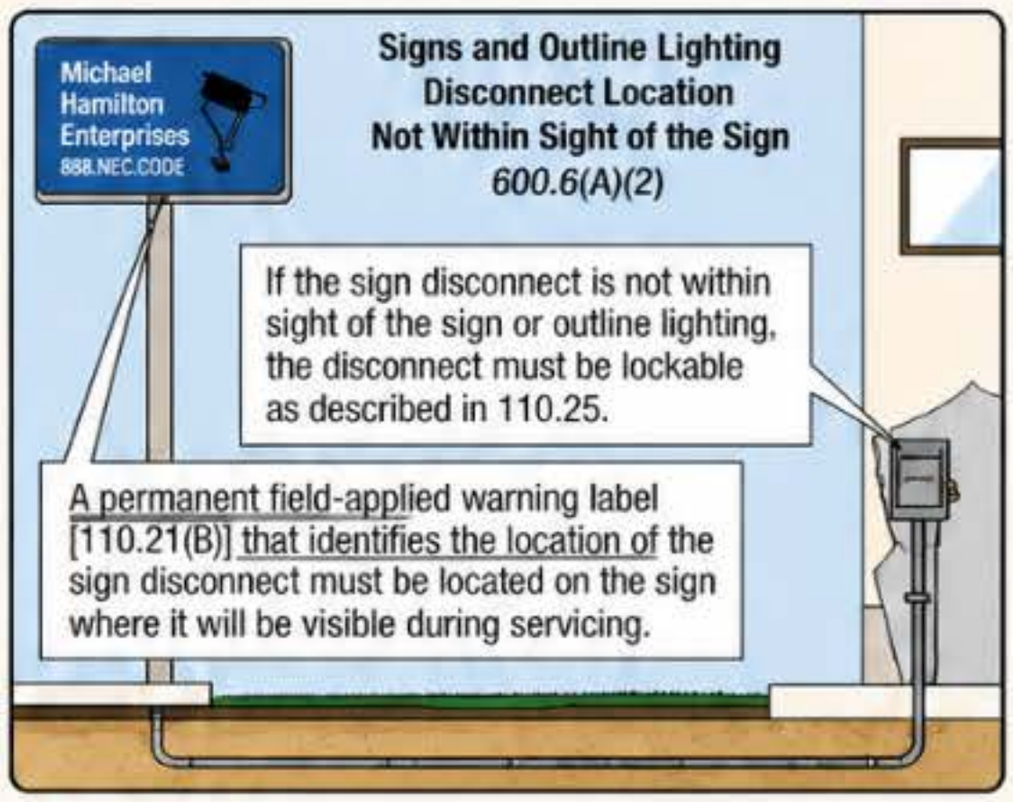
Ex 2: A sign disconnect is not required to be located at the point the conductors enter a sign enclosure or sign body for a feeder that supplies a panelboard located within the sign under the following conditions: The feeder conductors must be enclosed where not accessible in a Chapter 3 raceway or metal-jacketed cable, a permanent field-applied warning label having sufficient durability to withstand the environment involved, complying with 110.21(B), and visible during servicing is applied to the raceway or metal-clad cable at or near the point of the feeder circuit conductors' entry into the sign enclosure or sign body, and the warning label reads:

DANGER, THIS RACEWAY CONTAINS ENERGIZED CONDUCTORS

The warning label must identify the location of the sign disconnect and it must be capable of being locked in the open position with provisions for locking to remain in place whether the lock is installed or not [110.25].

(2) Within Sight of the Sign. The sign disconnect must be within sight of the sign or outline lighting system it controls. ▸ **Figure 600–11**

If the sign disconnect is not within sight of the sign or outline lighting, the disconnect must be capable of being locked in the open position with provisions for locking to remain in place whether the lock is installed or not [110.25]. A permanent field-applied warning label, having sufficient durability to withstand the environment involved and complying with 110.21(B) that identifies the location of the sign disconnect, must be located on the sign where it will be visible during servicing. ▸ **Figure 600–12**



▸ Figure 600–12

Author's Commentary:

"Within Sight" means the disconnect is visible and no more than 50 ft from the equipment's location.

— Michael Hamilton

(3) Controller Disconnect as Sign Disconnect. Signs or outline lighting systems operated by controllers located external to the sign or outline lighting system must have a disconnect for the sign controller in accordance with the following:

(1) The controller disconnect must be located within sight of or within the controller enclosure.

(2) The controller disconnect must disconnect the sign or outline lighting and the controller from all phase conductors. ▸ **Figure 600–13**

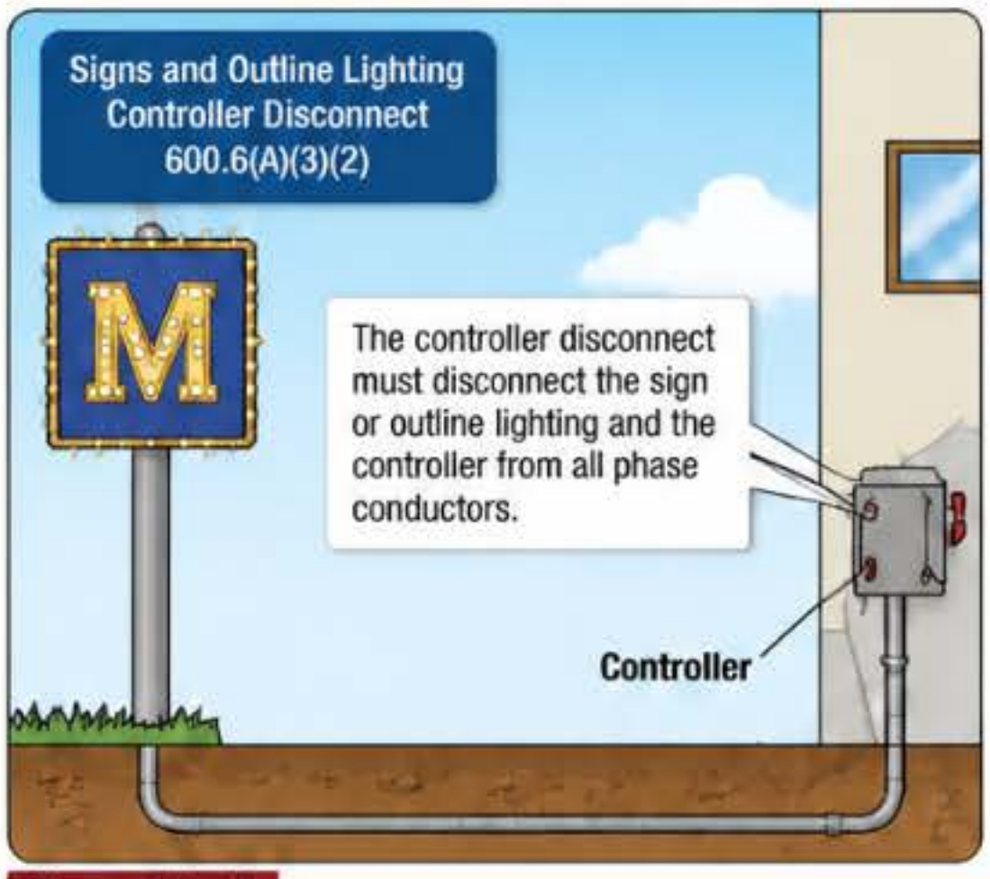


Figure 600–13

(3) The controller disconnect must be capable of being locked in the open position with provisions intended to keep it from being moved back to the closed position, whether locked or not [110.25].

__Example:__ When the disconnect for the controller is out of the operator's line of sight, a permanent field-applied warning label must be affixed that explains that the location must provide enough odurability to withstand the environment involved and must meet 110.21(B). These elements define where the disconnect must be observable by maintenance personnel.

(4) Remote Location. If the disconnecting means is situated far from the sign, sign structure, or pole, it must be mounted in an accessible location for irst responders and service staff. ▶ **Figure 600–14**

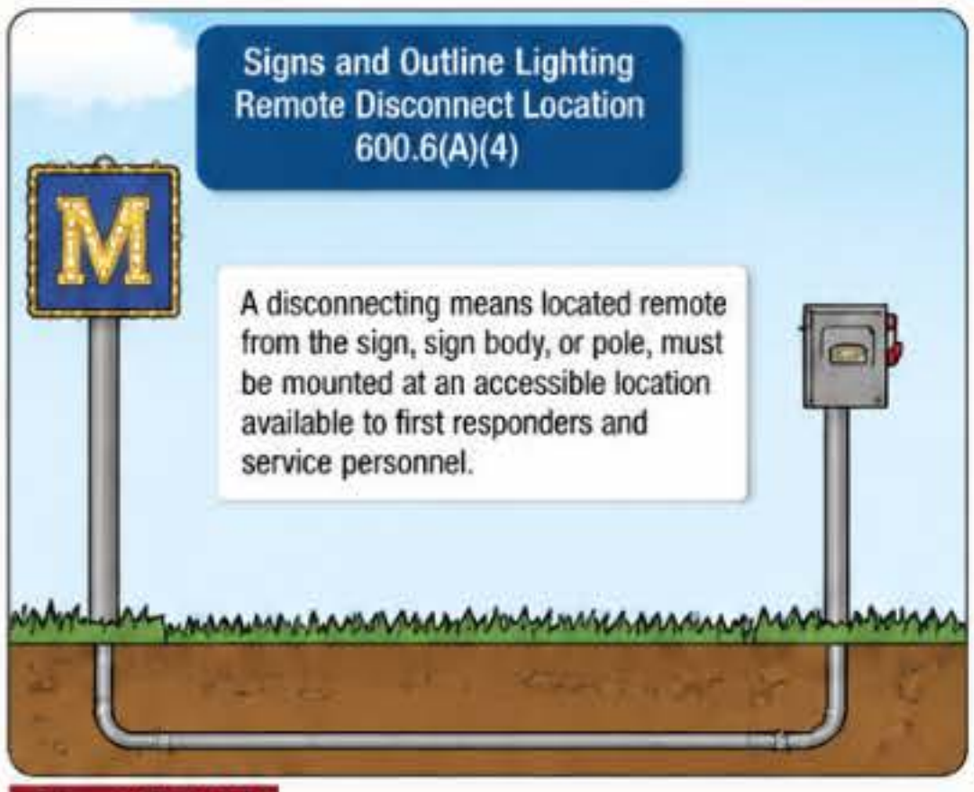


Figure 600–14

The location of the disconnect must be identified with a permanent label at the sign or outline lighting equipment and designated as the disconnect for that sign or outline system. The label must be durable, readily visible, resistant to field use, suitable for the environment involved, and comply with 110.21(B).

600. 600.7 Grounding and Bonding

(A) Equipment Grounding Conductor and Grounding.

(1) Equipment Grounding Conductor. Metal equipment of signs, outline lighting systems, and metal tubing frameworks must connect to the circuit equipment grounding conductor of a kind listed in 250.118.

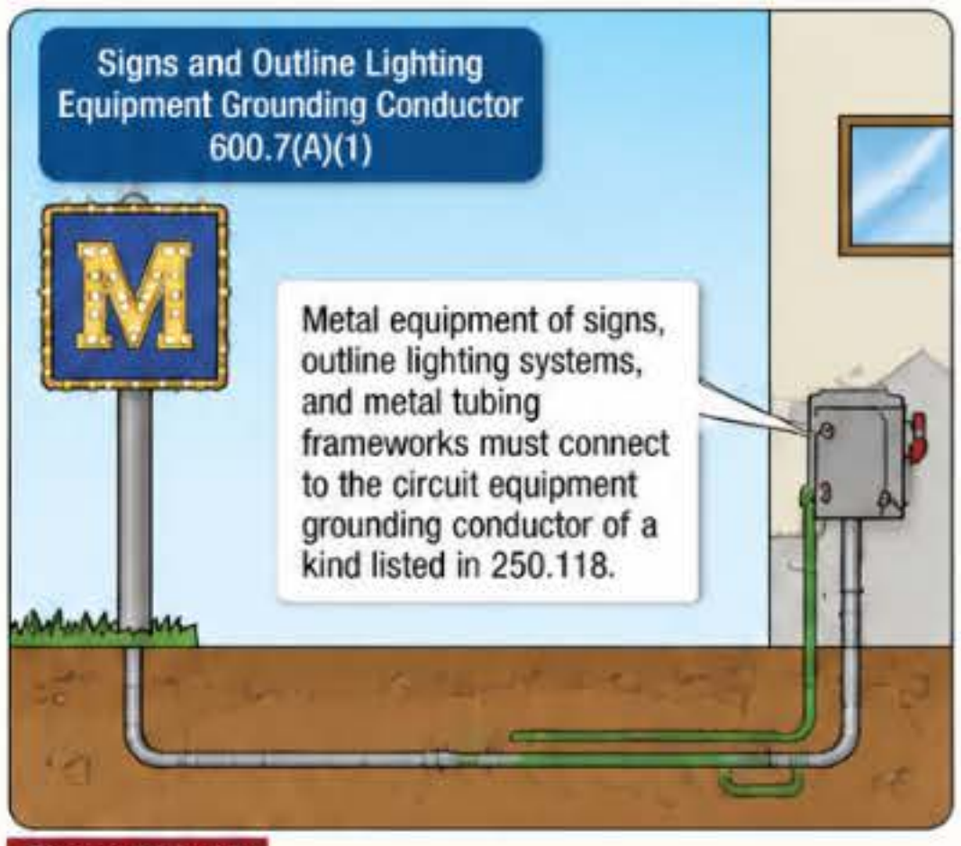


Figure 600–15

(2) Size of Equipment Grounding Conductor. If the equipment grounding conductor is a wire type, it must be sized in accordance with 250.122.

(3) Connections. Equipment grounding conductor connections must be made in accordance with a method specified in 250.130 or a method described in 250.8.

Author's Commentary:

According to 250.8, equipment grounding conductors of the wire type must be connected using one of these methods:

(1) Pressure connectors
(2) Terminal bars
(3) Pressure connectors designated for grounding or bonding
(4) Exothermic welding

— *Michael Hamilton*

ELECTRIC SIGNS AND OUTLINE LIGHTING 600.7

(5) Machine screws that engage at least two threads or are secured with a nut

(6) Self-tapping machine screws that engage at least two threads

(7) Connections that are part of a listed assembly

(8) Other listed means

(4) Auxiliary Grounding Electrode. Auxiliary grounding electrodes are not required for signs and outline lighting, but if installed, they must comply with 250.54. **Figure 600–16**

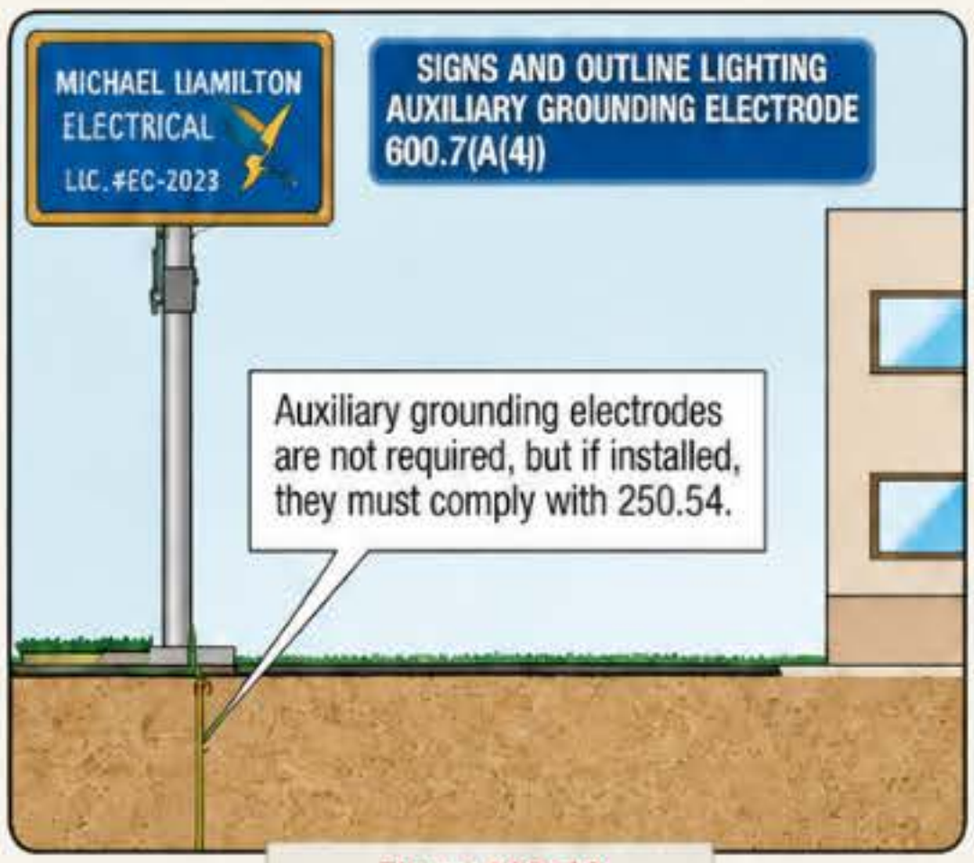


Figure 600–16

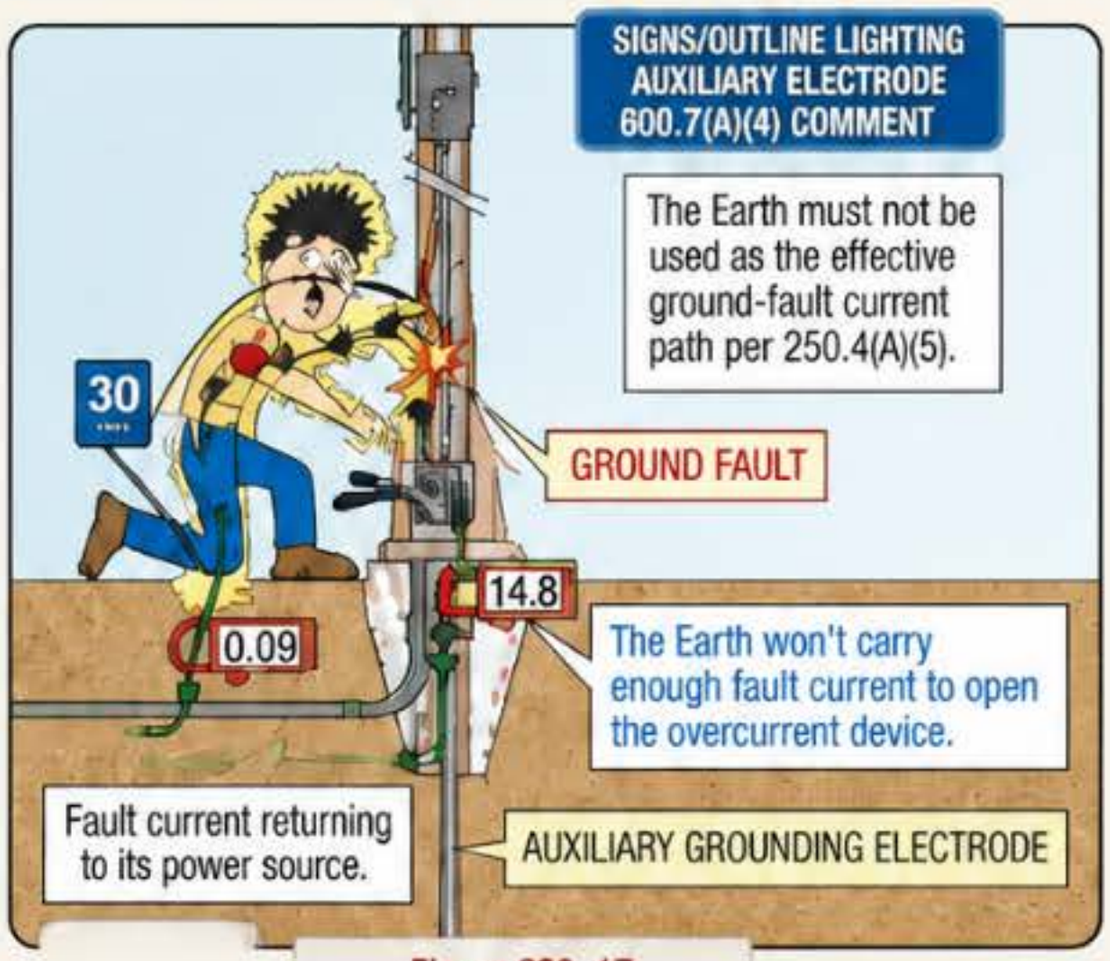


Figure 600–17

(B) Bonding.

(1) Metal Parts. Metal parts of signs and outline lighting systems must be bonded to the transformer or power-supply equipment grounding conductor.

Example: *The metal parts of a section sign or outline lighting system supplied from a remote Class 2 power supply are not required to be connected to an equipment grounding conductor.*

(2) Bonding Connections. Bonding connections must be made **in accordance with 250.8.**

Author's Commentary:

- According to 250.54, auxiliary electrodes need not be bonded to the building grounding electrode system, the grounding conductor to the electrode need not be sized in accordance with 250.66, and the contact resistance of the electrode to the Earth is not required to comply with the 25-ohm requirement of 250.53(A)(2) Ex.
- The Earth must not be used as the effective ground-fault current path required by 250.4(A)(4) and 250.4(A)(5). This is because the contact resistance of a grounding electrode to the Earth is high, and very little ground-fault current returns to the electrical supply source via the Earth. The result is the circuit overcurrent protective device will not open and clear a ground fault; therefore, metal parts will remain energized with dangerous step and touch voltage.

— Michael Hamiiton

Author's Commentary:

- According to 250.8, bonding conductors must terminate in any of the following methods:

(1) Listed pressure connectors

(2) Terminal bars

(3) Pressure connectors listed for grounding and bonding

(4) Exothermic welding

(5) Machine screws that engage at least two threads or are secured with a nut

(6) Self-tapping machine screws that engage at least two threads

(7) Connections that are part of a listed assembly

(8) Other listed means

— Michael Hamilton

600.9 | Electric Signs and Outline Lighting

(4) Flexible Metal Conduit Length. The length of flexible metal conduit or any listed liquidtight flexible metal conduit used for secondary circuit conductors from raceway to neon tubing may be used as the bonding means only if the total length of conduit does not exceed 100 feet.

(7) Bonding conductors.

(1) Bonding conductors must be copper and have a size no smaller than 14 AWG.

(2) Bonding conductors installed outside of a sign or raceway must be shielded from physical damage.

600.9 Location

(A) Vehicles. Sign and outline lighting equipment must be at least 14 ft above the areas where vehicles can reach it, unless physical damage is otherwise prevented. See **Figure 600–18.**

Sign and outline lighting equipment must be at least 14 ft above areas accessible to vehicles unless protected from physical damage.

Figure 600–18

(B) Pedestrians. Neon tubing for signs, decorative elements, skeleton tubing, or artwork must be positioned where people cannot easily come into contact with it.

(C) Adjacent to Combustible Materials. Sign and outline lighting systems must be installed so that nearby combustible materials are not exposed to temperatures higher than 194°F (90°C).

(D) Wet Location. Sign and outline lighting systems in damp or wet areas must be suitable for those conditions and must include drain openings.

600.21 Ballasts, Transformers, Class 2 Power Sources, and Electronic Power Supplies

Ballasts, transformers, electronic power supplies, and Class 2 power sources must be self-contained or enclosed in a listed sign body or in a separate listed enclosure.

(A) Accessibility. Equipment such as ballasts, transformers, Class 2 power sources, and electronic power supplies must be securely fastened.

(B) Location. Keep the secondary conductors from ballasts, transformers, Class 2 power sources, and electronic power supplies as short as possible.

(C) Working Space. Provide a clear working area with a minimum height of 3 ft, width of 3 ft, and depth of 3 ft in front of each ballast, transformer, Class 2 power source, and electronic power supply that is not installed in a sign.

(D) Attic Locations. Ballasts, transformers, Class 2 power sources, and electronic power supplies may be installed in attics and soffits when access doors (at least 22.5 in. by 22.5 in.) are provided and a walkway at least 3 ft wide by 2 ft long with a permanent surface extends at least 1 ft beyond the front of each unit.

At least one lighting outlet controlled by a switch or breaker must be installed at the usual point of entry to these areas. The outlet must be located at or near the equipment that requires service.

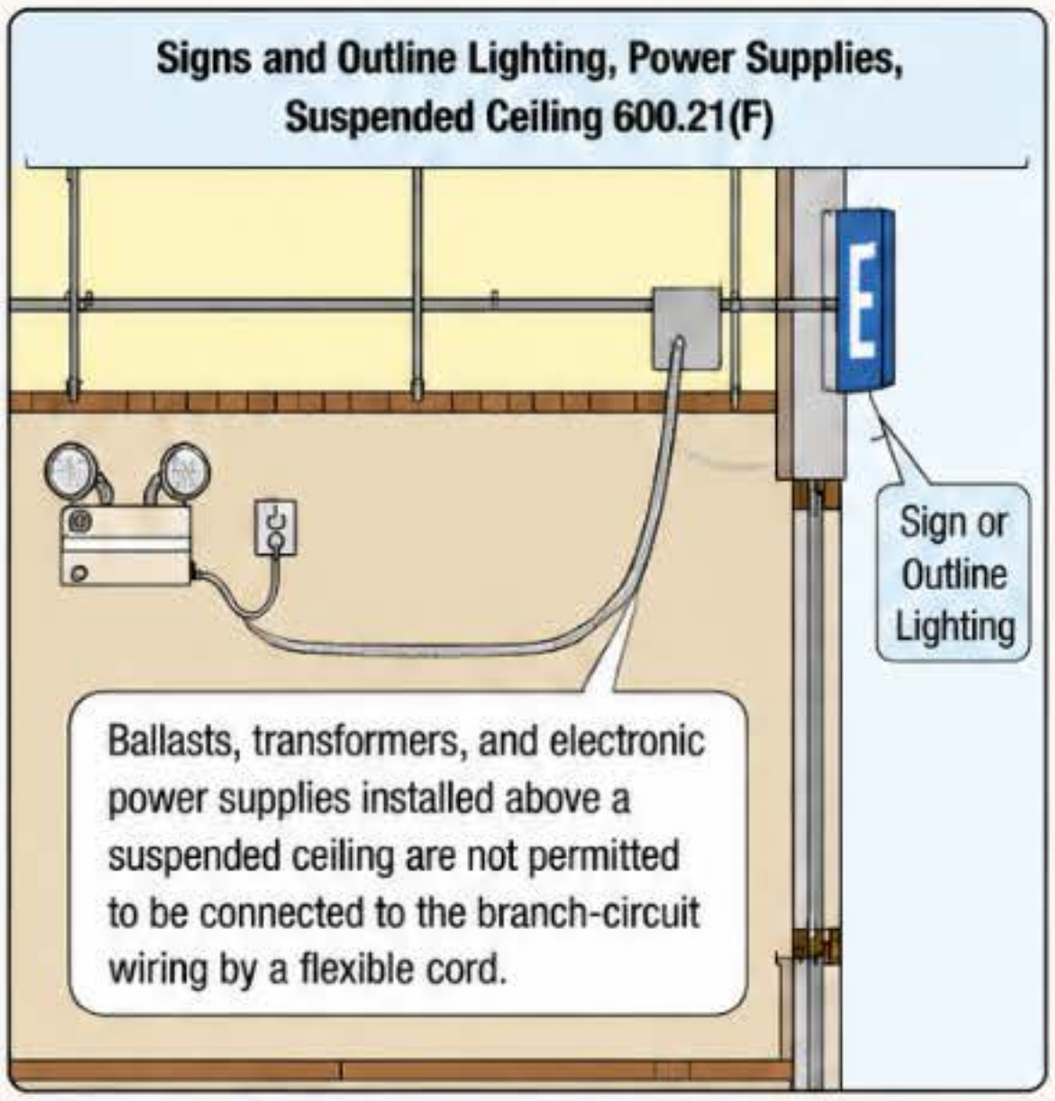
(E) Suspended Ceilings. These devices may be placed above suspended ceilings, provided the enclosures are firmly secured and are not attached to the suspended-ceiling framework.

600.24 Class 2 Power Sources

(A) Listing. Use listed Class 2 power supplies and sources for electrical signs and outline lighting systems or as a component within a listed sign.

(B) Grounding. All metal parts of Class 2 power sources must be connected to the circuit equipment grounding conductor that supplies the power.

Electric Signs and Outline Lighting | 600.35



▶ Figure 600–19

Part II. Field-Installed Skeleton Tubing, Outline Lightning, and Secondary Wiring

600.34 Photovoltaic (PV) Powered Sign

Field wiring of PV installations must follow Article 690, and installation instructions. In addition, the following apply:

(A) Equipment. PV components intended for use in PV powered sign systems must be certified for PV use.

(B) Wiring. All wiring that runs outside the PV sign housing must:

(1) Be identified, marked, and listed for photovoltatic service.

(2) Be installed adjacent to the sign body or enclosure.

(3) Be secured as needed and at intervals not greater than 3 ft.

(4) Be protected from physical damage.

(C) Flexible Cords. Flexible cords must comply with Article 400, be identified as extra-hard usage, rated for outdoor use, and be water and sunlight resistant.

(D) Grounding. PV signs must be grounded in accordance with Article 690, Part V and 600.7.

(E) Disconnecting Means. The PV system disconnect must comply with Article 690, Part III and 600.6.

600.35 Retrofit Kits

(A) General. A general-use or sign-specific retrofit kit for a sign or outline lighting system must include installation instructions and requirements for field conversion of a host sign. The retrofit kit must be listed and labeled.

(B) Installation. The retrofit kit must be installed in accordance with the installation instructions.

(1) Wiring Methods. Wiring methods must be in accordance with Chapter 3.

Ex: If powered from a Class 2 source, wiring methods must be in accordance with 600.12(C)(1)(2) and (C)(2), 600.24, and 600.33.

(2) Damaged Parts. All parts not replaced by a retrofit kit must be inspected for damage. Any part found to be damaged or that becomes damaged during conversion must be replaced or repaired to maintain the sign or outline lighting system's dry, damp, or wet location rating.

(3) Workmanship. Field conversion workmanship must be in accordance with 110.12.

(4) Marking. The retrofitted sign must be marked in accordance with 600.4(B).

Notes

ARTICLE 604 MANUFACTURED WIRING SYSTEMS

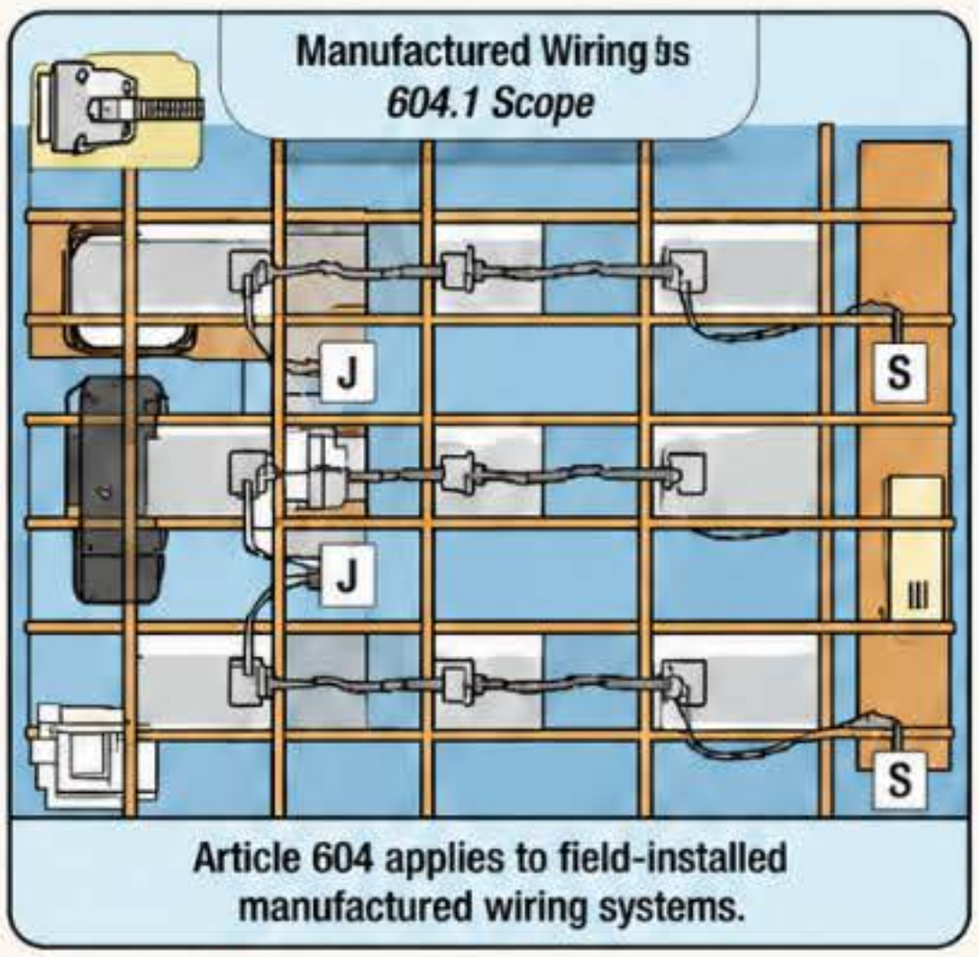
Introduction to Article 604—Manufactured Wiring Systems

Article 604 applies to field-installed manufactured wiring systems. These come with manufacturer's instructions, so *Code* compliance is almost automatic if you follow them.

The specific requirements contained in this article are not difficult to understand, but you should be familiar with them before installing manufactured wiring systems or wired partitions.

604.1 Scope

Article 604 applies to field-installed manufactured wiring systems. ▶▶Figure 604–1



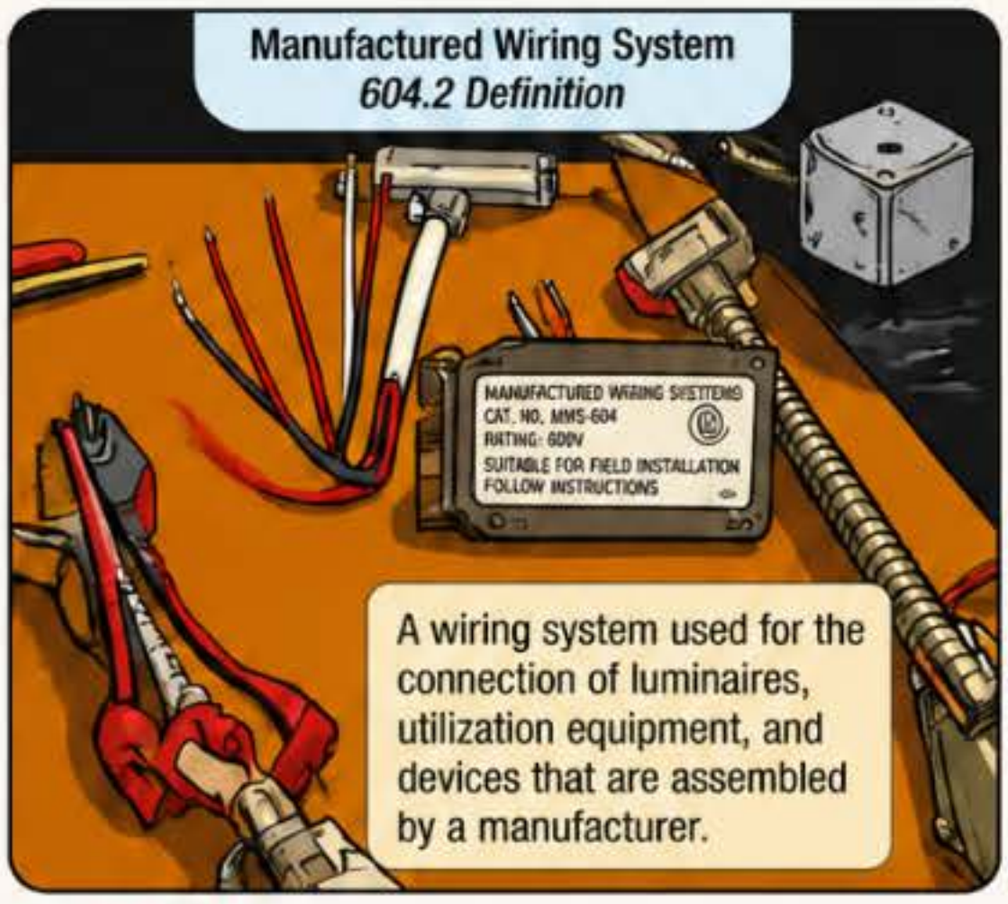
Article 604 applies to field-installed manufactured wiring systems.

▶ Figure 604–1

604.2 Definition

Manufactured Wiring System. A system used for the connection of luminaires, utilization equipment, and devices that are assembled by a manufacturer with components which cannot be inspected at the building site without damage to, or destruction of, the components.

▶ Figure 604–2



▶ Figure 604–2

Author's Commentary:

Manufactured wiring systems are typically used in commercial and institutional buildings because their ability to be readily installed and relocated meets changing needs.

— Michael Hamilton

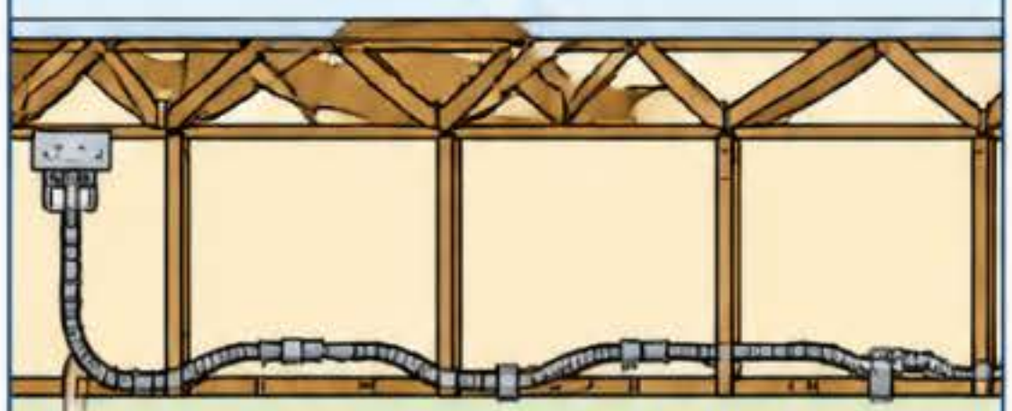
604.6 Listing Requirements

Manufactured wiring systems and associated components must be listed.

604.7 Installation—Securing and Supporting

Type AC and Type MC cable used for manufactured wiring systems must be secured and supported in accordance with the requirements of Article 320 for Type AC cable and Article 330 for Type MC cable. ▸Figure 604-3

Manufactured Wiring Systems Securing and Supporting 604.7



If AC cable, secure at intervals not exceeding 4½ ft [320.30].
If MC cable, secure at intervals not exceeding 6 ft [330.30].

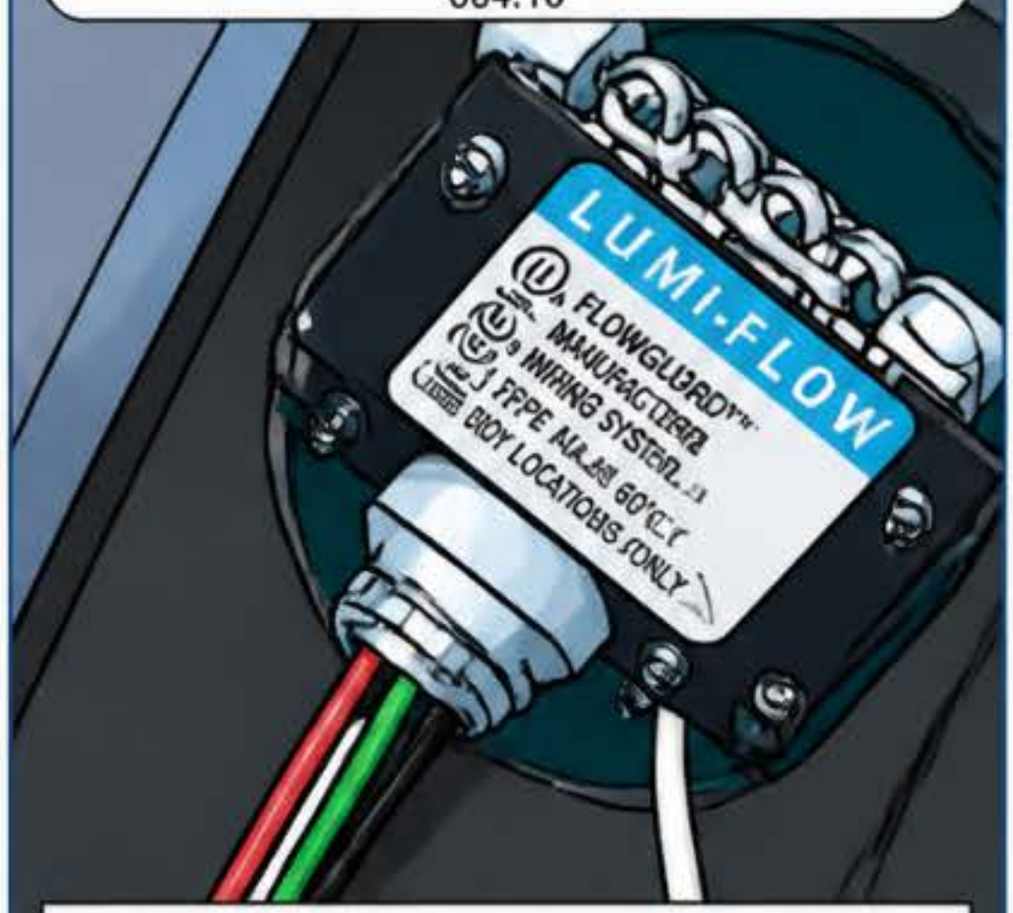
Type AC and Type MC cable used for manufactured wiring systems must be secured and supported according to the requirements of Article 320 for Type AC cable and Article 330 for Type MC cable.

▸Figure 604-3

604.10 Uses Permitted

Manufactured wiring systems can be installed in accessible and dry locations, and in plenum spaces in accordance with 300.22(C). ▸Figure 604-4

Manufactured Wiring Systems, Uses Permitted 604.10



Manufactured wiring systems can be installed in accessible and dry locations, and in plenum spaces per 300.22(C).

▸Figure 604-4

Author's Commentary:

- Type AC cable must be fastened at intervals not exceeding 4½ ft [320.30], and Type MC cable must be fastened at intervals not exceeding 6 ft [330.30].

— Michael Hamilton

ARTICLE 620 ELEVATORS, ESCALATORS, AND MOVING WALKS

Introduction to Article 620—Elevators, Escalators, and Moving Walks

Elevator and escalator equipment covered by Article 620 transports people. Because it relies on live electrical power, the NEC requires many things to keep individuals safe. Article 620 in the 2023 NEC is organized into 10 major parts:

- **Part I. General.** Presents the article's scope, definitions, and voltage limitation.
- **Part II. Conductors.** Provides the single-line diagram in Figure 620.13 and lists how Part II requirements relate to the NEC.
- **Part III. Wiring.** Covers wiring installation methods and branch-circuit requirements for different equipment.
- **Part IV. Installation of Conductors.** Details how Part IV addresses conductor supports and related matters.
- **Part V. Traveling Cables.** Has rules for installing, suspending, locating, and protecting moving cables used on elevators or lifts.
- **Part VI. Disconnecting Means and Control.** Lists disconnecting means and control requirements, which vary based on the application.
- **Part VII. Overcurrent Protection.** Most guidance here refers to Article 430, but additional needs such as selective coordination are also included.
- **Part VIII. Machine and Control Rooms and Spaces.** Aims to prevent unauthorized access to these areas.
- **Part IX. Equipment Grounding Conductor.** While most of this part cross-references Article 250, extra requirements apply. Examples include 15A and 20A, 125V receptacles in certain locations that must have GFCI protection.
- **Part X. Emergency and Standby Systems.** This part covers sources of emergency or standby power and the disconnecting means required to separate an elevator from normal and emergency/standby systems.

Part I. General

620.1 Scope

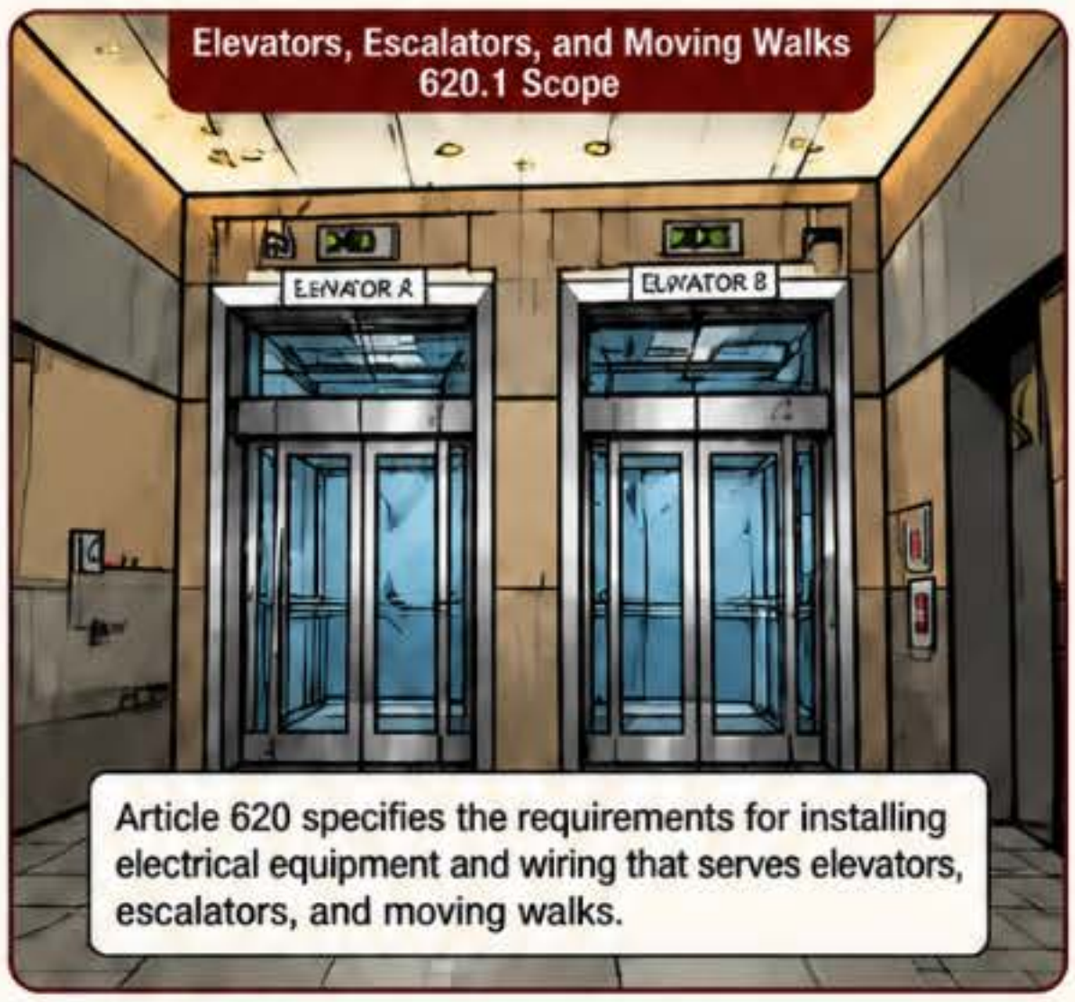
Article 620 specifies the requirements for installing electrical equipment and wiring that serves elevators, escalators, and moving walks.

▶ **Figure 620-1** and ▶ **Figure 620-2**

620.6 GFCI-Protected Receptacles

Receptacles rated 15A and 20A, 125V found in pits, hoistways, car tops of elevators, and in escalator and moving walk wellways must be of the GFCI type.

▶ **Figure 620-3**



▶ **Figure 620-1**

620.13 | Elevators, Escalators, and Moving Walks

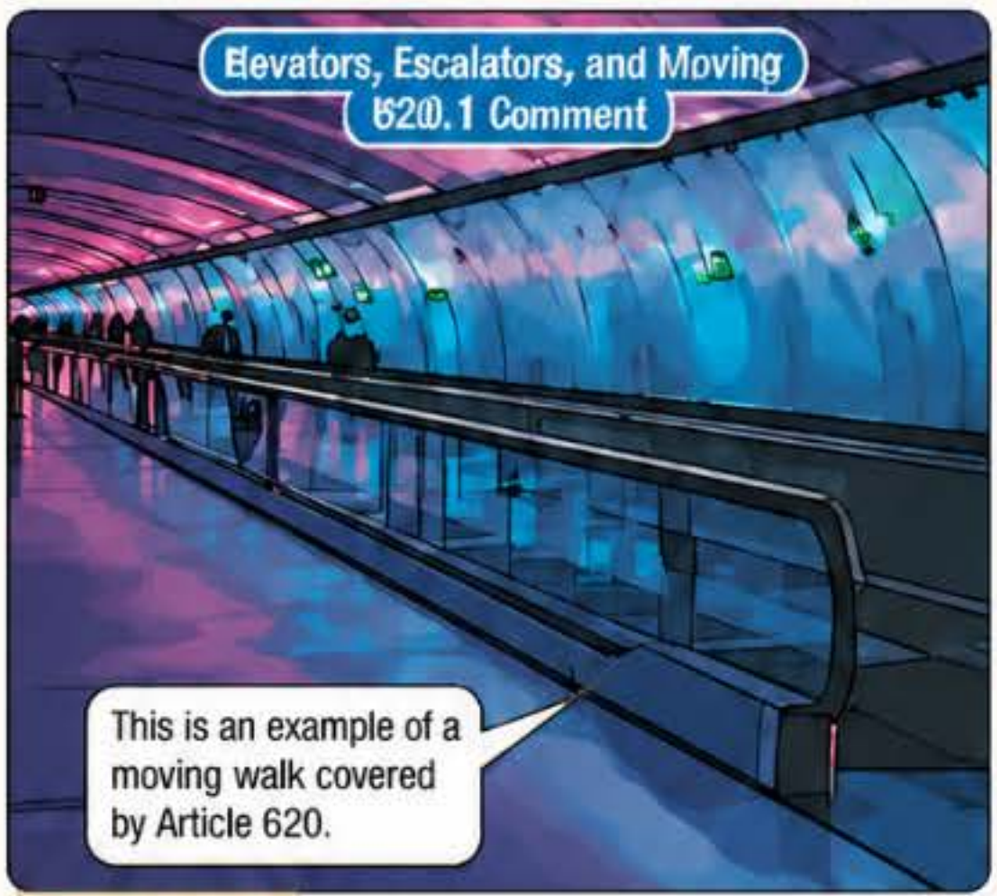


Figure 620–2

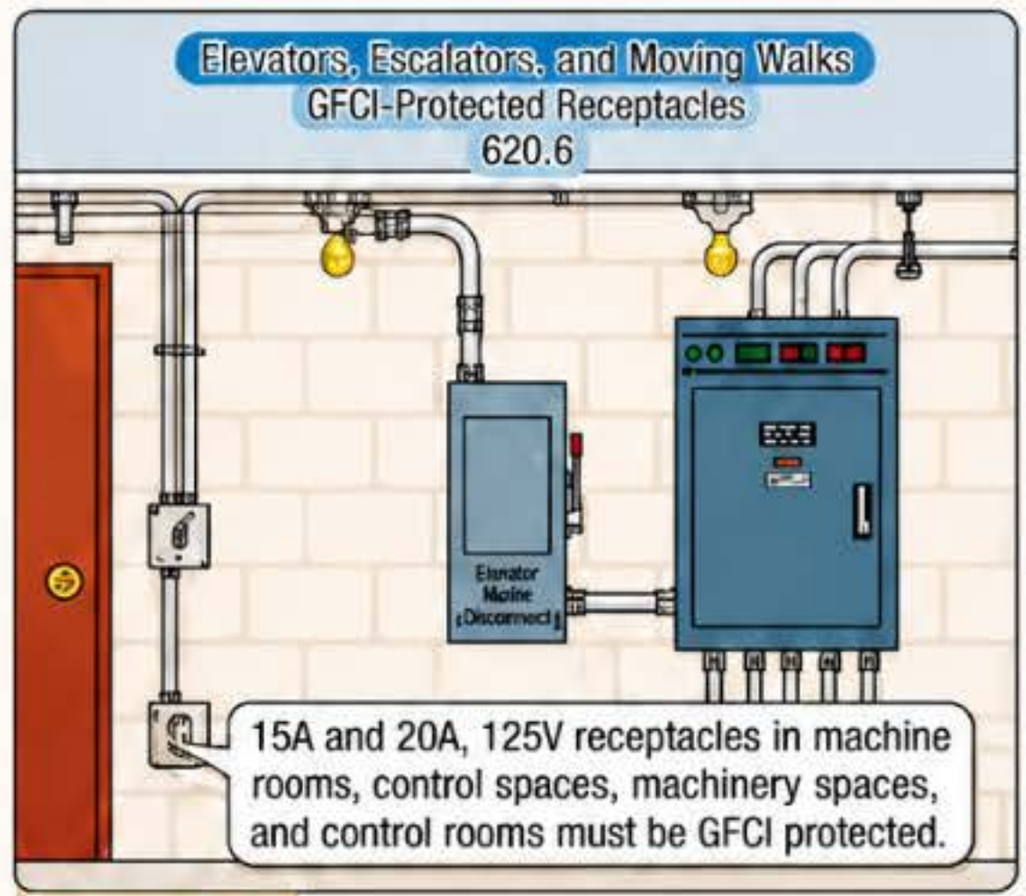


Figure 620–4

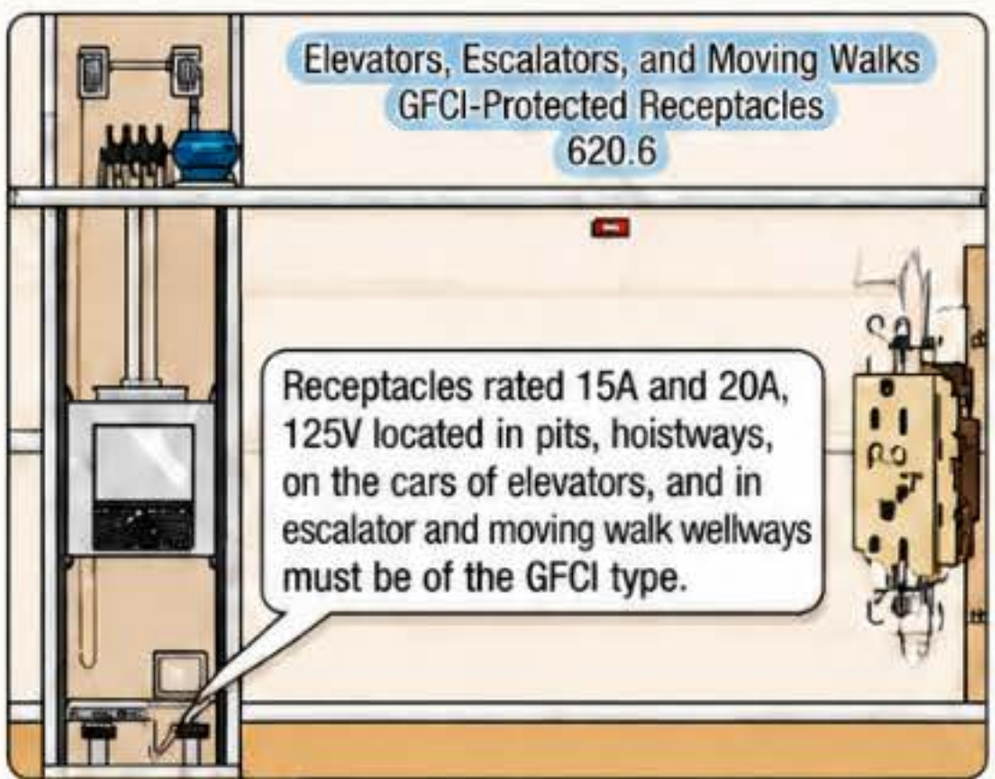


Figure 620–3

Receptacles rated 15A and 20A, 125V installed in machine rooms, control spaces, machinery spaces, and control rooms must be GFCI protected. Figure 620–4

A permanently installed sump pump must be hard wired or be supplied by a single receptacle that is GFCI protected.

Part II. Conductors

620.13 Feeder and Branch-Circuit Conductors

(A) Conductor Supplying Single Motor. The ampacity of the branch circuit must not be less than the motor nameplate and 430.22(E).

(D) Conductor Supplying Multiple Motors. The ampacity of the feeder must not be less than the motor nameplate, 430.22(E), 430.24, and demanded by 620.14.

620.16 Short-Circuit Current Rating

(A) Marking. Elevator control panels must be marked with a short-circuit rating to be able to withstand the available fault current at the line terminals [110.10].

Part III. Wiring

620.22 Branch Circuits for Elevator Car(s)

(A) Car Light, Receptacles, Auxiliary Lighting, and Ventilation. A separate branch circuit must supply the car lights. The car branch circuit is permitted to supply receptacles, accessory tquipment (alarm devices, alarm bells, and monitoring devices not part of the control system), axxiliary lighting power source, and ventilation on each elevator car or inside the operation controller.

Where there is no machine room, control room, machinery space, or control space outside the hoistway, the overcurrent device must be located outside the hoistway and accessible to qualified persons only.

(B) Air-Conditioning and Heating Source. Air-conditioning and heating units must be supplied by a separate branch circuit for each car.

Elevators, Escalators, and Moving Walks | 620.24

Author's Commentary:

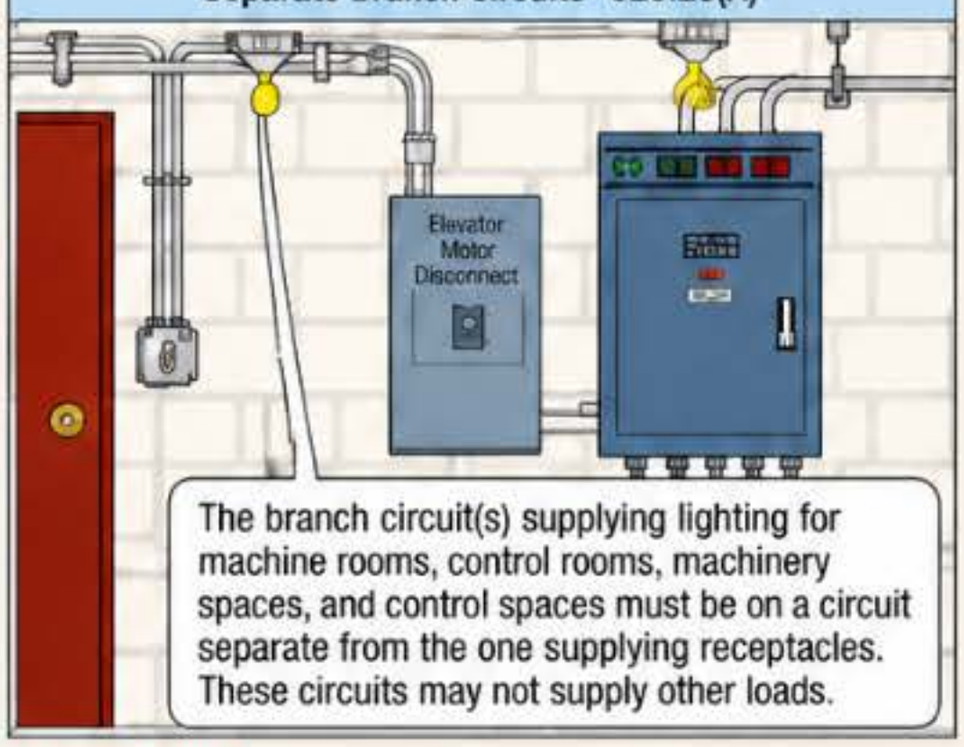
Each elevator car that is equipped with either air-conditioning or heating must be supplied by a dedicated circuit. Where more than one elevator car has lights, a branch circuit for those lights is allowed to serve several cars. Branch-circuit overcurrent protective devices for elevator cars have to be located in the elevator machine room.

— Michael Hamilton

620.23 Branch Circuits for Machine Room/Machinery Space

(A) Separate Branch Circuits. Provide distinct branch circuit(s) to supply lighting for machine rooms, control rooms, machinery spaces, and control spaces. These circuits must be fed from separate receptacles. They must not supply any other loads. ▸ Figure 620-5

Elevators, Escalators, and Moving Walks Machine Room/Machinery Space, Separate Branch Circuits 620.23(A)



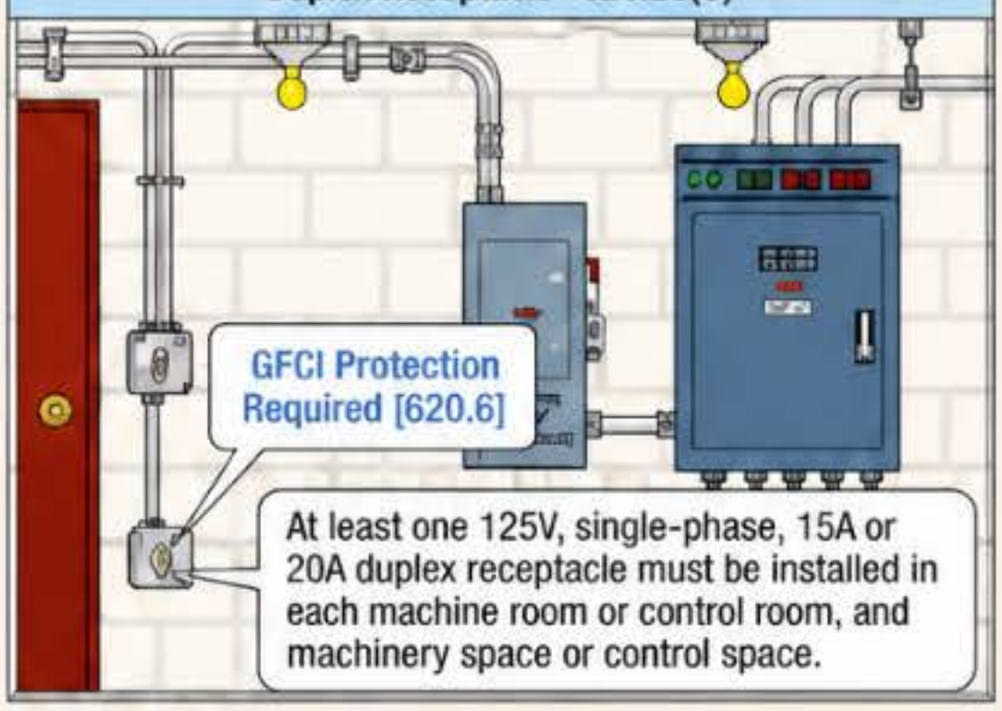
▸ Figure 620-5

The required lighting in these spaces is not permitted to be connected to the load side of a GFCI.

(B) Light Switch. The switch for machine rooms, control rooms, and machinery spaces or control spaces lighting must be located at the point of entry for these areas.

(C) Duplex Receptacle. Install at least one 125V, single-phase, 15A or 20A duplex receptacle in each machine room or control room, and in each machinery space or control space [620.6]. ▸ Figure 620-6

Elevators, Escalators, and Moving Walks, Branch Circuit for Machine Room/Machinery Space, Duplex Receptacle 620.23(C)



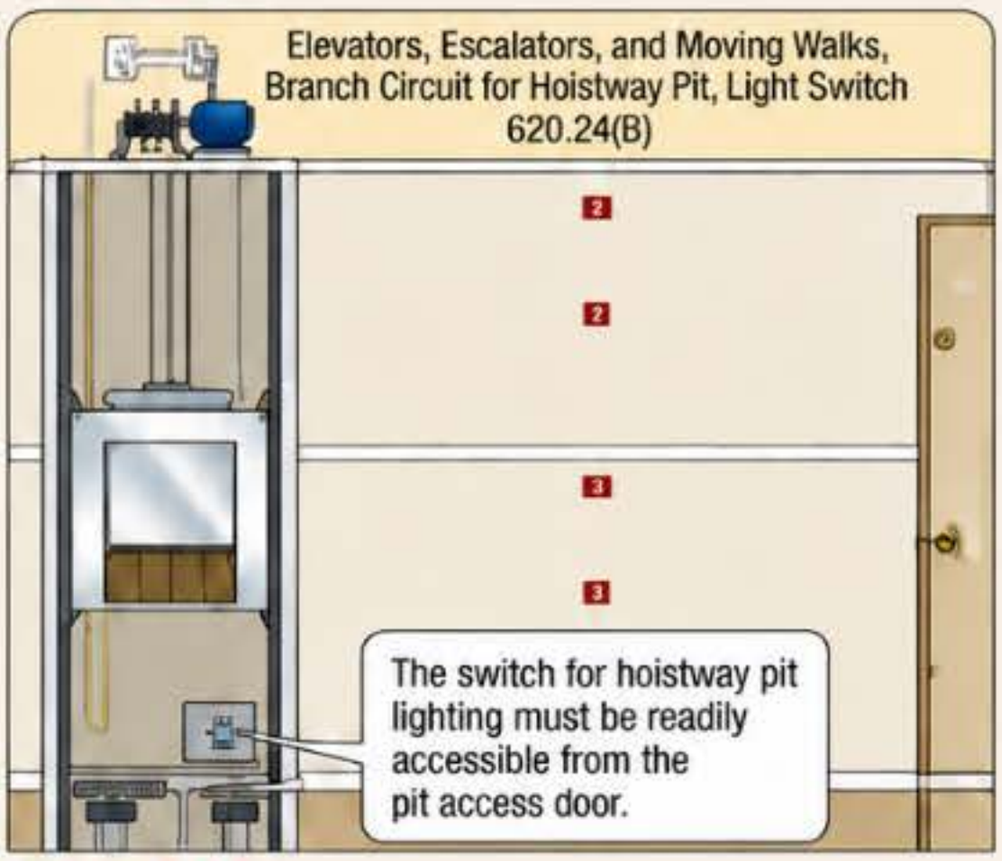
▸ Figure 620-6

620.24 Branch Circuit for Hoistway Pit Lighting and Receptacles

(A) Separate Branch Circuits. Dedicated branch circuits are required for supplying hoistway pit lighting and the required lighting. Connection to the load side of a GFCI [620.85] is not permitted.

(B) Light Switch. The switch controlling the hoistway pit lighting must be easily reached from the pit access door. ▸ Figure 620-7

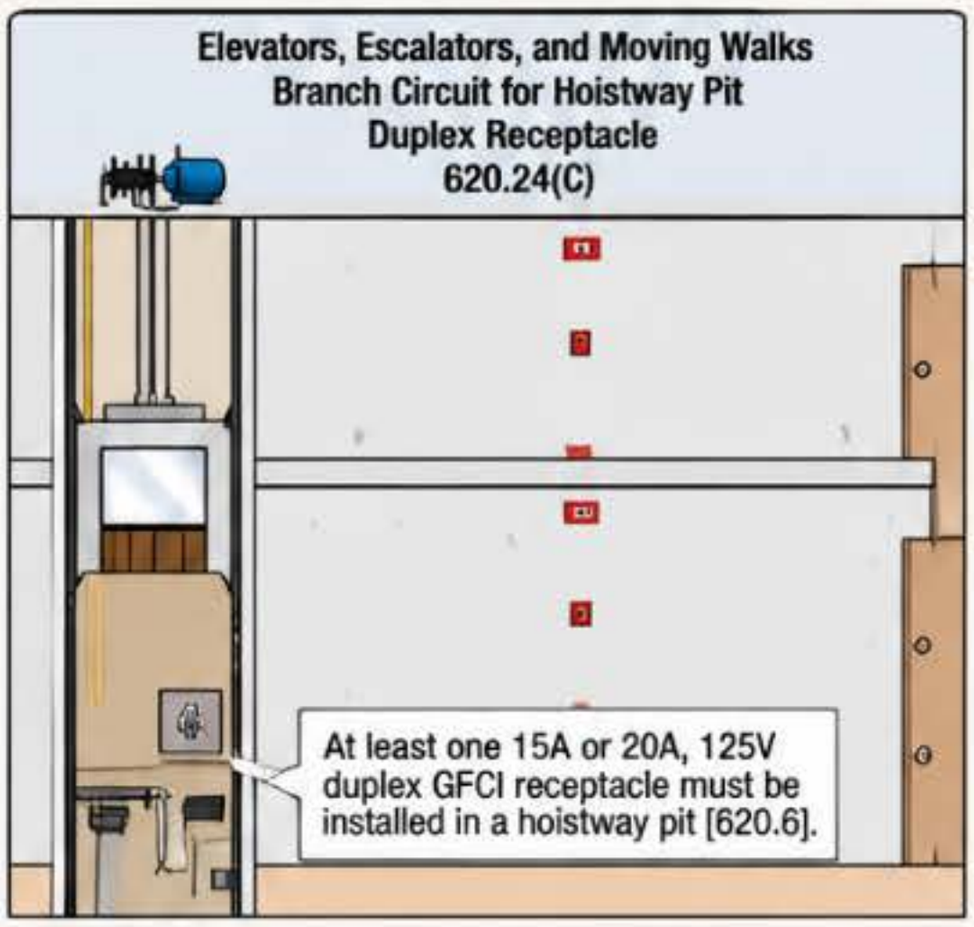
Elevators, Escalators, and Moving Walks, Branch Circuit for Hoistway Pit, Light Switch 620.24(B)



▸ Figure 620-7

(C) Duplex Receptacle. At least one 15A or 20A, 125V duplex GFCI receptacle must be installed in a hoistway pit [620.6]. ▸ Figure 620-8

Note 2: See 620.6 for GFCI requirements.

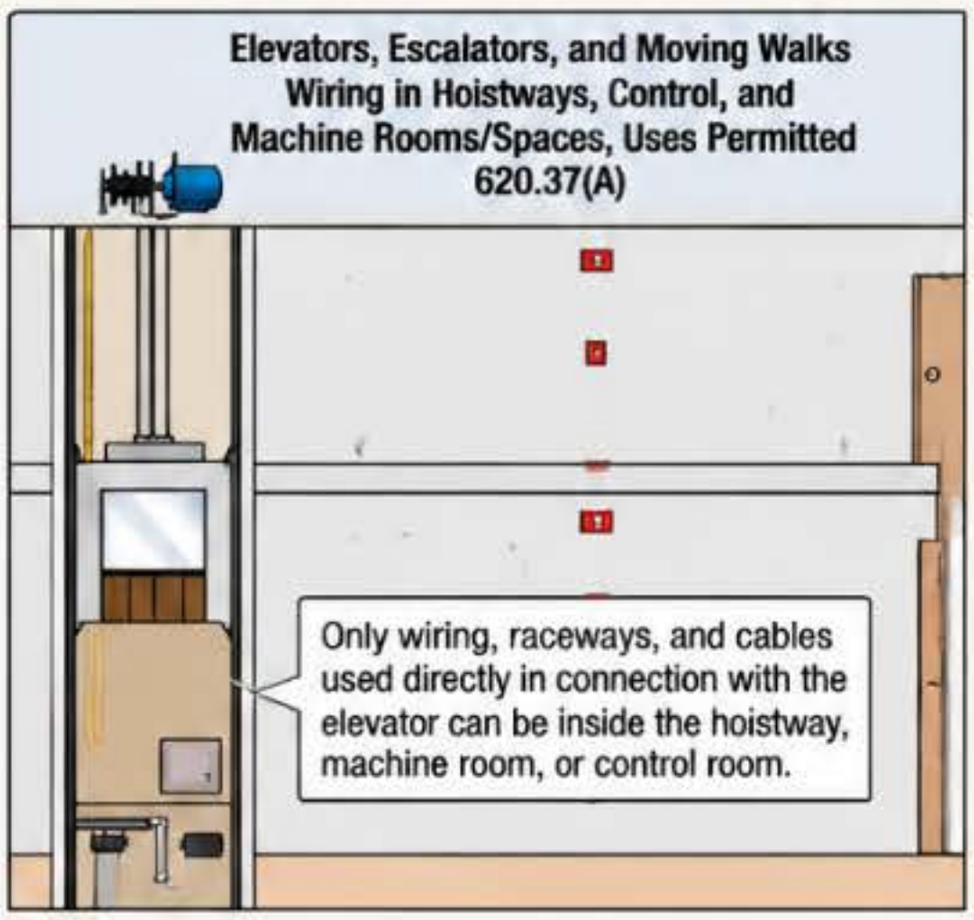


▶ Figure 620–8

Part IV. Installation of Conductors

620.37 Wiring in Elevator Hoistways, Control, and Machine Rooms/Spaces

(A) Uses Permitted. Only wiring, raceways, and cables including communications, fire detection, power, lighting, heating, ventilating, and air-conditioning associated with the elevator are permitted inside the elevator hoistway, machine room, or control room. **Figure 620–9**



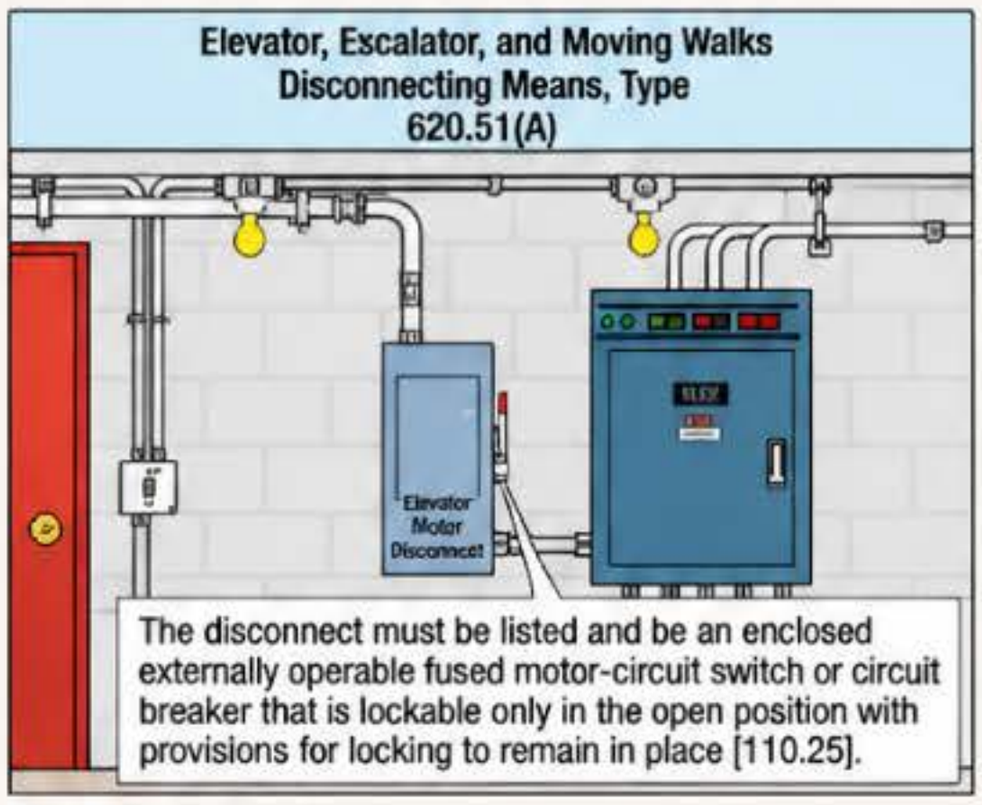
▶ Figure 620–9

Part VI. Disconnecting Means and Control

620.51 Disconnecting Means

A disconnect that opens all phase conductors must be provided for each elevator, escalator, or moving walk. The disconnect for the main power supply conductors is not permitted to disconnect power to the branch circuits required in 620.22, 620.23, and 620.24.

(A) Type. The disconnect must be listed and be an enclosed externally operable fused motor-circuit switch or circuit breaker that is lockable only in the open position, with provisions for locking to remain in place whether the lock is installed or not [110.25]. **Figure 620–10**



▶ Figure 620–10

Note: See ASME A17.1/CSA B44, *Safety Code for Elevators and Escalators*, for additional information for the disconnect.

(C) Location. The disconnect must be readily accessible to qualified persons.

> **Author's Commentary:**
> With advancements in technology, and in an effort to save space, many elevators without machine rooms are being installed. The disconnect is located on the elevator itself and is considered readily accessible to qualified persons.
> ***— Michael Hamilton***

(D) Identification and Signs.

(2) Available Fault Current Marking. Elevator control panels must be marked with the available fault current at the line terminal.

(E) Surge Protection. Where the disconnecting means is designated as part of an emergency or standby system, surge protection must be provided.

> **Author's Commentary:**
> Surge protection helps safeguard critical elevator systems during power disturbances or lightning events to keep passengers safe.
> ***— Michael Hamilton***

ARTICLE 625 ELECTRIC VEHICLE POWER TRANSFER SYSTEM

Introduction to Article 625—Electric Vehicle Power Transfer System

Electric vehicles have been around for a long time. Anyone who has worked in a factory or warehouse, or visited a big box store, has probably encountered an electric lift truck. And, of course, we are all familiar with golf carts. These and other off-road vehicles have charging requirements that are easily accommodated by small charging systems.

But today, a new challenge has emerged and is becoming increasingly common. That challenge is the electrically powered passenger vehicle, bus, truck, and motorcycle. Such vehicles, especially an electric car or bus, can weigh considerably more than a golf cart and just moving one takes a proportionately larger motor. In fact, many designs use multiple drive motors.

Those motors are powered by batteries. Adding to the battery sizing requirement are other demands. For example, these vehicles:

- Must be able to travel at highway speeds over distances roughly comparable to those traveled by their internal combustion engine counterparts.
- Have powered accessories that you typically will not find on a golf cart, such as air conditioning, electric windows, stereo systems, windshield wipers, security systems, and window defrosters.
- Are expected to start in summer heat and in brutal winter cold.

The battery system for an electrically powered passenger vehicle is therefore considerably larger than that for a golf cart or other typical off-road electric vehicle. Consequently, the charging system must have the capability of delivering far more power than the one for a typical off-road electric vehicle.

An electrically powered passenger vehicle needs a dedicated charging circuit. Article 625 defines the requirements for the installation of the electrical equipment needed to charge automotive-type electric and hybrid vehicles including cars, motorcycles, and buses.

This article consists of three parts:

- **Part I. General.** This includes the scope of the article, definitions, voltages, and listing/labeling requirements.
- **Part II. Equipment Construction.** Most of this applies to the manufacturer, but there are a few requirements you need to know.
- **Part III. Installation.** This part covers overcurrent protection and the disconnect in addition to the different requirements for indoor and outdoor locations.

Part I. General

625.1 Scope

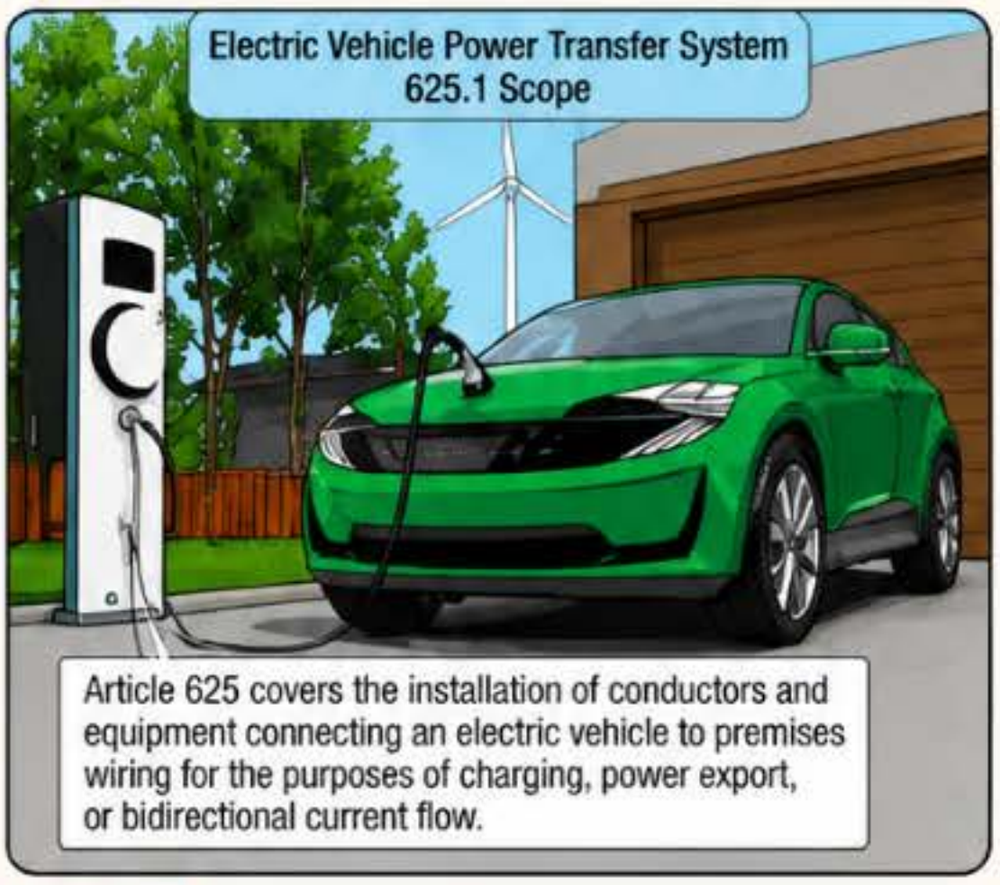
Article 625 covers the installation of conductors and equipment connecting an electric vehicle to premises wiring for the purposes of charging, power export, or bidirectional current flow. ▼ **Figure 625–1**

Figure 625–1

625.2 Definitions

The following definitions only apply within this article.

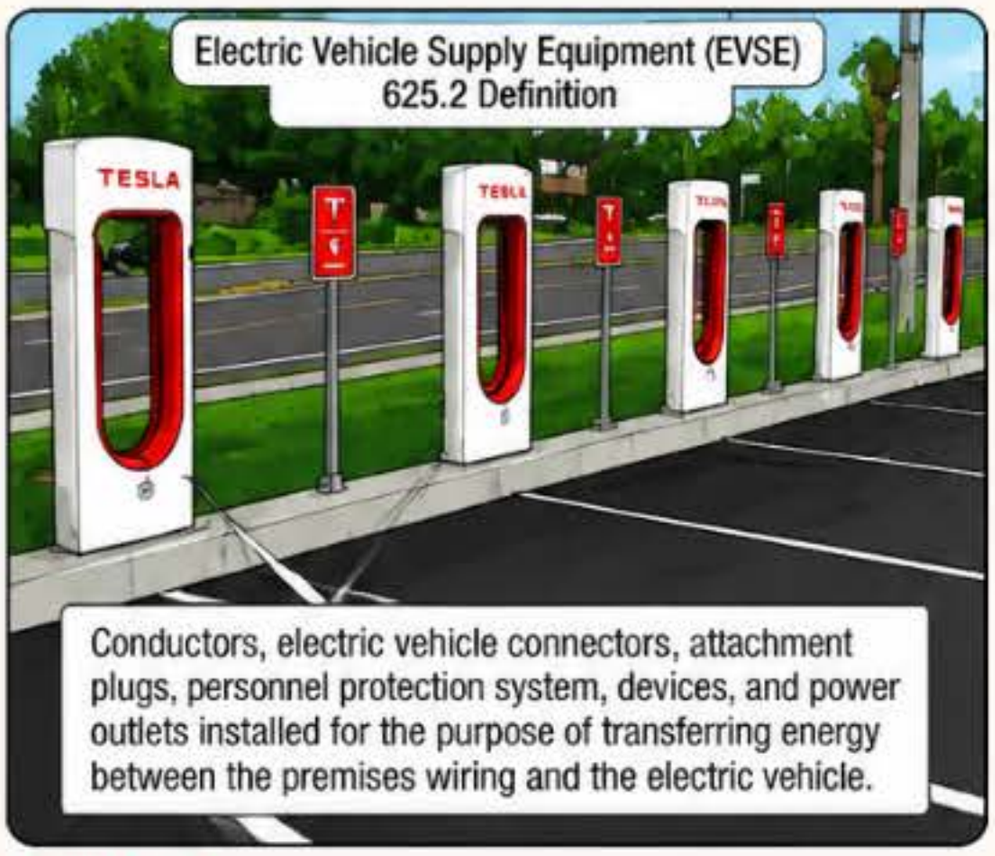
Electric Vehicle Power Export Equipment (EVPE). The equipment, including the outlet on the vehicle, that is used to provide electrical power at voltages greater than 30V ac or 60V dc to loads external to the vehicle as the source of supply.



▸Figure 625–1

Note: Electric vehicle power export equipment and electric vehicle supply equipment are sometimes contained in one piece of equipment, referred to as a "bidirectional EVSE."

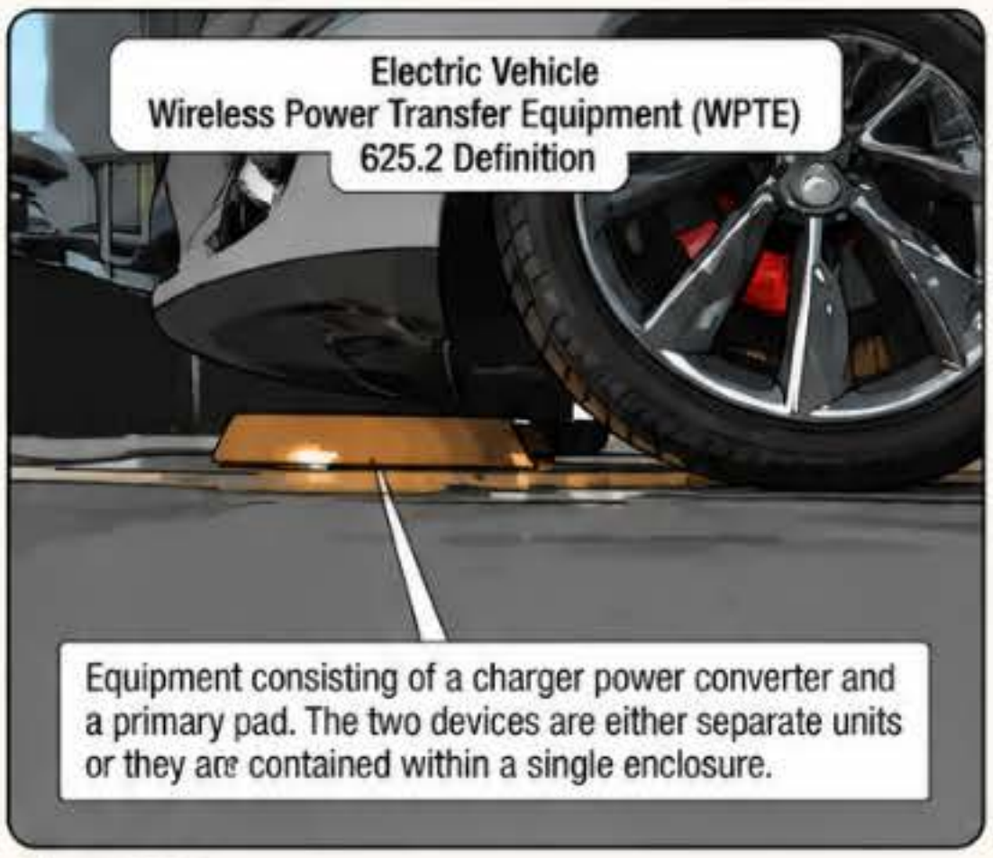
Electric Vehicle Supply Equipment (EVSE). Conductors, electric vehicle connectors, attachment plugs, personnel protection system, devices, and power outlets installed for the purpose of transferring energy between the premises wiring and the electric vehicle. ▸Figure 625–2



▸Figure 625–2

Note: Electric vehicle power export equipment and electric vehicle supply equipment are sometimes contained in one piece of equipment, sometimes referred to as a "bidirectional EVSE."

Wireless Power Transfer Equipment (WPTE). Equipment consisting of a charger power converter and a primary pad. The two devices are either separate units or they are contained within a single enclosure. ▸Figure 625–3



▸Figure 625–3

625.5 Listed

All electric vehicle power transfer equipment covered by this article must be listed.

Part III. Installation

625.40 Electric Vehicle Branch Circuit

Each outlet for electric vehicle supply equipment must be supplied by a dedicated branch circuit that serves no other outlets.

625.41 Overcurrent Protection

Overcurrent protection for circuits supplying electric vehicle supply equipment (EVSE), including bidirectional EVSE and wireless equipment (WPTE), must be sized no less than 125 percent of the maximum load of the electric vehicle supply equipment. ▸Figure 625–4

Author's Commentary:

- If the charging load for EVSE is required to be rated less than 125 percent of the load, then the conductors must be sized to be protected by the circuit overcurrent protective device in accordance with 240.4, including 110.14(C)(1) considerations, as well as 310.16.

— Michael Hamilton

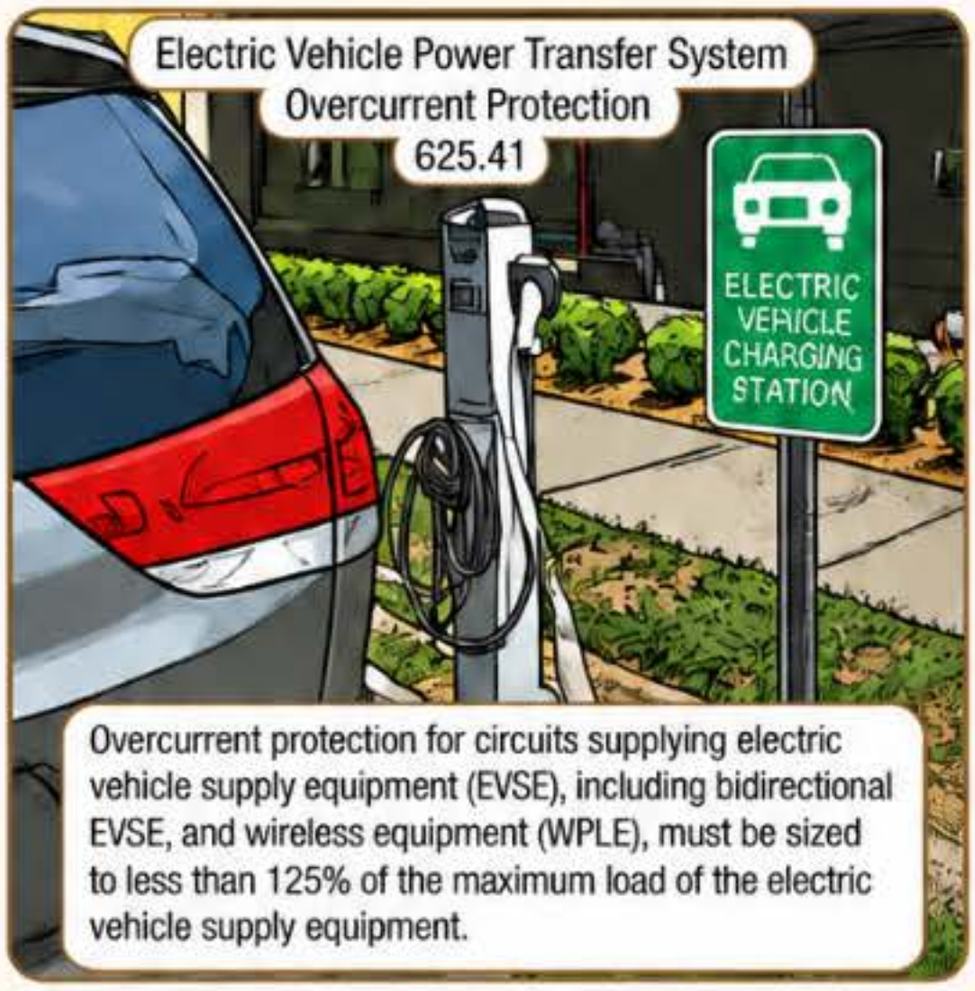


Figure 625–4

625.42 Rating

Power transfer equipment must be capable of continuously supplying the expected load. Charging loads for electric vehicles are treated as continuous per this article. Components such as services and feeders shall be selected to match their nameplate ratings. If an automatic load management system is employed, use the highest load allowed by that system and confirm that the automatic system does not exceed its maximum.

Adjustments are permitted only at equipment that is permanently installed. If a change affects the rating label, the new rating must be in agreement with the manufacturer's instructions and must adequately represent the equipment involved.

Electric vehicle supply equipment with restricted access to an ampere adjustment means is permitted to have an ampere rating(s) equal to the current setting. The settings for the service and the feeder must match the adjustment allowed.

Restricted access is intended to keep users from changing settings. Restricted access shall be achieved by at least one of the methods below:

1. Provide a cover or door that requires a tool to open.
2. Limit access through locked doors available only to qualified individuals.
3. Use password-protected commissioning software that can be accessed only by qualified personnel.

625.43 Disconnecting Means

Electric vehicle equipment rated more than 60 A or over 150 V to ground must have a readily accessible disconnect that can be locked open with provisions for locking to keep it in the open position. Whether a lock is installed or not is allowed [110.25].

625.48 Interactive Systems

Electric vehicle supply equipment (EVSE) that includes a power export function and is part of an interactive system may use an optional standby source, an electric power production source, or a bidirectional power feed. When used as an optional standby system, the requirements of Article 702 apply; when used as an electric power production source, the requirements of Article 705 apply.

Electric vehicle power export equipment (EVPE), consisting of a receptacle outlet only, must comply with 625.60.

Author's Commentary:

Welcome advances in technology, but study the Code for how it adapts. Installations used to export energy from vehicles to wiring or bidirectional current flow are now addressed [90.2].

— Michael Hamilton

625.50 Location

Electric vehicle supply equipment (EVSE) shall be located to allow direct electrical coupling of the vehicle connector to the vehicle.

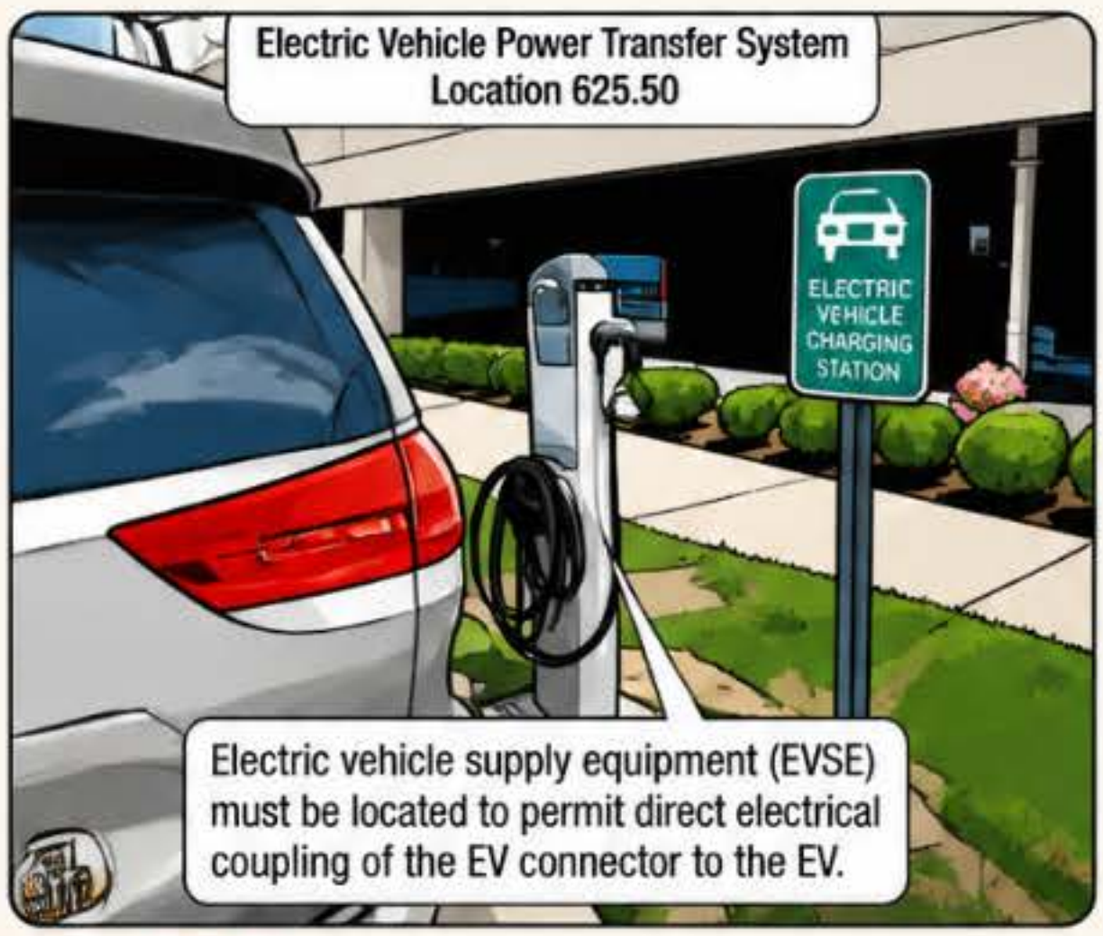
Unless specifically listed and labeled otherwise, the charging system (EVSE) must be mounted at least 18 in. above the floor in indoor spaces and at least 24 in. above grade in outdoor locations.

625.52 Ventilation

Ventilation for charging an electric vehicle in an indoor enclosed space is established by any of the following:

(A) Ventilation Not Required. Mechanical ventilation is not necessary when the equipment for supplying power is intended for indoor charging without ventilation.

625.54 | Electric Vehicle Power Transfer System

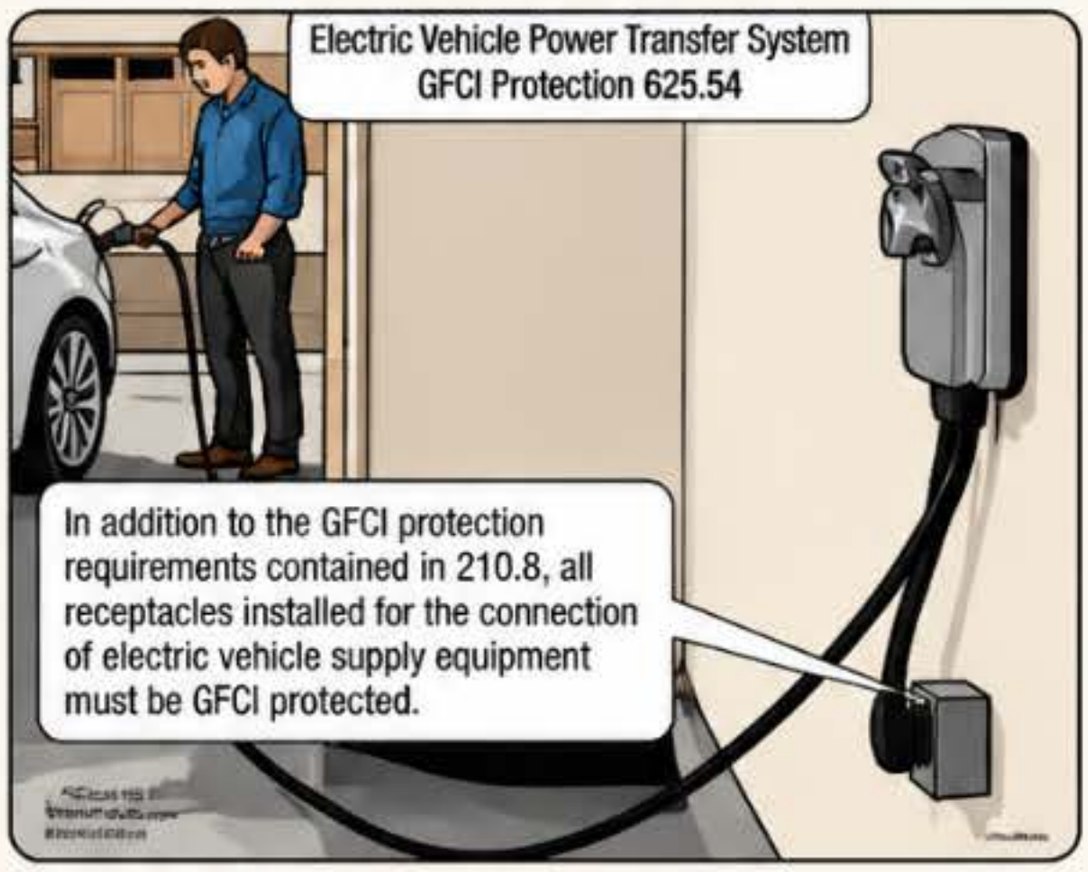


▶ **Figure 625-5**

(B) Ventilation Required. Mechanical ventilation is required where the electric vehicle supply equipment is listed for charging electric vehicles with ventilation for indoor charging. The ventilation must include both supply and exhaust equipment permanently installed and located to intake and vent directly to the outdoors.

625.54 Ground-Fault Circuit-Interrupter Protection for Personnel

In addition to the GFCI protection requirements contained in 210.8, all receptacles installed for the connection of electric vehicle supply equipment must be GFCI protected. ▶ **Figure 625-6**



▶ **Figure 625-6**

Author's Commentary:

- GFCI breakers or receptacles typically used in dwelling units are not suitable for back feeding. That would prohibit their use for a bidirectional EVSE. This GFCI requirement only applies to cord-and-plug-connected EVSE, making hard wired EVSE the only type suitable for bidirectional use.

— Michael Hamilton

625.60 Alternating-Current Electric Vehicle Power Export (EVPE) Receptacles

Alternating-current receptacles installed in electric vehicles and intended to allow for connection of off-board utilization equipment must comply with:

(A) Type. The receptacle must be listed.

(B) Rating. The receptacle outlet must be rated a maximum of 50A, 250V, single-phase.

(C) Overcurrent Protection. The overcurrent protection must be integral to the power export system.

(D) GFCI Protection for Personnel. Ground-fault protection for personnel must be provided for all receptacles. The GFCI reset and indication must be in a readily accessible location.

Note: There are various methods available to achieve GFCI protection.

ARTICLE 630 ELECTRIC WELDERS

Introduction to Article 630—Electric Welders

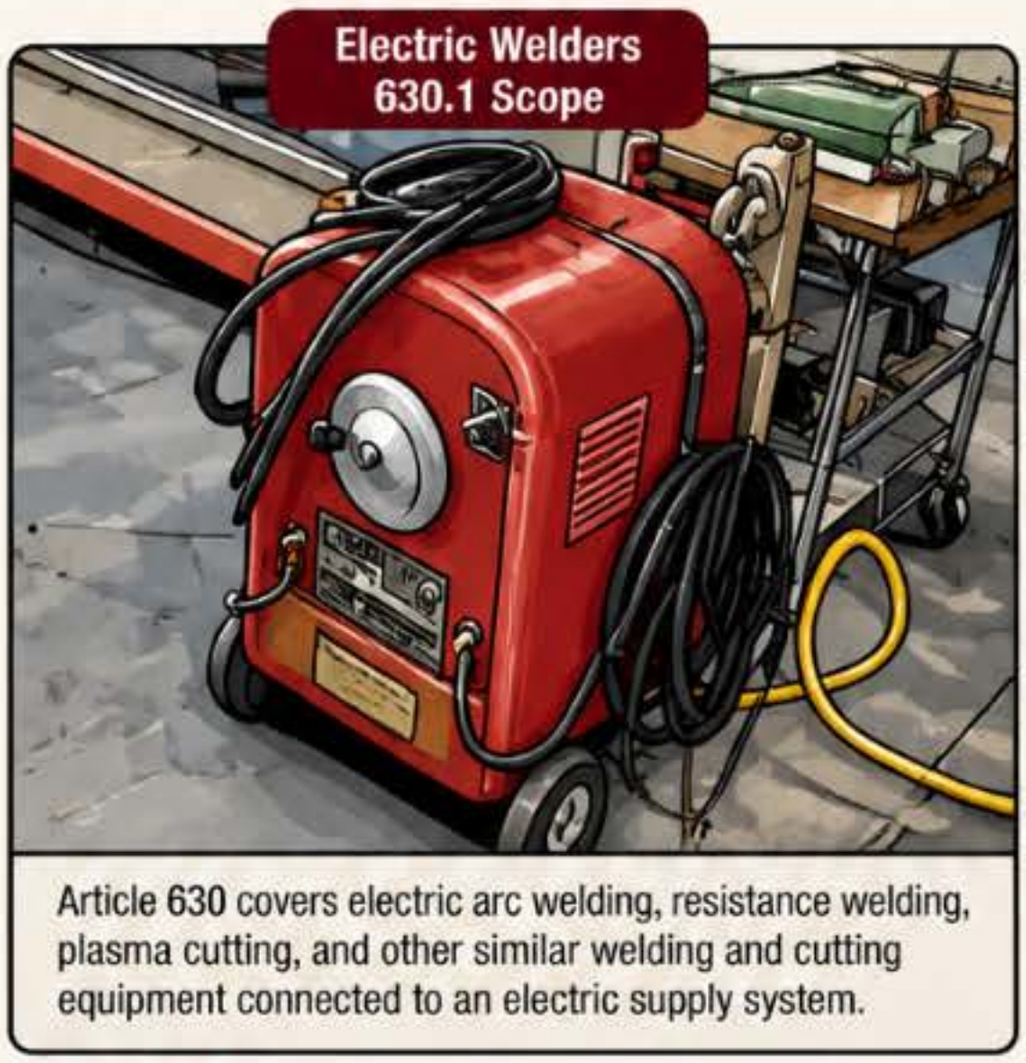
Welding gear generates either an electric arc between two workpieces or extreme heat from a rod that melting due to the flow of current. Both methods can create a strong, momentary surge of current. Welders are built in many different forms and sizes. At the small end are portable units used for manual welding, often in fabrication shops. At the large end are fixed machines installed in facilities for making everything from car and truck bodies to refrigerator panels. All of these must comply with Article 630.

A key worry in this article is making sure the conductors and overcurrent protection are correctly sized for the expected load. Designers and electricians should consult Article 630 for details to place on the equipment nameplate. This article shows how to size conductors and overcurrent protection properly.

Part I. General

630.1 Scope

Article 630 covers electric arc welding and resistance welding apparatus, plasma cutting, and other similar welding and cutting equipment connected to an electric supply system.



Article 630 covers electric arc welding, resistance welding, plasma cutting, and other similar welding and cutting equipment connected to an electric supply system.

▶ Figure 630-1

Author's Commentary:

- There are two principal types of electric welding—arc welding and resistance welding. Arc welding uses an electrode rod that melts when it hits the metal. Resistance welding, also called "spot welding," uses a pair of electrodes that press two metal pieces together while a large current flows. The resistance of the joint heats the metal at the contact point, creating a spot weld.

— *Michael Hamilton*

630.6 Listing

Welding equipment must be listed by a recognized nationally recognized testing laboratory.

Part II. Arc Welders

630.11 Ampacity of Supply Conductors

(A) Individual Arc Welders. The supply conductors for arc welders must have an ampacity of at least the arc welder nameplate rating. If the nameplate rating is not available, the supply conductors must have an ampacity of at least than the rated primary current multiplied by the factor in Table 630.11(A) based on the duty cycle of the arc welder.

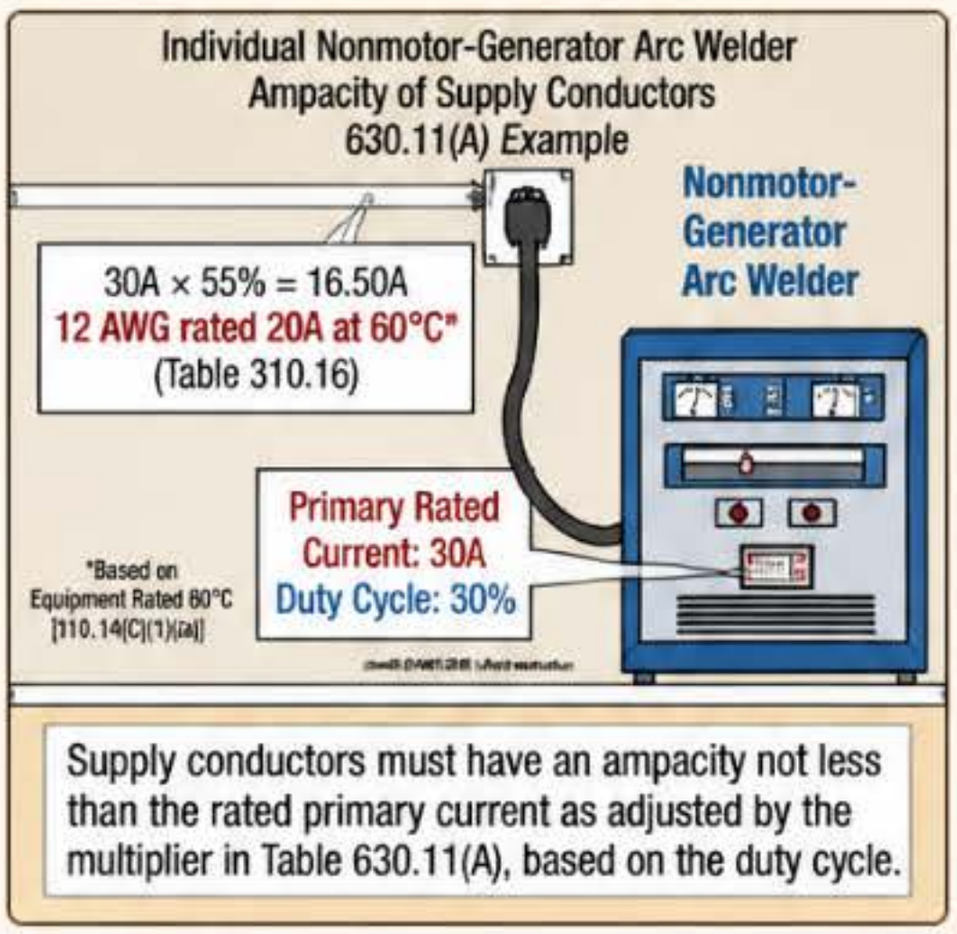
Table 630.11(A) Duty Cycle Multiplication Factors for Arc Welders

Duty Cycle	Multiplier for Arc Welders	
	Nonmotor-Generator	Motor-Generator
100	1.00	1.00
90	0.95	0.96
80	0.89	0.91
70	0.84	0.86
60	0.78	0.81
50	0.71	0.75
40	0.63	0.69
30	0.55	0.62
20 or less	0.45	0.55

▶ Individual Nonmotor-Generator Arc Welder Example 1

Question: *A nonmotor-generator arc welder has a primary current rating of 30A with a duty cycle of 30 percent. What is the minimum size branch-circuit conductor permitted to be used for this welder?* ▶ **Figure 630–2**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG



▶ **Figure 630–2**

Solution:

Demand Load = Primary Rating × Multiplier [Table 630.11(A)]

Demand Load = 30A × 55%

Demand Load = 16.50A

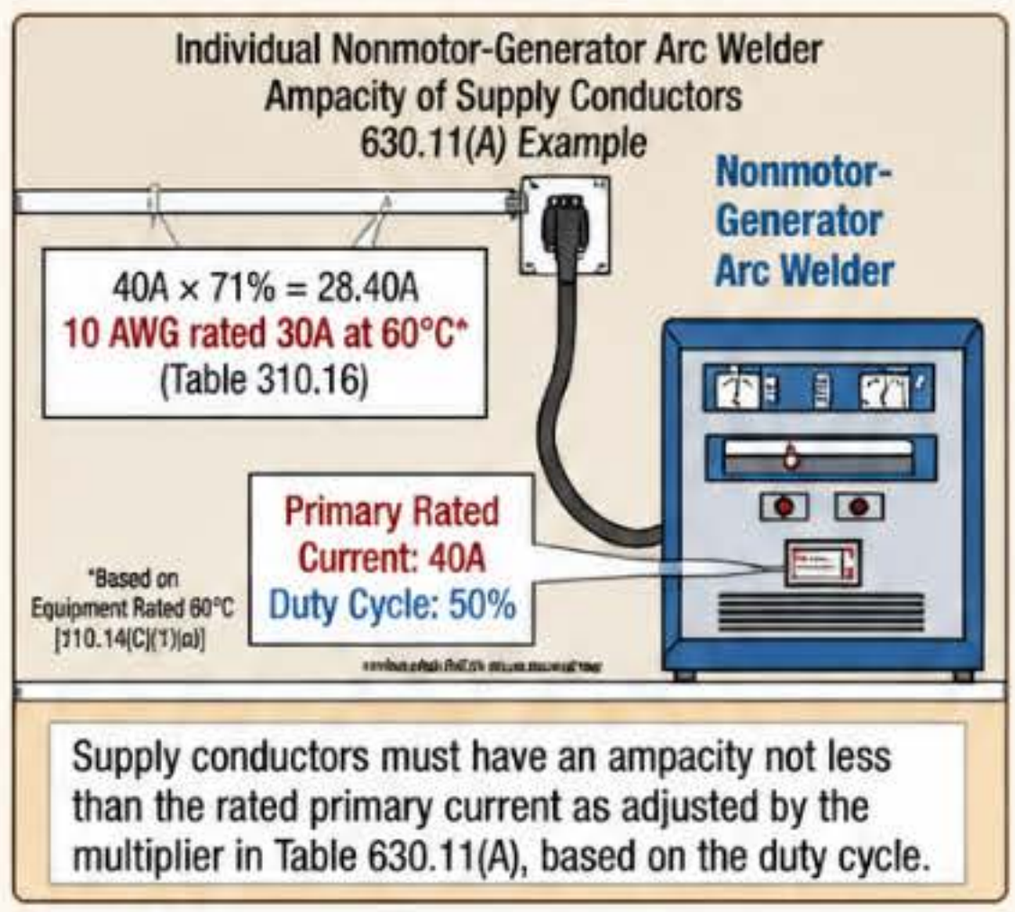
Use 12 AWG rated 20A at 60°C [110.14(C)(1)(a)] and Table 310.16].

Answer: *(a) 12 AWG*

▶ Individual Nonmotor-Generator Arc Welder Example 2

Question: *A nonmotor-generator arc welder has a primary current rating of 40A with a duty cycle of 50 percent. What is the minimum size branch-circuit conductor permitted to be used for this welder?* ▶ **Figure 630–3**

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG



▶ **Figure 630–3**

Solution:

Demand Load = Primary Rating × Multiplier [Table 630.11(A)]

Demand Load = 40A × 71%

Demand Load = 28.40A

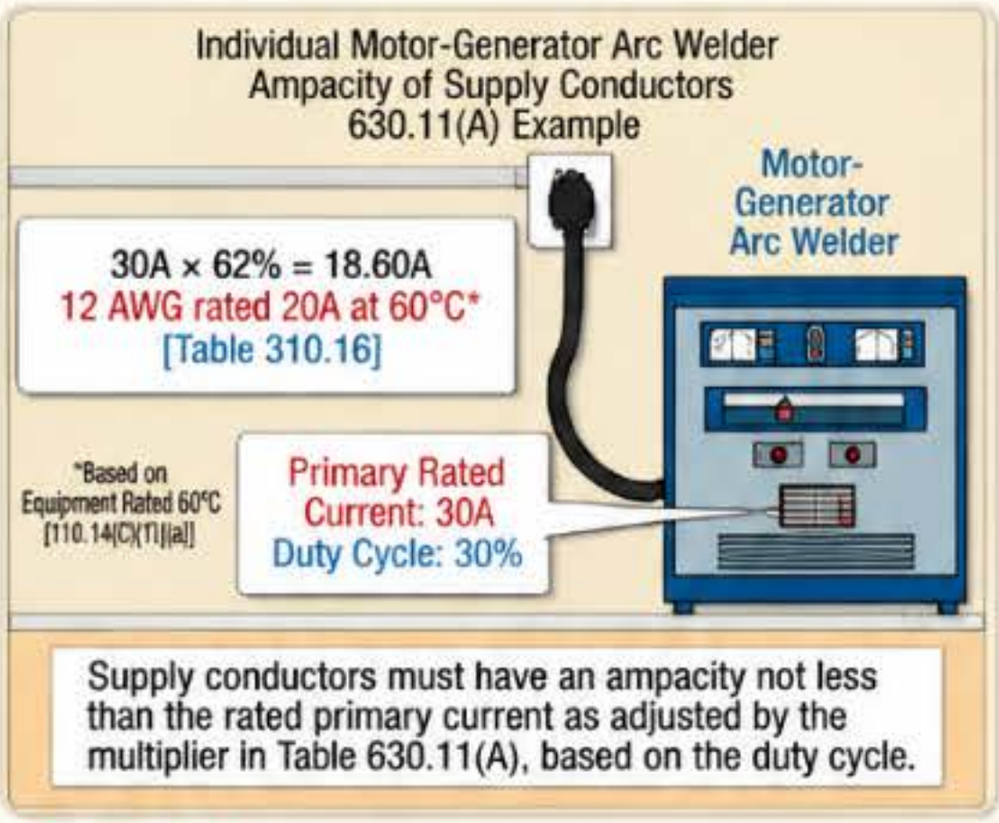
Use 10 AWG rated 30A at 60°C [110.14(C)(1)(a)] and Table 310.16].

Answer: *(c) 10 AWG*

▶ Individual Motor-Generator Arc Welder Example 1

Question: *A motor-generator arc welder has a primary current rating of 30A with a duty cycle of 30 percent. What is the minimum size branch-circuit conductor permitted to be used for this welder?* ▶ **Figure 630-4**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG



▼ **Figure 630-4**

Solution:

Demand Load = Primary Rating × Multiplier [Table 630.11(A)]

Demand Load = 30A × 62%

Demand Load = 18.60A

Use 12 AWG rated 30A at 60°C [110.14(C)(1)(a)] and Table 310.16].

Answer: *(a) 12 AWG*

▶ Individual Motor-Generator Arc Welder Example 2

Question: *A motor-generator arc welder has a primary current rating of 40A with a duty cycle of 50 percent. What is the minimum size branch-circuit conductor permitted to be used for this welder?* ▶ **Figure 630-5**

(a) 14 AWG (b) 12 AWG (c) 10 AWG (d) 8 AWG

Solution:

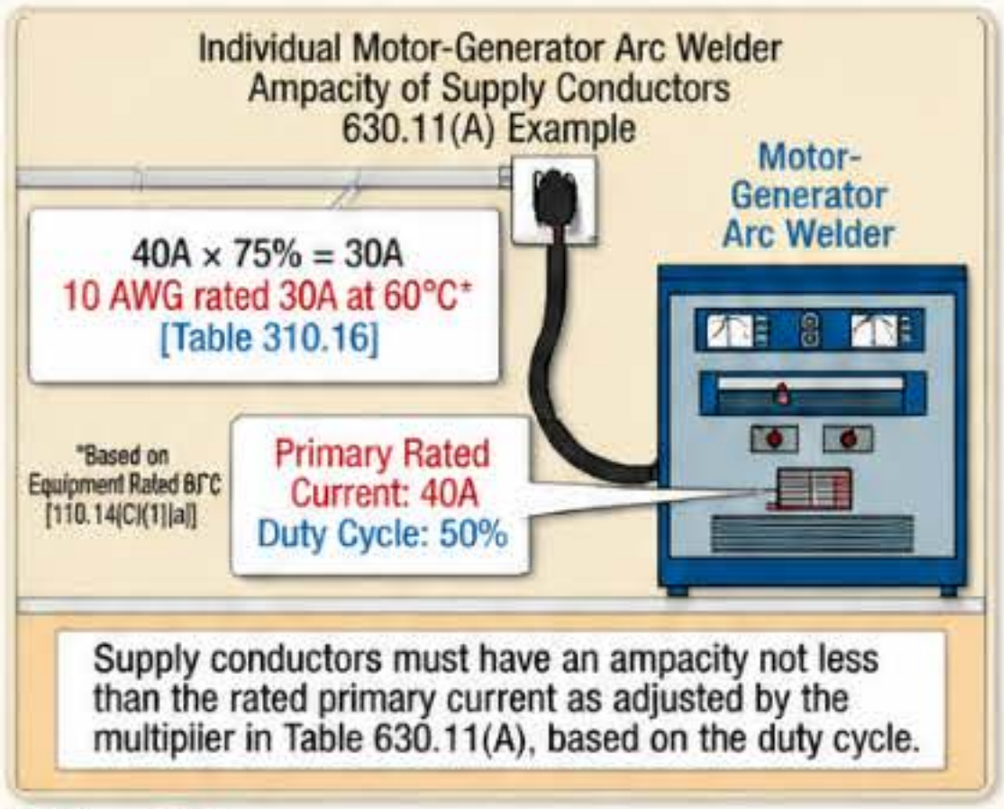
Demand Load = Primary Rating × Multiplier [Table 630.11(A)]

Demand Load = 40A × 75%

Demand Load = 30A

Use 10 AWG rated 30A at 60°C [110.14(C)(1)(a)] and Table 310.16].

Answer: *(c) 10 AWG*



▼ **Figure 630-5**

(B) Group of Welders. Feeder conductors that supply a group of arc welders must have a minimum ampacity of not less than the sum of the currents as determined in 630.11(A) based on 100 percent of the two largest arc welders, 85 percent for the third largest arc welder, 70 percent for the fourth largest arc welder, and 60 percent for all remaining arc welders.

Author's Commentary:
This calculation method provides an ample margin of safety under high-production conditions.
— *Michael Hamilton*

▶ Group of Arc Welders Example 1

Question: *What is the minimum feeder conductor size for five 30A nonmotor-generator arc welders with a duty cycle of 30 percent?*

(a) 4 AWG (b) 1 AWG (c) 1/0 AWG (d) 2/0 AWG

Solution:

Demand Load = Primary Rating × Multiplier [Table 630.11(A)] × Arc Welder Percentage [630.11(B)]

Welder 1	*30A × 55% = 16.50A × 100%*	*16.50A*
Welder 2	*30A × 55% = 16.50A × 100%*	*16.50A*
Welder 3	*30A × 55% = 16.50A × 85%*	*14.03A*
Welder 4	*30A × 55% = 16.50A × 70%*	*11.55A*
Welder 5	*30A × 55% = 16.50A × 60%*	*9.90A*
Total Demand Load		*68.61A*

Minimum Conductor Size = 4 AWG rated 70A at 60°C [110.14(C)(1)(a)] and Table 310.16]

Answer: *(a) 4 AWG*

Group of Arc Welders Example 2

Question: *What is the minimum feeder conductor size for five 50A nonmotor-generator arc welders with a duty cycle of 50 percent?*

(a) 4 AWG (b) 3 AWG (c) 1/0 AWG (d) 2/0 AWG

Solution:

Demand Load = Primary Rating × Multiplier [Table 630.11(A)] × Arc Welder Percentage (630.11(B))

Welder 1	*50A × 71% = 35.50A × 100%*	*35.50A*
Welder 2	*50A × 71% = 35.50A × 100%*	*35.50A*
Welder 3	*50A × 71% = 35.50A × 85%*	*30.18A*
Welder 4	*50A × 71% = 35.50A × 70%*	*24.85A*
Welder 5	*50A × 71% = 35.50A × 60%*	*+21.30A*
Total Demand Load		***147.33A***

Minimum Conductor Size = 1/0 AWG rated 150A at 75°C [110.14(C)(1)(b) and Table 310.16]

Answer: *(c) 1/0 AWG*

630.12 Overcurrent Protection

Where the calculated overcurrent protection value does not correspond to the standard protective device ratings in 240.6(A), the next higher standard rating is permitted.

(A) Welders. Each arc welder must have overcurrent protection rated at not more than 200 percent of the maximum rated supply current at the maximum rated output nameplate, or not more than 200 percent of the rated primary current of the arc welder.

(B) Conductors. The conductors must be protected by an oe-vercurrent protective device rated at not more than 200 percent of the conductor ampacity rating.

Overcurrent Protection Example

Question: *What is the maximum overcurrent protection rating for 10 THHN conductors used for an arc welder branch circuit?*

(a) 30A (b) 40A (c) 50A (d) 60A

Solution:

Overcurrent Protection = 30A × 200%

= 60A

Answer: *(d) 60A*

630.13 Disconnecting Means

A disconnect is required for each arc welder that is not e-equipped with an integral disconnect.

Part III. Resistance Welders

630.31 Ampacity of Supply Conductor

(A) Individual Resistance Welders.

Note: To limit voltage drop to a permissible performance value for resistance welders, conductors are usually sized larger than that which is required to prevent overheating.

Author's Commentary:

To avoid cold welds due to insufficient power, follow the equipment voltage ranges stated in the listing or labeling instructions [110.3(B)].

— Michael Hamilton

(1) The ampacity of the supply conductors for varied-duty cycle resistance welders must not be less than 70 percent of the rated primary current for seam and automatically fed resistance welders, and 50 percent of the rated primary current for manually operated resistance welders [630.31(A)(1)].

(2) The supply conductors for resistance welders with a specific duty cycle and nonvarying current levels must have an ampacity of not less than the rated primary current multiplied by the factors in Table 630.31(A)(2), based on the duty cycle of the resistance welder.

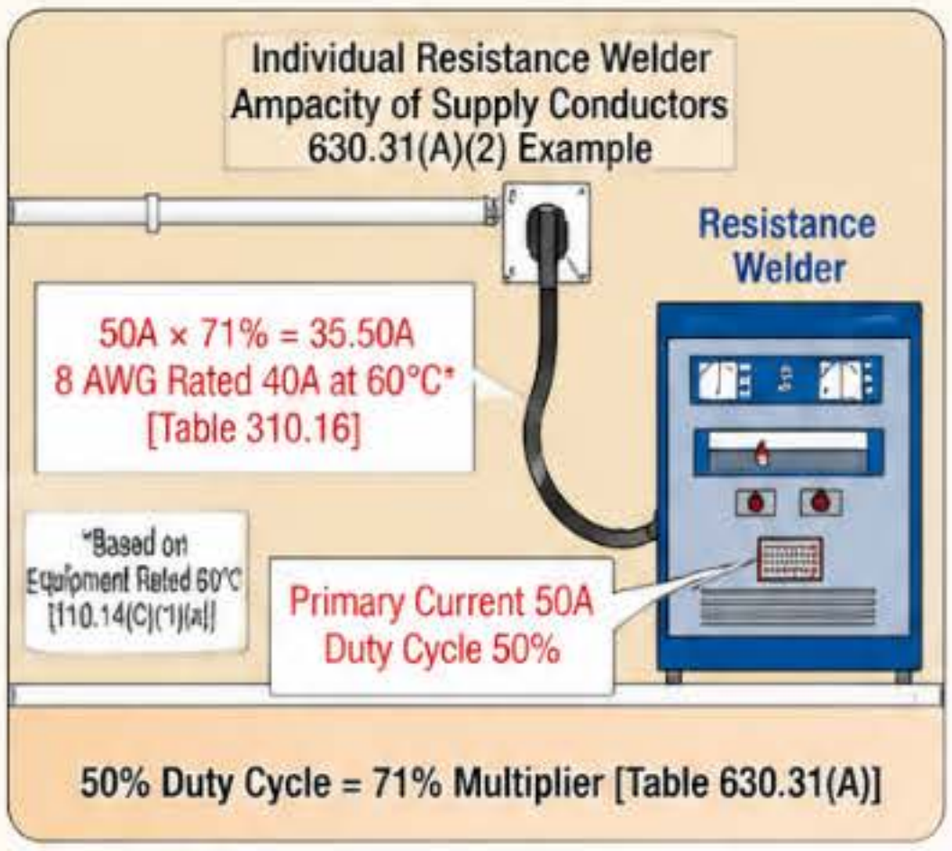
Table 630.31(A)(2) Duty Cycle Multiplication Factors for Resistance Welders

Duty Cycle	Multiplier
30	0.55
25	0.50
20	0.45
15	0.39
10	0.32
7.50	0.27
5 or less	0.22
50	0.71
40	0.63

▶ Individual Resistance Welders Example 1

Question: *What size branch-circuit conductors are required for a 50A resistance welder having a duty cycle of 50 percent?* ▶**Figure 630–6**

(a) 8 AWG (b) 6 AWG (c) 4 AWG (d) 2 AWG



▶**Figure 630–6**

Solution:

Demand Load = Primary Rating × Multiplier [Table 630.31(A)(2)]

Demand Load = 50A × 71%

Demand Load = 35.50A

Use 8 AWG rated 40A at 60°C [110.14(C)(1)(a) and Table 310.16].

Answer: *(a) 8 AWG*

▶ Individual Resistance Welders Example 2

Question: *What size branch-circuit conductors are required for a 30A resistance welder having a duty cycle of 30 percent?* ▶**Figure 630–7**

(a) 12 AWG (b) 10 AWG (c) 8 AWG (d) 6 AWG

Solution:

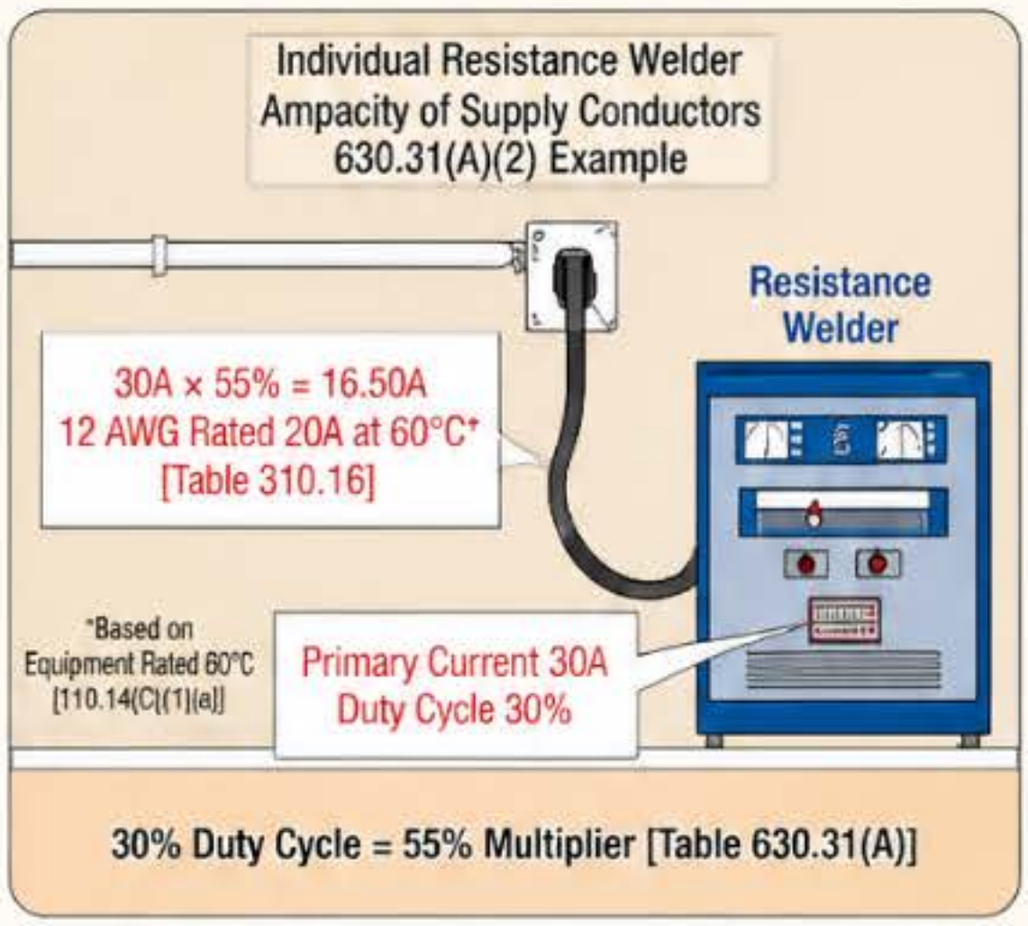
Demand Load = Primary Rating × Multiplier [Table 630.31(A)(2)]

Demand Load = 30A × 55%

Demand Load = 16.50A

Use 12 AWG rated 20A at 60°C [110.14(C)(1)(a) and Table 310.16].

Answer: *(a) 12 AWG*



▶**Figure 630–7**

(B) Groups of Resistance Welders. Feeder conductors that supply a group of resistance welders must have an ampacity of not less than the sum of the value determined using 630.31(A)(2) for the largest resistance welder in the group, plus 60 percent of the values determined for all remaining resistance welders [630.31(B)].

▶ Group of Resistance Welders Example 1

Question: *What is the minimum feeder conductor size for five 30A resistance welders with a duty cycle of 30 percent?*

(a) 4 AWG (b) 3 AWG (c) 2 AWG (d) 1 AWG

Solution:

Demand Load = Primary Rating × Multiplier [Table 630.31(A)(2)] × Resistance Welder Percentage [630.31(B)]

Welder 1	*30A × 55% = 16.50A × 100%*	*16.50A*
Welder 2	*30A × 55% = 16.50A × 60%*	*9.90A*
Welder 3	*30A × 55% = 16.50A × 60%*	*9.90A*
Welder 4	*30A × 55% = 16.50A × 60%*	*9.90A*
Welder 5	*30A × 55% = 16.50A × 60%*	*+ 9.90A*
Total Demand Load		*56.10A*

Minimum Conductor Size = 4 AWG rated 70A at 60°C [110.14(C)(1)(a) and Table 310.16]

Answer: *(a) 4 AWG*

▶ Group of Resistance Welders Example 2

Question: *What is the minimum feeder conductor size for five 50A resistance welders with a duty cycle of 50 percent?*

(a) 4 AWG (b) 3 AWG (c) 2 AWG (d) 1 AWG

Solution:

Demand Load = Primary Rating × Multiplier [Table 630.31(A)(2)] × Resistance Welder Percentage [630.31(B)]

Welder 1	*50A × 71% = 35.50A × 100%*	*35.50A*
Welder 2	*50A × 71% = 35.50A × 60%*	*21.30A*
Welder 3	*50A × 71% = 35.50A × 60%*	*21.30A*
Welder 4	*50A × 71% = 35.50A × 60%*	*21.30A*
Welder 5	*50A × 71% = 35.50A × 60%*	*+21.30A*
Total Demand Load		*120.70A*

Minimum Conductor Size = 1 AWG rated 130A at 75°C [110.14(C)(1)(b) and Table 310.16]

Answer: *(d) 1 AWG*

630.32 Overcurrent Protection

Where the calculated overcurrent protection value does not correspond with the standard protective device ratings in 240.6(A), the next higher standard rating is permitted.

(A) Welders. Each resistance welder must have overcurrent protection set at not more than 300 percent of the rated primary current.

(B) Conductors. Branch-circuit conductors must be protected by an overcurrent protective device rated at not more than 300 percent of the conductor rating.

630.33 Disconnecting Means

A switch or circuit breaker is required to disconnect each resistance welder and its control equipment from the supply circuit.

ARTICLE 640 AUDIO SIGNAL AMPLIFICATION AND REPRODUCTION EQUIPMENT

Introduction to Article 640—Audio Signal Amplification and Reproduction Equipment

By understanding the three primary objectives of Article 640, you will be better prepared to interpret and apply its requirements. These objectives are:

- Minimize the spread of fire and smoke.
- Conform with other applicable articles.
- Reduce the risk of electrical shock.

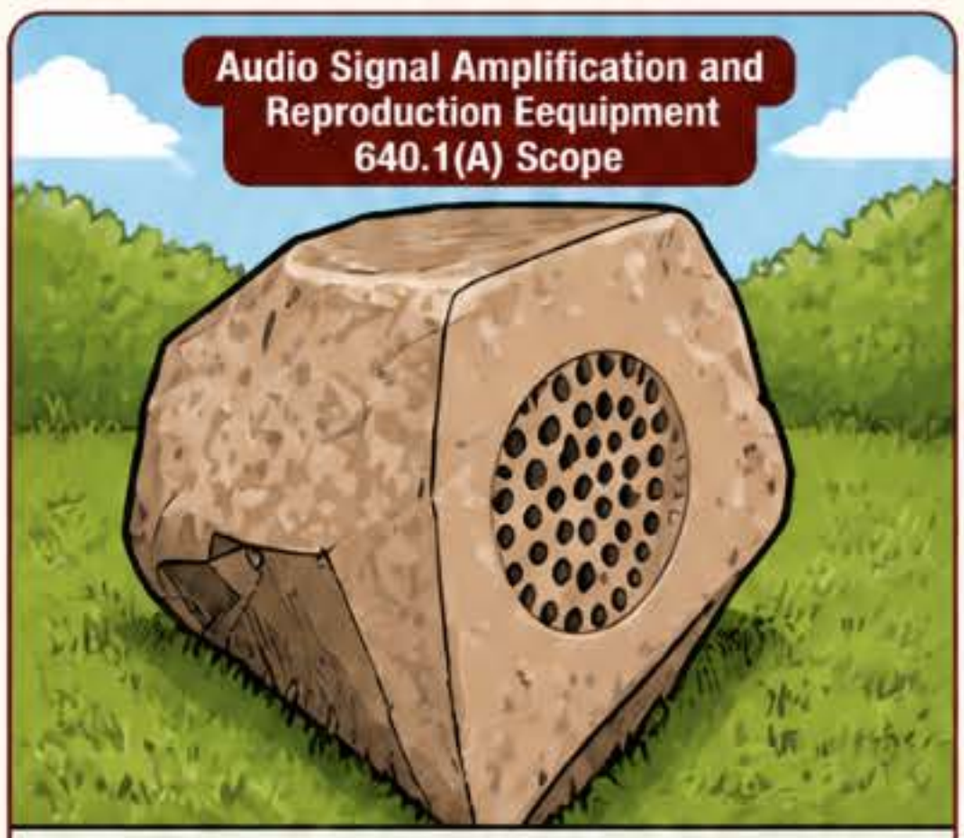
This article contains a series of rules that specify how work must be performed and what is required for audio equipment installed near bodies of water to lessen the likelihood of electrical hazards.

In addition, Article 640 differentiates between permanent and temporary setups. Part II covers rules for permanent installations, while Part III addresses the needs of portable and temporary installations.

Part I. General

640.1 Scope

(A) Covered. Article 640 governs the installation of equipment and wiring for permanently installed and temporary audio systems, including audio sound equipment and systems used for public address announcements. See Figure 640-1.



Article 640 applies to the installation of equipment and wiring for permanently and temporarily installed audio systems used for sound reinforcement and public address applications.

▶ **Figure 640-1**

Note: Audio system locations (but not limited to) include restaurants, hotels, office buildings, retail and commercial sales spaces, churches, schools, auditoriums, theaters, stadiums, and outdoor venues for events such as fairs, festivals, circuses, public gatherings, and concerts.

(B) Not Covered. This article does not apply to audio systems used for fire alarm or burglary alarm functions.

640.2 Definitions

The following definitions apply specifically to Article 640.

Abandoned Cable. An installed audio distribution cable that is no longer in service, has no connected equipment, and is not identified for future use with a tag.

Author's Commentary:

- Section 640.6(B) requires that accessible portions of abandoned audio cables be removed, and 640.6(C) specifies the tagging requirements if the cable is reserved for future use.

— **Michael Hamilton**

Audio System. All equipment and interconnected wiring used to perform signal processing tasks such as amplification, filtering, mixing, timing alignment, and playback of audio signals.

Loudspeaker. Equipment designed to convert an alternating-current electrical signal into audible sound.

640.3 Locations and Other Articles

(A) Spread of Fire or Products of Combustion. Audio circuits must be routed through walls, partitions, floors, or ceilings that provide fire resistance or be protected to keep fire and combustion byproducts from spreading beyond limits established by the manufacturer for that type of cable and construction material (such as drywall, brick, and so on) per 300.21.

Author's Commentary:

- Openings through fire-rated assemblies—walls, floors, partitions, or ceilings—must be sealed with a listed method to prevent the passage of fire or combustion byproducts.
- Although junction boxes aren't required for audio circuits, a listed box is still necessary at a fire-rated assembly.

— Michael Hamilton

Audio Signal Amplification
Spread of Fire or Products of Combustion
640.3(A) Comment

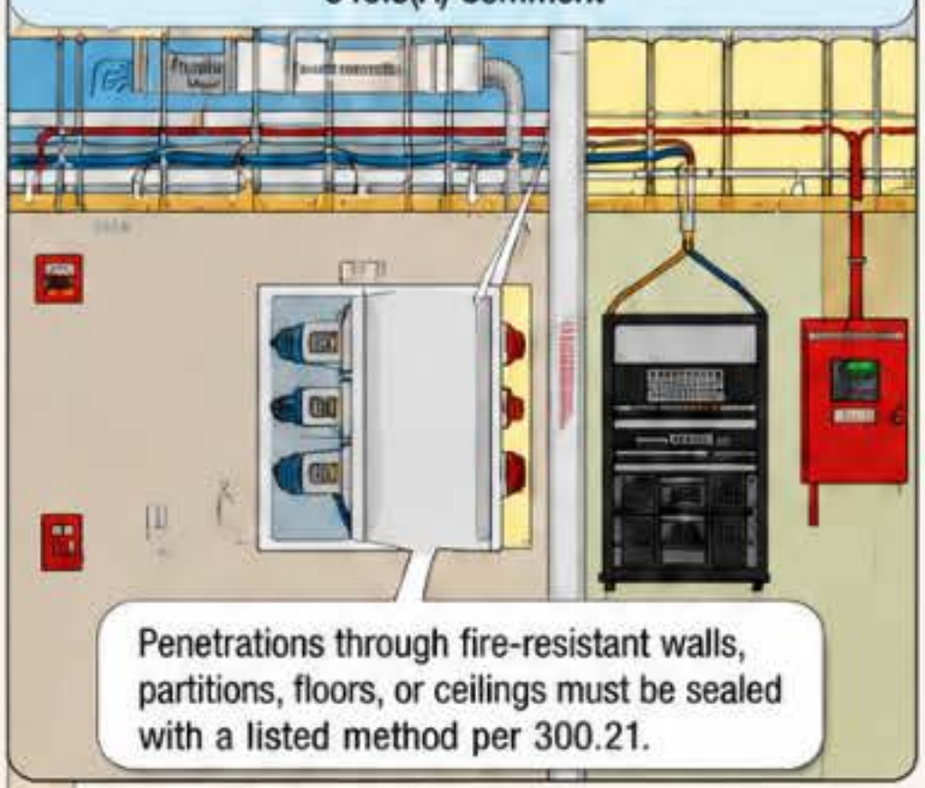


Figure 640–2

(B) Ducts and Plenum Spaces. Audio conductors in air ducts that are part of the environmental air system must comply with 300.22(B), and cabling inside plenum spaces must comply with 300.22(C).

Ex 1: Class 2 plenum-rated cables installed in accordance with 725.135(B) and Table 725.154 can be installed in ducts constructed for environmental air.

Ex 2: Class 2 plenum-rated cables installed in accordance with 725.135(C) and Table 725.154 can be installed in plenum spaces.

640.4 Protection of Electrical Equipment

Amplifiers, loudspeakers, and other audio equipment must be installed or shielded from environmental exposure or physical damage that could lead to fire, shock, or injury.

640.6 Mechanical Execution of Work

(A) Installation of Audio Cables. Audio cables that are visible must be supported so that normal building use will not harm them. Straps, staples, cable ties, hangers, and similar devices used for support must be suitable for audio cables and must not damage them. **Figure 640–3**

Audio Signal Amplification, Mechanical Execution of Work
Installation of Audio Cables
640.6(A)

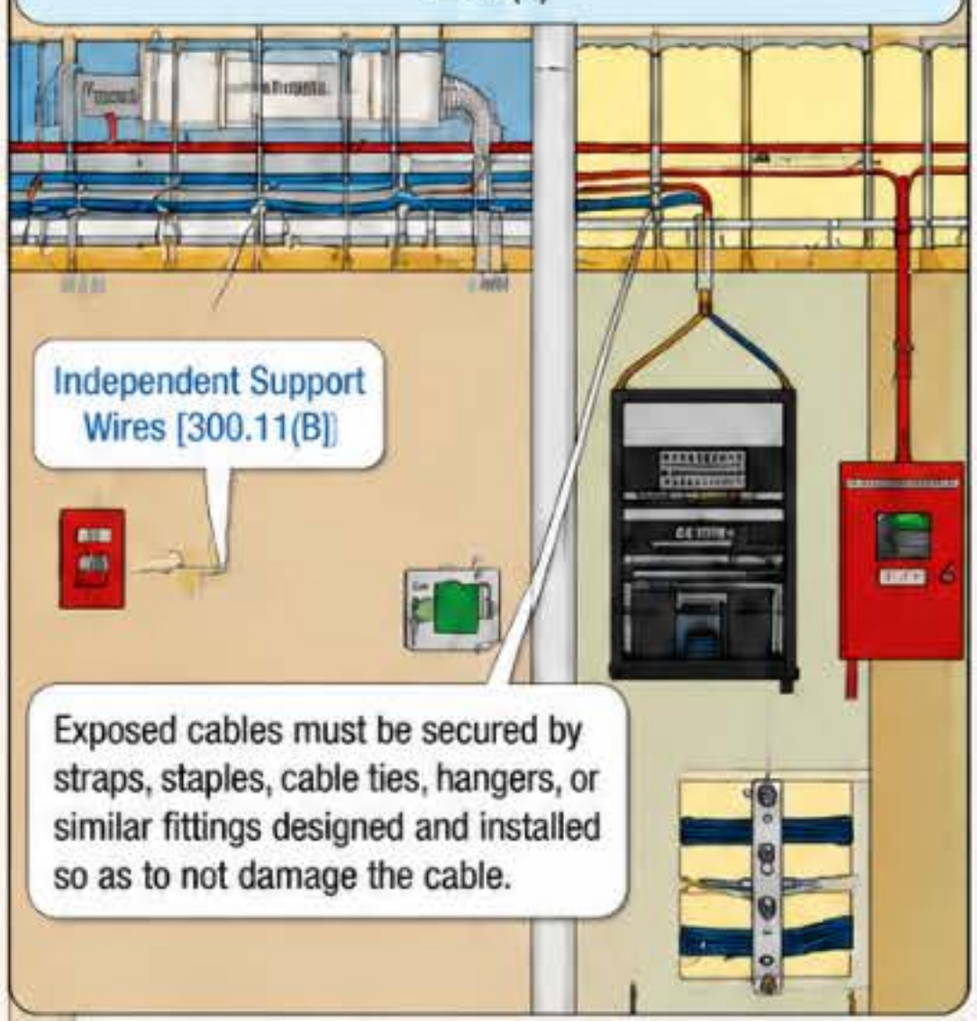


Figure 640–3

Audio cables installed parallel or perpendicular to framing members must be shielded from damage due to nails or screws, or must be at least 1¼ in. away from the face of the framing member or protected by a suitable metal plate, following 300.4(D). **Figure 640–4**

(B) Abandoned Audio Cables. Unused or abandoned sections of audio cable must be removed. **Figure 640–5**

Audio Signal Amplification and Reproduction Equipment 640.10

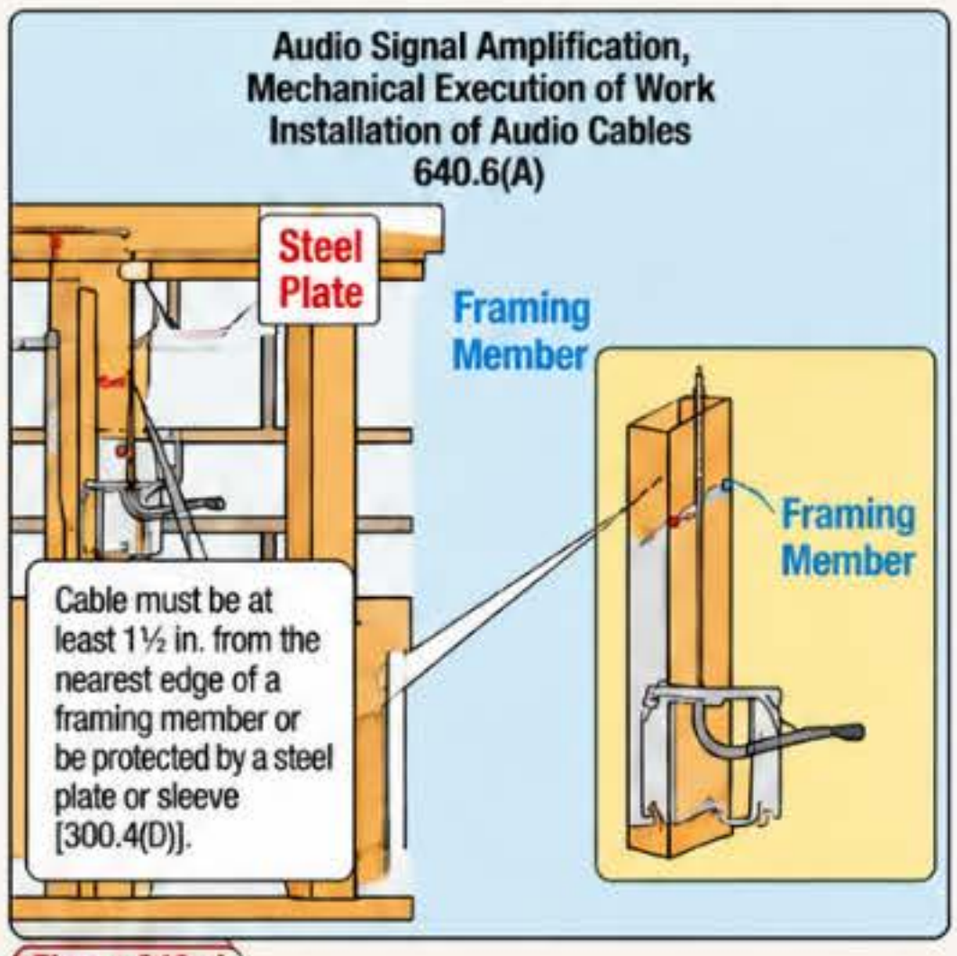


Figure 640–4

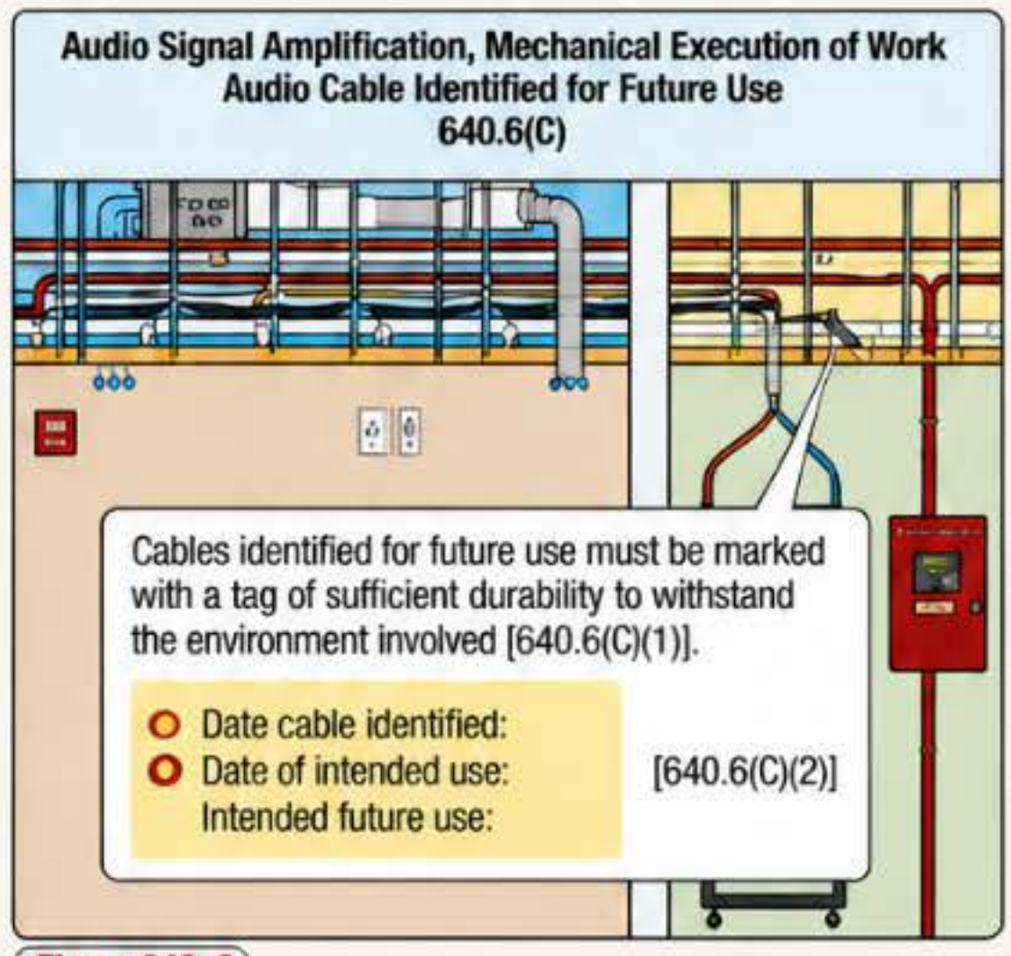


Figure 640–6

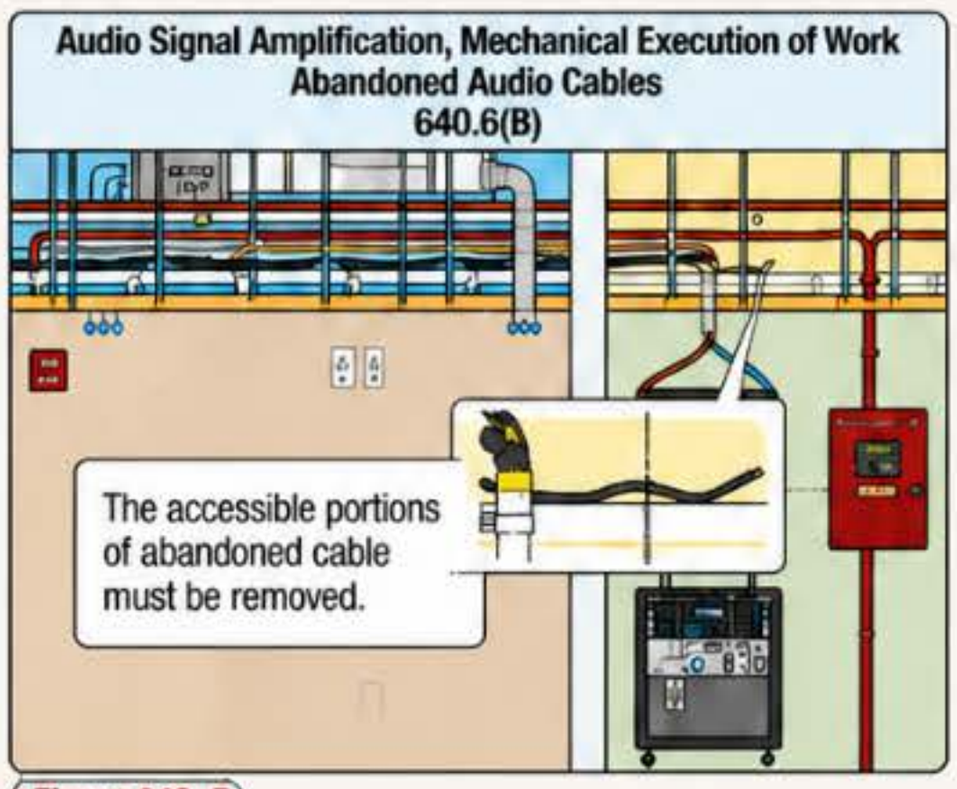


Figure 640–5

Author's Commentary:

- An abandoned audio distribution cable is one that is no longer connected to equipment and has not been tagged for future use [640.2].
- This provision does not require the removal of concealed cables that are left in place. That includes cables run in raceways. Per Article 100, cables in raceways considered concealed and not readily accessible are not required to be removed.

— Michael Hamilton

(C) Audio Cable Identified for Future Use. Figure 640–6

(1) Cables identified for future use must be marked with a tag of sufficient durability to withstand the environment involved.

(2) Cable tags must include the following information:

(1) The date the cable was identified for future use.

(2) The date of expected use.

(3) The intended future use of the cable.

640.9 Wiring Methods

(A) Wiring to and Between Audio Equipment.

(1) Branch Circuit. Branch-circuit wiring for audio equipment must comply with Chapters 1 through 4.

(3) Audio Circuits Output Wiring. Audio output wiring must be installed in accordance with Article 725.

640.10 Audio Systems Near Bodies of Water

(A) Branch-Circuit Power. Audio equipment supplied by a branch circuit is not permitted to be placed within 5 ft horizontally of the inside wall of a pool, spa, hot tub, or fountain. In addition to the requirements in 210.8(B), the equipment must be supplied by a GFCI-protected branch circuit where required by other articles of the *Code*.

Note: See 680.27(A) for installation of underwater audio equipment.

(B) Class 2 Power Supply. Audio system equipment powered by a listed Class 2 power supply or an amplifier listed for use with Class 2 wiring, are restricted in their placement near bodies of water by the manufacturer's instructions.

Part II. Permanent Audio System Installations

640.21 Use of Flexible Cords and Flexible Cables

(A) Branch-Circuit Power. Power-supply cords for permanent audio equipment are allowed where the interconnection, upkeep, or servicing of the equipment is done by means of a power-supply cord.

(B) Loudspeakers. Cables that feed loudspeakers must comply with the requirements of Article 725, and the conductors used for outdoor loudspeakers have to be suitable for the environment in which they are installed.

(C) Between Equipment. Cables that carry audio signals from one piece of equipment to another must meet the requirements set in Article 725.

640.23 Conduit or Tubing

(A) Number of Conductors. The quantity of conductors inside a conduit or tubing must not exceed the percentage fill limits specified in Chapter 9, Table 1.

Author's Commentary:

Selecting the correct cords, cables, and conduit ensures audio systems operate reliably and safely. Following Articles 725 and the conduit fill limits prevents overheating, equipment damage, and installation problems during future maintenance.

— Michael Hamilton

ARTICLE 645 INFORMATION TECHNOLOGY EQUIPMENT (ITE)

Introduction to Article 645—Information Technology Equipment (ITE)

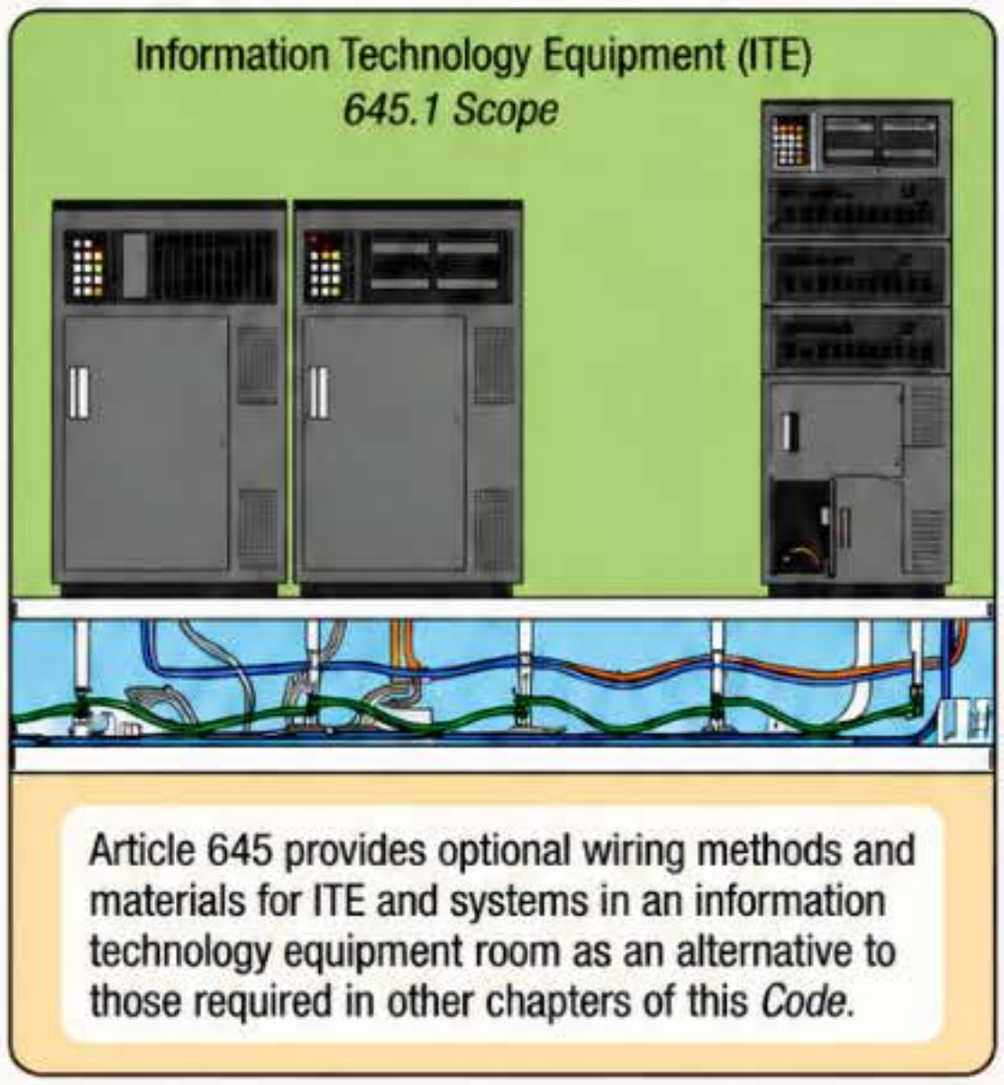
A distinctive feature of Article 645 is its requirement for an emergency disconnect switch that can shut down the information technology equipment (ITE) area [645.10]. This rule may appear counterintutive because it gives someone the ability to remove power from the IT room with a single action. However, given the presence of uninterruptible power supplies (UPSs) and the many protective steps already in place against power failures, that vulnerability becomes far less concerning.

The rest of Article 645 focuses on limiting the spread of fire and smoke. Elevated-floor IT spaces introduce special challenges that this article addresses, as it devotes a significant share of its text to floor assemblies. Requirements also cover fire-resistance-rated walls, separate HVAC systems, and other related provisions that work together to meet these objectives.

645.1 Scope

Article 645 provides optional wiring methods and materials for information technology equipment (ITE) and systems in an information technology equipment room as an alternative to those required in other chapters of this *Code*.

Figure 645–1



▶ **Figure 645–1**

Note 1: An information technology equipment room is an enclosed area specifically designed to comply with the construction and fire protection provisions of NFPA 75, *Standard for the Fire Protection of Information Technology Equipment*.

645.2 Definitions

The following definitions apply only within this article.

Abandoned Cable. Installed supply circuits and interconnecting cables that are not terminated at equipment and not identified for future use with a tag.

645.3 Other Articles

Circuits and equipment must comply with 645.3(A) through (I) as applicable.

(A) Spread of Fire or Products of Combustion. Electrical circuits and equipment must be installed so that the spread of fire or products of combustion will not be substantially increased. Openings into or through fire-rated walls, floors, and ceilings for electrical equipment must be firestopped using methods approved by the authority having jurisdiction to maintain the fire-resistance rating of the fire-rated assembly [300.21, 770.26, and 800.26].

645.4 INFORMATION TECHNOLOGY EQUIPMENT (ITE)

(B) Plenum Spaces. The rules below govern wiring and cabling in a plenum area located above an information technology equipment room.

(1) Wiring must follow 300.22(C)(1).

(2) Class 2 plenum-rated cables are installed in accordance with 725.135(C) and Table 725.154.

(3) Plenum-rated fire alarm cables are installed in accordance with 760.53(B)(2), 760.135(C), and Table 725.154.

(4) Plenum-rated optical fiber cables are installed in accordance with 770.113(C) and Table 770.154(a).

(5) Plenum-rated communications cables are installed in accordance with 800.113 and Table 800.154(a).

(6) Plenum-rated coaxial cables are installed in accordance with 800.113 and Table 800.154(a).

Author's Commentary:

A variety of wiring approaches and cable types are used in the installation of signaling, data communications, data transmission, audio, radio, and television systems, along with other similar technologies. Most of these methods have been consolidated within Article 800 of the 2023 *NEC*.

— Michael Hamilton

(D) Classification of Data Circuits. Data circuits for information technology systems are divided into Class 2 circuits per 725.121(A)(4) and must be installed according to Article 725 [725.1].

Class 2 circuit conductors installed together with communication circuits are considered communications circuits, and the cable must be identified as a communications cable [725.139(D)(1) and 800.133(A)(1)(c)].

(E) Fire Alarm Cables and Equipment. Parts I, II, and III of Article 760 apply to fire alarm system wiring and equipment inside an information technology equipment room. Only fire alarm cables that comply with Part IV of Article 760 and are listed for fire alarm equipment may be installed in this type of room.

(H) Optical Fiber Cables. Optical fiber cables listed in accordance with 770.179 are permitted in an information technology equipment room.

645.4 SPECIAL REQUIREMENTS

The wiring methods allowed by 645.5 are limited to situations where all of the following conditions are satisfied:

(1) A disconnecting means that meets 645.10 is provided.

(2) A dedicated heating, ventilating, and air-conditioning (HVAC) system is supplied for the information technology equipment room and is physically separated from other spaces.

(3) The information technology and communications equipment is located within the room.

(4) The room is used only by authorized personnel for maintenance and operation of the information equipment equipment.

(5) The information technology equipment room is isolated from adjacent spaces by fire-resistance-rated walls, floors, and ceilings that include protected openings.

(6) Only electrical equipment and wiring that pertain to the operation of the information technology room are installed within it.

Note: This includes HVAC systems, communications systems (twisted pair, antennas, and coaxial cable), fire alarm systems, security systems, water detection systems, and other related protective equipment.

645.5 SUPPLY CIRCUITS AND INTERCONNECTING CABLES

(A) Branch-Circuit Conductors. Branch-circuit conductors for information technology equipment must have an ampacity of at least 125 percent of the total connected load.

(B) Power-Supply Cords. Information technology equipment may be connected to a branch circuit using a power-supply cord, provided the following criteria are met: **Figure 645–2**

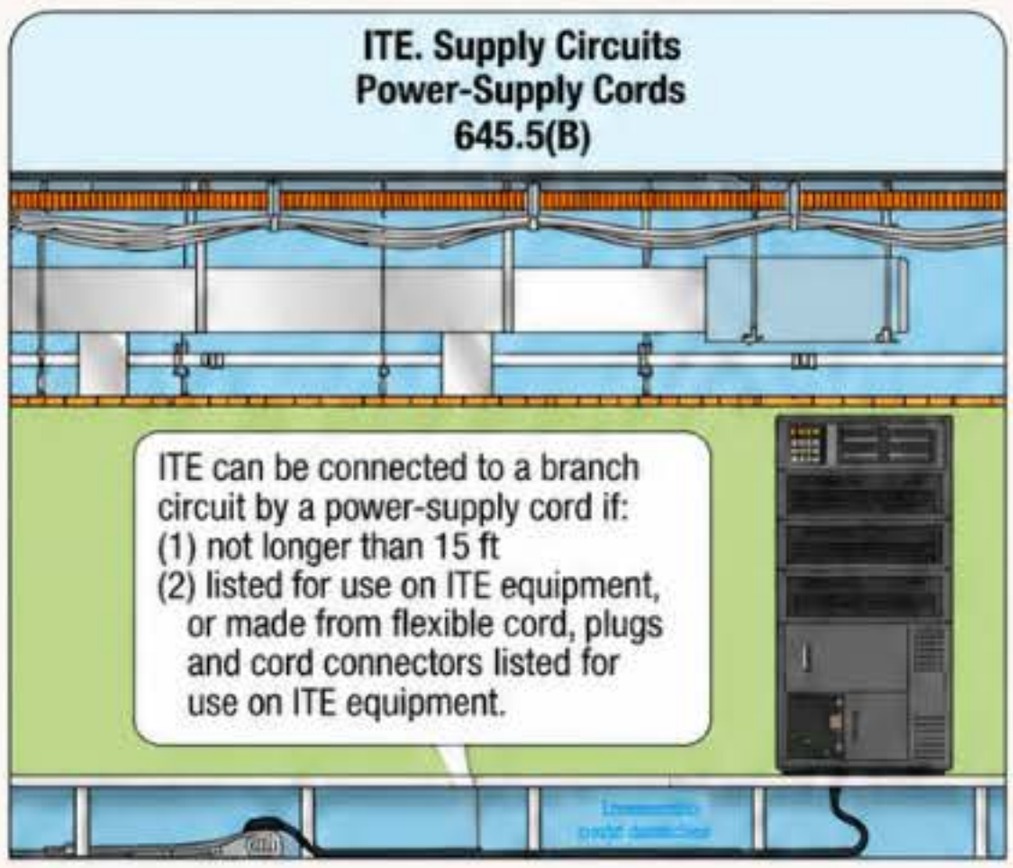
(1) The power cord must not exceed 15 ft in length.

(2) The power cord and its attachment plug must be listed for use with information technology equipment or be made from flexible cord, plugs, and connectors that are listed for ITE use.

(C) Interconnecting Cables. Cables used to interconnect information technology equipment without a 15-foot cable length limitation are allowed in accordance with 645.5(B)(1).

(D) Physical Damage. All supply circuits and interconnecting cables must be protected from physical damage.

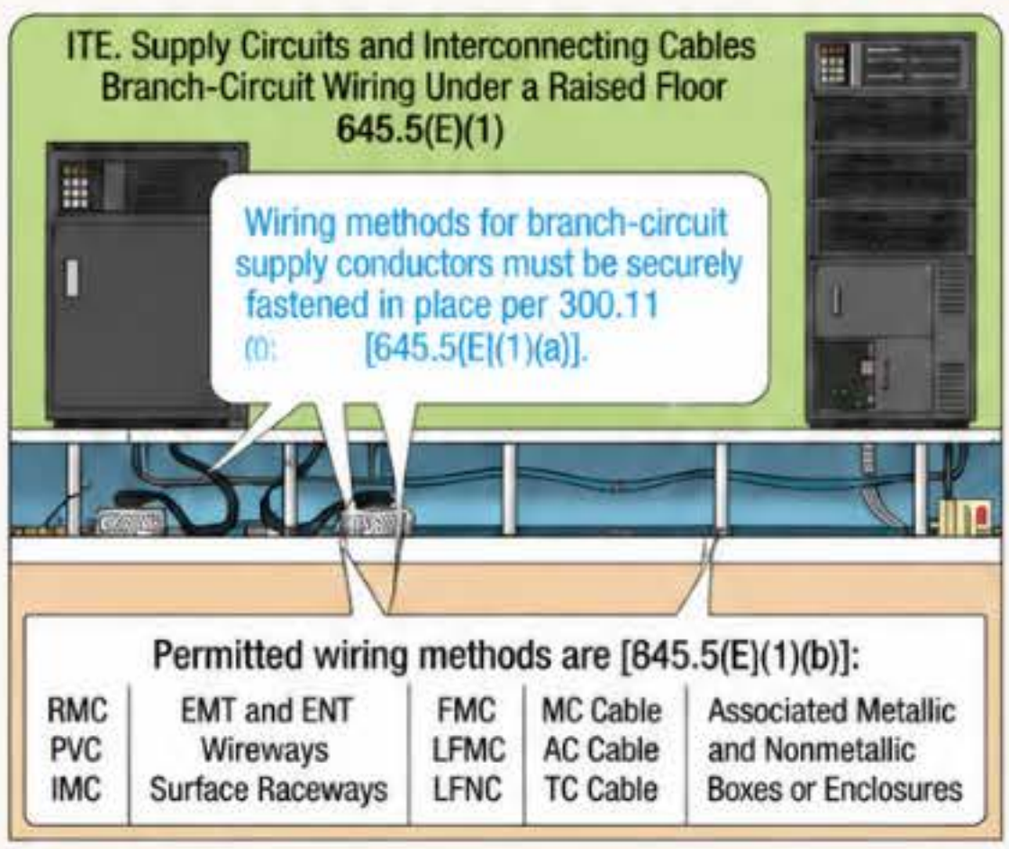
Information Technology Equipment (ITE) | 645.5



▶ Figure 645–2

(E) Under Raised Floors. Areas beneath raised floors should be kept open and accessible. Pathways and openings are provided to reduce the entry of debris from above, while still allowing for the installation of power cables, communications and data connecting cables, interconnecting cables, cord-and-plug assemblies, and receptacles belonging to information technology equipment. To meet installation requirements, all of the following must be satisfied:

(1) Branch-Circuit Wiring Under a Raised Floor. ▶ Figure 645–3



▶ Figure 645–3

(a) Branch-circuit wiring under a raised floor must be securely fastened in place in accordance with 300.11.

(b) The following wiring methods are permitted under a raised floor:

(1) Rigid metal conduit

(2) PVC conduit

(3) Intermediate metal conduit

(4) Electrical metallic tubing

(5) Electrical nonmetallic tubing

(6) Metal wireway

(7) Nonmetallic wireway

(8) Surface metal raceway with metal cover

(9) Surface nonmetallic raceway

(10) Flexible metal conduit

(11) Liquidtight flexible metal conduit

(12) Liquidtight flexible nonmetallic conduit

(13) Type MI cable

(14) Type MC cable

(15) Type AC cable

(16) Associated metallic and nonmetallic boxes or enclosures

(17) Type TC power and control tray cable

(2) Power-Supply Cords, Data Cables, Cables, and Conductors. Within the space below a raised floor, routing of power cords, interconnecting cables, cables, and conductors is allowed only in the following manner:

(1) Power-supply cords must be listed information technology equipment in accordance with 645.5(B).

(2) Interconnecting cables enclosed within a raceway

(3) Equipment grounding conductors

(4) Where the air space under a raised floor is protected by an automatic fire suppression system, in addition to wiring installed in accordance with 725.135(C), Types CL2P, CL3R, CL2, and CL3 and substitute cables including CMP, CMR, CM, and CMG installed in accordance with 725.154(A) are permitted under raised floors.

Note: Figure 725.154(A) in the *NEC* illustrates the cable substitution hierarchy for Class 2 cables.

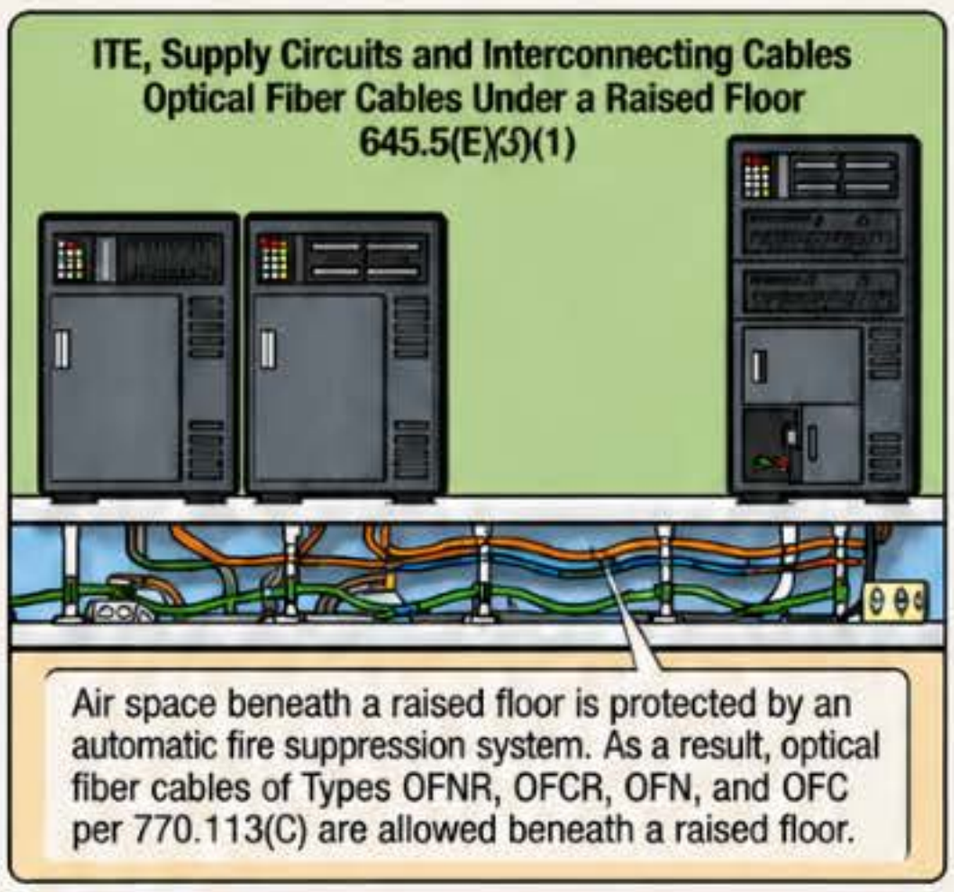
(5) Where the air space under a raised floor is not protected by an automatic fire suppression system, in addition to wiring installed in accordance with 725.135(C), substitute Type CMP cable installed in accordance with 725.154(A) is permitted under raised floors.

(6) Listed Type DP cable

(3) Installation Requirements for Optical Fiber Cables Under a Raised Floor.

645.5 | Information Technology Equipment (ITE)

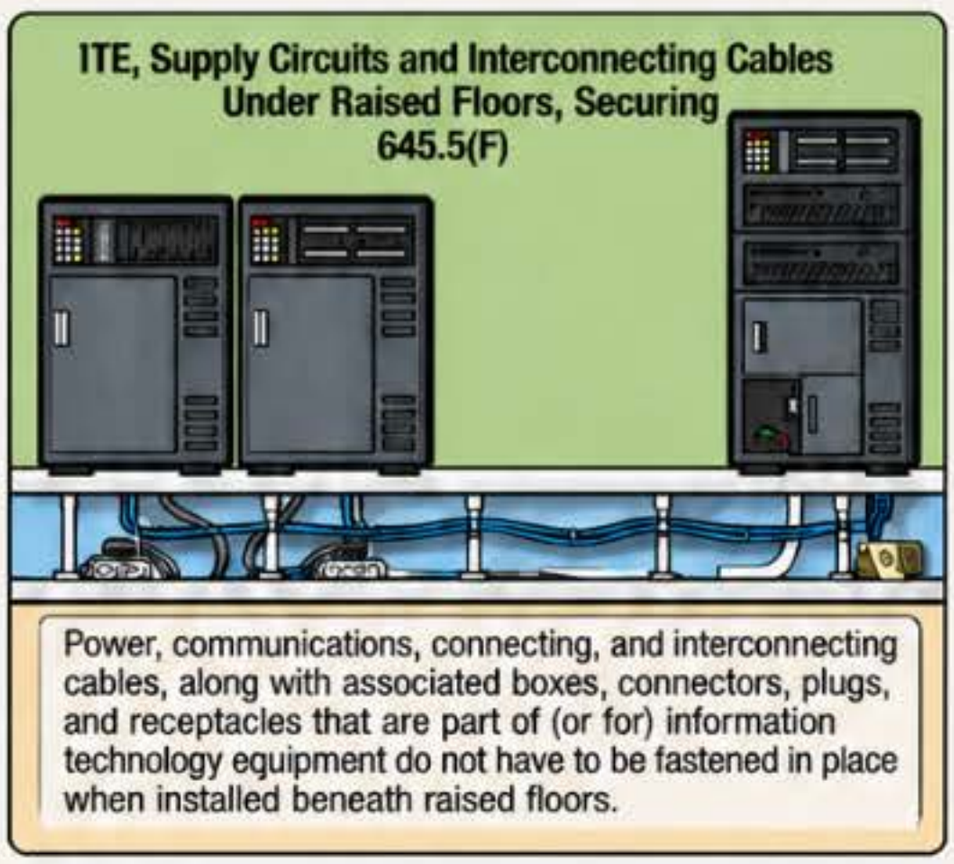
(1) Optical Fiber Cables Under a Raised Floor. When air space exists beneath a raised floor, install optical fiber cables of Types OFNR, OFCR, OFN, or OFC in a way that complies with 770.113(C). These cables are permitted under raised floors. ▶ Figure 645–4



▶ Figure 645–4

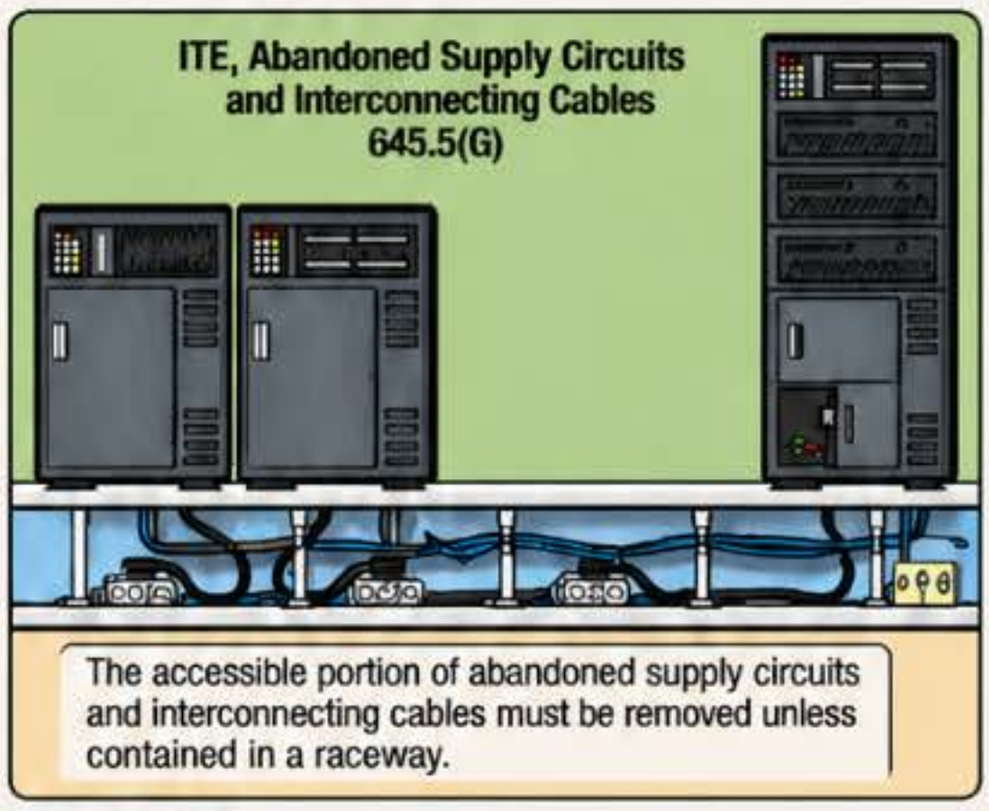
(2) Where the air space under a raised floor is not protected by automatic fire suppression, only optical fiber cables installed per 770.113(C) are permitted under raised floors.

(F) Securing in Place. Power cables, communications cables, connecting cables, interconnecting cables, and associated boxes, connectors, plugs, and receptacles that are part of (or for) information technology equipment are not required to be secured in place when installed under raised floors. ▶ Figure 645–5



▶ Figure 645–5

(G) Abandoned Supply Circuits and Interconnecting Cables. The accessible portion of abandoned supply circuits and interconnecting cables must be removed unless contained in raceway. ▶ Figure 645–6



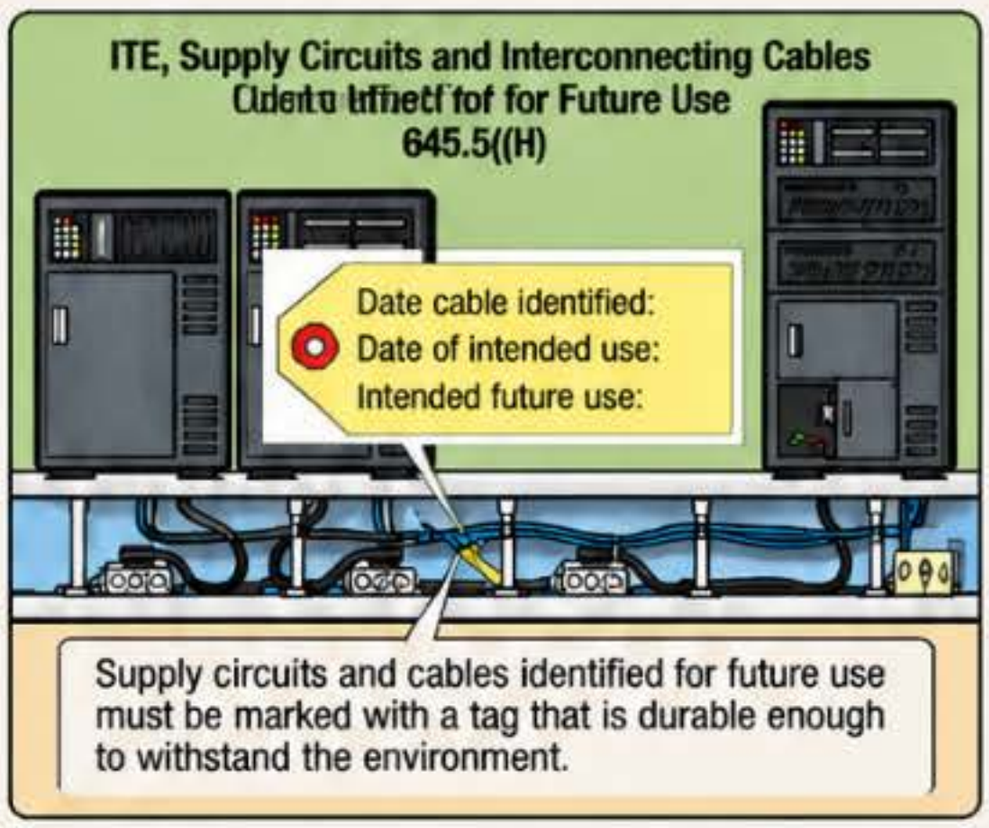
▶ Figure 645–6

Author's Commentary:

An abandoned cable is one that is not terminated to equipment and is not identified for future use with a tag [645.2].

— Michael Hamilton

(H) Installed Supply Circuits and Interconnecting Cables Identified for Future Use. ▶ Figure 645–7



▶ Figure 645–7

(1) Supply circuits and interconnecting cables identified for future use must be marked with a tag of sufficient durability to withstand the environment involved.

Information Technology Equipment (ITE) | 645.15

(2) Supply circuit tags and interconnecting cable tags must include these three items:

① Date identified for future use

② Date of intended use

③ Information relating to the intended future use

645.10 Disconnecting Means

A disconnect is required for electronic equipment in the information technology equipment room and for dedicated HVAC systems serving the room or in designated areas within the room.

(A) Remote Disconnect Controls.

① Remote disconnect controls must be positioned in an approved, readily accessible location.

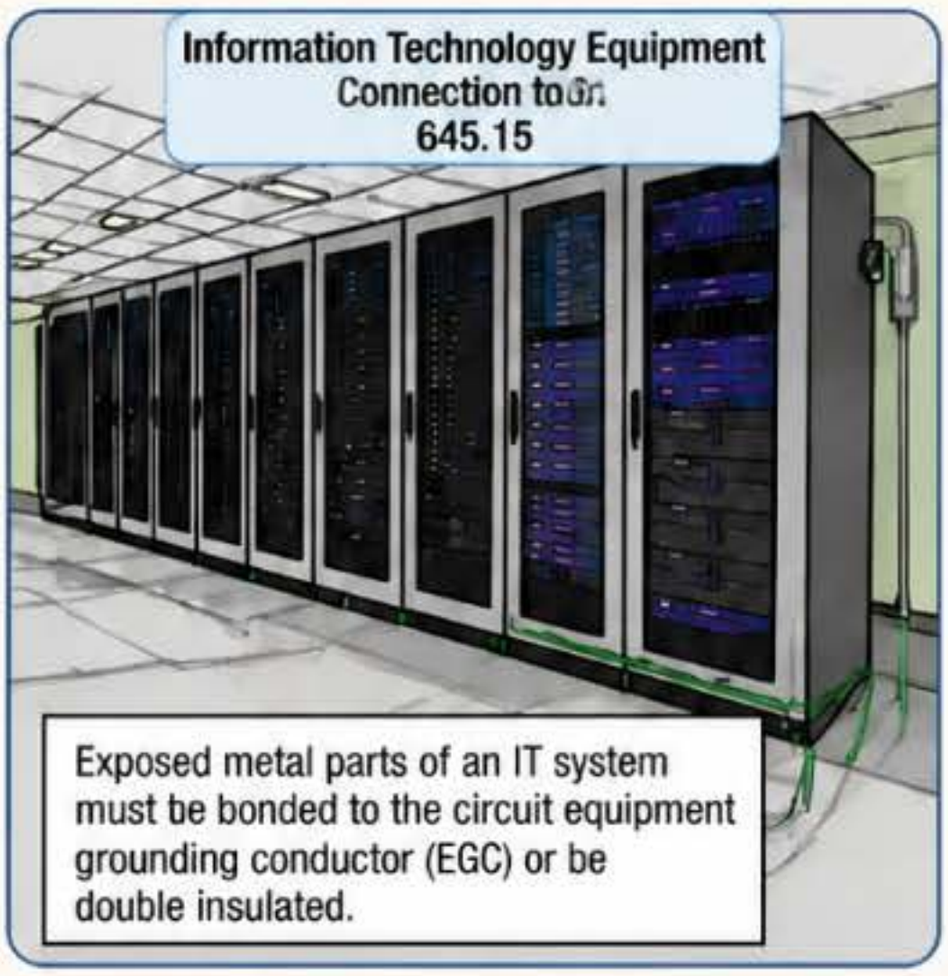
② The remote disconnect means for the control of electronic equipment power and HVAC systems must be grouped and identified. A single means to control both is allowed.

③ Additional measures aimed at preventing unintended operation of remote disconnect controls are allowed.

645.15 Equipment Grounding and Bonding

Exposed metal parts of information technology equipment must be connected to the circuit equipment grounding conductor or be double insulated.

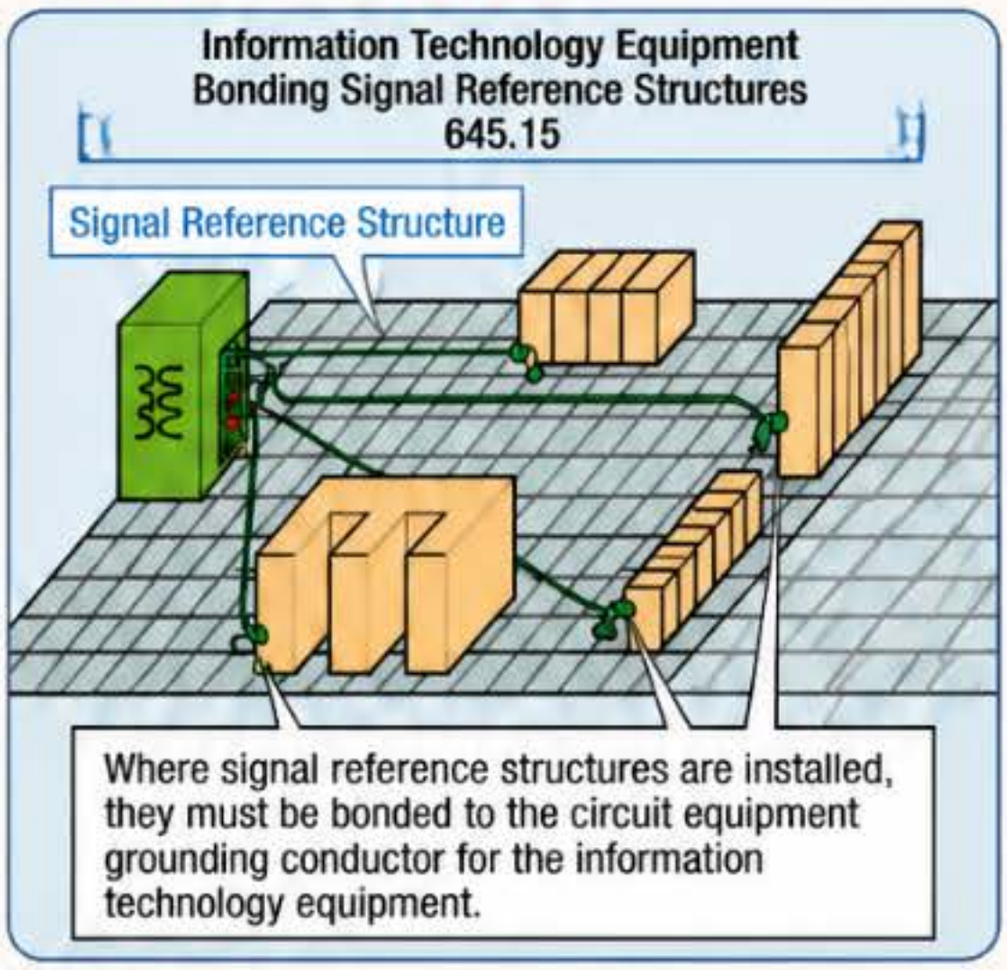
▶ **Figure 645–8**



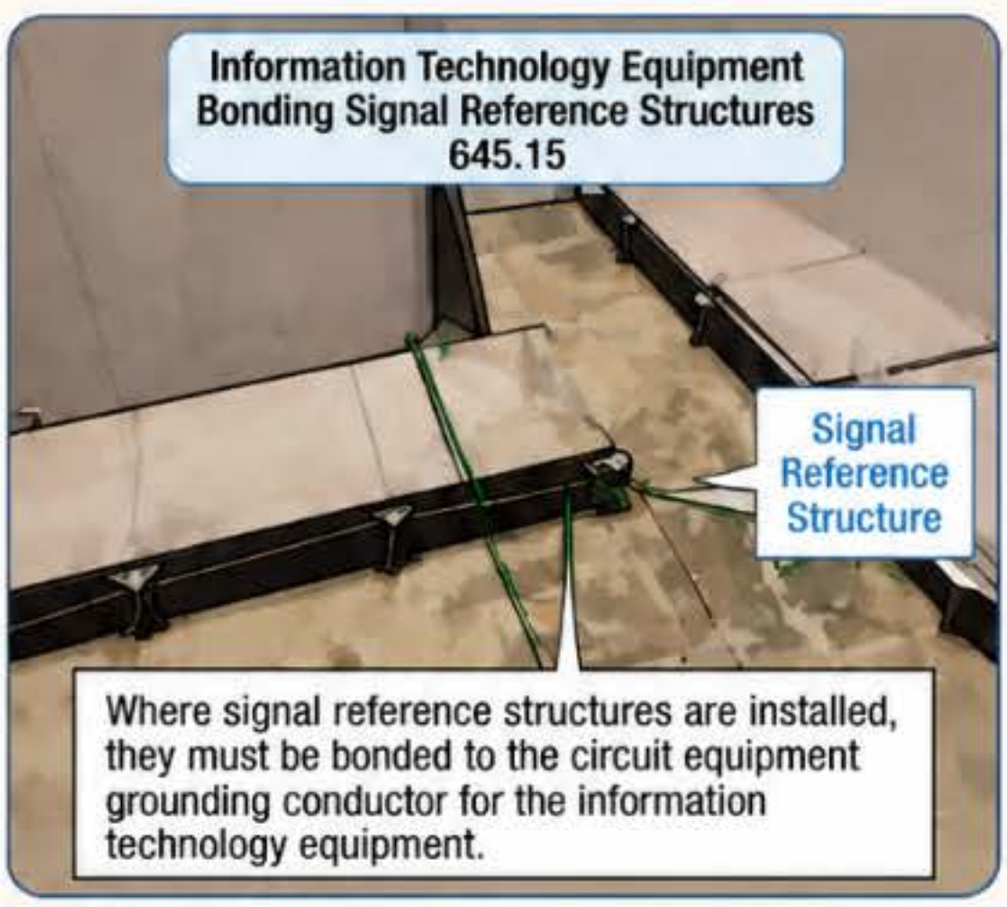
▶ **Figure 645–8**

Where signal reference structures are installed, they must be bonded to the circuit equipment grounding conductor for the information technology equipment.

▶ **Figure 645–9** and **Figure 645–10**



▶ **Figure 645–9**



▶ **Figure 645–10**

Note 2: If isolated ground receptacles are installed, they must be connected to an insulated equipment grounding conductor in accordance with 250.146(D) and 406.3(D).

Notes

ARTICLE 680 SWIMMING POOLS, SPAS, HOT TUBS, FOUNTAINS, AND SIMILAR INSTALLATIONS

Introduction to Article 680—Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations

The rules in Article 680 govern the installation of electrical wiring and equipment for swimming pools, spas, hot tubs, fountains, hydromassage bathtubs, and electrically powered pool lifts. A major reason for these requirements is to protect people from electric shock.

Article 680 is organized into eight parts. Because each part covers different types of installations, it's important to identify which sections apply to a given job. Part I applies to spas and hot tubs installed outdoors, except those modified in the field in accordance with Part IV. Hydromassage bathtubs are addressed only in Part VII. Read Article 680 carefully so you can deliver a safe installation.

- **Part I. General.**
- **Part II. Permanently Installed Pools.** Installations for permanently installed pools must comply with both Parts I and II.
- **Part III. Storable Swimming Pools, Storable Spas, and Storable Hot Tubs.** Installations of storable pools, storable spas, and storable hot tubs must comply with Parts I and III of Article 680.
- **Part IV. Spas and Hot Tubs.** Spas and hot tubs must comply with Parts I and IV of this article; outdoor spas and hot tubs must also comply with Part II in accordance with 680.42.
- **Part V. Fountains.** Parts I and V apply to permanently installed fountains. If they have water in common with a pool, Part II also applies. Self-contained, portable fountains are covered by Article 422, Parts II and III.
- **Part VI. Pools and Tubs for Therapeutic Use.** Parts I and VI apply to pools and tubs for therapeutic use in health care facilities, gymnasiums, athletic training rooms, and similar installations.
- **Part VII. Hydromassage Bathtubs.** Only Part VII of Article 680 applies to hydromassage bathtubs.
- **Part VIII. Electrically Powered Pool Lifts.** Parts I and II apply to electrically powered pool lifts only when referenced in Part VIII.

Part I. General Requirements for Pools, Spas, Hot Tubs, and Fountains

Author's Commentary:

This part establishes the baseline rules for permanently installed pools (680.20), storable pools (680.30), spas and hot tubs (680.42 and 680.43), fountains (680.50), and pool lifts (680.80).

— Michael Hamilton

680.1 Scope

Figure 680–1

Article 680 covers electrical wiring and equipment for swimming pools, hot tubs, spas, fountains, hydromassage bathtubs, and pool lifts.

680.2 | Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations

Figure 680–1

680.2 Definitions

The definitions in this section apply only within this article.

Corrosive Environment. Locations where pool sanitation chemicals are stored, handled, or dispensed; and enclosed spots below decks next to such areas as well as locations with circulation pumps, automatic chlorinators, filters, open areas beneath decking adjacent to or abutting the pool structure, and comparable sites. ▸ Figure 680–2

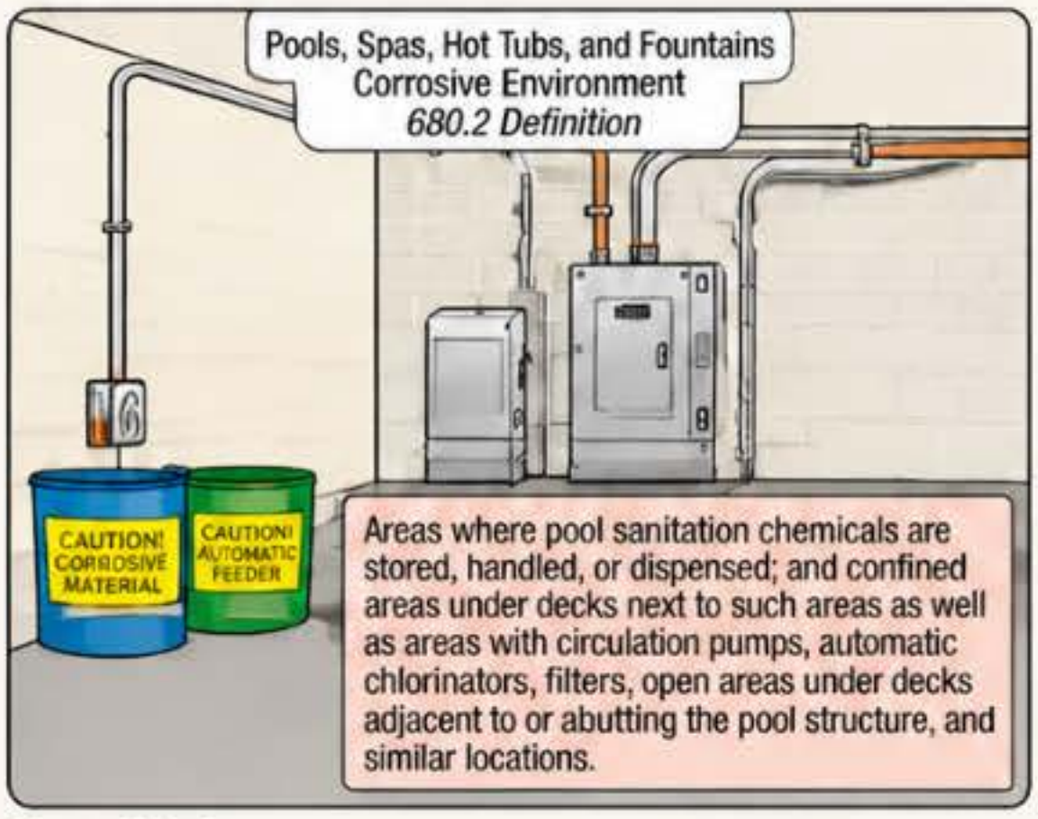


Figure 680–2

Note: Sanitation chemicals and pool water pose a risk of corrosion that can gradually weaken or destroy materials because of the presence of ***oxidizers*** (for example, calcium hypochlorite, sodium hypochlorite, bromine, and chlorinated isocyanurates) and ***chlorinating agents*** that release chlorine when dissolved in water. These substances liberate chlorine when they dissolve. Additional information on swimming pool chemicals can be found on or linked from the following resources:

1. Environmental Protection Agency website
2. NFPA 400, *Hazardous Materials Code*
3. *Advisory: Swimming Pool Chemicals: Chlorine,* OSWER 90-008.1, available from the EPA National Service Center for Environmental Publications (NSCEP)

Electrically Powered Pool Lift. An electrically powered lift that provides accessibility to and from a pool or spa for people with disabilities. ▸ Figure 680–3

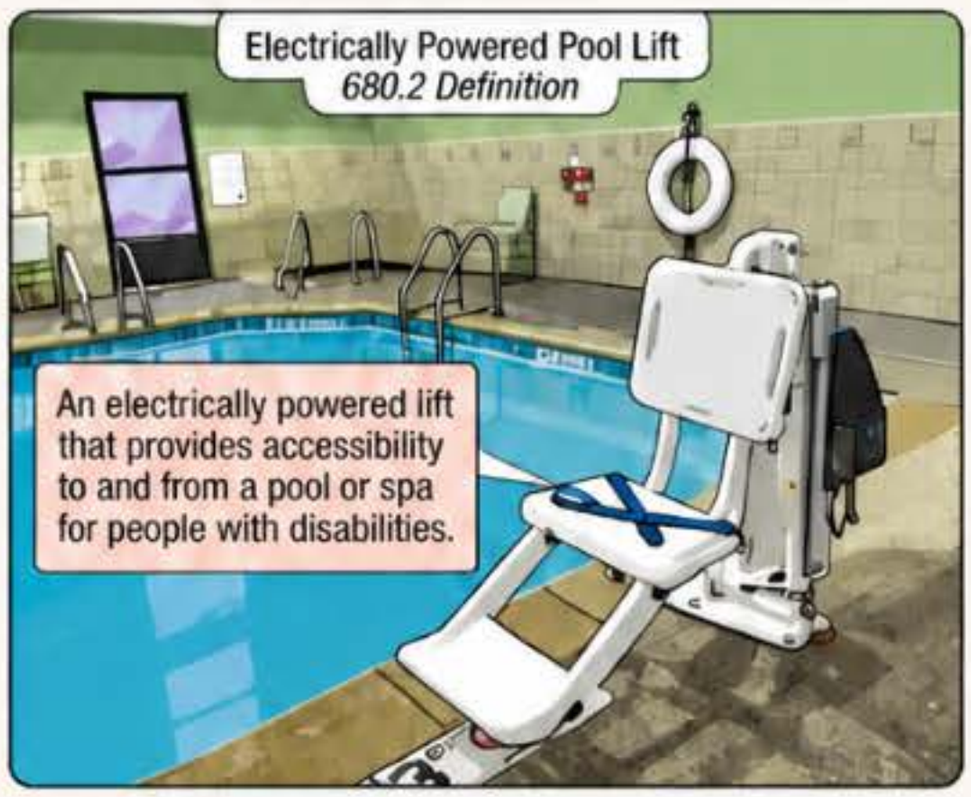


Figure 680–3

Forming Shell. A structure designed to support a wet-niche luminaire. ▸ Figure 680–4

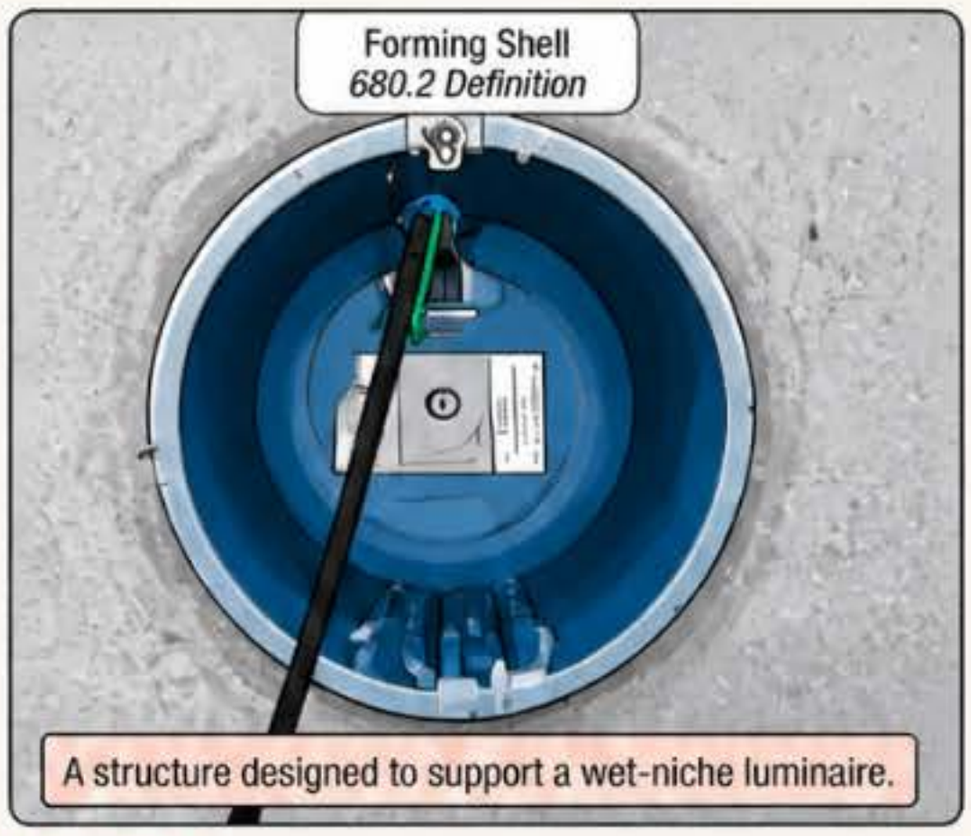
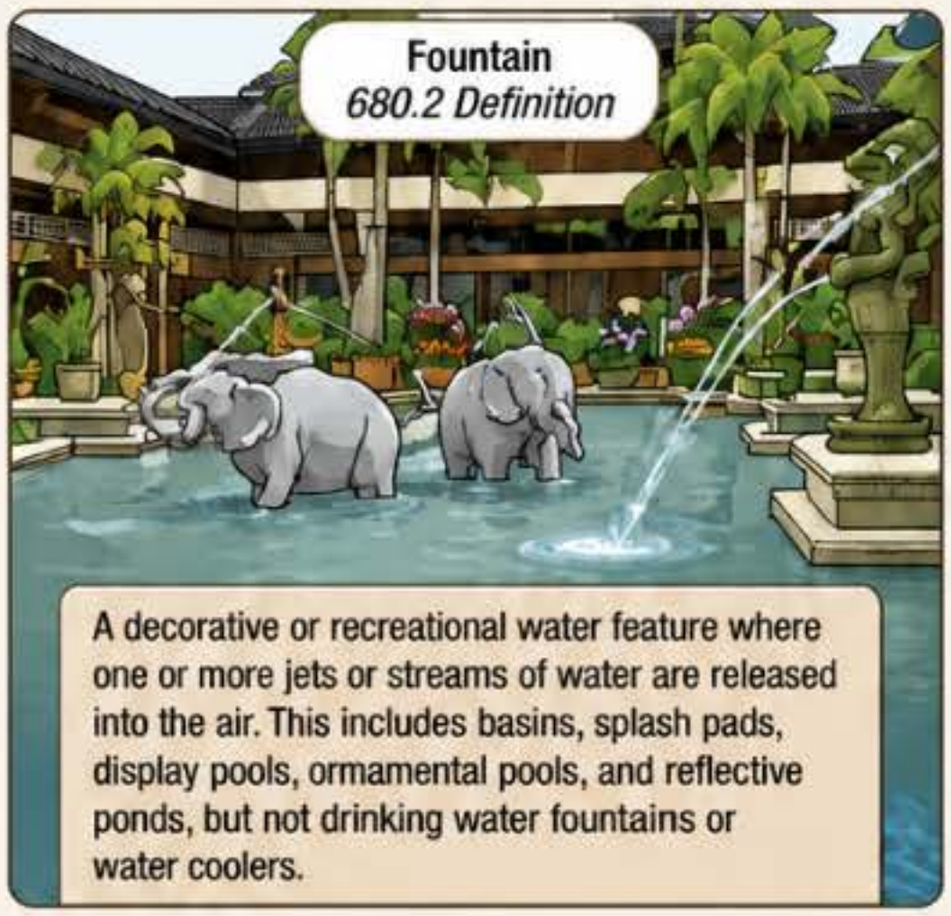


Figure 680–4

Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations | 680.2

Fountain. A fountain is a decorative water feature or recreational installation where one or more jets or streams of water are released into the air or flow across water that collects in basins, splash pads, display pools, ornamental pools, or reflective ponds. This definition does not include fixtures intended only for drinking water fountains or water coolers.



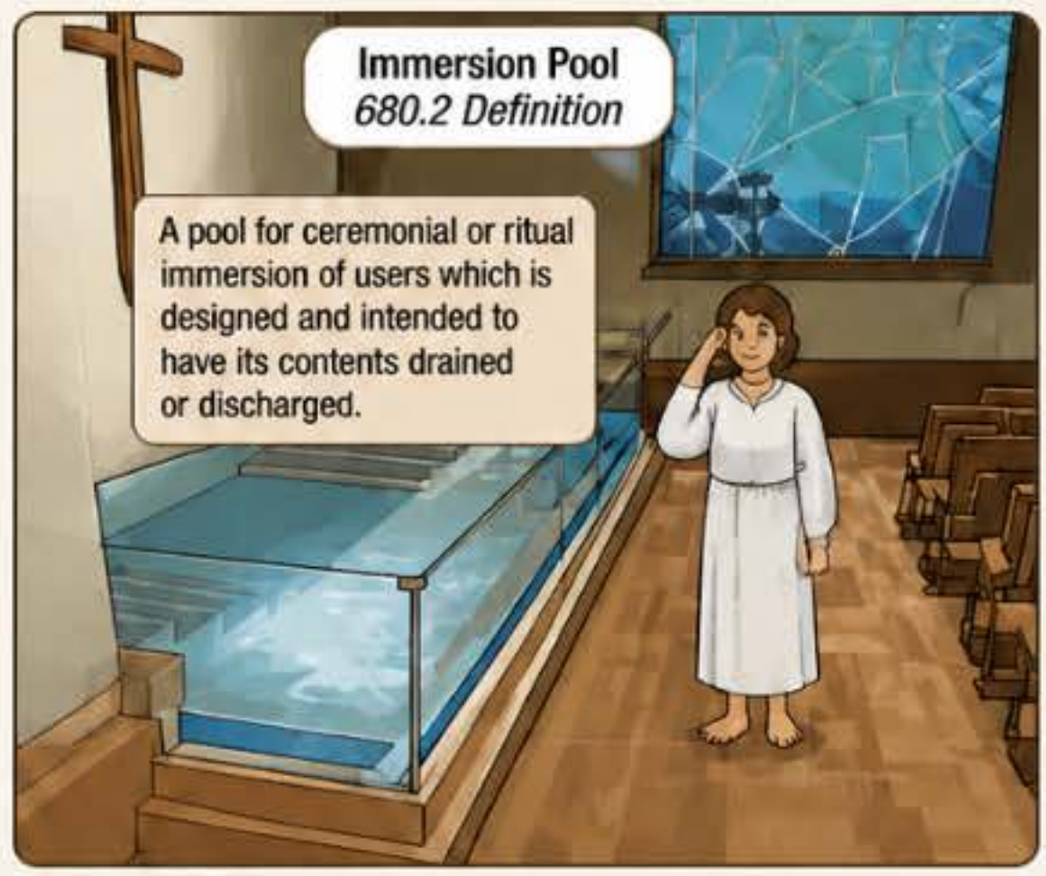
▶ Figure 680-5

Hydromassage Bathtub. A permanently installed tub equipped with a recirculating piping system that accepts, circulates, and discharges water after each use.

▶ Figure 680-6

Immersion Pool. A pool used for ceremonial or ritual immersion of users that is intended to have its contents drained or discharged.

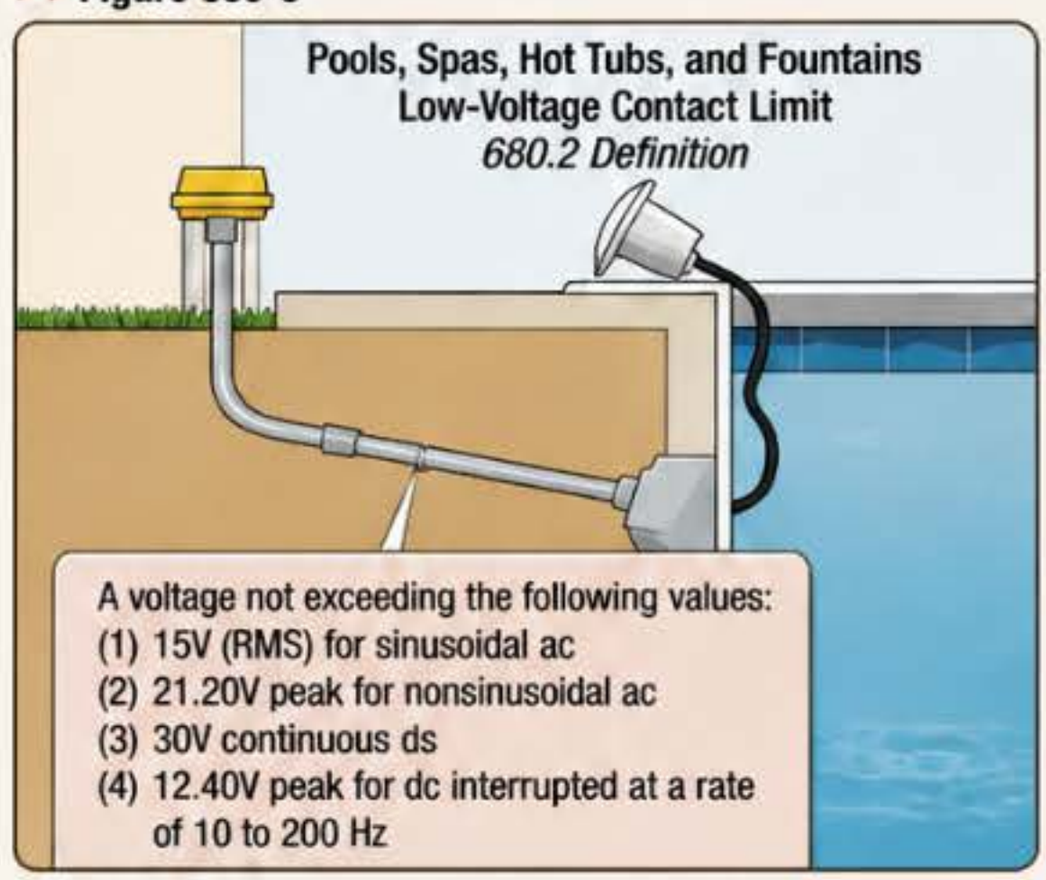
▶ Figure 680-7



▶ Figure 680-7

Low-Voltage Contact Limit. A voltage not exceeding the following values:

▶▶ Figure 680-8



▶ Figure 680-8

(1) 15V (RMS) for sinusoidal alternating current.

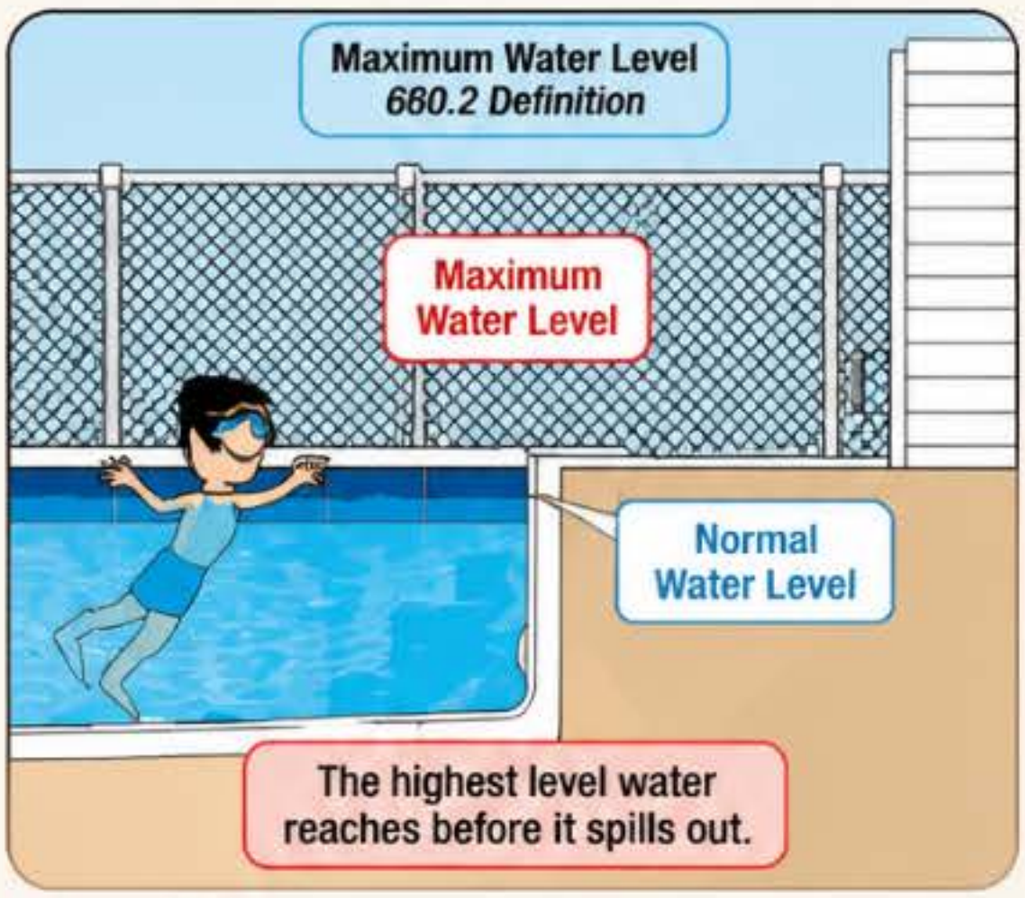
(2) 21.20V peak for nonsinusoidal alternating current.

(3) 30V for continuous direct current.

(4) 12.40V peak for direct current that is interrupted at a rate of 10 to 200 Hz.

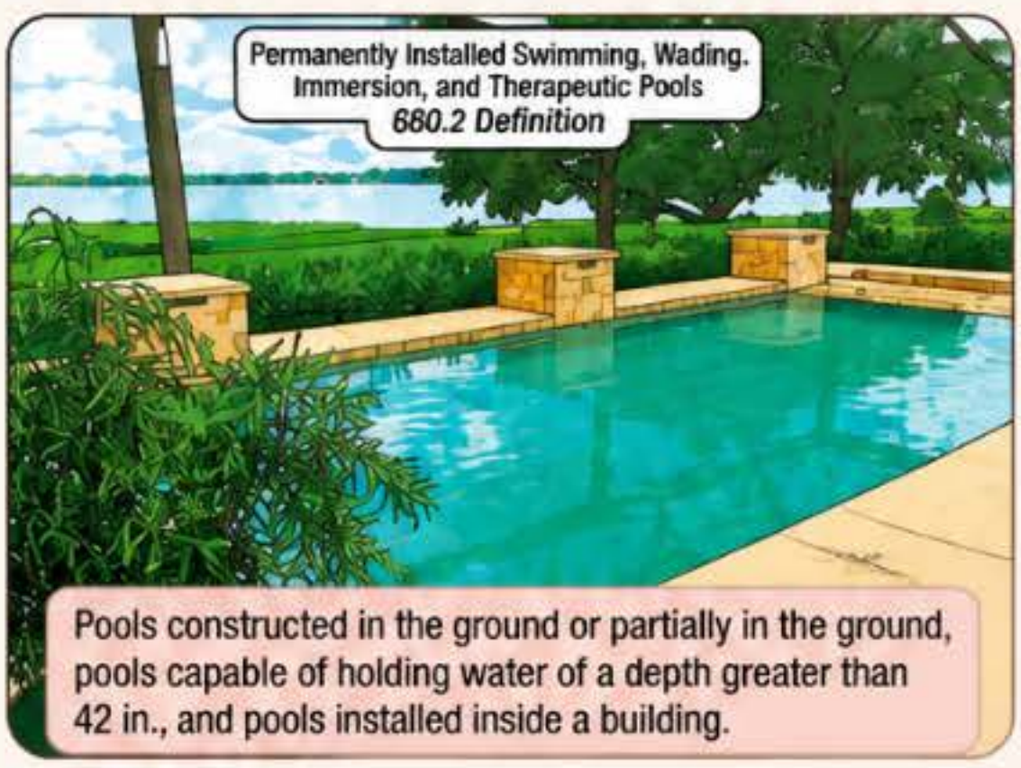
Maximum Water Level. The highest level water reaches before it spills out. ▶ Figure 680-9

680.2 Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations



▶ **Figure 680–9**

Permanently Installed Swimming, Wading, Immersion, and Therapeutic Pools. Pools constructed in the ground or partially in the ground, pools capable of holding water of a depth greater than 42 in., and pools installed inside of a building. **Figure 680–10**



▶ **Figure 680–10**

Pool. Manufactured or field-constructed equipment designed to contain water on a permanent or semipermanent basis and used for swimming, wading, immersion, or other purposes.

Author's Commentary:

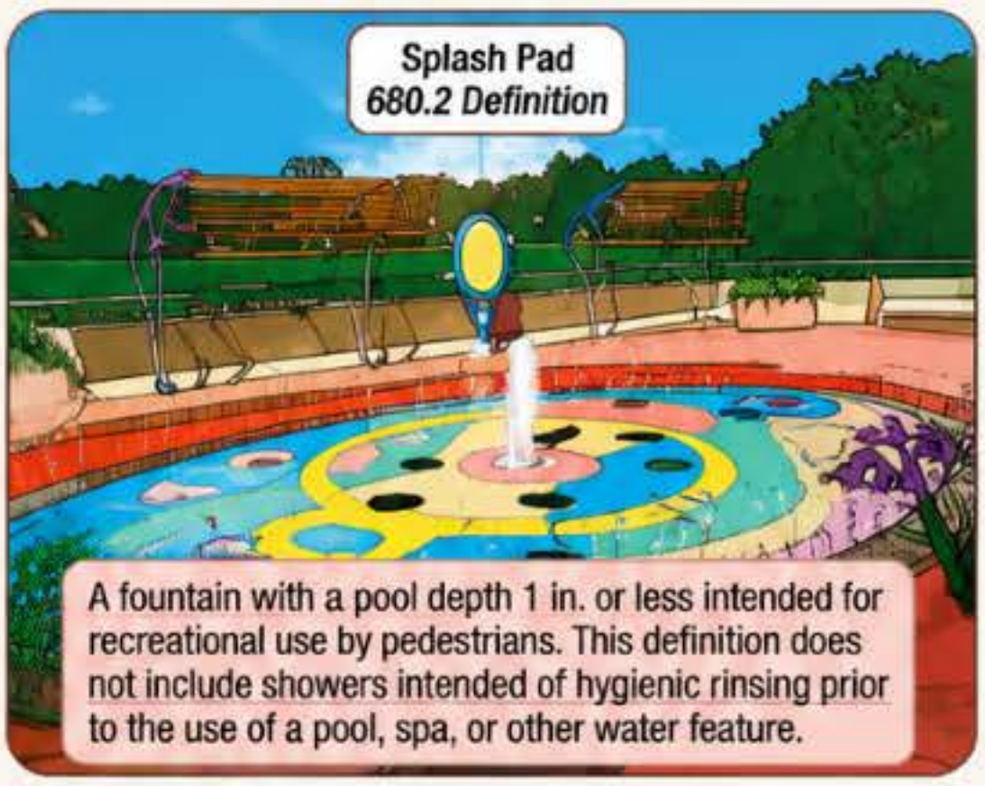
- The definition of a pool includes baptisteries (immersion pools) which must comply with the requirements of Article 680.
- An above ground pool having a maximom water depth greater than 42 in. is considered a permanent pool. See the definition of "storable pool."

— Michael Hamilton

Spa or Hot Tub. A hydromassage pool or tub designed for recreational or therapeutic use typically not drained after each use. **Figure 680–11**

▶ **Figure 680–11**

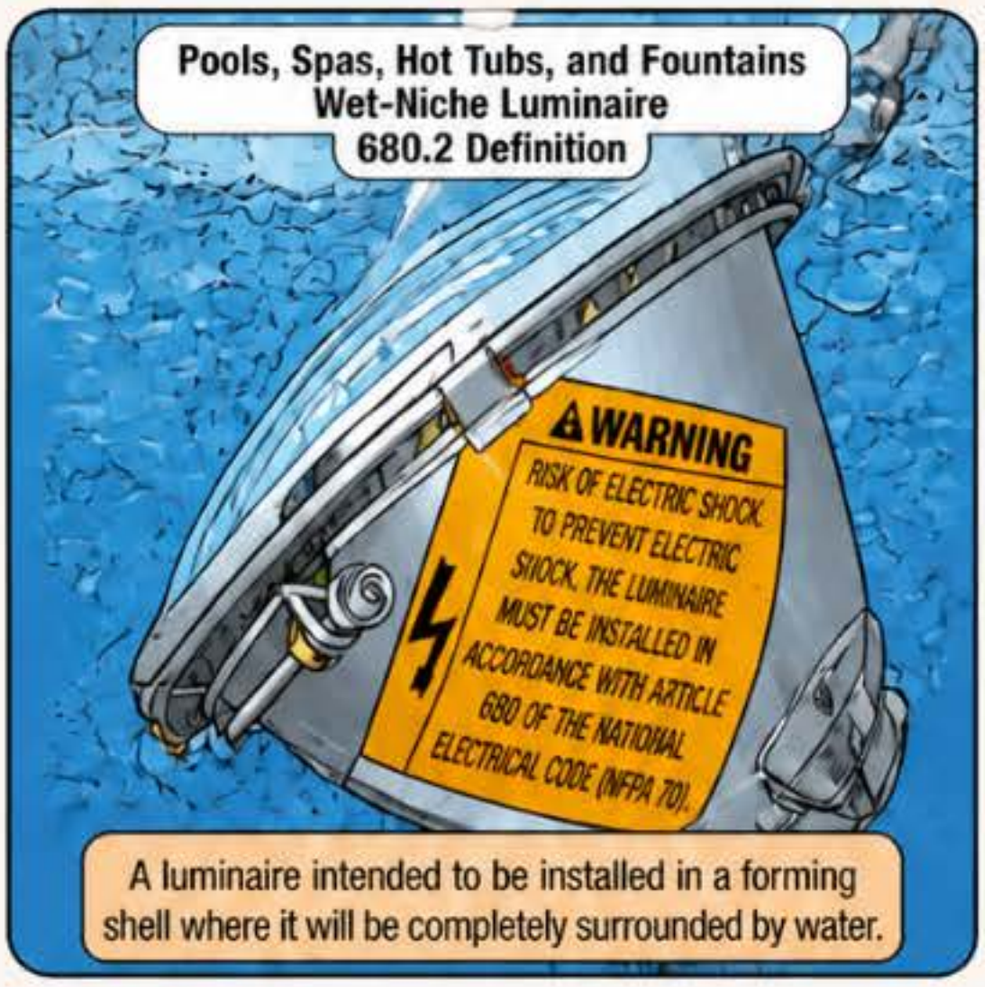
Splash Pad. A fountain with a water depth 1 in. or less intended for recreational use by pedestrians. This definition does not include showers intended for hygienic rinsing prior to use of a pool, spa, or other water feature. **Figure 680–12**



▶ **Figure 680–12**

Storable Swimming Pools. A pool that is intended to be stored when not in use, constructed on or above the ground, and is capable of holding water to a depth of 42 in., or a pool constructed with nonmetallic, molded polymeric walls or inftatable fabric walls regardless of dimensions.

Wet-Niche Luminaire. A luminaire intended to be installed in a forming shell where it will be completely surrounded by water. **Figure 680–13**



▸ Figure 680–13

680.3 Approval of Equipment

Electrical devices and products addressed in this article must be listed and installed in a manner that complies with this article.

680.4 Inspections After Installation

The authority having jurisdiction is allowed to require periodic inspections and testing.

680.5 Ground-Fault Circuit Interrupters

The GFCI requirements in Article 680, unless otherwise noted, are in addition to the requirements in 210.8.

680.6 Bonding and Equipment Grounding

Electrical equipment must be bonded according to Part V of Article 250 and connected to the equipment grounding conductor requirements of Parts VI and VII of that article. Equipment must be connected by the wiring methods in Chapter 3 unless changed by this article. Equipment subject to these requirements include:

(1) Through-wall lighting assemblies and underwater luminaires except for listed low-voltage lighting.

(2) All electrical equipment within 5 ft of the inside wall of the specified body of water.

(3) All electrical equipment associated with the water recirculating system.

(4) Junction boxes.

(5) Transformer and power-supply enclosures.

(6) Ground-fault circuit interrupters.

(7) Subpanels that supply associated equipment.

680.7 Bonding and Equipment Grounding Terminals

Terminals used for bonding and equipment grounding must be identified as suitable for use in wet and corrosive locations. Field-installed terminals in damp, wet, and corrosive settings must be copper, copper alloy, or stainless steel and are listed for direct burial use. ▸ Figure 680–14

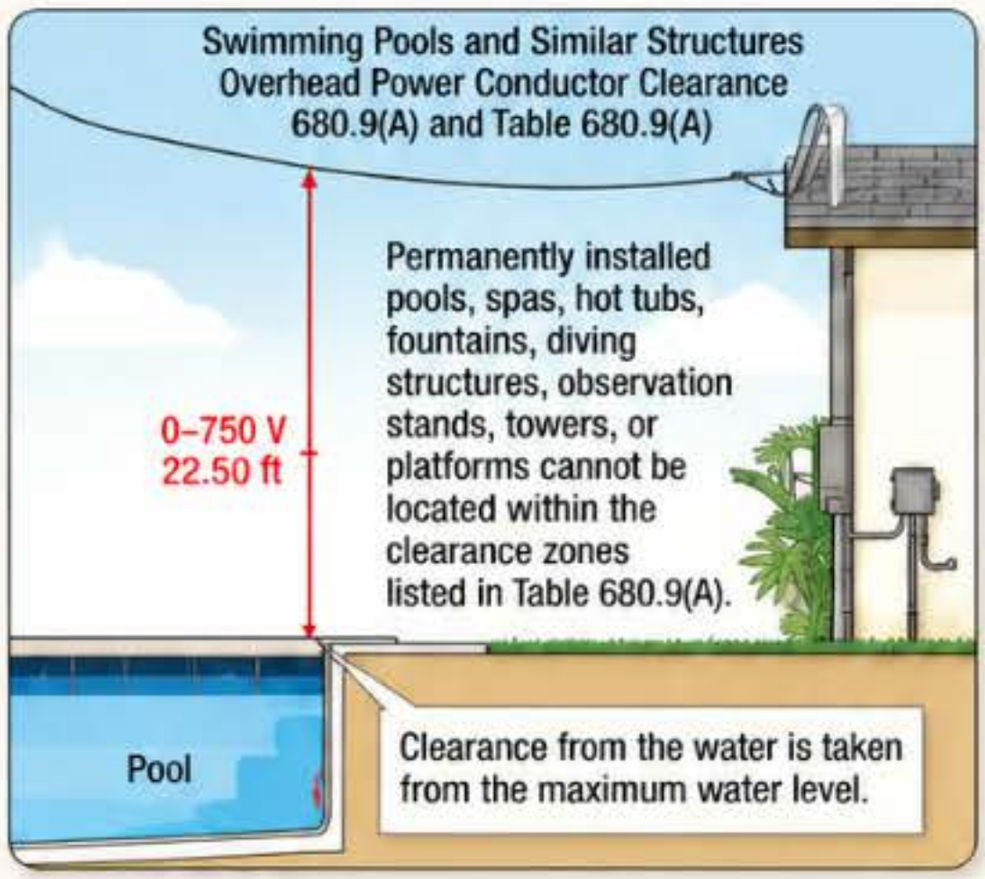
▸ Figure 680–14

680.9 Overhead Conductor Clearance

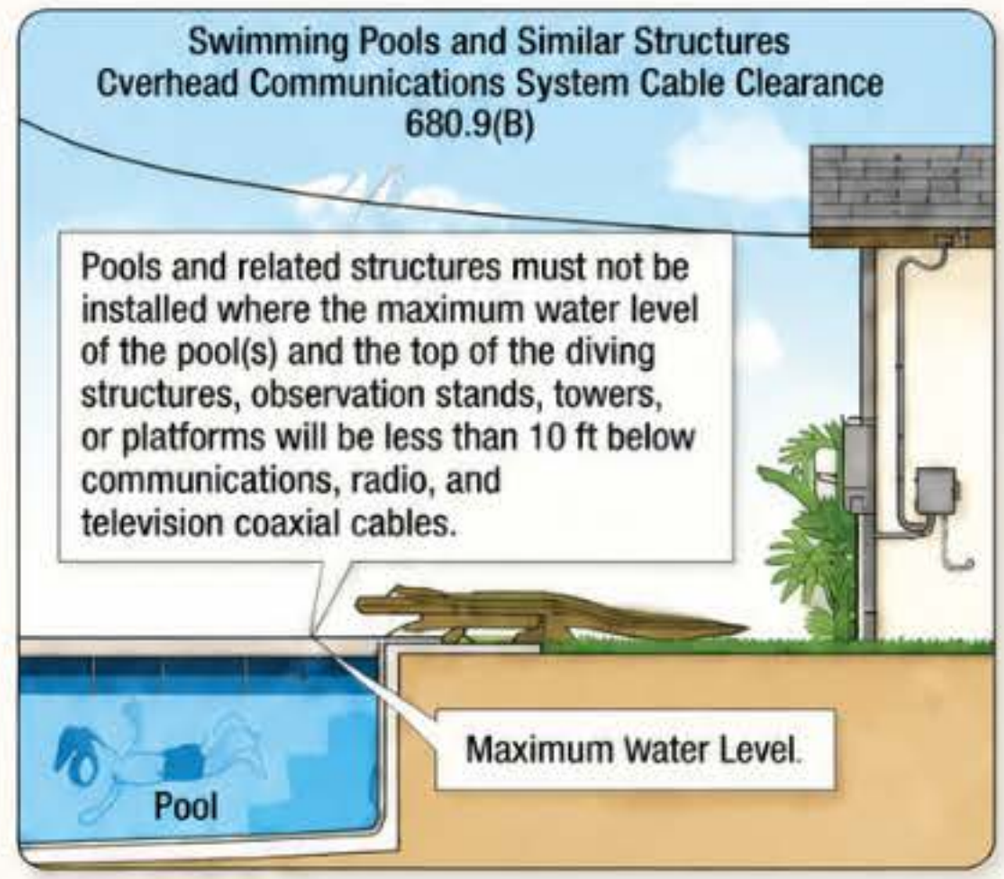
Overhead conductors must maintain the minimum clearance from the maximum water level requirements shown in Table 680.9(A).

(A) Overhead Power Conductors. Permanently installed pools, spas, hot tubs, fountains, diving structures, observation stands, towers, or platforms cannot be placed within the clearances listed in Table 680.9(A). ▸ Figure 680–15 and ▸ Figure 680–16

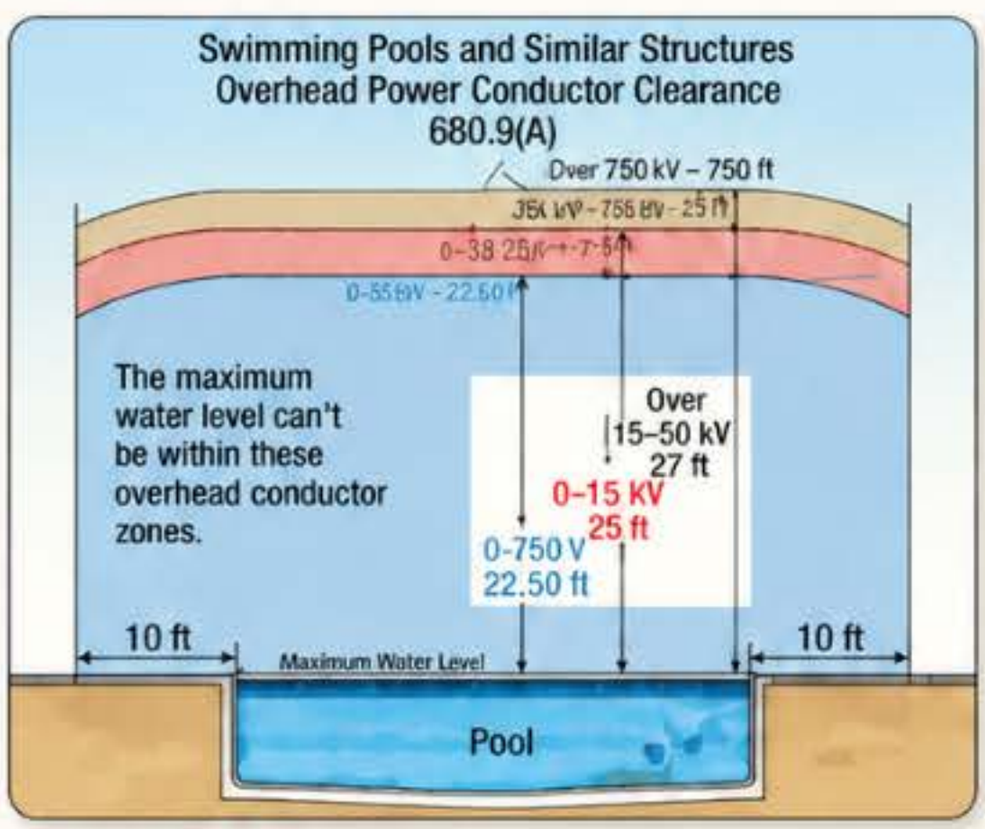
680.10 | Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations



▸ Figure 680–15



▸ Figure 680–17



▸ Figure 680–16

Author's Commentary:

This rule does not allow a utility-owned communications overhead cable to be installed over a pool, spa, hot tub, or fountain [90.2(B)(4)]. It also prohibits placing a pool, spa, hot tub, or fountain under an existing communications utility overhead supply if it would be less than 10 ft above the water.

— Michael Hamilton

Author's Commentary:

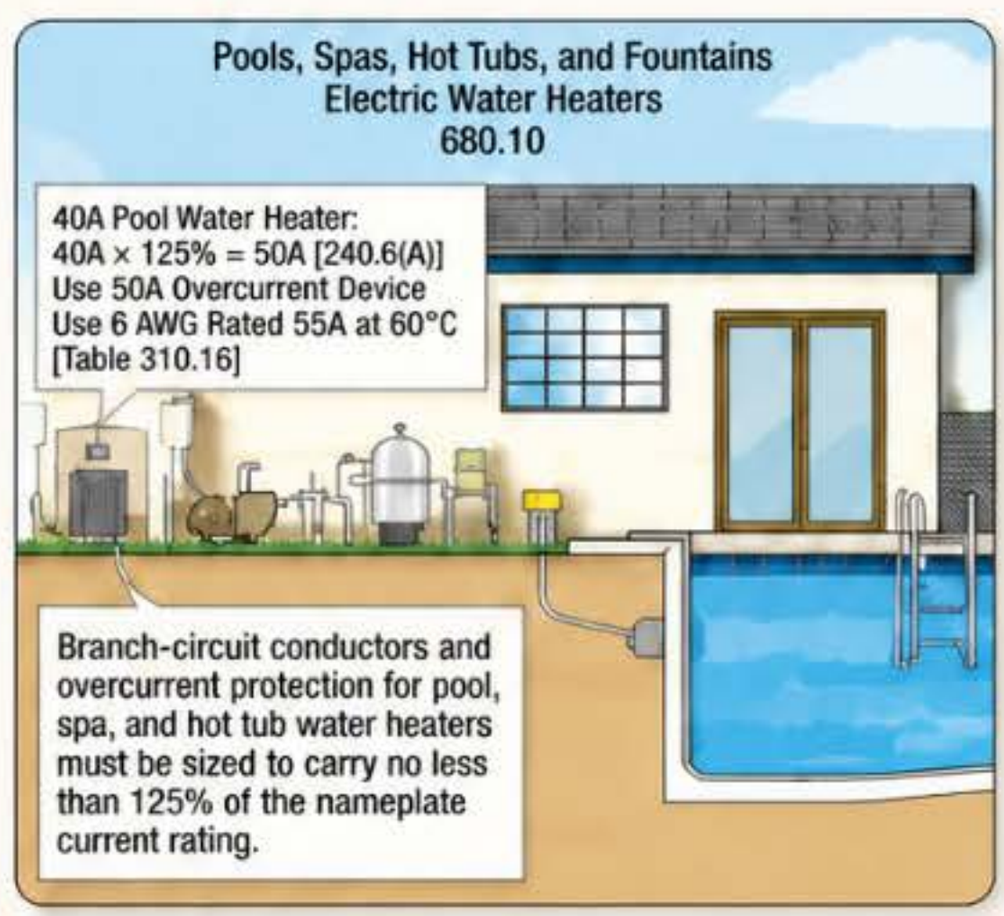
This rule does not permit utility-owned overhead service-drop conductors to be installed over a pool, spa, hot tub, or fountain [90.2(B)(5)]. However, it also disallows placing a pool, spa, hot tub, or fountain under an existing service drop if it would be less than 22½ ft above the water.

— Michael Hamilton

(B) Communications Systems. Swimming and wading pools, and diving structures, observation stands, towers, or platforms must not be installed where the maximum water level of the pool(s) and the top of the diving structures, observation stands, towers, or platforms will be less than 10 ft below communications, radio, and television coaxial cables. ▸ Figure 680–17

680.10 Electric Water Heaters

Branch-circuit conductors and overcurrent protection for pool, spa, and hot tub water heaters must be sized to carry no less than 125 percent of the nameplate current rating. ▸ Figure 680–18



▸ Figure 680–18

680.11 Underground Wiring

(A) Underground Wiring. Buried conductors located within 5 ft horizontally from the interior pool wall must be installed using one of these approved wiring methods. ▸ Figure 680–19

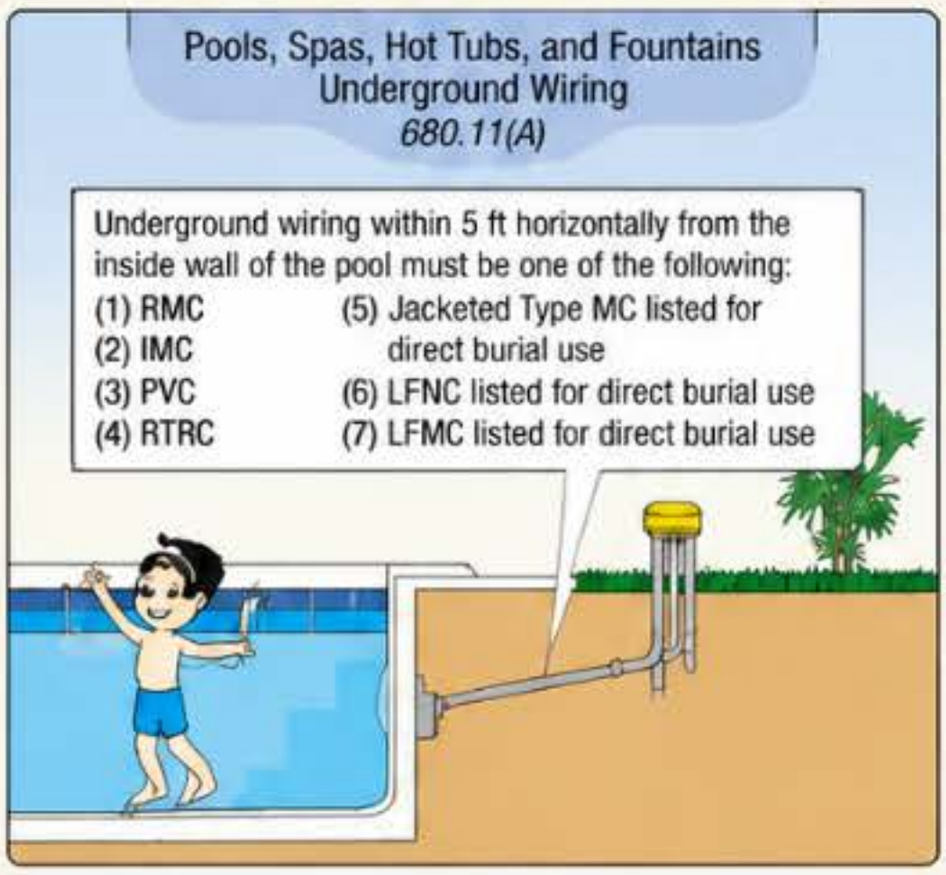


Figure 680–19

(1) Rigid metal conduit
(2) Intermediate metal conduit
(3) Rigid polyvinyl chloride conduit
(4) Reinforced thermosetting resin conduit
(5) Jacketed Type MC cable listed for direct burial use
(6) Liquidtight flexible nonmetallic conduit listed for direct burial use
(7) Liquidtight flexible metal conduit listed for direct burial use

(B) Wiring Under Pools. Conductors buried below pools are permitted to be supplied by equipment permitted by this article and by no other sources.

(C) Minimum Cover Requirements. A minimum soil cover of 300.5 applies.

680.12 Equipment Rooms and Pits

Permanently installed pools, portable pools, spas, hot tubs, or fountain systems may not be placed in equipment rooms or pits that do not have drainage provisions designed to prevent water accumulation during normal operation or maintenance. ▸ Figure 680–20

Equipment must be suitable for the corrosive environment in accordance with 300.6.

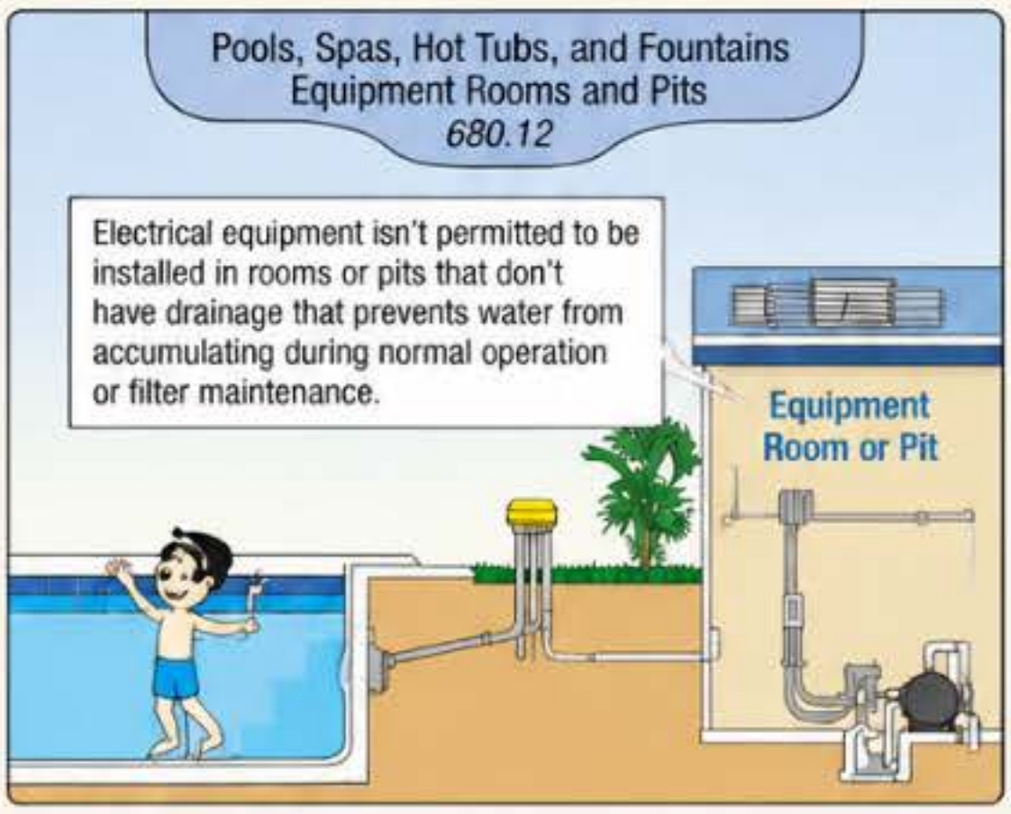


Figure 680–20

680.13 Maintenance Disconnecting Means

A maintenance disconnect is required for pool, spa, hot tub, or fountain equipment other than lighting. The disconnect must be conveniently accessible and located within clear sight and at least 5 ft from the pool, spa, hot tub, or fountain equipment unless separated from the open water by a permanently installed barrier. distance is distance measured from the water's edge along the shortest practical path to the disconnect. ▸ Figure 680–21

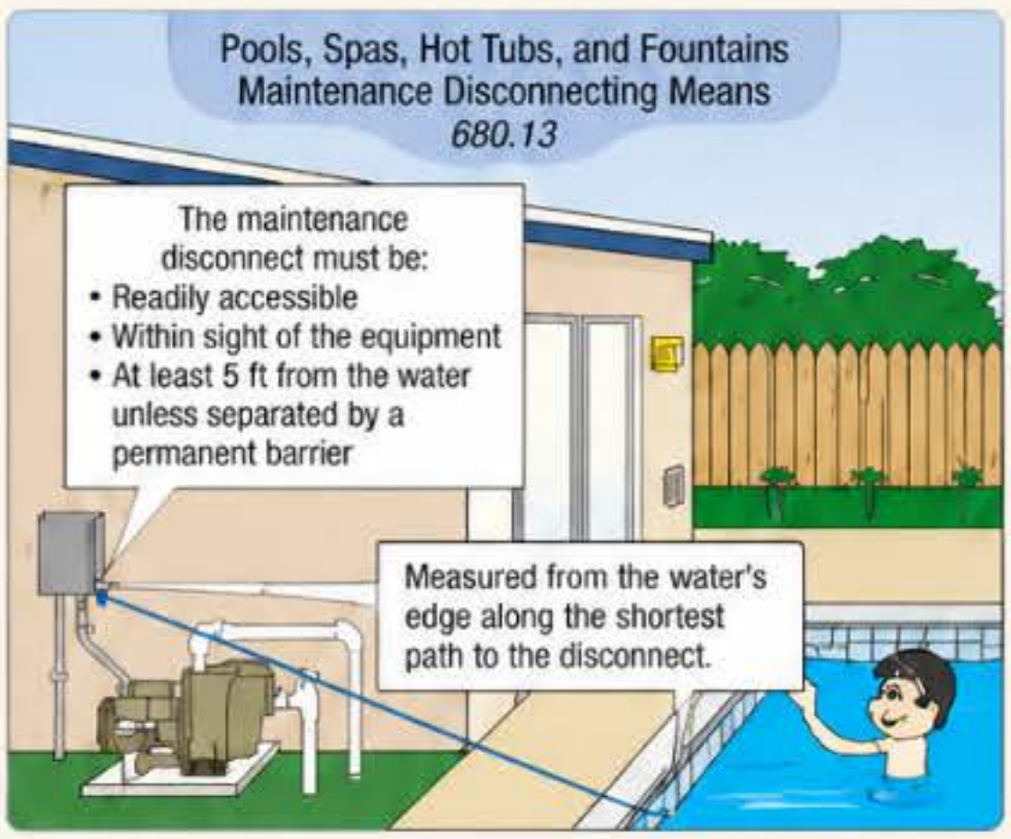


Figure 680–21

Author's Commentary:
Article 100, "Within Sight," means that it is clearly visible and not more than 50 ft from the equipment.

— Michael Hamilton

680.14 Wiring Methods in Corrosive Environment

Wiring in corrosive locations must be protected by suitable metal raceway—rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit, or reinforced thermosetting resin conduit. **Figure 680–22**

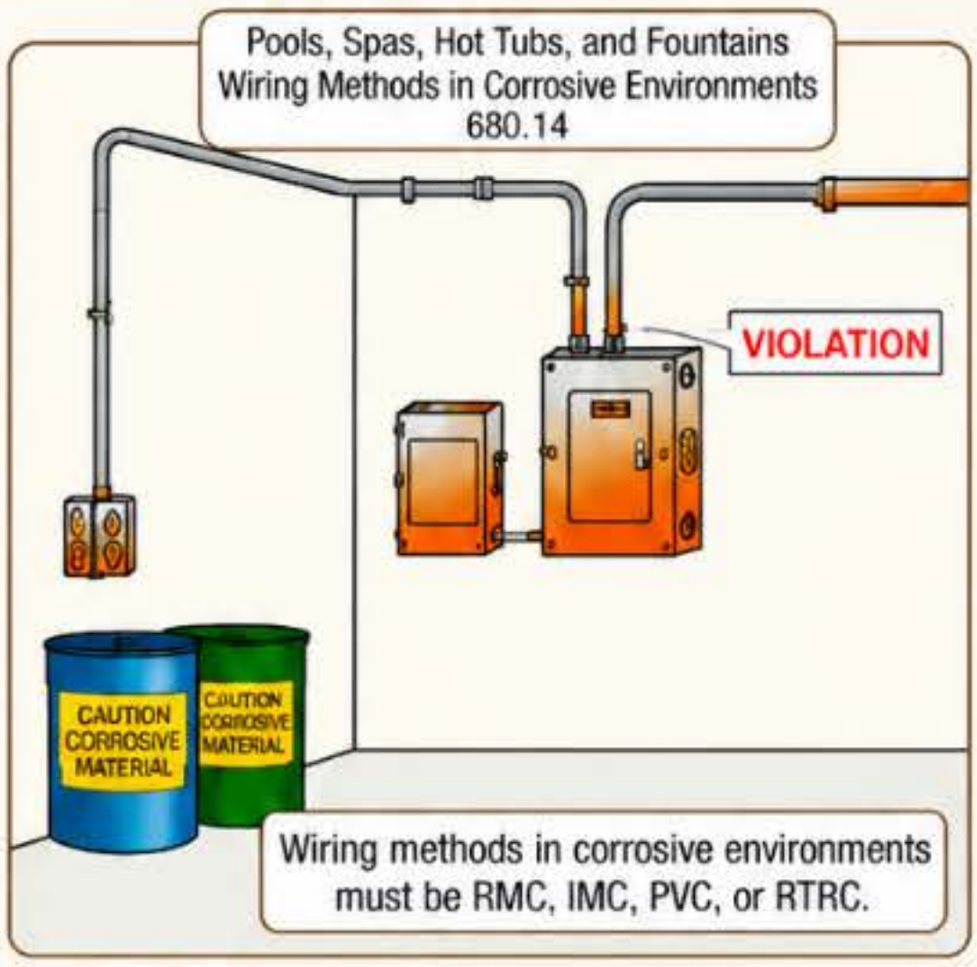


Figure 680–22

Part II. Permanently Installed Pools

680.20 General

The requirements in Part I and Part II apply to permanently installed pools as defined by 680.2 and aboveground pools having a water depth greater than 42 in.

680.21 Pool Motors

(A) Wiring Methods. The wiring to a pool-associated motor must comply with 680.21(A)(1) unless modified by (A)(2) or (A)(3).

(1) General. Branch-circuit wiring for pool-associated motors installed in corrosive locations must be protected by rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit, reinforced thermosetting resin conduit (680.14), or Type MC cable listed for the location. **Figure 680–23**

The wiring methods must include an insulated copper equipment grounding conductor sized per 250.122, but in no case shall it be smaller than 12 AWG. **Figure 680–24**

Where installed in noncorrosive environments, any Chapter 3 wiring method is permitted.

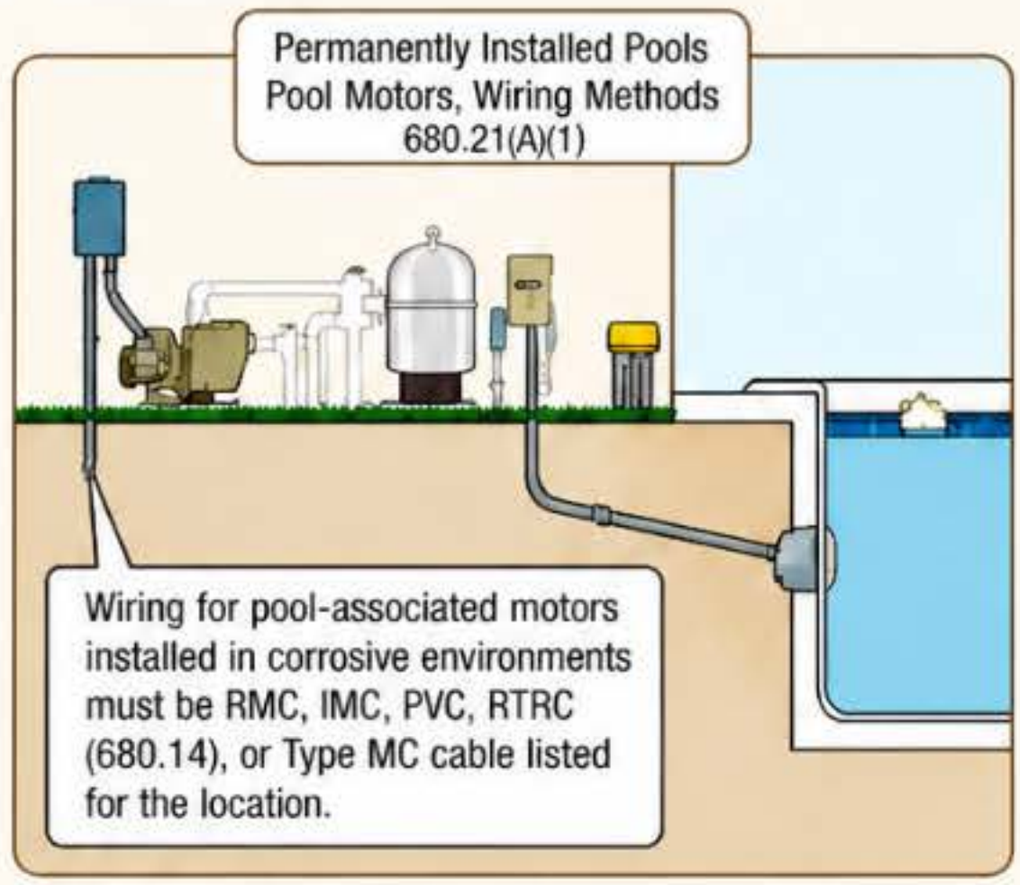


Figure 680–23

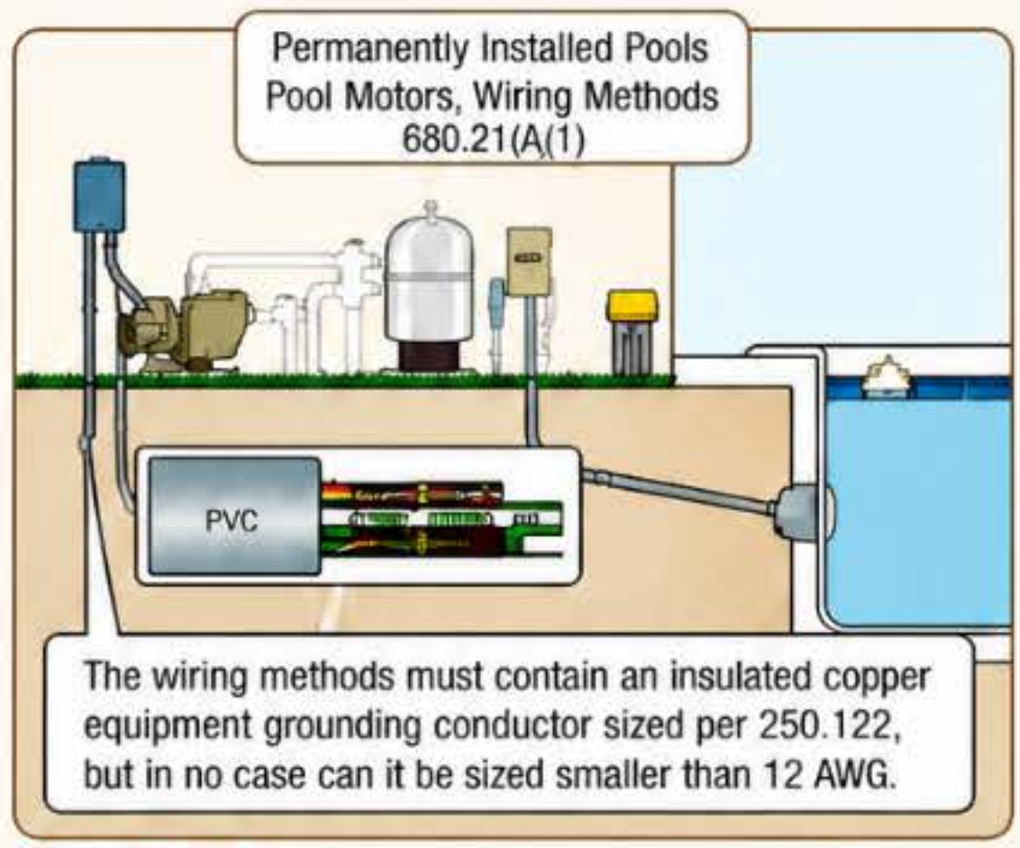


Figure 680–24

(2) Flexible Connections. Liquidtight flexible metal and liquidtight flexible nonmetalic conduit are permitted.

(C) GFCI Protection. GFCI protection is required for all pool rated 60A or less and not over 150V to ground, whether connected by receptacle or by direct connection. **Figure 680–25**

EX: Listed low-voltage motors not requiring grounding, with ratings not exceeding the low-voltage contact limit supplied by transformers or power supplies that comply with 680.23(2), may be installed without GFCI protection.

(D) Pool Pump Motor Replacement. Where a pool pump motor is replaced, the replacement pump motor must be provided with GFCI protection. **Figure 680–26**

Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations 680.22

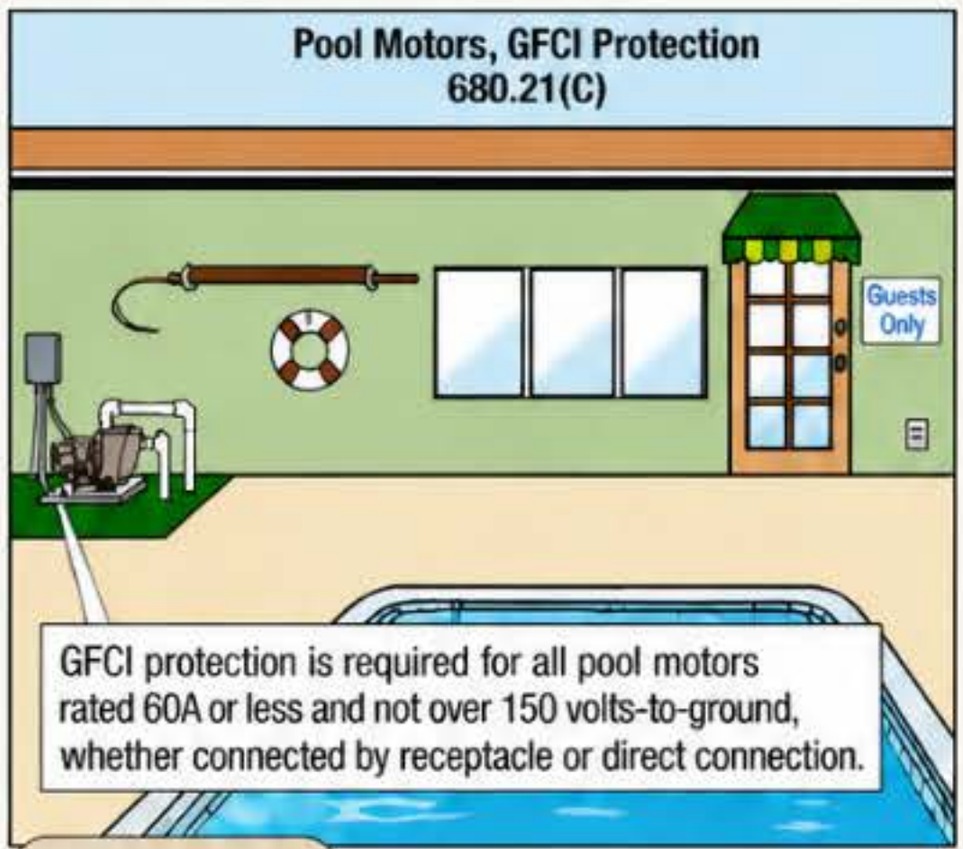


Figure 680–25

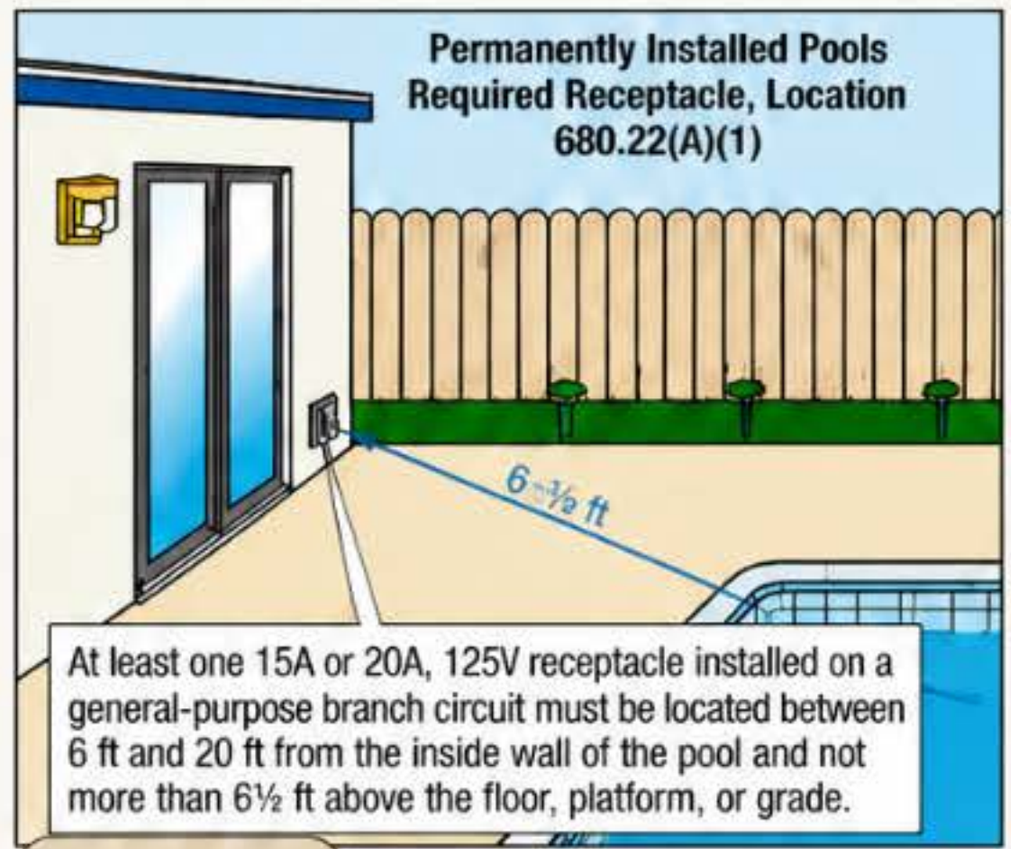


Figure 680–27

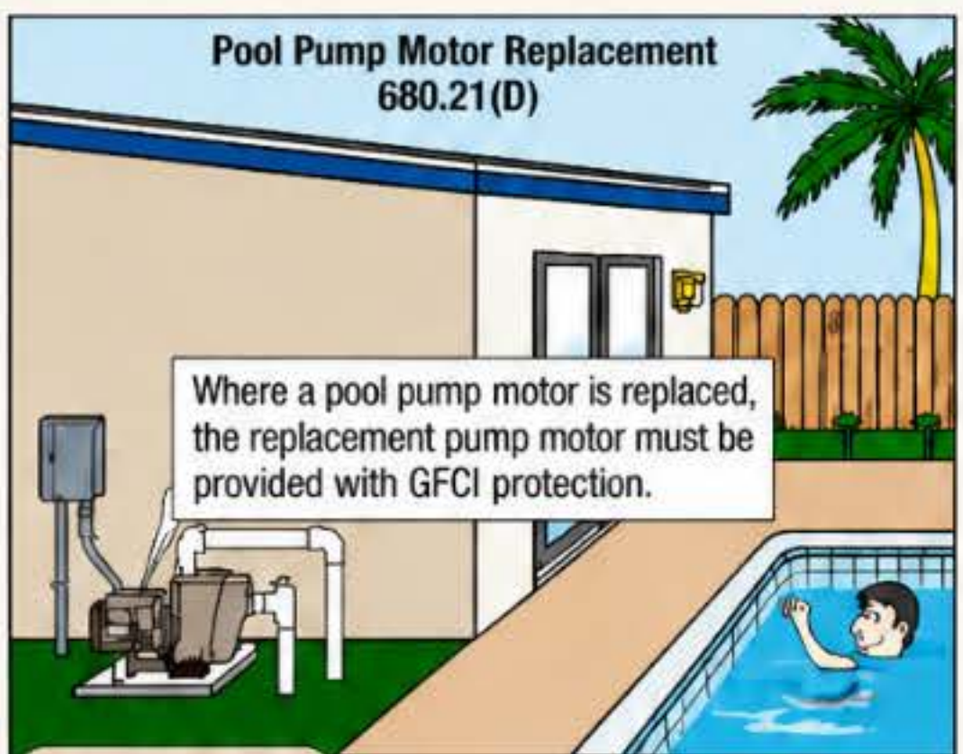


Figure 680–26

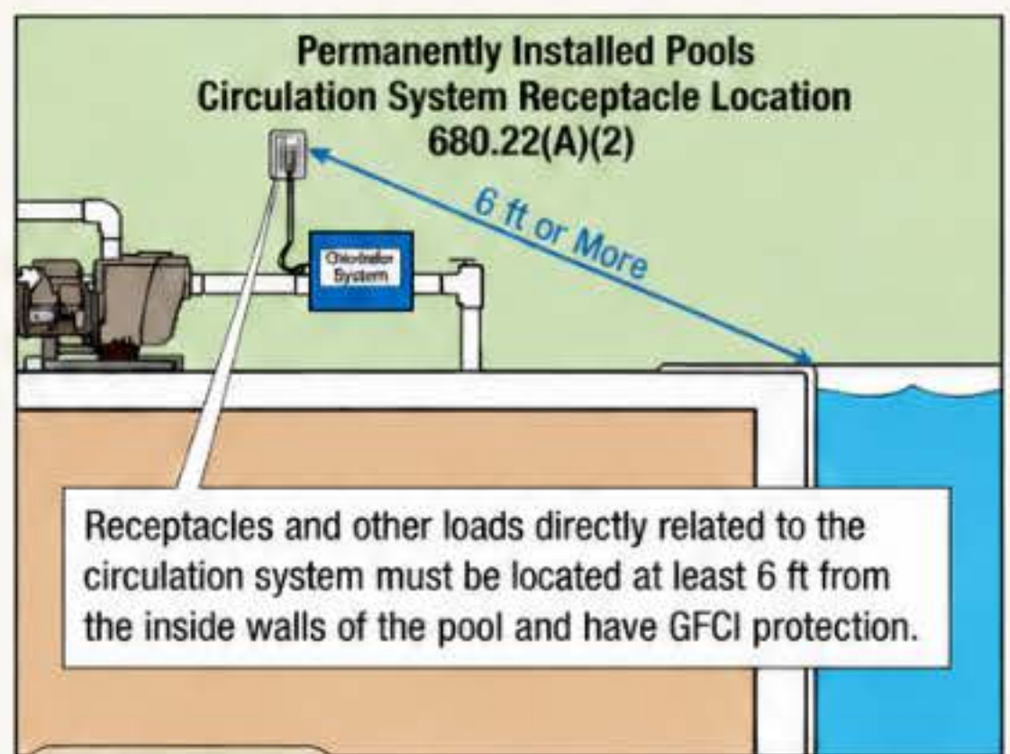


Figure 680–28

680.22 Receptacles, Luminaires, and Switches

(A) Receptacles.

(1) Required Receptacle, Location. At least one 15A or 20A, 125V receptacle installed on a general-purpose branch circuit must be located not less than 6 ft and not more than 20 ft from the inside wall of a permanently installed pool. This receptacle must be located not more than 6½ ft above the floor, platform, or grade level serving the pool. ▸ Figure 680–27

(2) Circulation System. Receptacles for permanently installed pool motors, or other loads directly related to the circulation system, must be located at least 6 ft from the inside walls of the pool and have GFCI protection. ▸ Figure 680–28

(3) Other Receptacles. Receptacles for loads not directly related to the circulation system must be located not less than 6 ft from the inside walls of a permanently installed pool. ▸ Figure 680–29

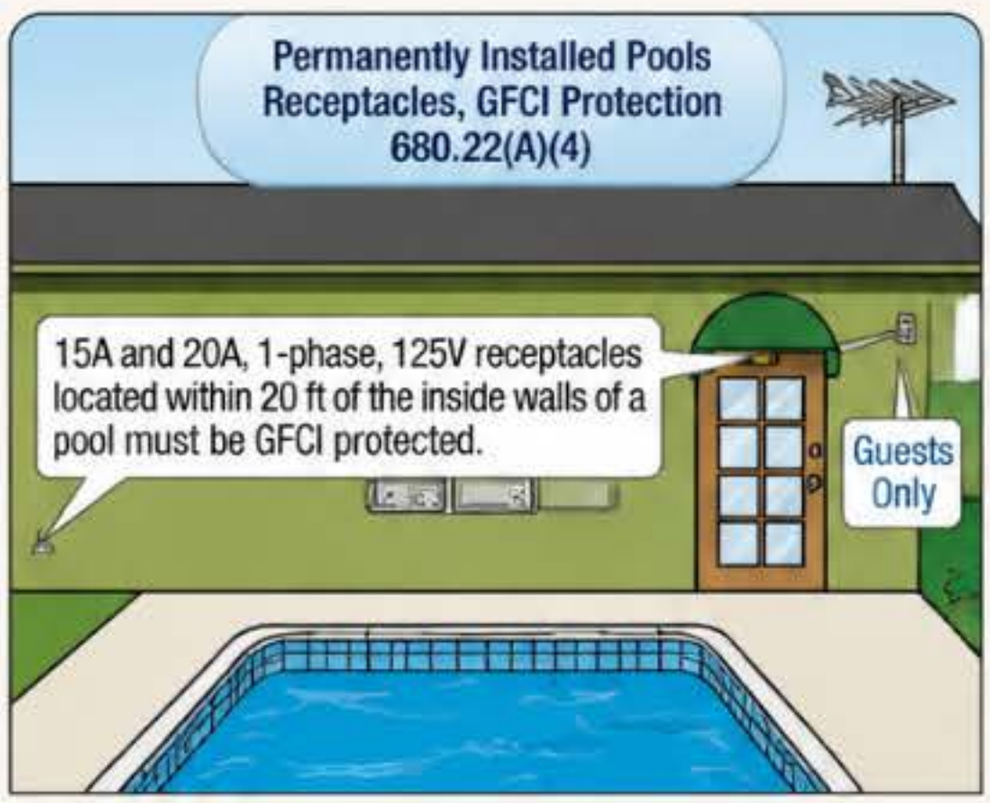
(4) GFCI Protection. 15A and 20A, single-phase, 125V receptacles located within 20 ft of the inside walls of a pool must be GFCI protected. ▸ Figure 680–30

(5) Pool Equipment Room. At least one GFCI-protected 15A or 20A, 125V receptacle must be located within a pool equipment room. Receptacles rated 150V or less to ground within the pool equipment room must be GFCI protected. ▸ Figure 680–31

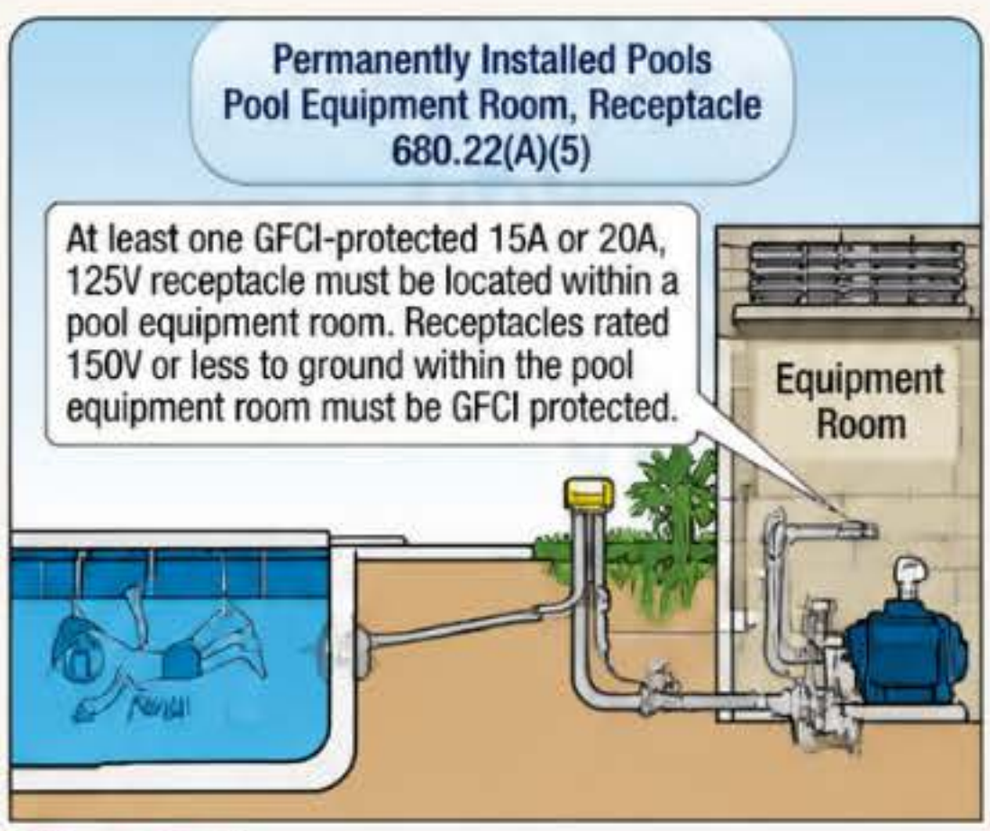
(6) Measurements. The receptacle distance is measured as the shortest path an appliance cord will follow without passing through a wall, doorway, or window.

680.22 | Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations

▶ Figure 680–29



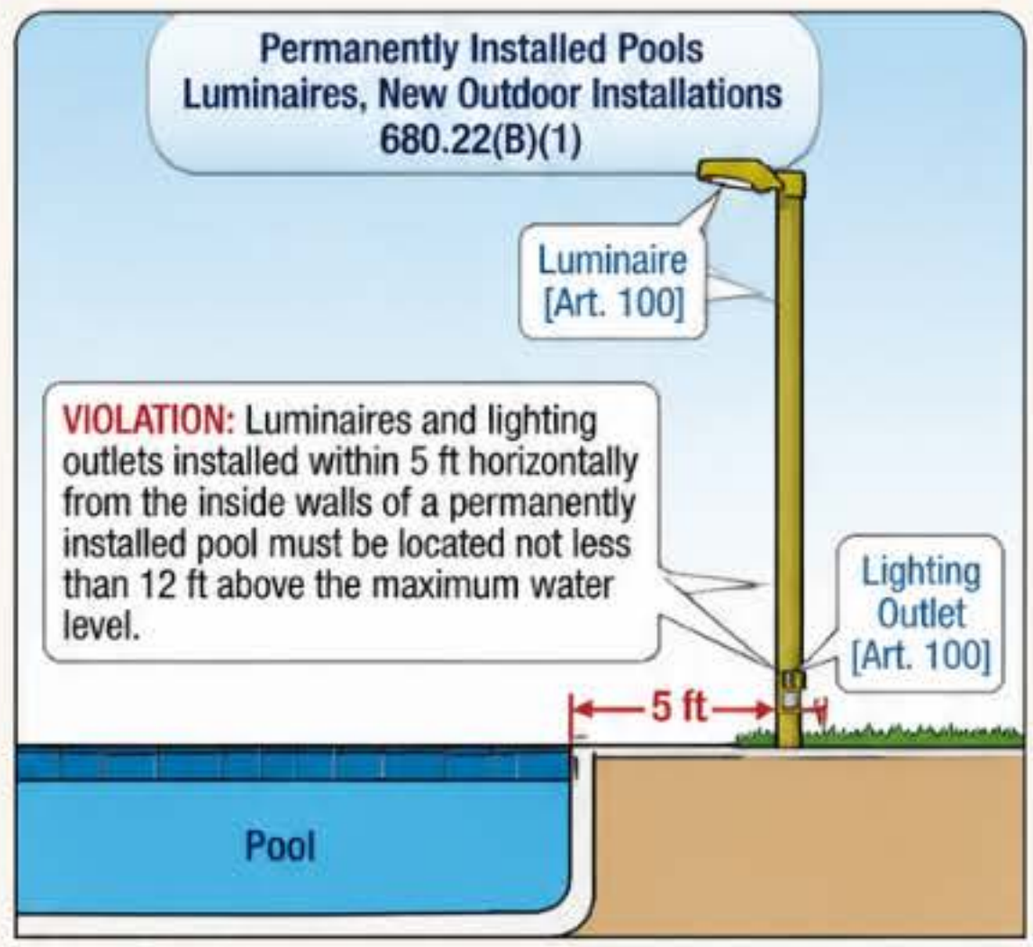
▶ Figure 680–30



▶ Figure 680–31

(B) Luminaires and Ceiling Fans.

(1) New Outdoor Installations. Outdoor lighting and luminaire outlets installed for new work must be positioned no closer than 5 ft horizontally from the interior walls of a permanently installed pool, and not less than 12 ft above the highest expected water level.



▶ Figure 680–32

Author's Commentary:

In accordance with 680.2, the "maximum water level" refers to the highest point the water is expected to reach before it overflows.

— Michael Hamilton

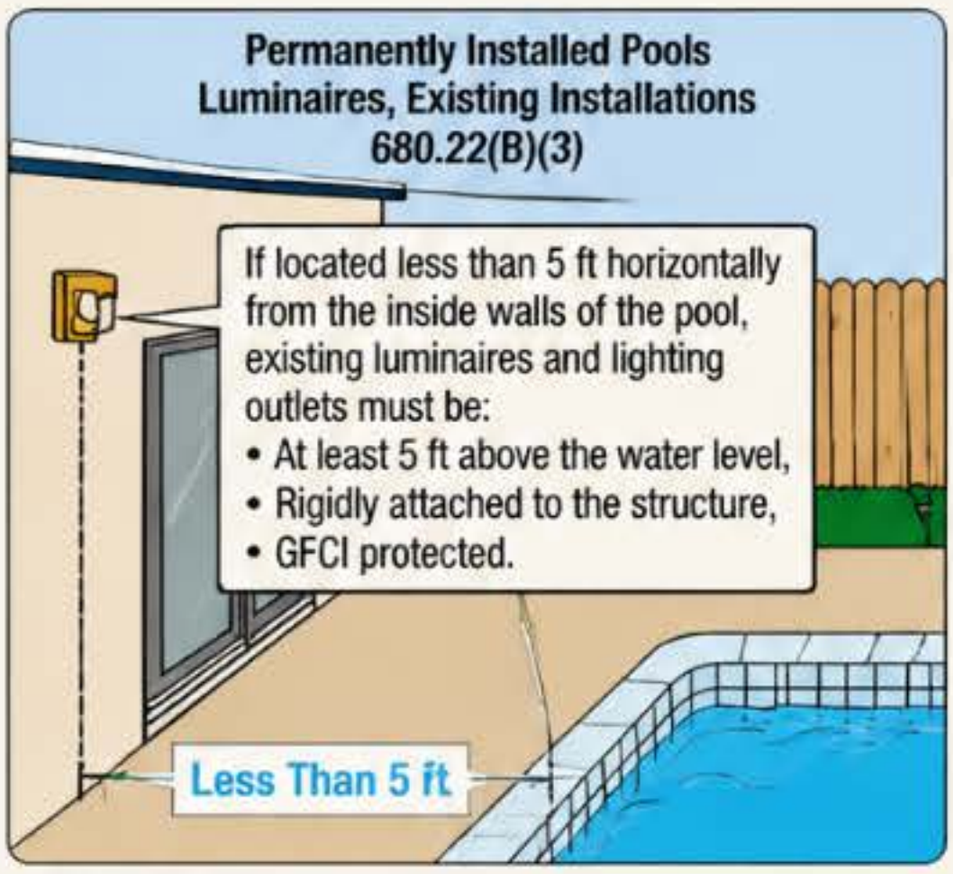
(3) Existing Installations. Receptacles and other outlets installed within 5 ft horizontally from the interior walls of an existing pool are not required to be higher than 5 ft above the surrounding surface of the maximum water level, provided they are firmly attached to the structure and are GFCI protected. Figure 680–33

(4) GFCI Protection in Adjacent Areas. Lighting outlets located between 5 ft and 10 ft horizontally from the interior walls of a permanently installed pool, and not less than 5 ft above the maximum water level, require GFCI protection.

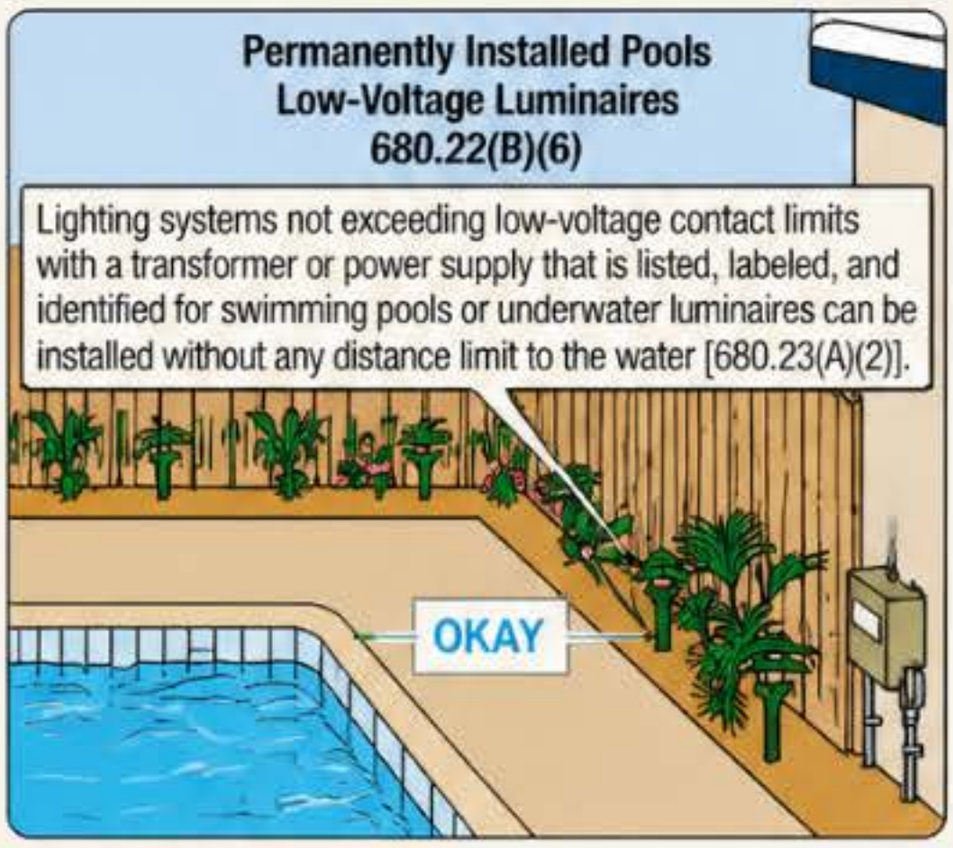
(6) Low-Voltage Luminaires. Low-voltage lighting systems that do not exceed the low-voltage contact limits—supplied by a listed transformer or power supply, labeled, and identified for use with pools or underwater fixtures—may be installed without any distance restrictions to the water [680.23(A)(2)]. Figure 680–34

All other low-voltage lighting must be installed within 10 ft from the water's edge in accordance with 411.5(B).

Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations | 680.23



▸ Figure 680–33

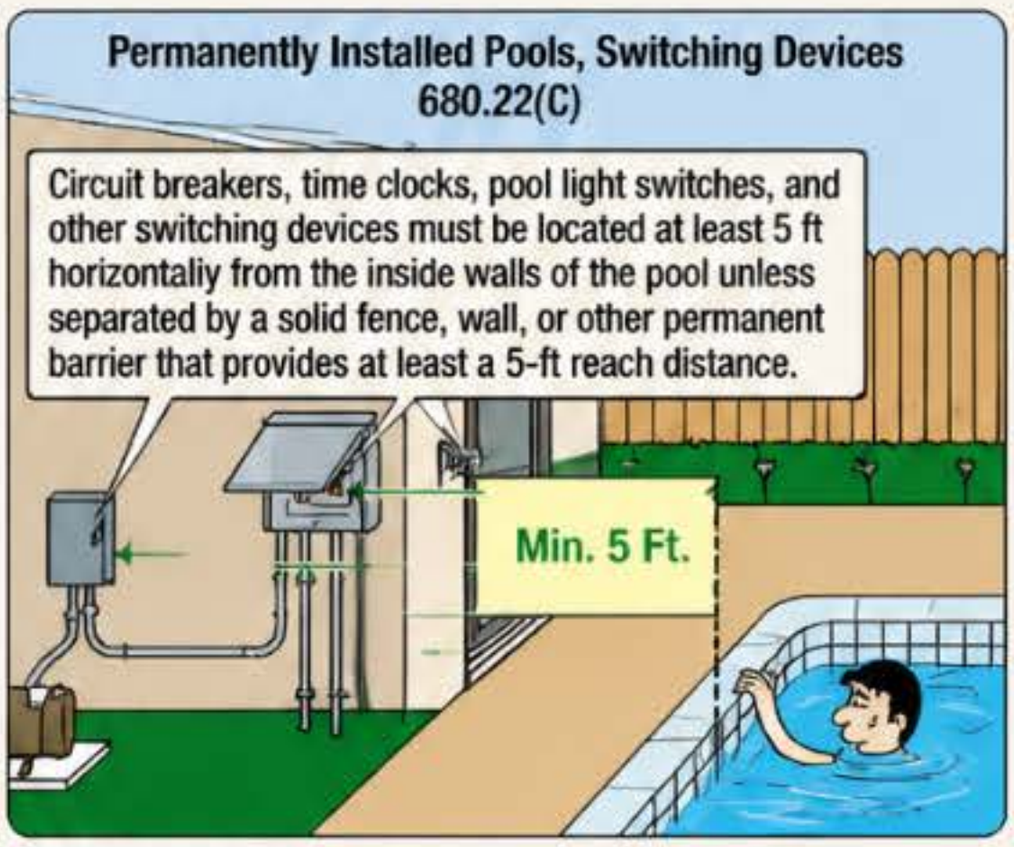


▸ Figure 680–34

(7) Low-Voltage Gas-Fired Luminaires, Fireplaces, Fire Pits, and Similar Equipment. Listed gas-fired luminaires, fireplaces, fire pits, and similar equipment using low-voltage ignitors supplied by listed transformers or power supplies that comply with 680.23(A)(2) and do not exceed the low-voltage contact limit can be located less than 5 ft from the inside walls of the pool.

(8) Measurements. In determining the dimensions in this section addressing luminaires, the distance to be measured must be the shortest path an imaginary cord connected to the luminaire will follow without piercing a floor, wall, ceiling, doorway with a hinged or sliding door, window opening, or other effective permanent barrier.

(C) Switching Devices. Circuit breakers, time clocks, pool light switches, and other switching devices must be located not less than 5 ft horizontally from the inside walls of a permanently installed pool unless separated by a solid fence, wall, or other permanent barrier that provides at least a 5-foot reach distance. ▸ Figure 680–35



▸ Figure 680–35

(D) Other Outlets. Other outlets must be not less than 10 ft from the inside walls of the pool.

Note: Other outlets may include (but are not limited to) remote-control, signaling, fire alarm, and communications circuits.

(E) Other Equipment. Other equipment with ratings exceeding the low-voltage contact limit must be located at least 5 ft horizontally from the inside walls of a pool unless separated from the pool by a solid fence, wall, or other permanent barrier. ▸ Figure 680–36

680.23 Underwater Pool Luminaires

(A) General.

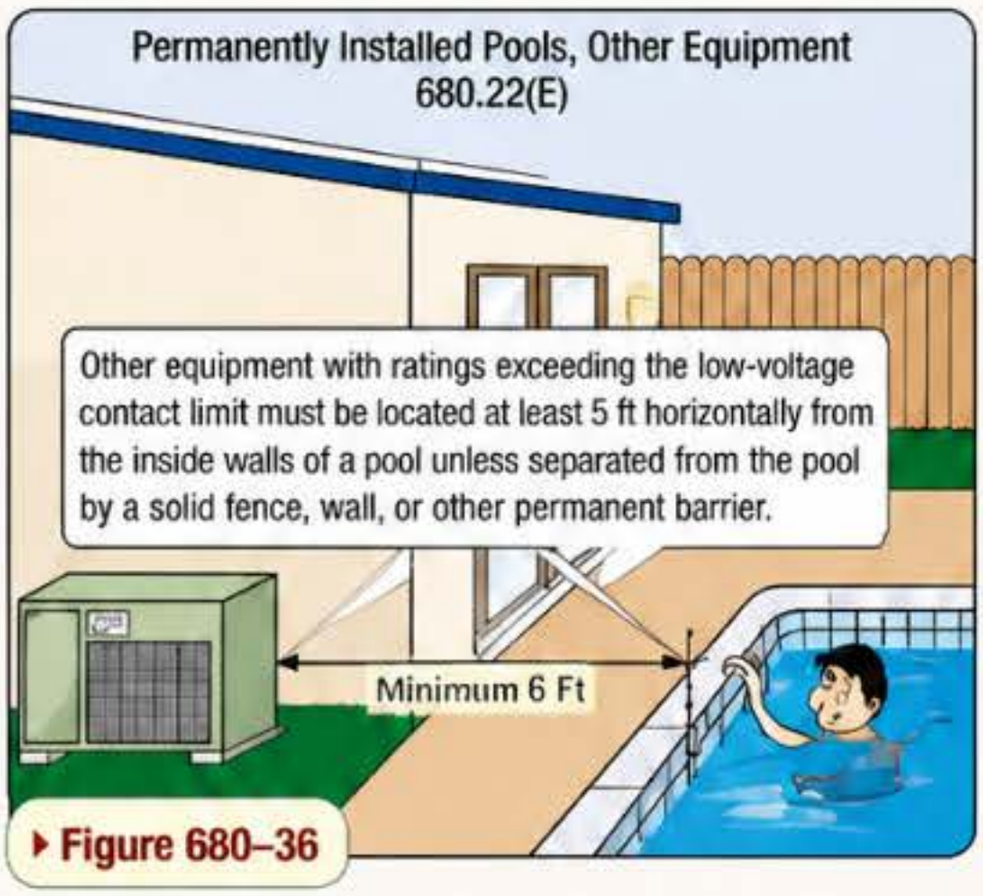
(2) Transformers and Power Supplies for Underwater Pool Luminaires. Transformers and power supplies for underwater pool luminaires must be listed, labeled, and identified for swimming pools use.

(3) GFCI Protection. Branch circuits supplying underwater pool luminaires at 120V must be GFCI protected. ▸ Figure 680–37

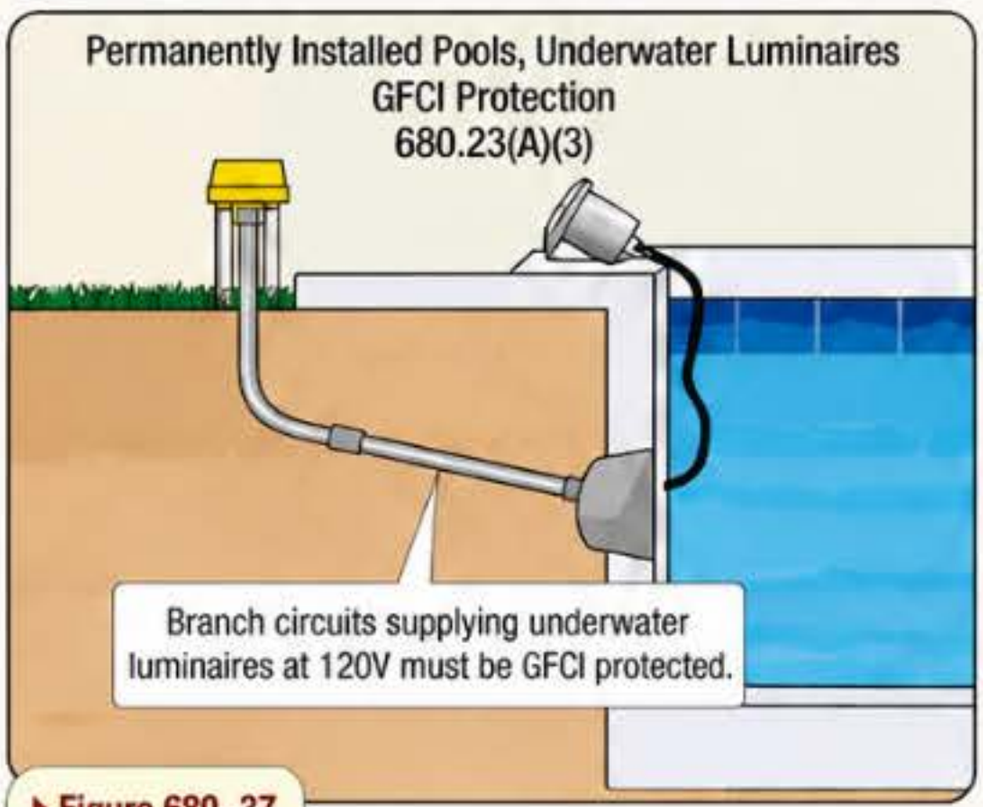
(5) Wall-Mounted Luminaires. Underwater wall-mounted luminaires must be installed so the top of the luminaire lens is not less than 18 in. below the normal water level. ▸ Figure 680–38

(B) Wet-Niche Luminaires.

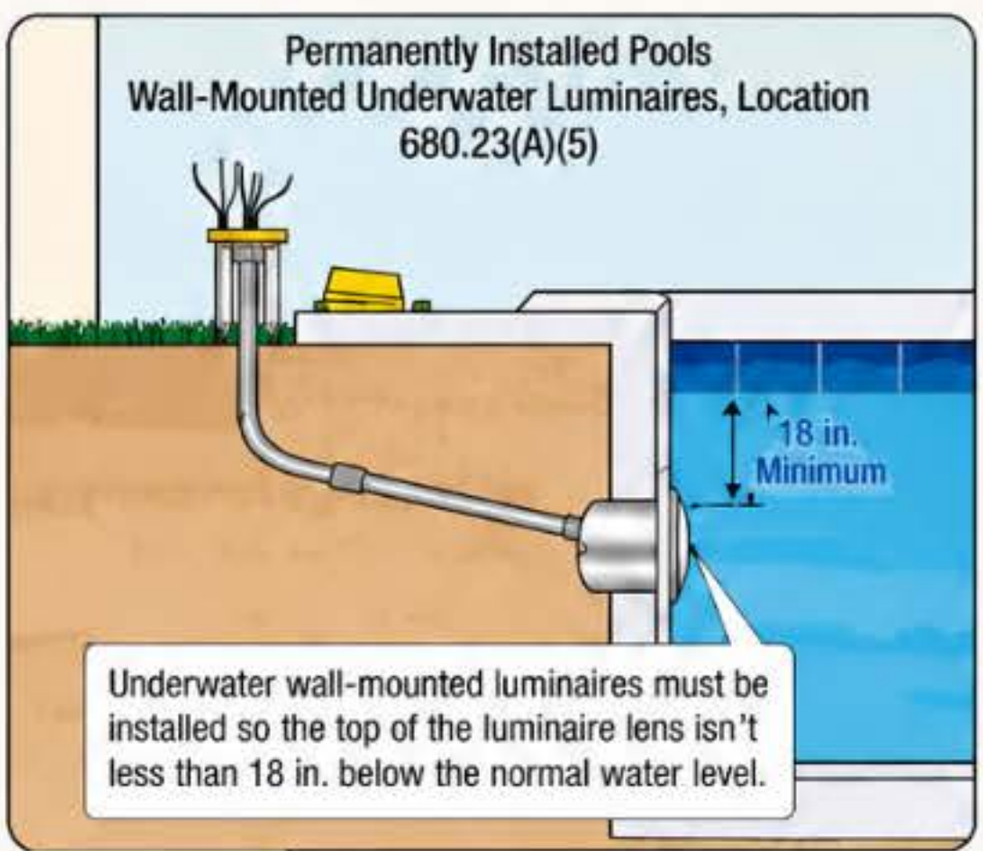
680.23 | Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations



▸ Figure 680–36



▸ Figure 680–37

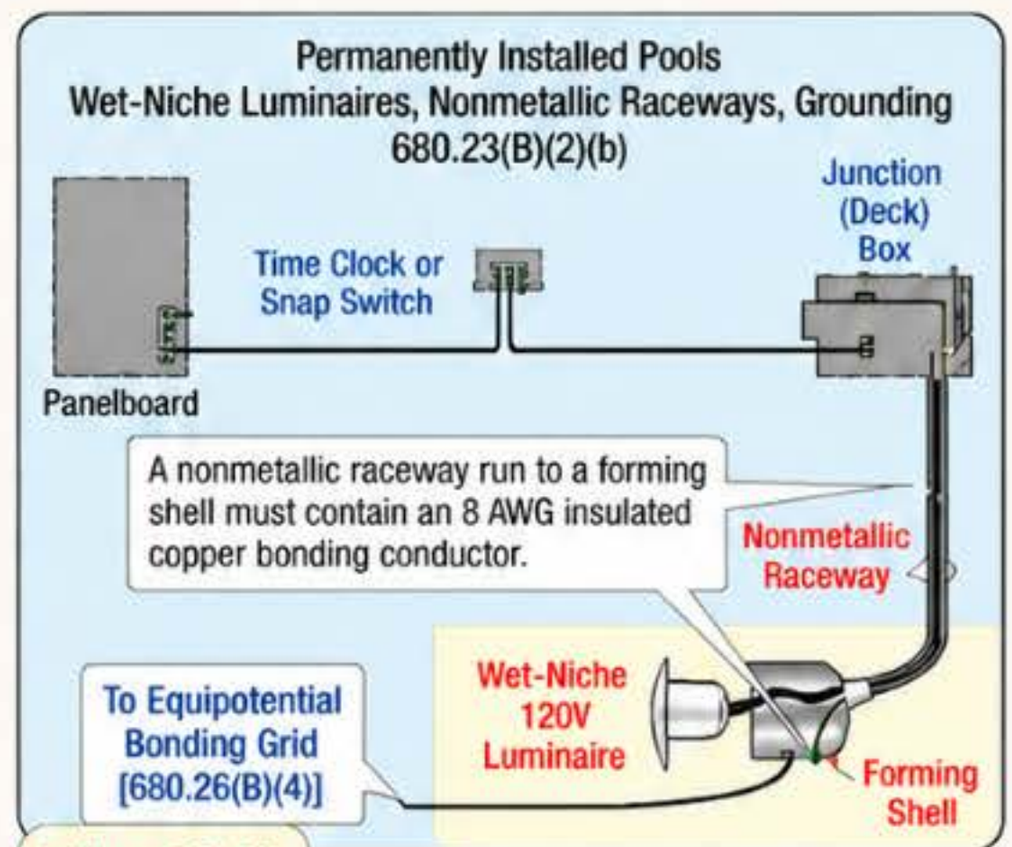


▸ Figure 680–38

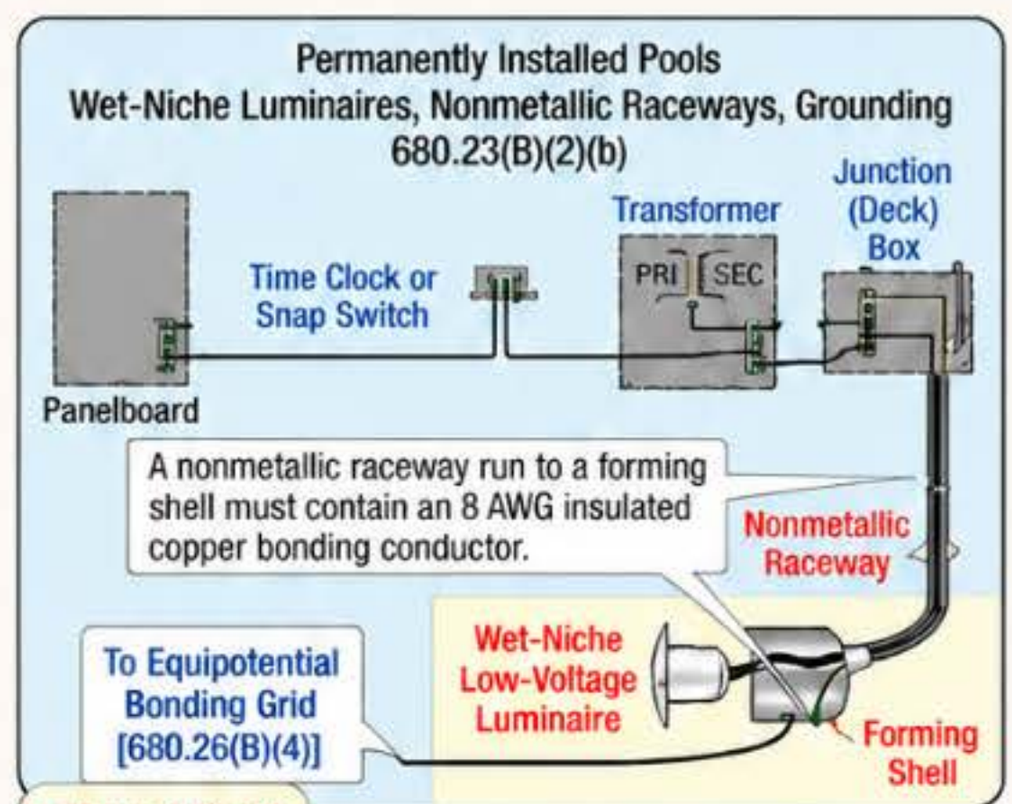
(2) Wiring to the Forming Shell.

(a) Metal Conduit. Metal conduit must be listed and identified as red brass or stainless steel.

(b) Nonmetallic Raceway. A nonmetallic raceway run to the forming shell of a wet-niche luminaire must contain an 8 AWG insulated (solid or stranded) copper conductor that terminates to the forming shell. ▸ Figure 680–39 and Figure 680–40



▸ Figure 680–39



▸ Figure 680–40

The termination of the 8 AWG bonding jumper in the forming shell must be covered with a listed potting compound to protect the connection from the possible deteriorating effects of pool water.

Author's Commentary:
Moisture and pool chemicals can corrode exposed terminations over time. Sealing the bonding conductor connection inside the forming shell helps keep the electrical path reliable and long-lasting.

— Michael Hamilton

Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations | 680.23

Author's Commentary:
Article 680.23 defines a "wet-niche luminaire" as a lighting fixture designed to be fully encased in water when mounted in the shell of a pool or fountain. See Figure 680–41.

— Michael Hamilton

Figure 680–41

Author's Commentary:
Article 680.23 describes a "forming shell" as the structure that remains in place to create the shape of a pool or fountain so a wet-niche luminaire can be installed. See Figure 680–42.

— Michael Hamilton

Figure 680–42

(3) Equipment Grounding Provisions for Cords. The power supply cord or cable for a low-voltage underwater luminaire that does not need grounding does not require an equipment grounding conductor. See Figure 680–43.

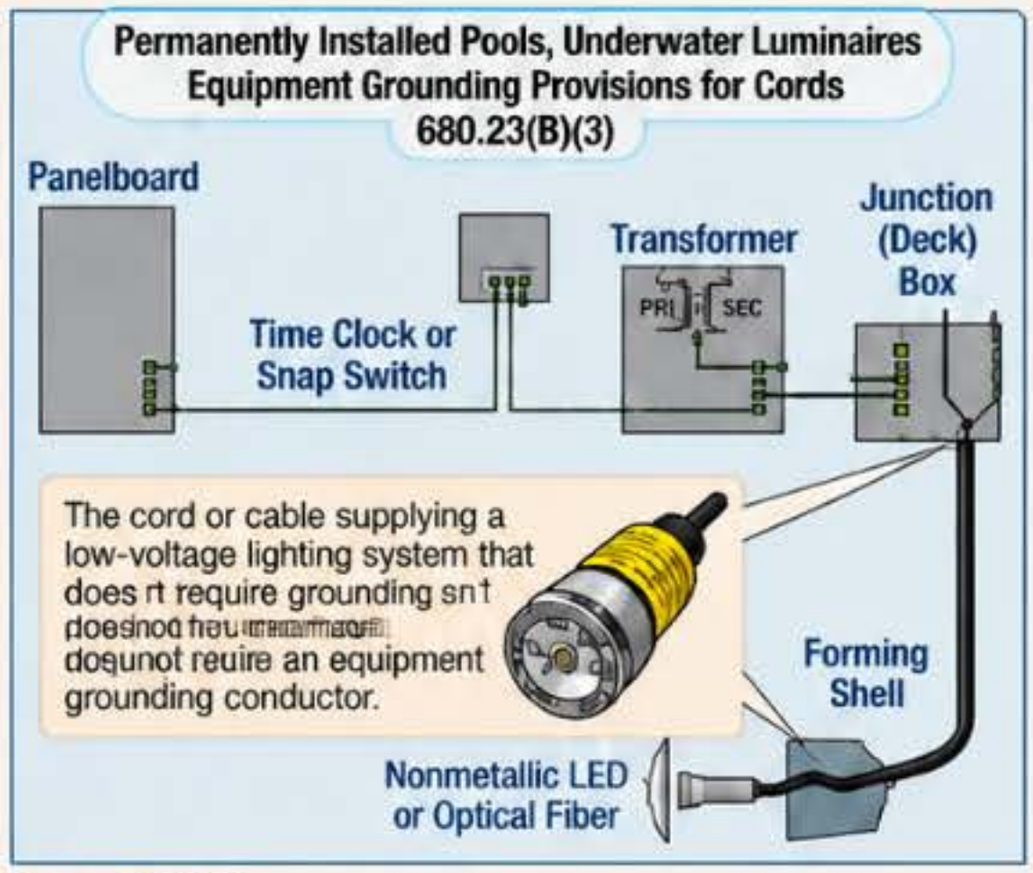


Figure 680–43

(6) Luminaire Servicing.

Pool. The location of the forming shell and length of flexible cord for wet-niche pool luminaires must allow for personnel to place the luminaire on the deck or other dry location for maintenance. See Figure 680–44.

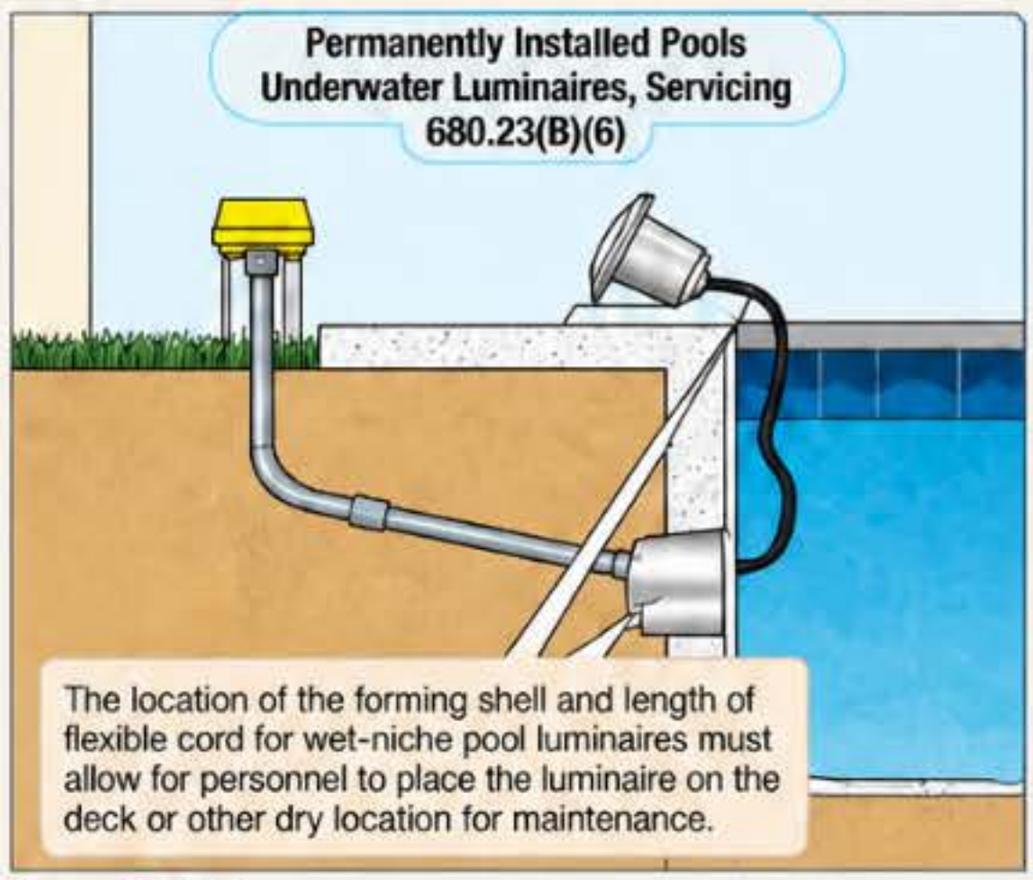


Figure 680–44

The luminaire maintenance location must be reachable without stepping into or entering the pool water.

Spa. For spas that are wet-niche, the luminaires must be installed in the footwell of the spa. The forming shell position and length of flexible cord for the underwater spa luminaire must allow for personnel to set the luminaire on the bench where the spa can be drained to make that location dry. See Figure 680–45.

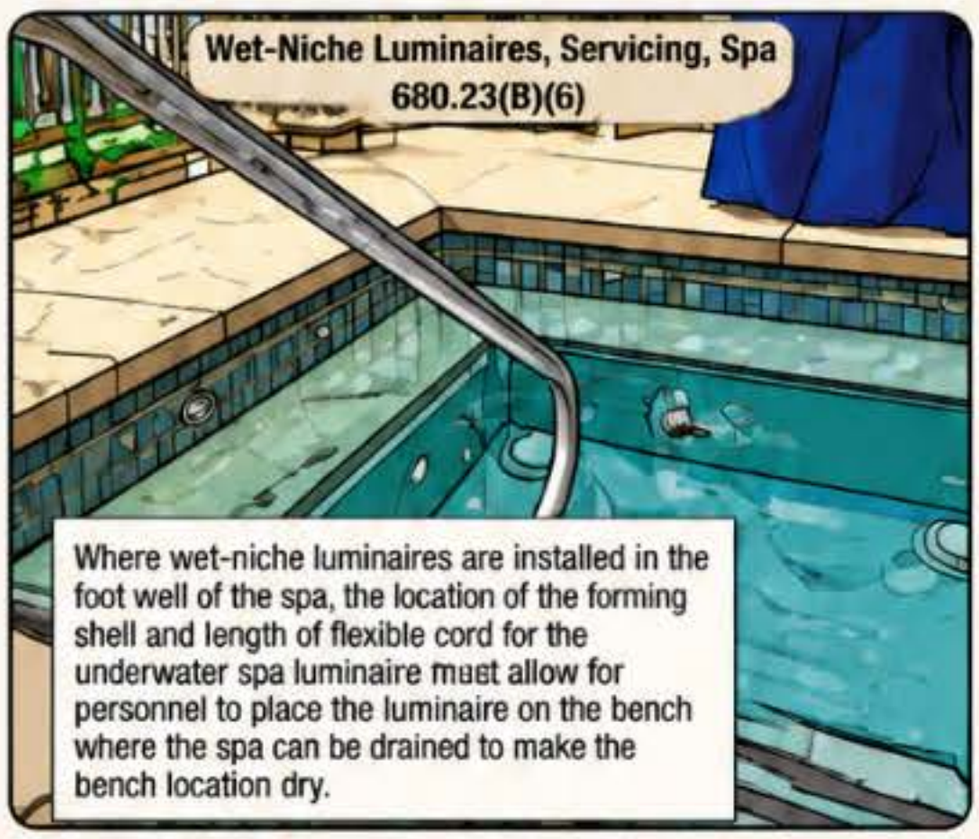


Figure 680–45

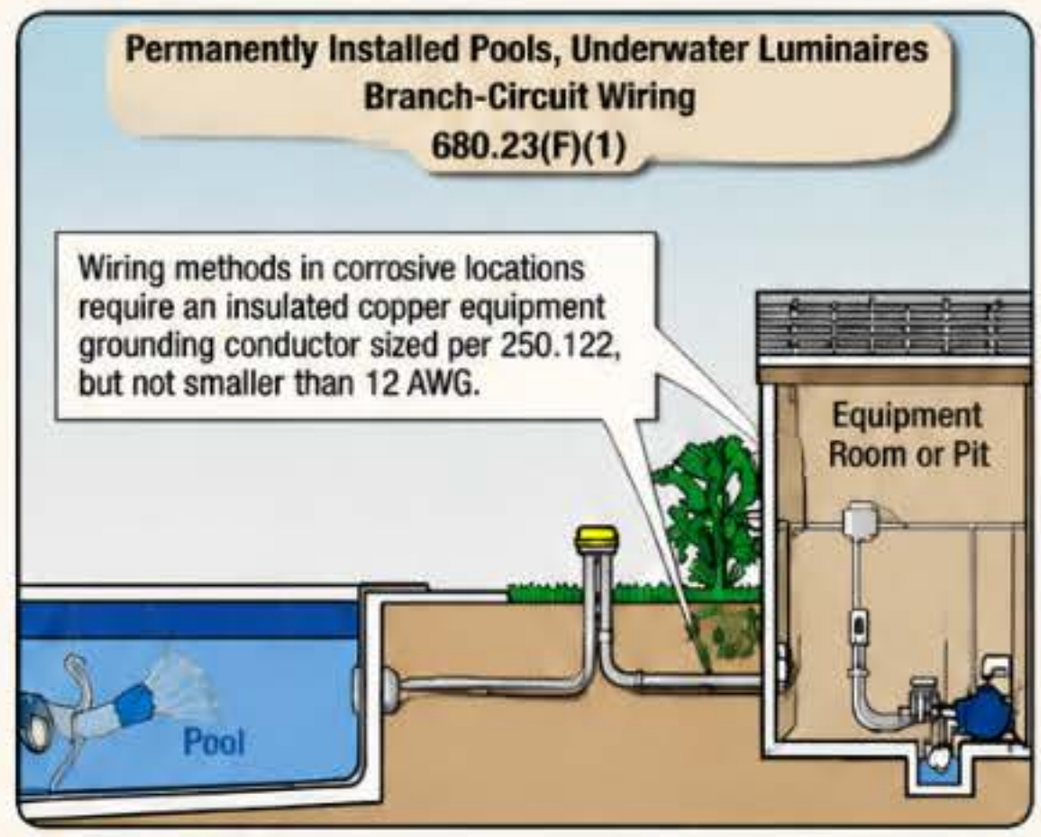


Figure 680–47

(F) Branch-Circuit Wiring.

(1) General. Electrical wiring used for branch circuits in corrosive environments must be run in one of the following: rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit, reinforced thermosetting resin conduit (680.141), or liquidtight flexible nonmetallic conduit.

Figure 680–46

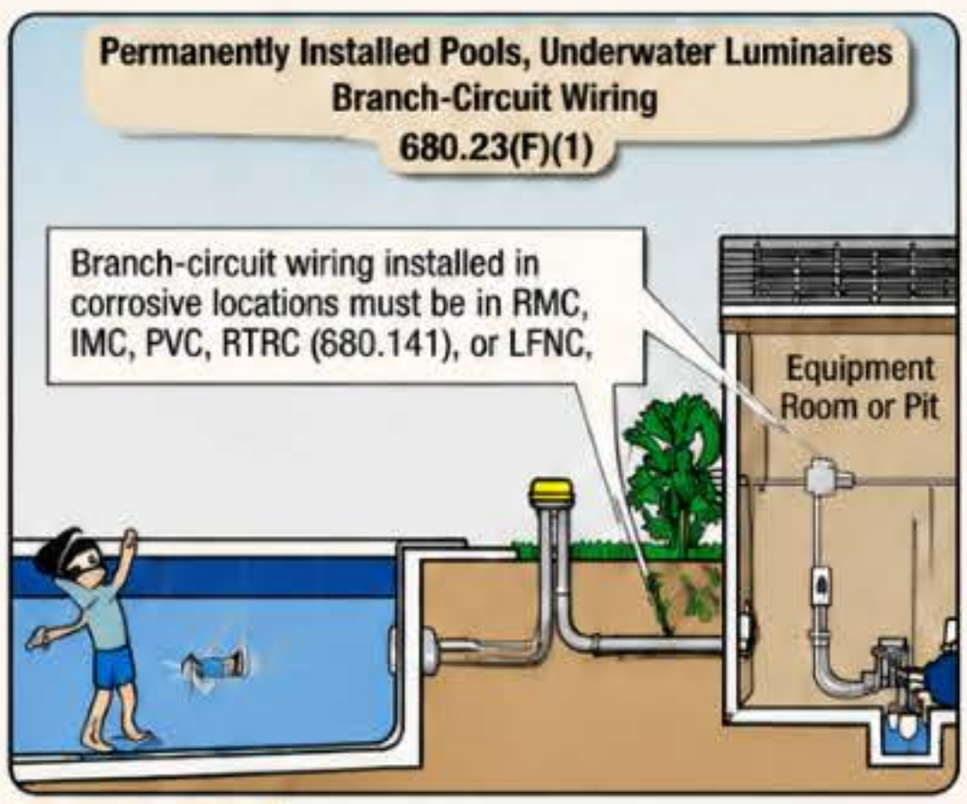


Figure 680–46

Wiring methods in corrosive environments must contain an insulated copper equipment grounding conductor sized in accordance with 250.122 but not smaller than 12 AWG.

Figure 680–47

Author's Commentary: In settings that do not expose wiring to corrosion, Chapter 3 wiring methods are acceptable. Corrosive areas demand tougher wiring systems plus a separate insulated copper equipment grounding conductor.

— Michael Hamilton

(2) Branch-Circuit Equipment Grounding Conductor.

Equipment grounding conductors for all throggh-wall underwater pool luminaires must be insulated copper equipment grounding conductors with no splices or joints except as allowed in 680.23(F)(2)(a) and (b), sized in accordance with 250.122, and not smaller than 12 AWG.

Figure 680–48

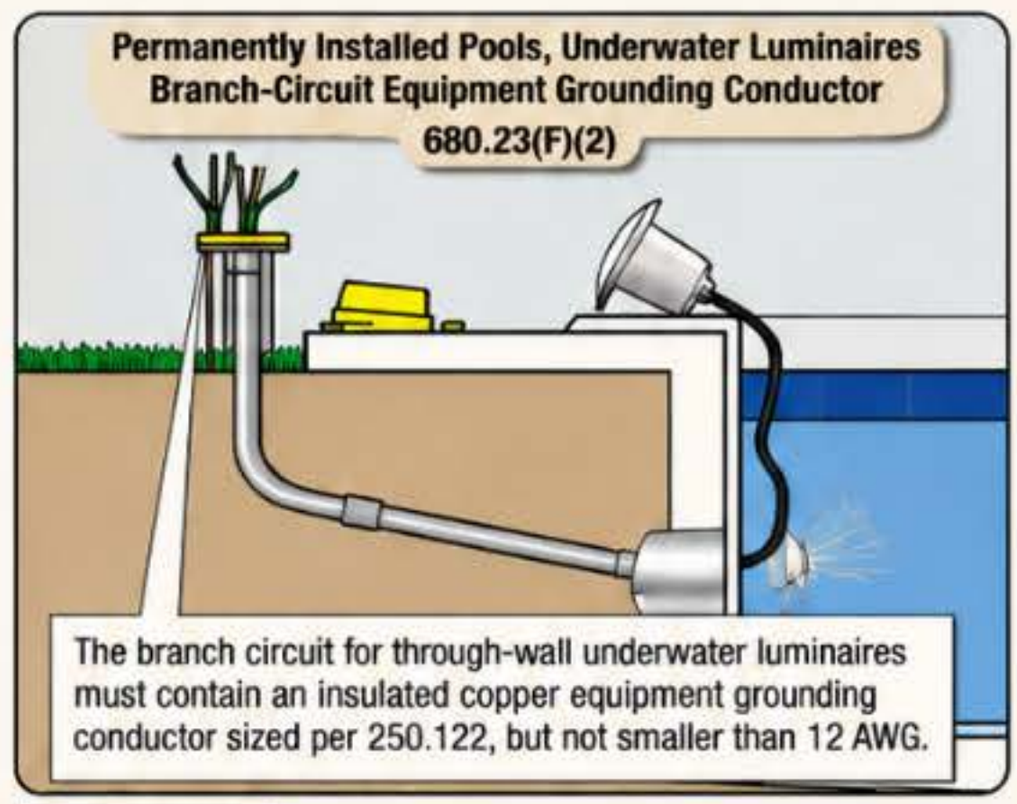


Figure 680–48

The circuit equipment grounding conductor for the underwater pool luminaire is not allowed to be spliced, except for these situations:

- **(a)** Where located in the equipment room or enclosure.
- **(b)** Where located above ground and protected from physical damage.

Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations | 680.24

(a) If more than one underwater pool luminaire is supplied by the same branch circuit, the equipment grounding conductor can be terminated at a listed pool junction box that meets the requirements of 680.24(A).

(b) The equipment grounding conductor is also allowed to terminate at the grounding terminal of a listed pool transformer that satisfies the requirements of 680.23(A)(2). **See Figure 680–49.**

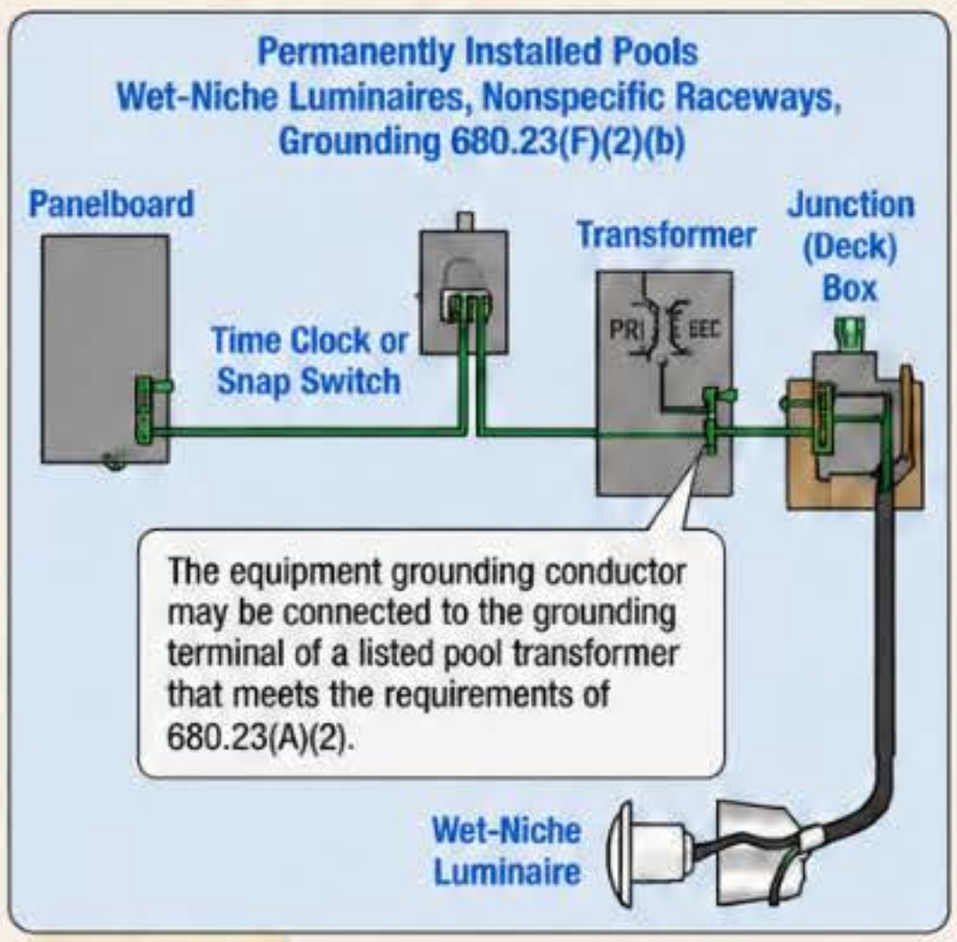


Figure 680–49

(3) Conductors. The branch-circuit conductors for the underwater pool luminaire on the load side of a GFCI or transformer used to comply with 680.23(A)(8) are not allowed to occupy raceways or enclosures with other conductors unless the other conductors are:

(1) GFCI protected, or
(2) Equipment grounding conductors and bonding jumpers as required by 680.23(B)(2)(b), or
(3) Supply conductors to a feed-through-type GFCI.

680.24 Junction Box, Transformer, or GFCI Enclosure

(A) Junction Box. If a junction box is connected to a raceway that extends directly to an underwater pool luminaire forming shell, the junction box must comply with the following:

(1) Construction. The junction box must be listed, labeled, and identified as a swimming pool junction box. **Figure 680–50**

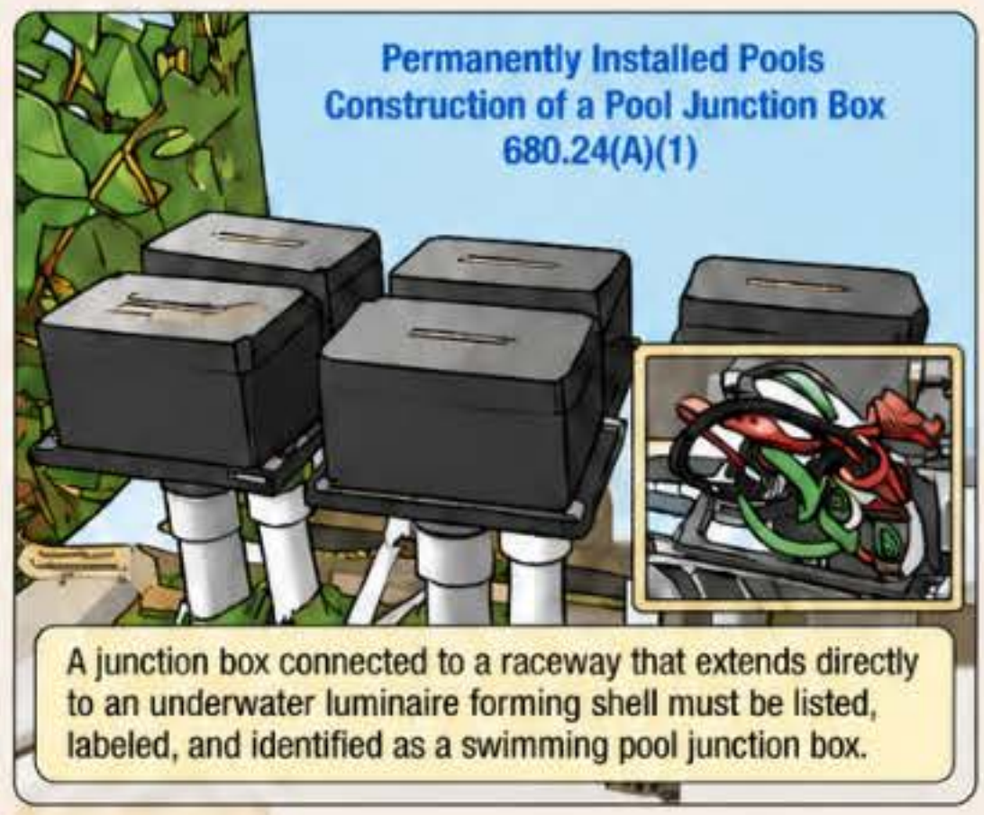


Figure 680–50

(2) Installation.

(a) Vertical Spacing. If the underwater pool luminaire operates at 120V, the junction box must be located not less than 4 in. above the ground or pool, or not less than 8 in. above the maximum water level, whichever provides the greater elevation. **Figure 680–51**

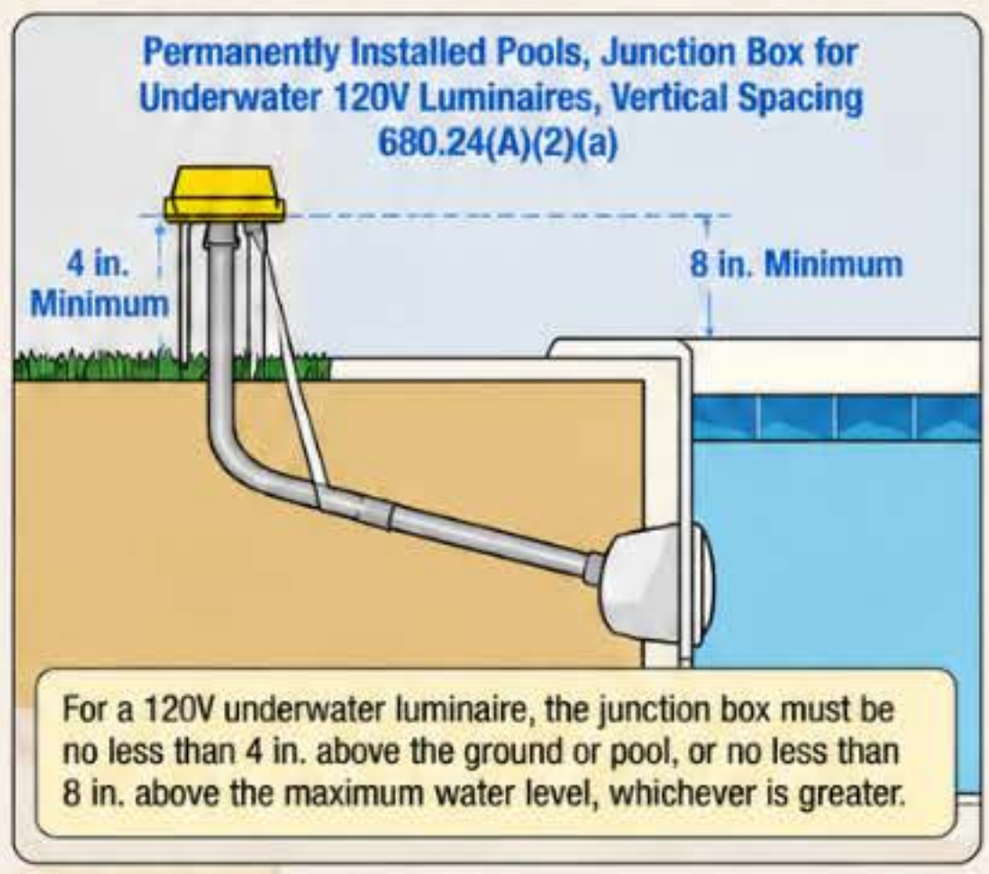


Figure 680–51

(b) Horizontal Spacing. If the underwater pool luminaire operates at 120V, the junction box must be located not less than 4 ft from the inside wall of the pool unless separated by a solid fence, wall, or other permanent barrier. **Figure 680–52**

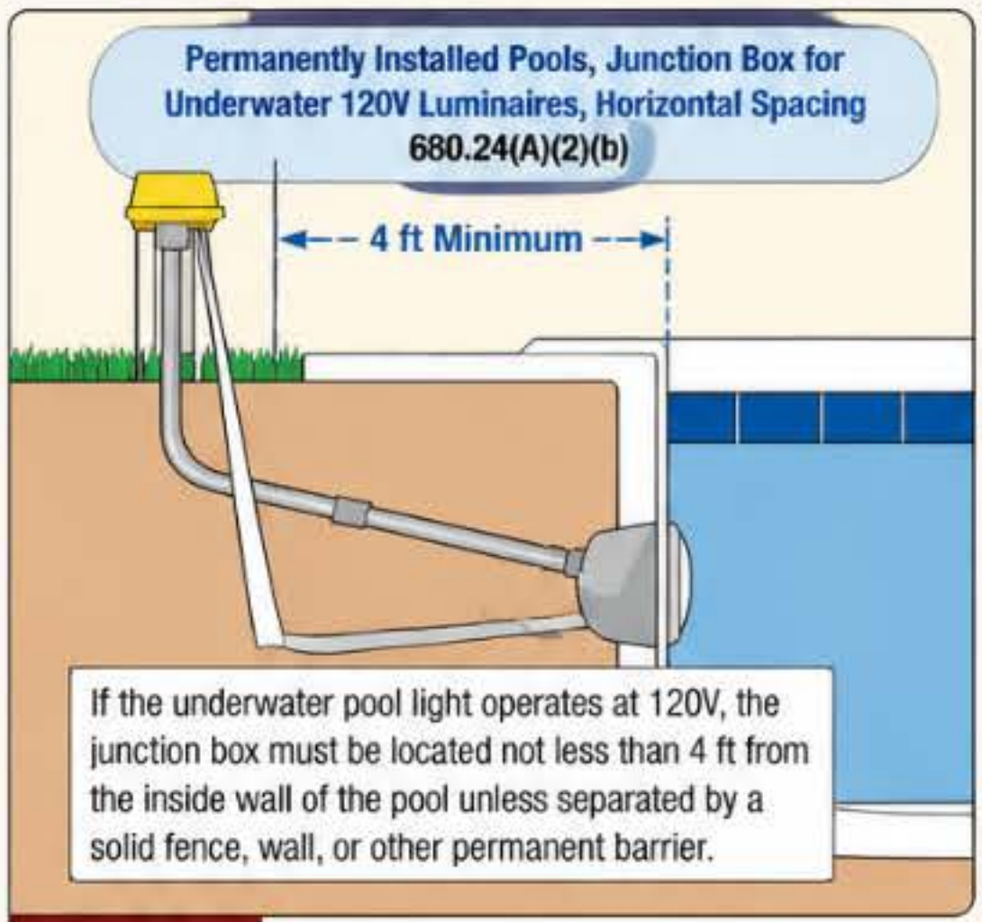


Figure 680–52

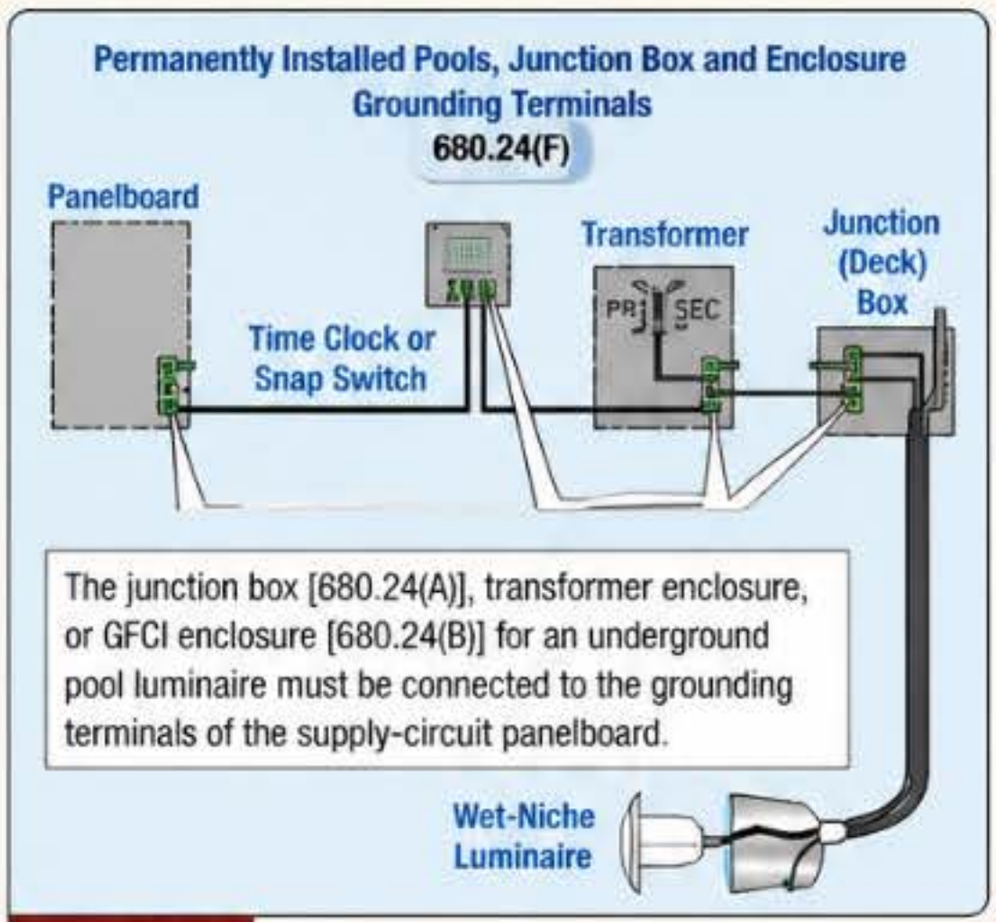


Figure 680–53

Author's Commentary:

- The junction box must be supported by two metal conduits threaded wrenchtight into the enclosure according to 314.23(E).

— Michael Hamilton

(B) Transformer or GFCI Enclosure. If the enclosure for a transformer or GFCI is connected to a raceway that extends directly to an underwater luminaire forming shell, the enclosure must be listed for this purpose.

(C) Physical Protection. Junction boxes for underwater luminaires are not permitted to be located in a walkway unless afforded protection by being located under driving boards or adjacent to fixed structures.

(F) Grounding. The junction box [680.24(A)], transformer enclosure, or GFCI enclosure [680.24(B)] for an underground pool luminaire must be connected to the grounding terminals of the supply-circuit panelboard. ▸ Figure 680–53

680.25 Feeders

(A) Wiring Methods. Where feeder wiring is installed in corrosive environments, the wiring methods must be rigid metal conduit, intermediate metal conduit, rigid polyvinyl chloride conduit, reinforced thermosetting resin conduit, or liquidtight flexible nonmetallic conduit [680.14].

The wiring methods in corrosive environments must have insulated copper equipment grounding conductors sized in accordance with Table 250.122, but not smaller than 12 AWG. ▸ Figure 680–54

Where installed in noncorrosive environments, any Chapter 3 wiring method is permitted.

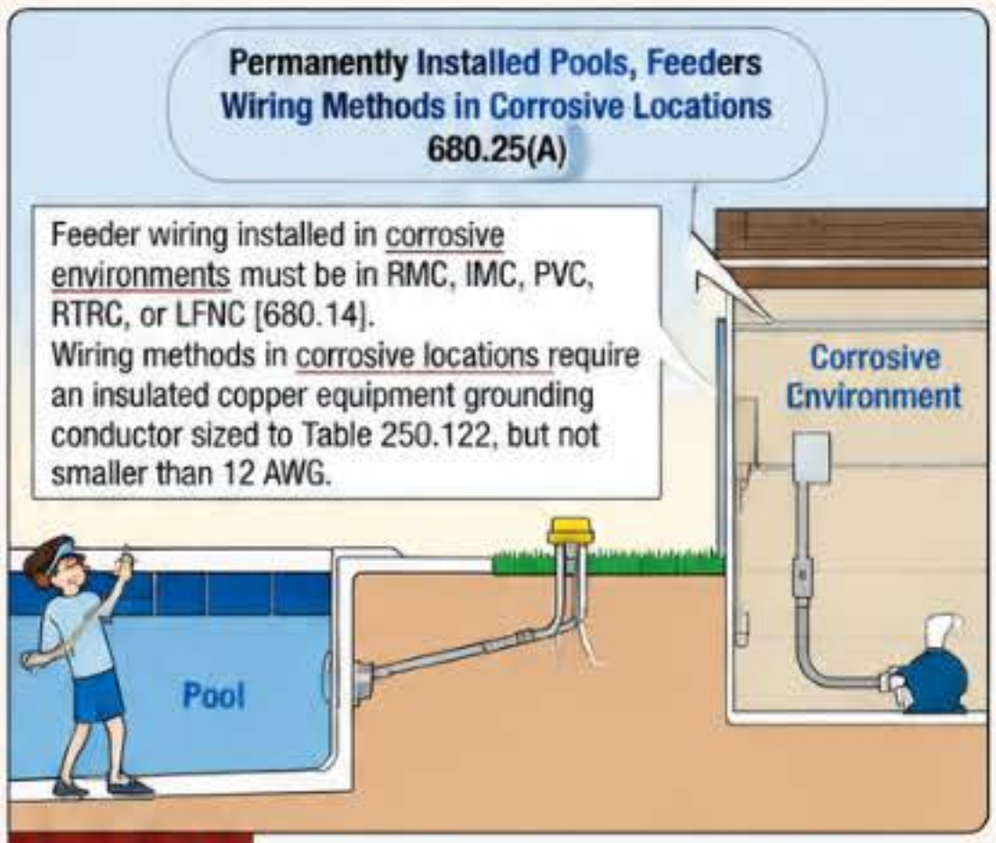


Figure 680–54

680.26 Equipotential Bonding

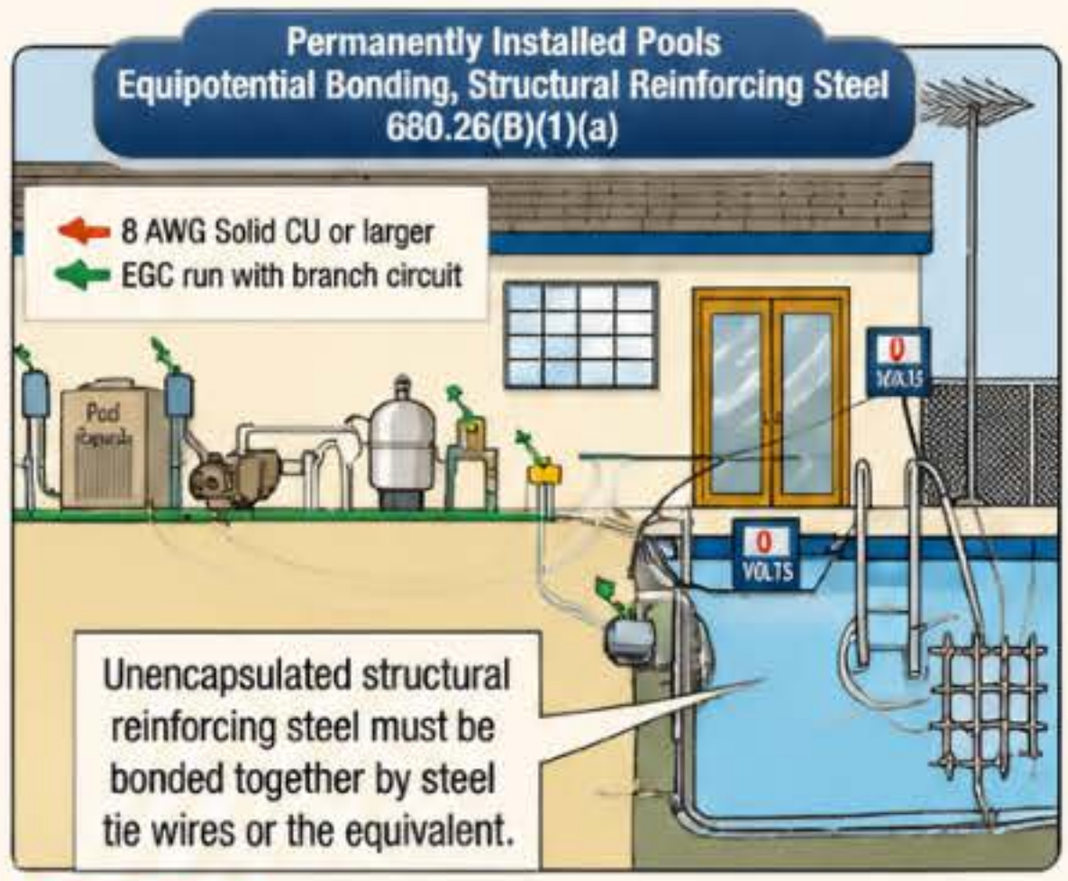
(A) Performance. Equipotential bonding is intended to reduce voltage gradients in the area around a permanently installed pool. Figure 680–55

(B) Bonded Parts. The parts of a permanently installed pool listed in (B)(1) through (B)(7) must be bonded together with a solid insulated or bare copper conductor not smaller than 8 AWG using a listed pressure connector, terminal bar, or other listed means in accordance with 250.8(A). ▸ Figure 680–56

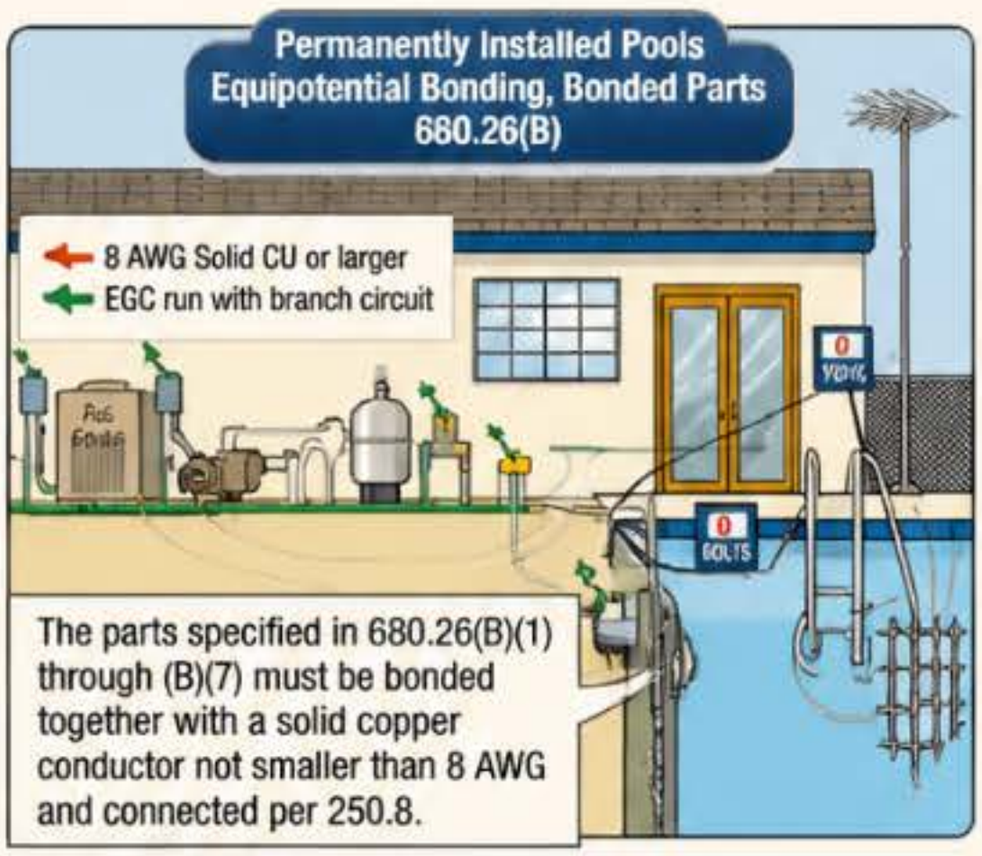
Equipotential bonding is not required to extend (or be attached) to any panelboard, service disconnect, or grounding electrode.

Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations 680.26

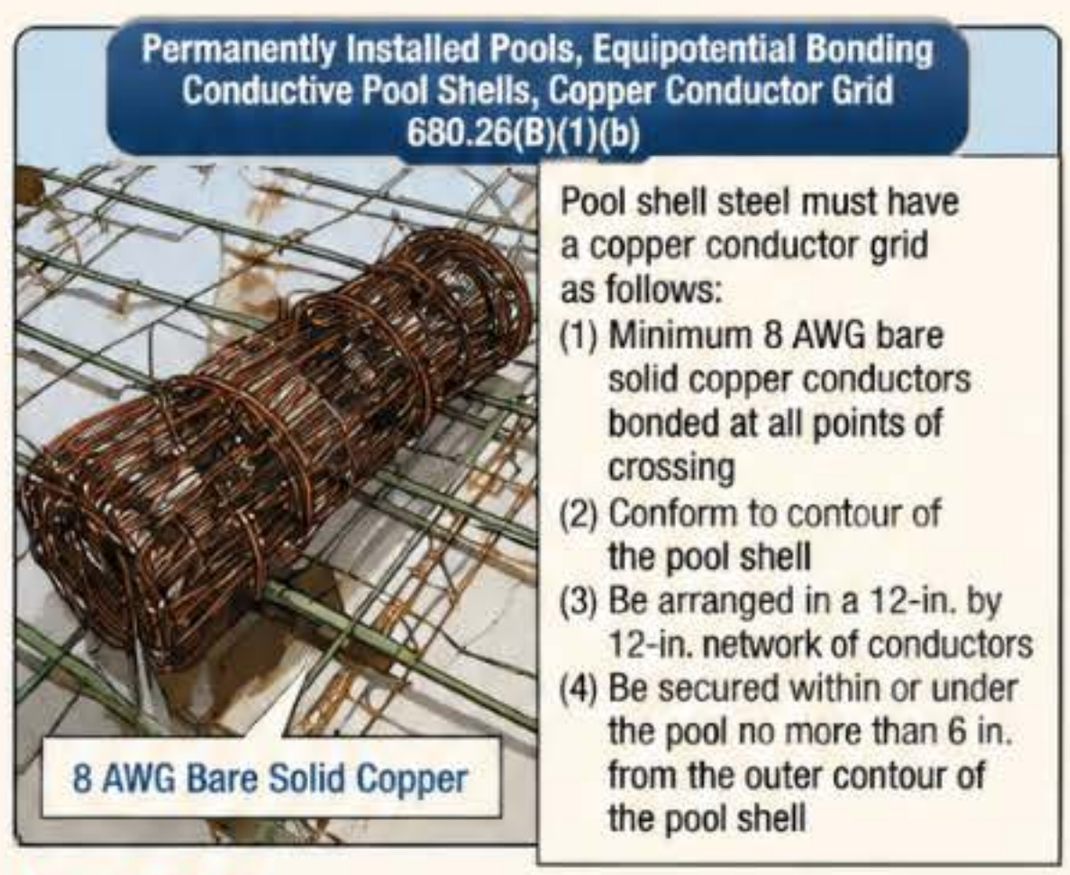
▸Figure 680–55



▸Figure 680–57



▸Figure 680–56



▸Figure 680–58

(1) Conductive Pool Shells. Cast-in-place concrete, pneumatically applied or sprayed concrete, and concrete block with painted or plastered coatings are considered conductive materials due to water permeability and porosity. Vinyl liners and fiberglass composite shells are considered nonconductive materials.

Reconstructed pool shells must also comply with this section.

(a) Structural Reinforcing Steel. Unencapsulated structural reinforcing steel must be bonded together by steel tie wires or the equivalent. ▸Figure 680–57

Where structural reinforcing steel is encapsulated in a nonconductive compound, a copper conductor grid must be installed in accordance with 680.26(B)(1)(b).

(b) Copper Conductor Grid. A copper conductor grid must comply with all of the following: ▸Figure 680–58

Author's Commentary:

Encapsulated structural reinforcing steel is used to prevent rebar corrosion and (if used) will make the pool shell insulated; therefore, a conductive copper grid is required in order to bond the pool shell.

— Michael Hamilton

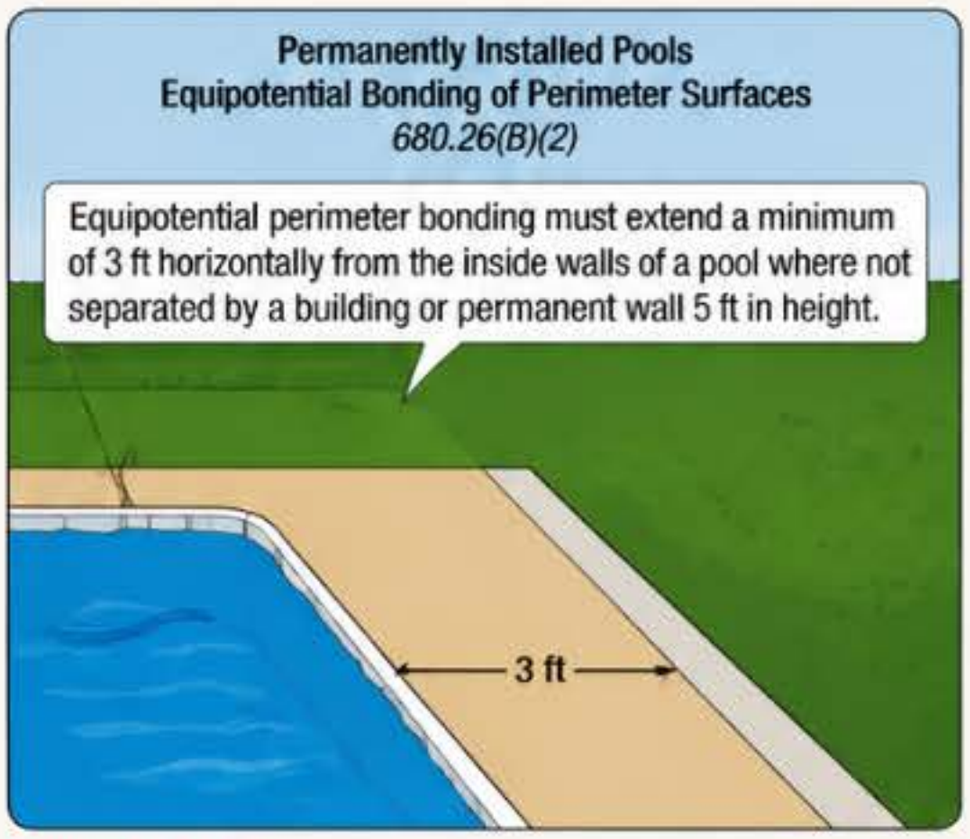
(1) Be constructed of a minimum of 8 AWG bare solid copper conductors bonded to each other at all points of crossing in accordance with 250.8, or other approved means.

(2) Conform to the contour of the pool.

(3) Be arranged in a 12-in. by 12-in. network of conductors in a uniformly spaced perpendicular grid pattern with a tolerance of 4 in.

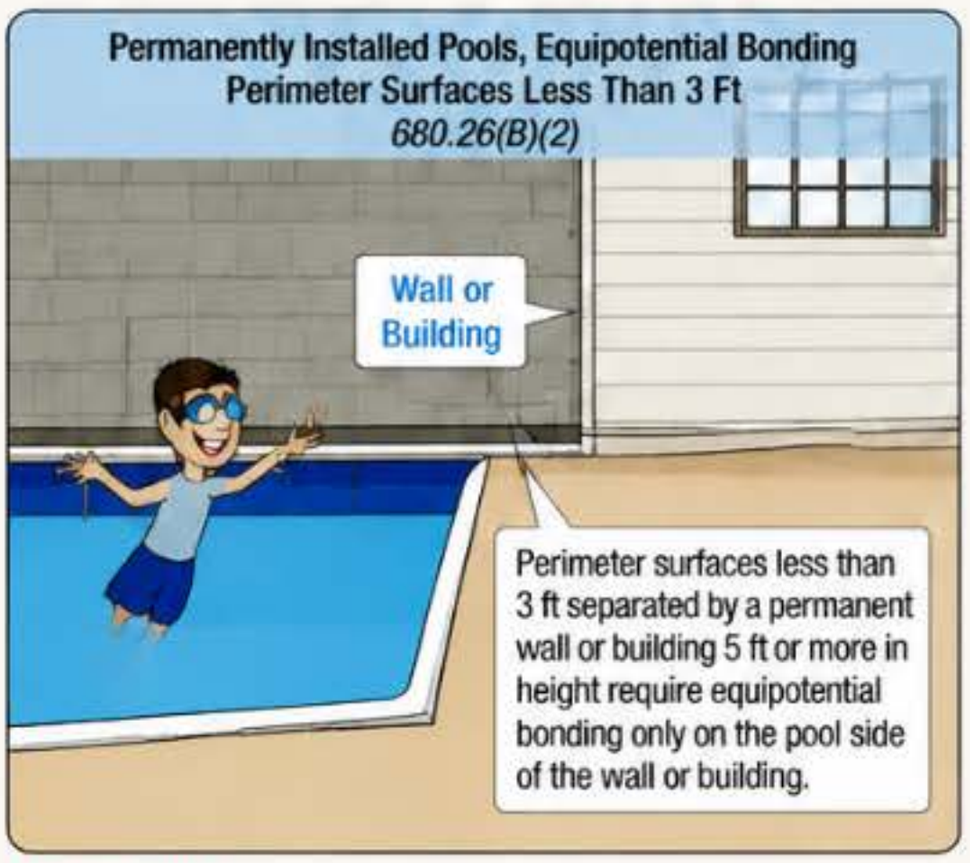
(4) Be secured within or under the pool no more than 6 in. from the outer contour of the pool shell.

(2) Perimeter Surfaces. Equipotential perimeter bonding must extend a minimum of 3 ft horizontally from the inside walls of a pool where not separated by a building or permanent wall 5 ft in height. ▸Figure 680–59



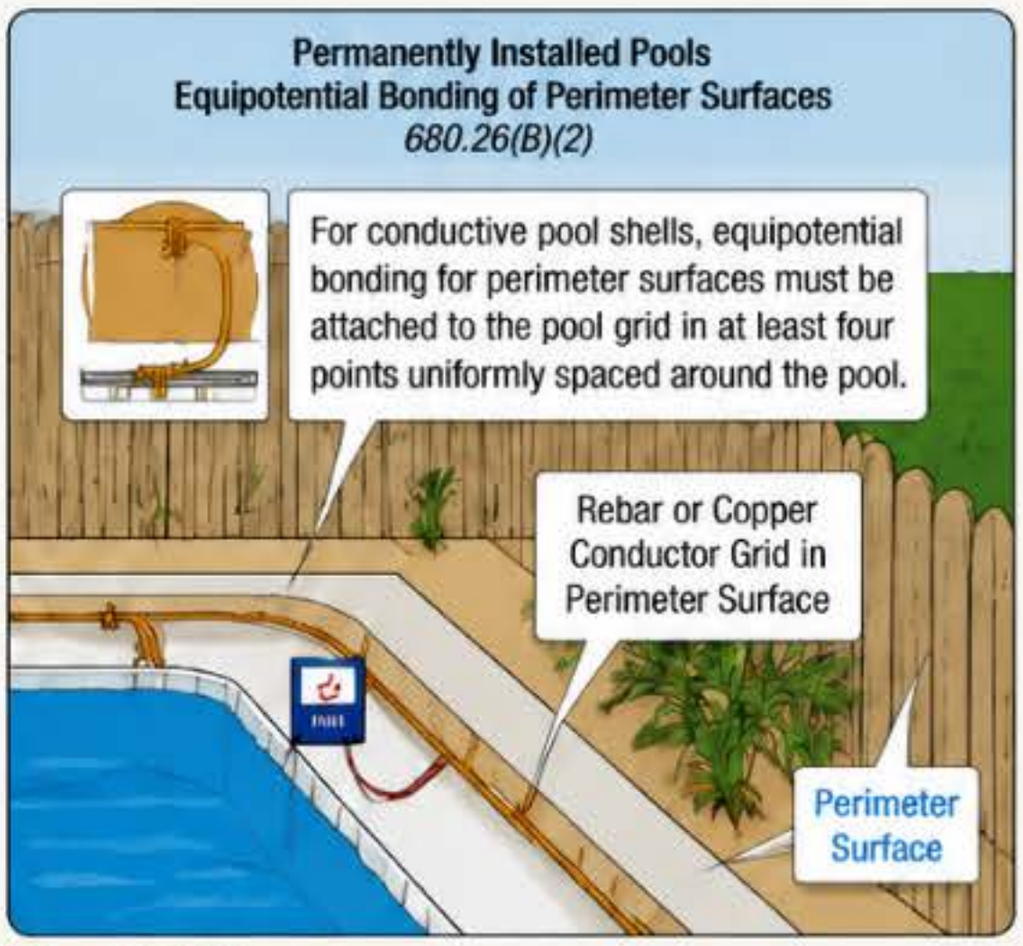
▸Figure 680–59

Perimeter surfaces less than 3 ft separated by a permanent wall or building 5 ft or more in height require equipotential bonding only on the pool side of the wall or building. ▸Figure 680–60



▸Figure 680–60

For conductive pool shells, equipotential bonding for perimeter surfaces must be attached to the concrete pool reinforcing steel or copper conductor grid at a minimum of four points uniformly spaced around the perimeter of the pool and be one of the following: ▸Figure 680–61



▸Figure 680–61

(a) Structural Reinforcing Steel. Unencapsulated structural reinforcing steel bonded together by steel tie wires or the equivalent in accordance with 680.26(B)(1)(a). ▸Figure 680–62

▸Figure 680–62

Author's Commentary:

The *NEC* does not provide any guidance on the installation requirements for structural reinforcing steel when used as a perimeter surface equipotential bonding method.

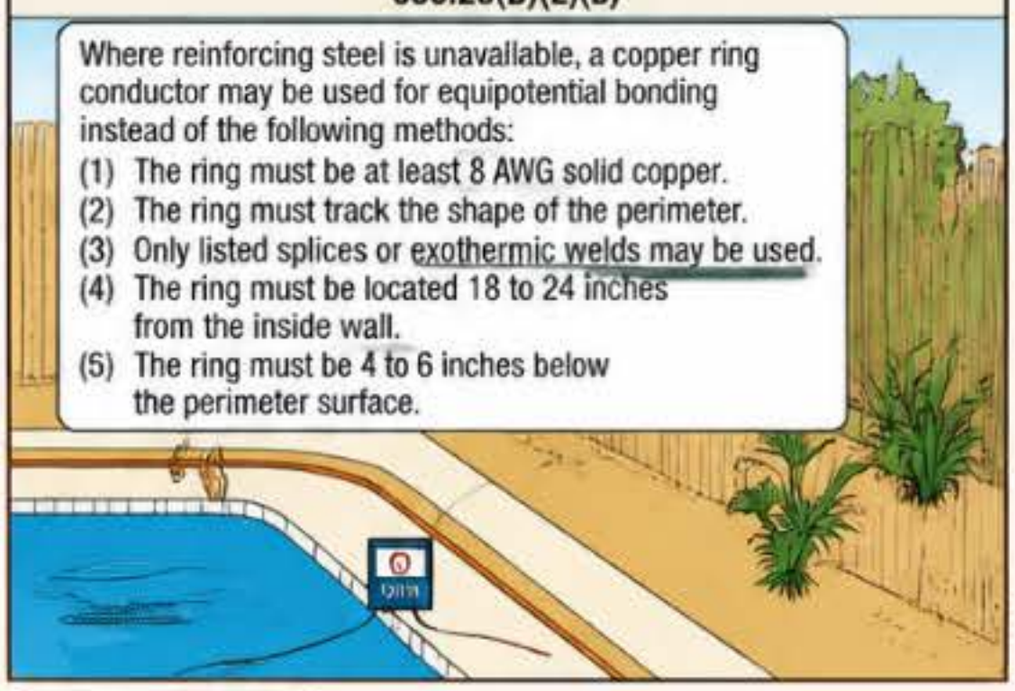
— Michael Hamilton

(b) Copper Ring. Where structural reinforcing steel is not available or is encapsulated in a nonconductive compound, a copper conductor can be used for equipotential perimeter bonding where the following requirements are met: ▸Figure 680–64

PERMANENTLY INSTALLED POOLS, EQUIPOTENTIAL BONDING STRUCTURAL REINFORCING STEEL IN PERIMETER SURFACE 680.26(B)(2)(a) COMMENT

▶ Figure 680–63

PERMANENTLY INSTALLED POOLS, EQUIPOTENTIAL BONDING OF PERIMETER SURFACES, COPPER RING 680.26(B)(2)(b)



▶ Figure 680–64

(1) Construct the copper ring using 8 AWG or larger solid bare copper.

(2) Follow the outline of the perimeter surface with the copper ring conductor.

(3) Use only listed splicing products or exothermic welding for connections.

(4) Place the conductor 18 to 24 inches away from the inside face of the pool.

(5) Secure the conductor either on or under the perimeter surface, positioned 4 to 6 inches beneath the finished grade.

Author's Commentary: When reinforcing steel is not available or cannot be encased in a nonconductive compound, an alternative bonding path is a copper ring. A copper grid can also satisfy the perimeter bonding criteria when all the listed conditions are met.

— **Michael Hamilton**

(1) Build the copper grid from 8 AWG solid bare copper and lay it out in a 12-inch by 12-inch matrix of conductors with uniform spacing at right angles, allowing a tolerance of 4 inches in any direction.

(2) Extend the copper grid following the perimeter contour horizontally at least 3 feet beyond the inside walls of the pool.

(3) Employ only listed splicing devices or exothermic welding for all connections.

(4) Fasten the copper grid either on or under decks and unpaved surfaces at depths of 4 to 6 inches below the subgrade.

(3) Metallic Components. All metal parts of the pool structure must be bonded together.

(4) Underwater Lighting. Bond every metal forming shell used for underwater luminaires.

Example: Low-voltage lighting with nonmetallic lampshades does not need to be bonded.

(5) Metal Fittings. Metal fittings 4 inches or larger in any direction, and those attached to the pool (such as ladders and handrails), must be connected to the pool's equipotential bonding system.

PERMANENTLY INSTALLED POOLS EQUIPOTENTIAL BONDING, METAL FITTINGS 680.26(B)(5)

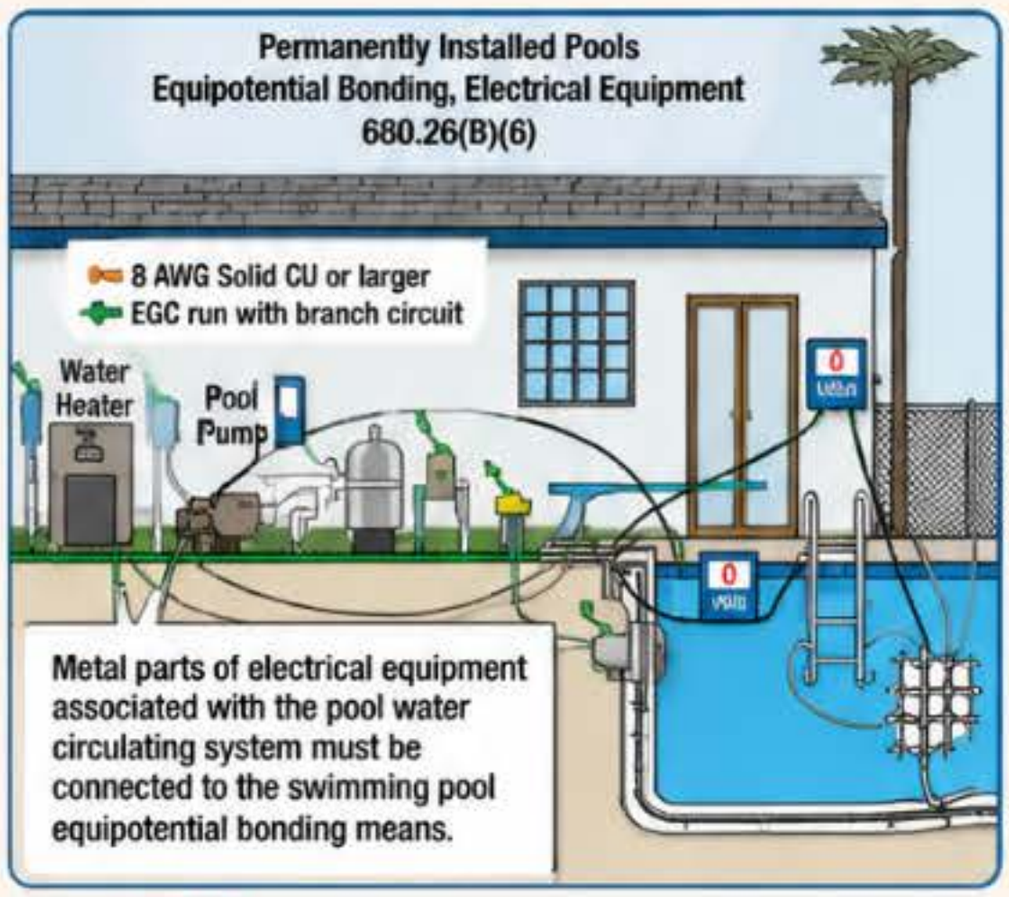
▶ Figure 680–65

(1) Metal anchors for pool cover attachments that are 1 inch or smaller in any dimension, or 2 inches or shorter in length, do not have to be connected to the equipotential bonding system.

(6) Electrical Equipment. Metal components of electrical gear associated with the pool water circulation system—including pool heaters, pumps, and metal parts of pool covers—must be connected to the pool's equipotential bonding system. ▶ Figure 680–66

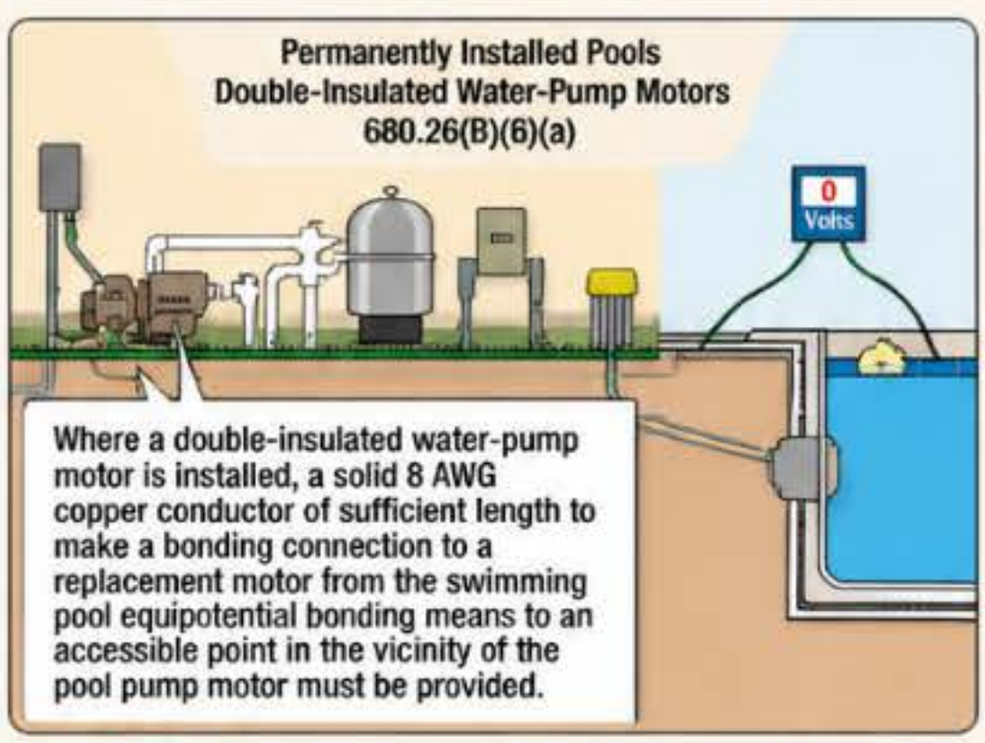
Author's Commentary: Bonding requirements extend to all metallic equipment tied to the pool's recirculating water system. This includes pool heaters, pumps, and metal elements of pool covers.

— **Michael Hamilton**



▸ Figure 680–66

(a) Double-Insulated Water-Pump Motors. Where a double-insulated water-pump motor is installed, a solid 8 AWG copper conductor of sufficient length to make a bonding connection to a replacement motor from the swimming pool equipotential bonding means to an accessible point in the vicinity of the pool pump motor must be provided. ▸ Figure 680–67



▸ Figure 680–67

Where there is no connection between the swimming pool equipotential bonding means and the equipment grounding system for the premises, this bonding conductor must be connected to the equipment grounding conductor of the motor circuit.

(7) Fixed Metal Parts. Fixed metal parts such as metal-sheathed cables and raceways, metal piping, metal awnings, metal fences, and metal door and window frames located within 5 ft horizontally [680.26(B)(7) Ex 2] and 12 ft vertically [680.26(B)(7) Ex 3] from the inside wall of the pool, must be connected to the swimming pool equipotential bonding means. ▸ Figure 680–68

▸ Figure 680–68

Ex 1: Those separated from the pool by a permanent barrier that prevents contact by a person are not required to be bonded.

Ex 2: Those separated by a distance greater than 5 ft horizontally from the inside walls of the pool are not required to be bonded. ▸ Figure 680–69

▸ Figure 680–69

(C) Pool Water. If the pool water in a nonconductive pool structure (vinyl or fiberglass) does not have a direct electrical connection to one of the bonded parts described in 680.26(B), an approved corrosion-resistant conductive surface that is at least 9 sq in. in contact with the water must be bonded in accordance with 680.26(B). ▸ Figure 680–70

Permanently Installed Pools, Nonmetallic Pool Structures
Pool Water Equipotential Bonding
680.26(C)

If the pool water in a nonconductive pool structure doesn't have a direct electrical connection to one of the bonded parts described in 680.26(B), an approved corrosion-resistant conductive surface at least 9 sq in. in contact with the water must be bonded per 680.26(B).

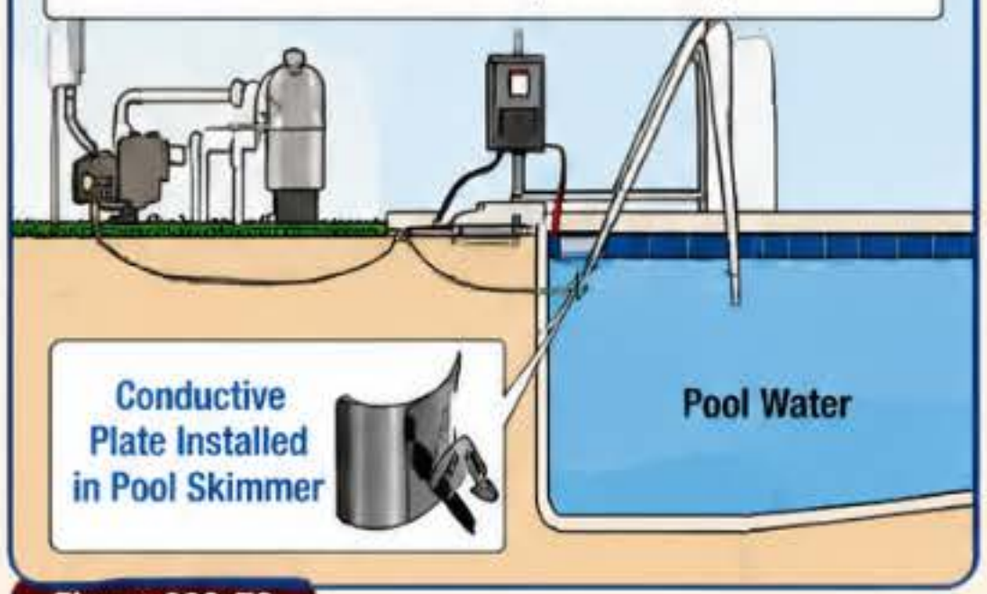


Figure 680-70

680.27 Specialized Equipment

(B) Electrically Operated Covers.

(1) Motors and Controllers. The electric motors, controllers, and wiring for an electrically operated cover must be located not less than 5 ft from the inside wall of a permenently installed pool unless separated by a permanent barrier.

(2) GFCI Protection. The branch circuit serving the electric motor and controller circuit must be GFCI protected.

680.28 Gas-Fired Water Heaters

Circuits serving gas-fired swimming pool water heaters operating at 120V must be GFCI protected.

Part III. Storable Pools, Spas, Hot Tubs, and Immersion Pools

680.30 General

Electrical installations for storable pools, storable spas, storable hot tubs, or storable immersion pools must comply with Part I as well as Part III of Article 680.

Author's Commentary:

The requirements contained in Part I of Article 680 include definitions, cord-and-plug-connected equipment, overhead conductor clearances, and the locations of maintenance disconnects.

— Michael Hamilton

- The bonding requirements contained in 680.26 (Part II of Article 680) do not apply to storable pools, storable spas, storable hot tubs, or storable immersion pools. **Figure 680-71**

Storable Pools, Spas, Hot Tubs, and Immersion Pools
Equipotential Bonding
680.30 Comment

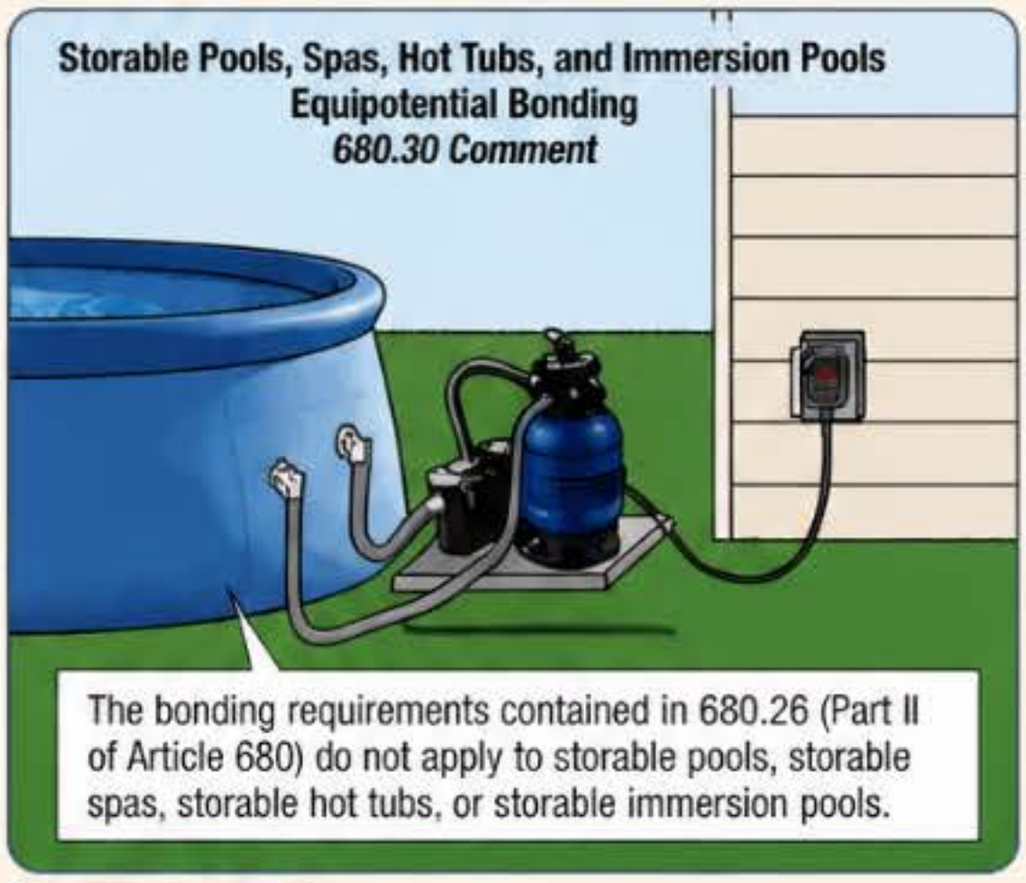


Figure 680-71

680.31 Pumps

A cord-connected pool filter pump must incorporate an approved system of double insulation or its equivalent and be provided with means for the termination of an equipment grounding conductor for the noncurrent-carrying metal parts of the pump.

An equipment grounding conductor must be run with the power-supply conductors in the flexible cord.

Cord-connected pool filter pumps must be provided with GFCI protection that is an integral part of the attachment plug or located in the power-supply cord within 12 in. of the attachment plug.

680.32 GFCI Protection

GFCI protection is required for electrical equipment associated with storable pools, and all 15A and 20A, 125V receptacles located within 20 ft from the inside walls of a storable pool, storable spa, or storable hot tub. **Figure 680-72**

680.34 Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations

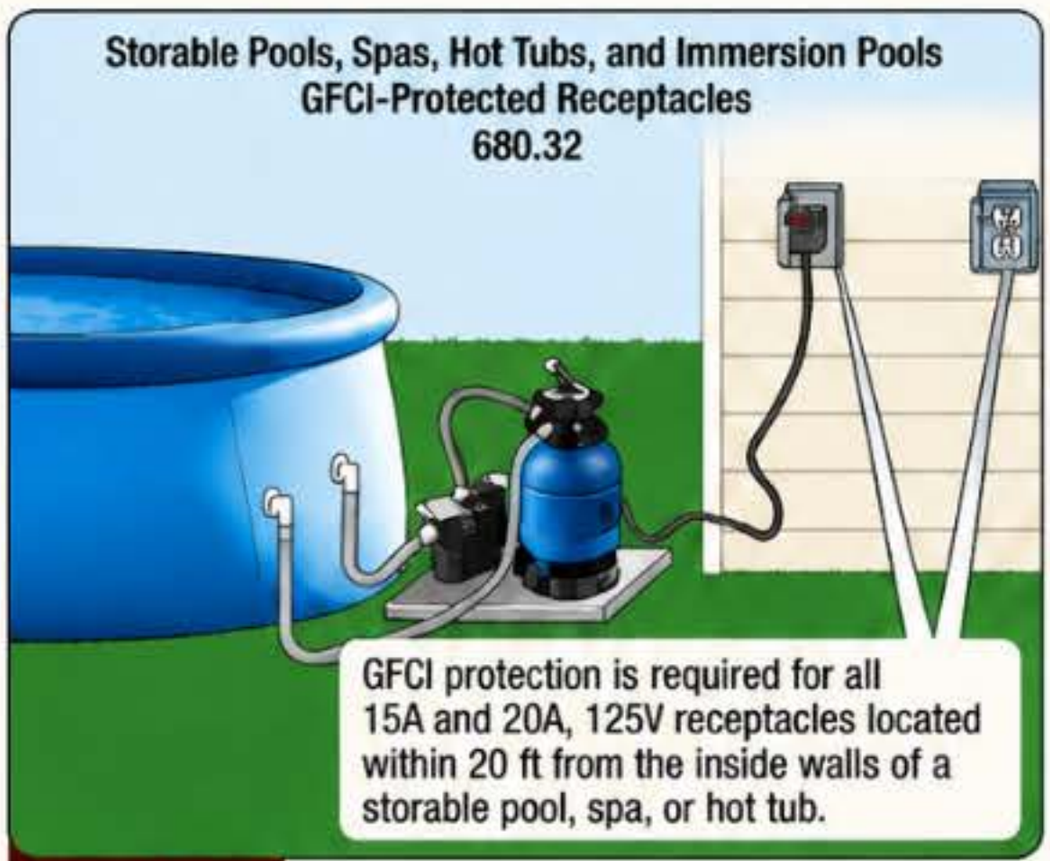


Figure 680–72

680.34 Receptacle Locations

Receptacles must not be located less than 6 ft from the inside walls of a storable pool, storable spa, or storable hot tub. The receptacle distance is measured as the shortest path a flexible cord will follow tnitbugrl a wail, odtrway, or window. ▸ Figure 680–73

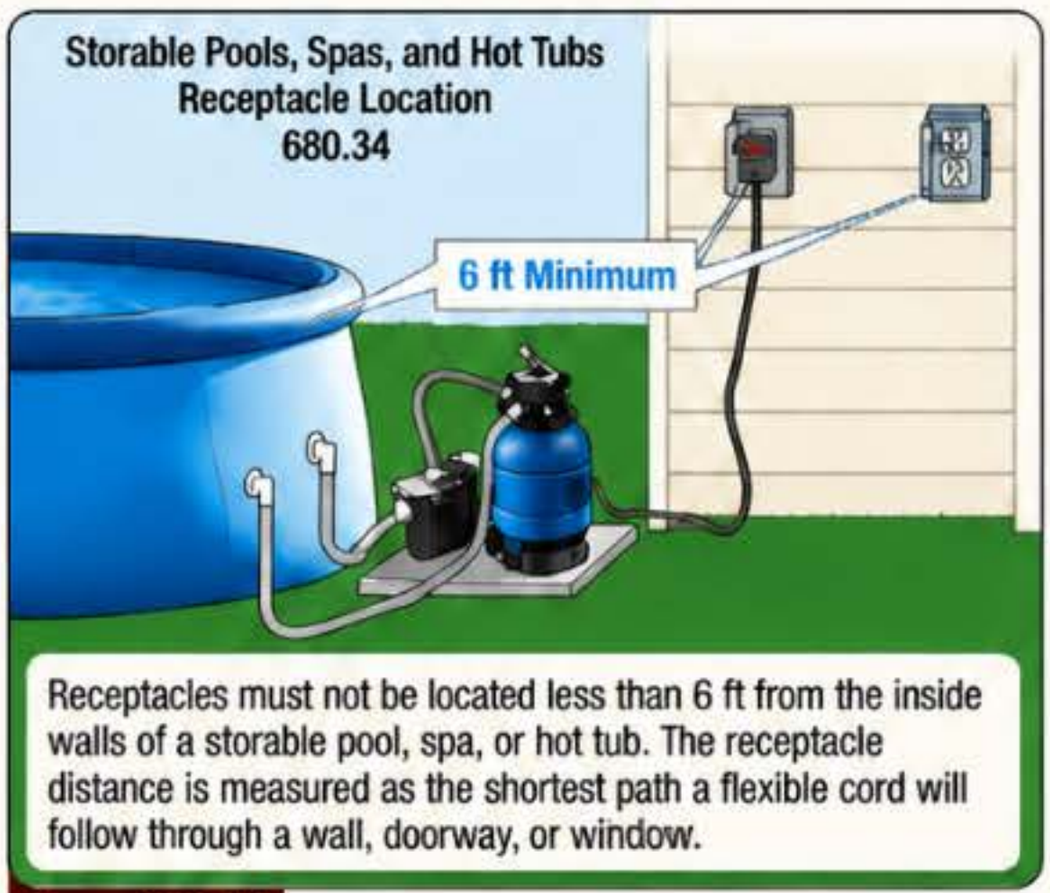


Figure 680–73

680.35 Storable and Portable Immersion Pools

Storable and portable immersion pools must comply with the additional requirements specified in 680.35(A) through (G) of the *Code*.

(A) Cord-Connected Storable and Portable Immersion Pools. Storable and portable immersion pools rated 20A, single-phase, 120V or less are permitted to be cord connected if they are GFCI protected.

(B) Pumps. A pump not built into the storable or portable immersion pool must be listed and labeled for swimming pool use.

(C) Heaters. If rated 20A and 30A, single-phase, 120V and 250V, the heater must be GFCI protected.

(E) Lighting Outlets. Unless within the low-voltage contact limit, lighting outlets must be located not less than 10 ft from the nearest point of an immersion pool.

(F) Switches. Switches, unless they are part of the unit, must be located not less than 5 feet from the immersion pool.

(G) Receptacles. All 15A, 250V or less receptacles within 20 ft of the inside wall of an immersion pool must be GFCI protected.

Part IV. Spas and Hot Tubs, and Permanently Installed Immersion Pools

680.40 General

Electrical installations for spas and hot tubs must comply with Part I as well as Part IV of Article 680.

680.41 Emergency Switch for Spas and Hot Tubs

In other than a one-family dwelling, a clearly labeled emergency spa or hot tub water recirculation and jet system shutoff is required. The emergency shutoff must be readily accessible to the users and located not less than 5 ft away, adjacent to, and within sight of the spa or hot tub. ▸ Figure 680–74

Figure 680–74

Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations 680.43

Author's Commentary:

- You can stop power to equipment covered by this section by either opening the maintenance disconnect [680.13] or by pressing a pushbutton that operates a relay. That relay must be installed in accordance with this section and used to achieve the required emergency shutoff.
- The goal of the emergency shutoff is to limit electrical hazards to people. Deaths and serious injuries have happened within 3 feet of water because someone became stuck to the water intake. This rule applies to both indoor and outdoor spas and hot tubs.

— Michael Hamilton

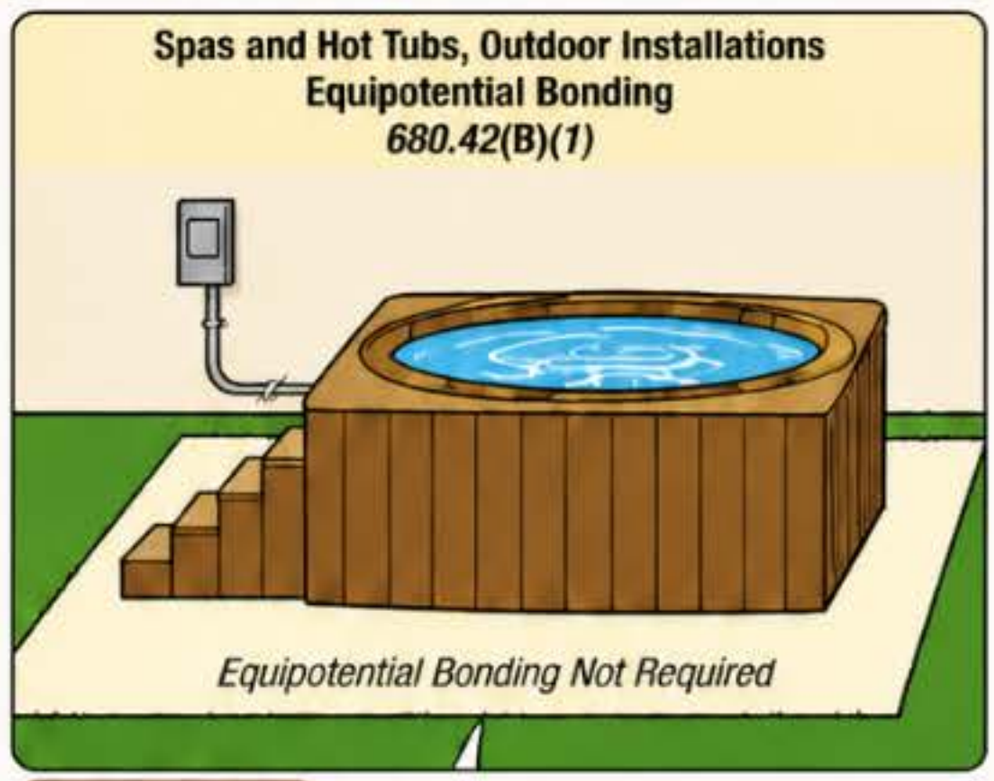


Figure 680–76

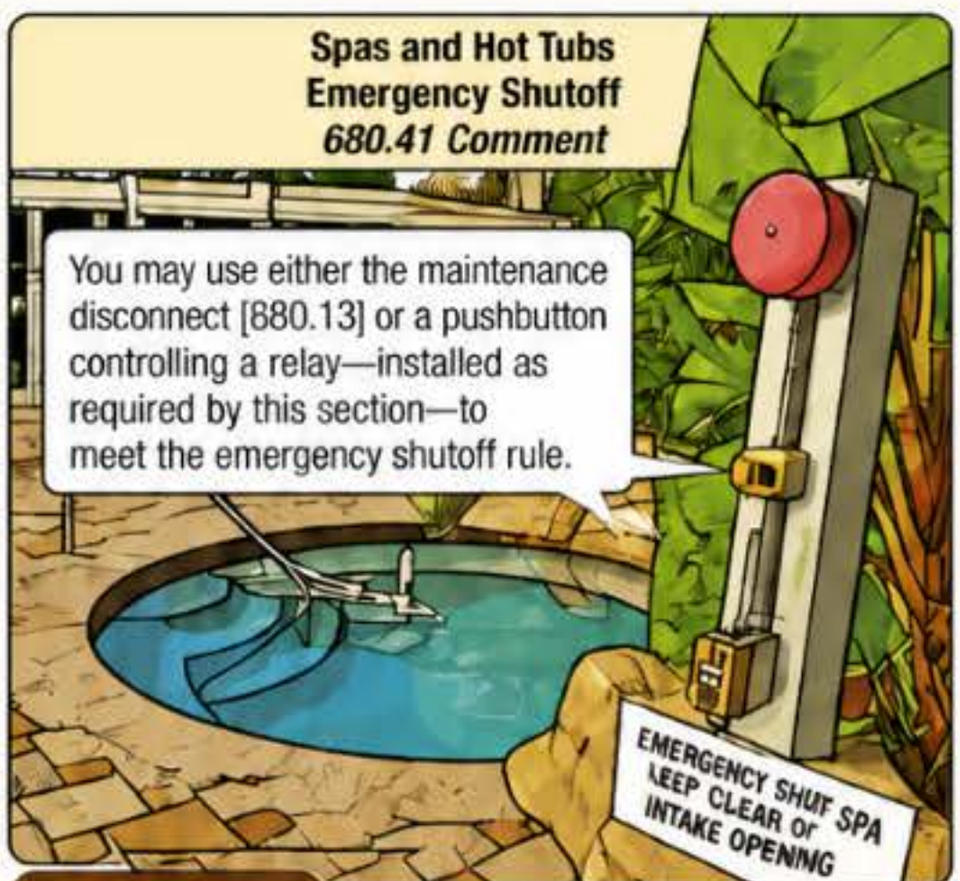


Figure 680–75

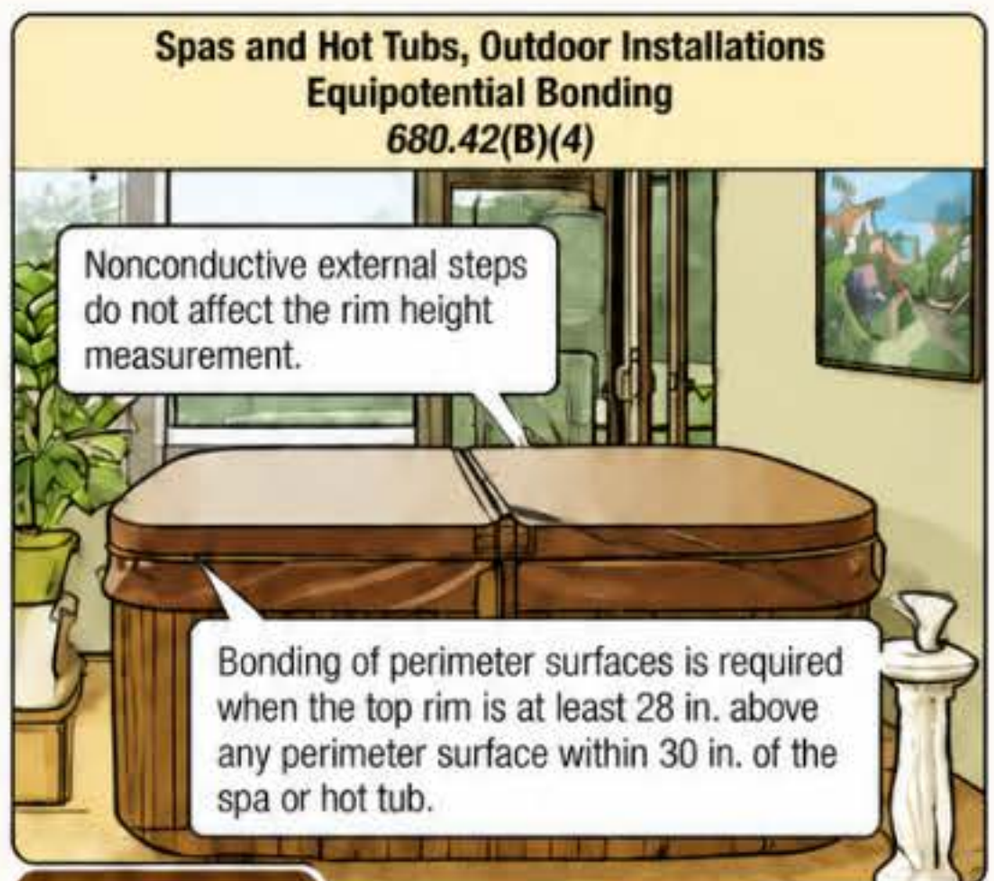


Figure 680–77

680.42 Outdoor Installations

(B) Equipotential Bonding. Equipotential bonding of perimeter surfaces for spas and hot tubs is not required if all the following conditions apply:

(1) The spa or hot tub is listed, labeled, and identified as a self-contained spa or hot tub for aboveground use.
(2) The spa or hot tub is not identified as suitable only for indoor use.
(3) The spa or hot tub is located on or above grade.
(4) The top rim of the spa or hot tub is at least 28 in. above any perimeter surface located within 30 in. of the spa or hot tub.

Nonconductive external steps do not apply to the rim height measurement. ▸**Figure 680–77**

(C) Wiring. Methods described in Chapter 3 are allowed inside a dwelling unit to connect to a disconnecting means for a spa or hot tub. ▸**Figure 680–78**

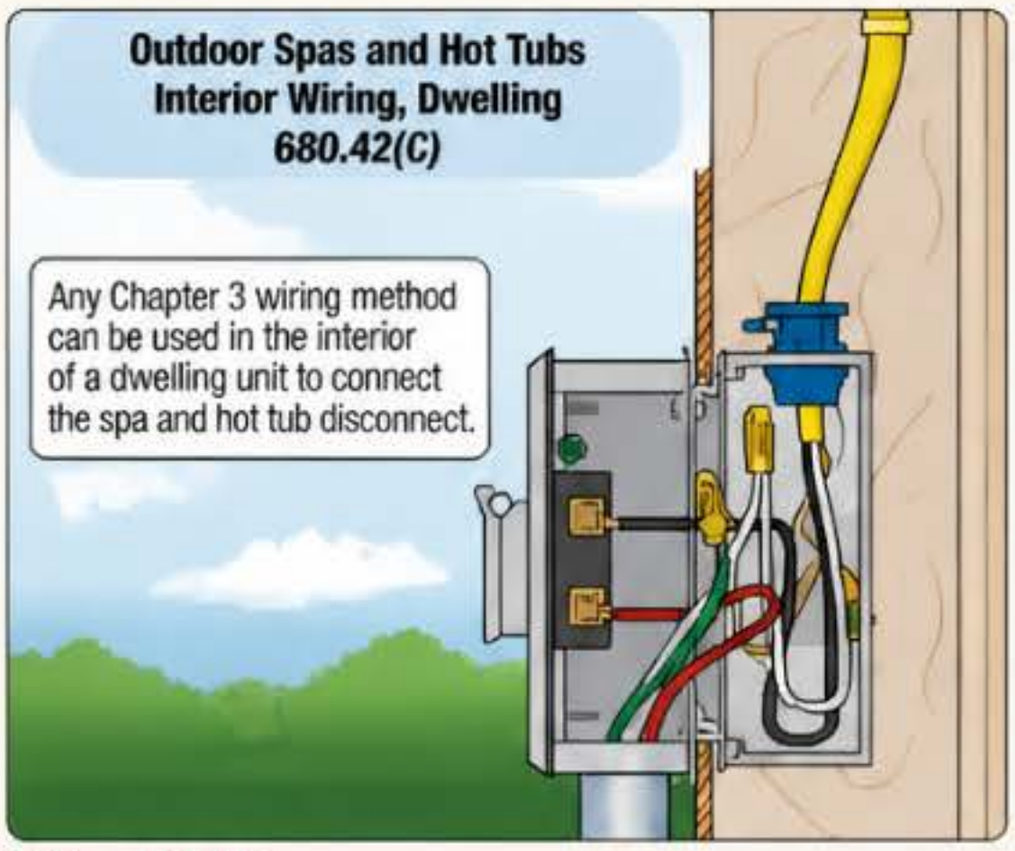
680.43 Indoor Installations

Electrical work for indoor spas and hot tubs must comply with Part I and Part II of Article 680, with the exceptions stated here.

Indoor installations can use any wiring method listed in Chapter 3.

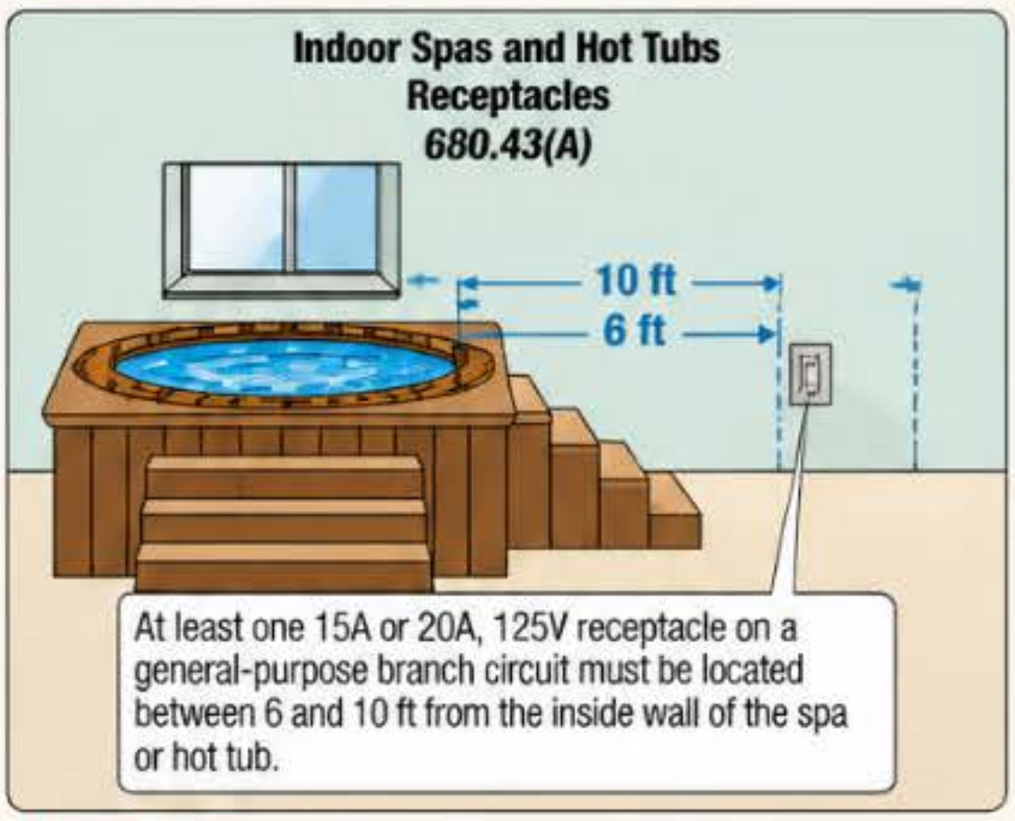
Ex 2: The requirement in 680.26(B)(2) about perimeter bonding for listed self-contained spas or hot tubs does not apply when installed above an indoor finished floor.

680.44 SWIMMING POOLS, SPAS, HOT TUBS, FOUNTAINS, AND SIMILAR INSTALLATIONS



▸ Figure 680-78

(A) Receptacles. At least one 15A or 20A, 125V receptacle on a general-purpose branch circuit must be located not less than 6 ft and not more than 10 ft from the inside wall of a spa or hot tub. ▸ Figure 680-79



▸ Figure 680-79

(1) Location. Receptacles must be installed not less than 6 ft, measured horizontally, from the inside walls of the spa or hot tub.

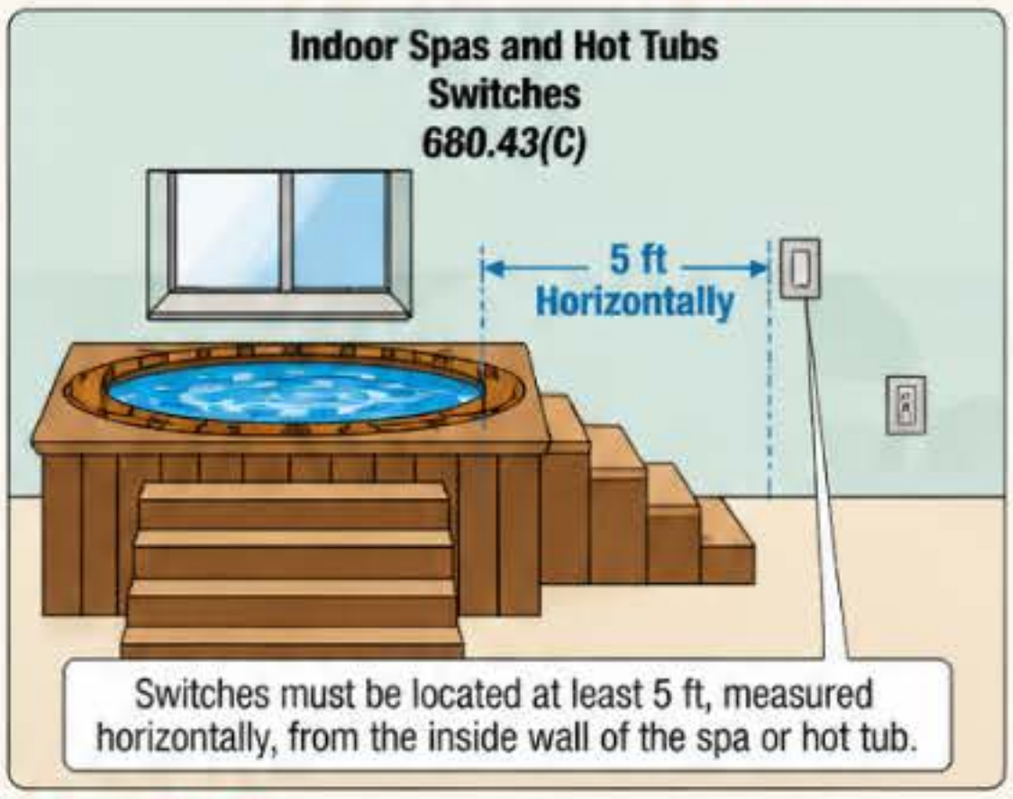
(2) Protection, General. Receptacles rated 30A, 125V or less and insatlled within 10 ft of the inside walls of a spa or hot tub must be GFCI protected.

(3) Protection, Spa or Hot Tub Supply Receptacle. Receptacles that provide power to spa or hot tub equipment must be GFCI protected.

Author's Commentary:
Always verify distances from the inside wall of the spa or hot tub, not from the outside. Measuring incorrectly is a common installation mistake.
— Michael Hamilton

(4) Measurements. To determine the dimensions in this section, identify the shortest path a flexible cord from the appliance connected to the receptacle will take without piercing a floor, wall, ceiling, doorway fitted with a hinged or sliding door, window opening, or any other type of permanent barrier.

(C) Switches. Switches must be mounted at least 5 ft from the inside wall of the spa or hot tub. ▸ Figure 680-80



▸ Figure 680-80

680.44 GFCI Protection

Outlets that supply self-contained or packaged spa and hot tub assemblies must be GFCI protected, unless the spa or hot tub is listed, labeled, and identified to contain integral GFCI protection [680.44(A)]. ▸ Figure 680-81

(A) Listed Units. If a self-contained or packaged spa or hot tub is marked, labeled, and identified as having integral GFCI protection, the equipment assembly (including integral GFCI protection for all electrical parts) does not require any additional GFCI protection. ▸ Figure 680-82

680.45 Permanently Installed Immersion Pools

Electrical installations for permanently installed immersion pools, whether indoors or outdoors, must comply with Parts I, II, and IV of this article, except as modified by section 680.45 and must be constructed in accordance with wiring methods of Chapter 3 of the *Code*. With respect to the provisions in Part IV of this article, an immersion pool is considered to be a spa or hot tub.

Author's Commentary:
Integral GFCI protection built into listed spas simplifies installation by removing the need for additional external GFCI devices.
— Michael Hamilton

Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations

Outlets that supply self-contained or packaged spa and hot tub assemblies must be GFCI protected, unless the spa or hot tub is listed, labeled, and identified to contain integral GFCI protection [680.44(A)].

▸ Figure 680–81

If so marked, a listed, labeled, and identified self-contained spa or hot tub, or a listed, labeled, and identified packaged equipment assembly that includes integral GFCI protection for all electrical circuits does not require additional GFCI protection.

▸ Figure 680–82

Part V. Fountains

680.50 General

The general installation requirements contained in Part I apply to fountains (including splash pads) planned for recreational use by pedeetrians. In addition, the requirements in Part V apply to fountains filled with water that are common to pools.

Author's Commentary:

A "fountain" in 680.2 refers to an ornamental structure or recreation water feature from which one or more jets or streams of water are projected into the air. Typical examples include splash pads, ornamental pools, display pools, and reflection pools.

— Michael Hamilton

680.51 Luminaires and Submersible Equipment

(A) GFCI Protection. All luminaires, submersible pumps, and other submersible equipment must have GFCI protection unless the equipment is **specifically listed** and is supplied through a transformer or power source that complies with 680.23(A)(2).

▸ Figure 680–83

GFCI protection is required for luminaires, submersible pumps, and other submersible equipment unless listed and supplied via a transformer or power source that complies with 680.23(A)(2).

▸ Figure 680–83

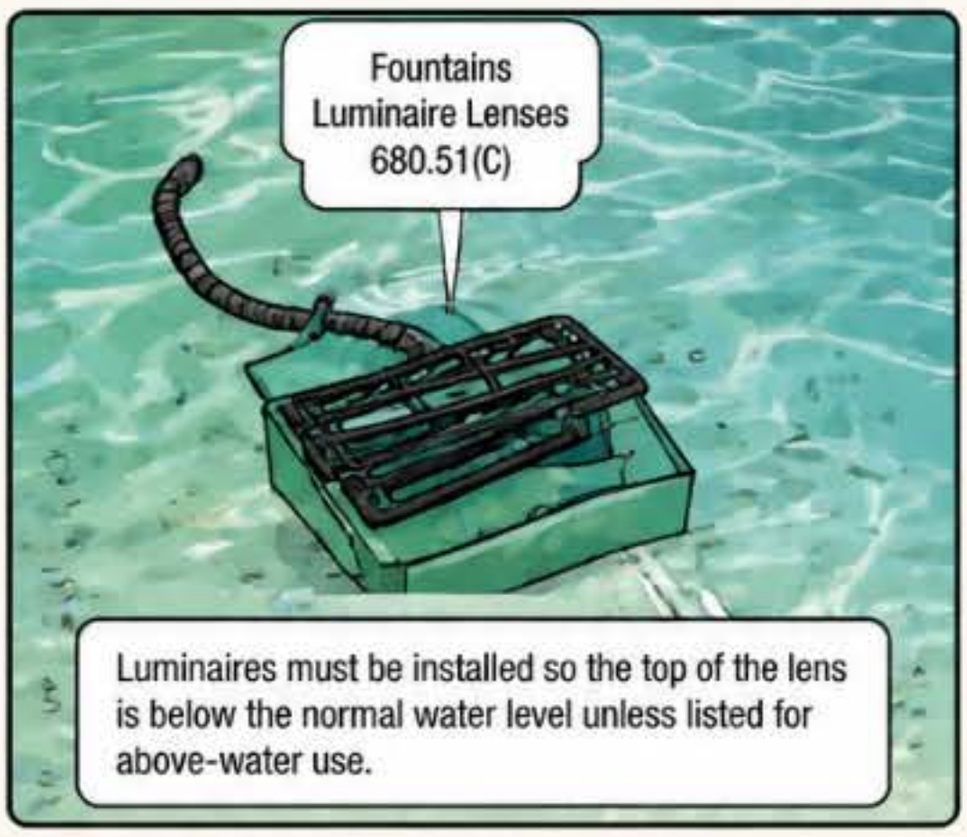
(C) Luminaire Lenses. Luminaires must be installed so the top of the luminaire lens is at or above the normal water level unless the luminaire is listed for this application.

▸ Figure 680–84

(E) Cords. The maximum length of any exposed flexible cord used in a fountain is 10 ft. Power-supply cords that extend beyond the perimeter must be enclosed in wiring enclosures approved by the authority having jurisdiction.

(F) Servicing. Equipment must be capable of being removed from the water for relamping or normal maintenance.

(G) Stability. Equipment must be intrinsically stable or firmly secured in place.



▶ Figure 680–84

680.54 Connection to an Equipment Grounding Conductor

(A) Connection to Equipment Grounding Conductor. The following equipment must be connected to the circuit equipment grounding conductor:

(1) Other than listed low-voltage luminaires not requiring grounding, all electrical equipment located within the fountain or within 5 ft of the inside wall of the fountain.

(2) All electrical equipment associated with the recirculating system of the fountain.

(3) Panelboards that are not part of the service equipment and supply any electrical equipment associated with the fountain.

Note: See 250.122 for the sizing of these conductors.

(B) Bonding. The following parts must be bonded together and connected to an equipment grounding conductor on a branch circuit supplying the fountain:

(1) All metal piping systems associated with the fountain

(2) All metal fittings within or attached to the fountain

(3) Metal parts of electrical equipment associated with the fountain water-circulating system including pump motors

(4) Metal raceways within 5 ft of the inside wall or perimeter of the fountain and not separated from it by a permanent barrier

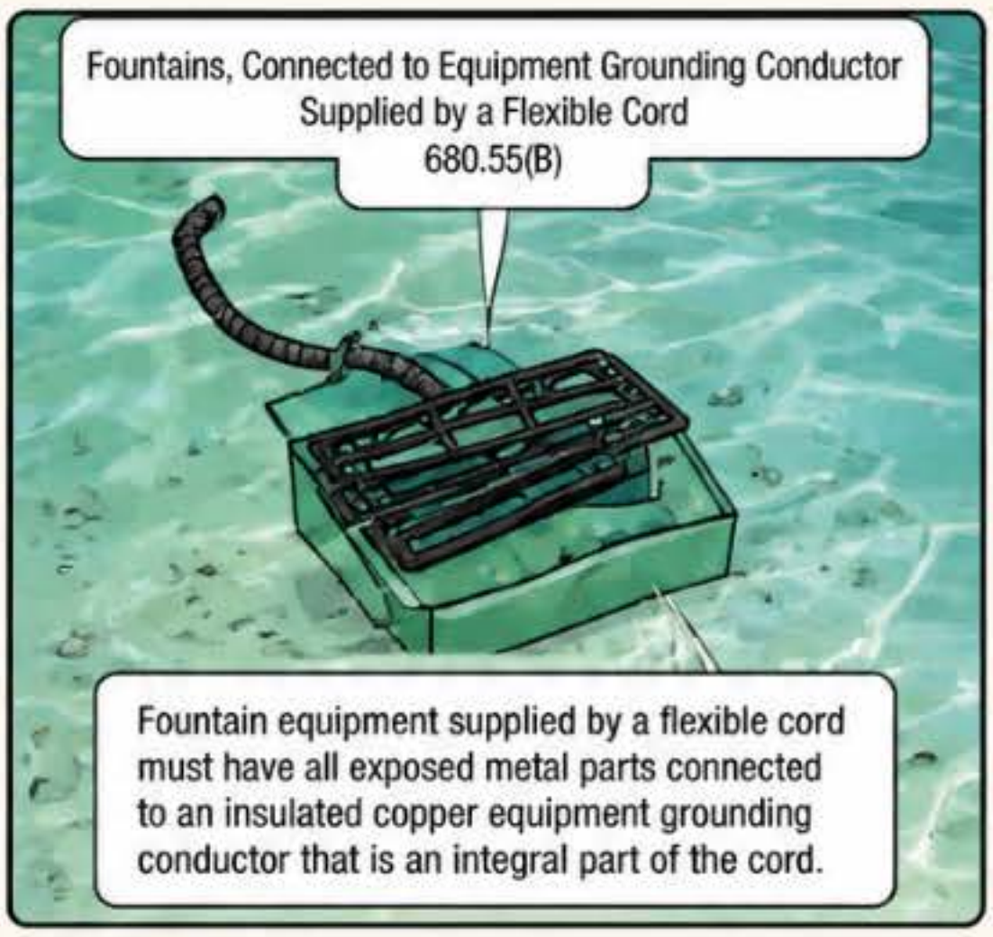
(5) All metal surfaces within 5 ft of the inside wall or perimeter of the fountain and not separated from it by a permanent barrier

(6) Electrical devices and controls not associated with the fountain and located less than 5 ft from its inside wall or perimeter.

680.55 Methods of Equipment Grounding

(A) Additional Requirements. The grounding requirements of 680.21(A), 680.23(B)(3), 680.23(F)(1) and (2), 680.24(F), and 680.25 apply to fountains.

(B) Supplied by Flexible Cord. Fountain equipment supplied by a flexible cord must have all exposed metal parts connected to an insulated copper equipment grounding conductor that is an integral part of the cord. • **Figure 680–85**



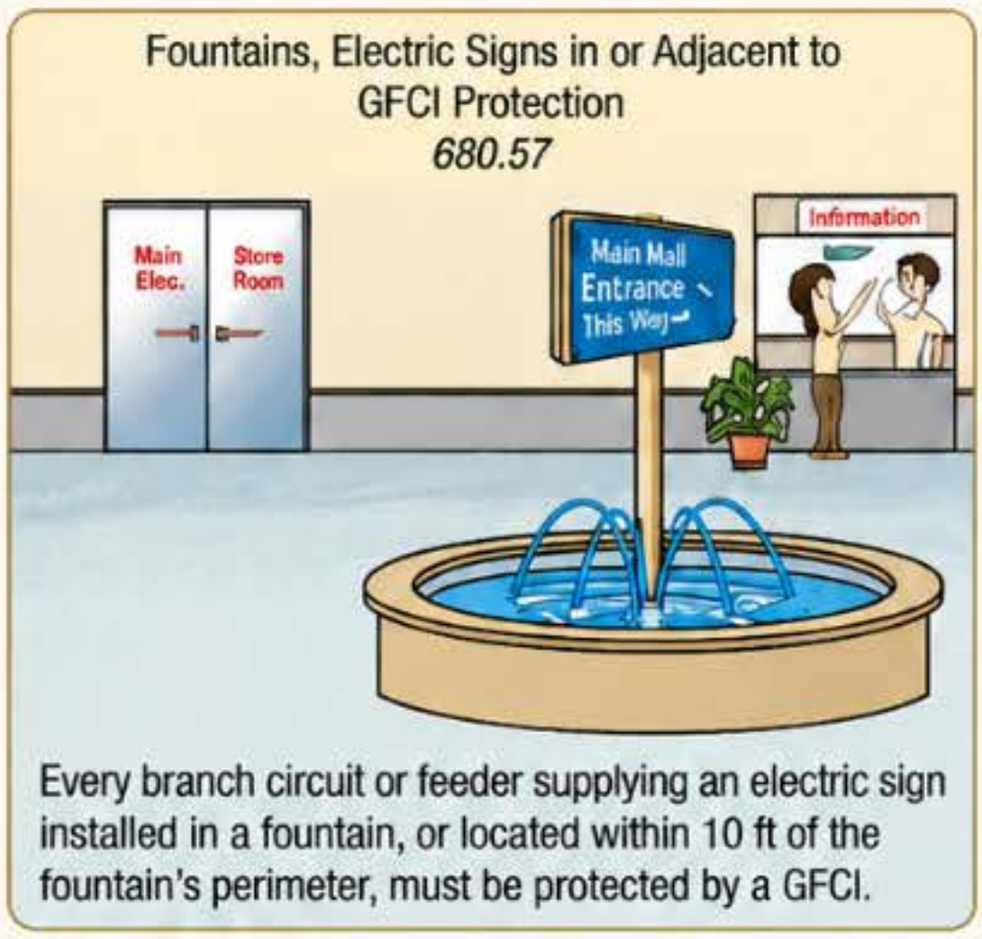
▶ Figure 680–85

680.56 Cord-and-Plug-Connected Equipment

(A) Ground-Fault Circuit Interrupter. All electrical equipment, including power-supply cords, must be GFCI protected.

680.57 Electric Signs in or Adjacent to Fountains

Each branch circuit or feeder that supplies an electric sign installed within a fountain, or within 10 ft of the fountain edge, must be GFCI protected. • **Figure 680–86**

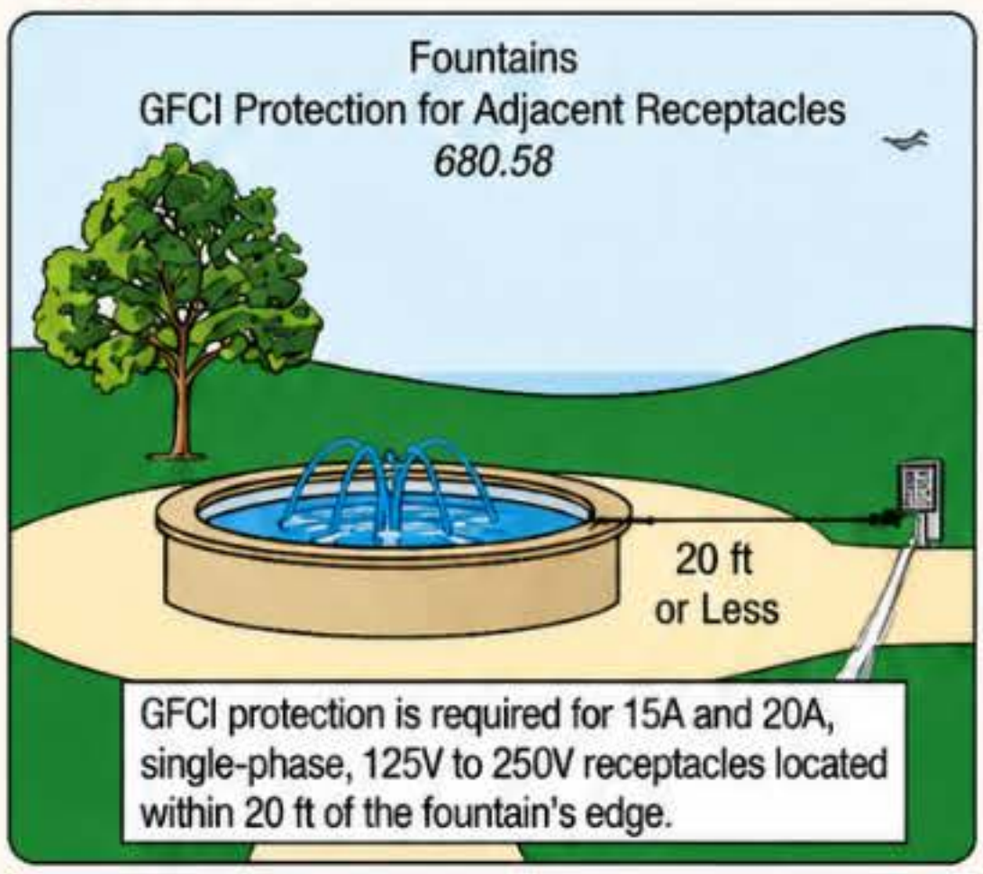


▸ Figure 680–86

680.58 GFCI Protection for Adjacent Receptacles

GFCI protection is required for 15A and 20A, single-phase, 125V through 250V receptacles located within 20 ft of the fountain's edge.

▸ Figure 680–87



▸ Figure 680–87

680.59 GFCI Protection for Permanently Installed Nonsubmersible Pumps

Outlets supplying permanently installed nonsubmersible pump motors rated 250V or less and 60A or less must be GFCI protected.

Part VII. Hydromassage Bathtubs

680.70 General

A hydromassage bathtuls is subject to the requirements of Part VII; it is not necessary to meet the provisions of the other sections of this article.

Author's Commentary:

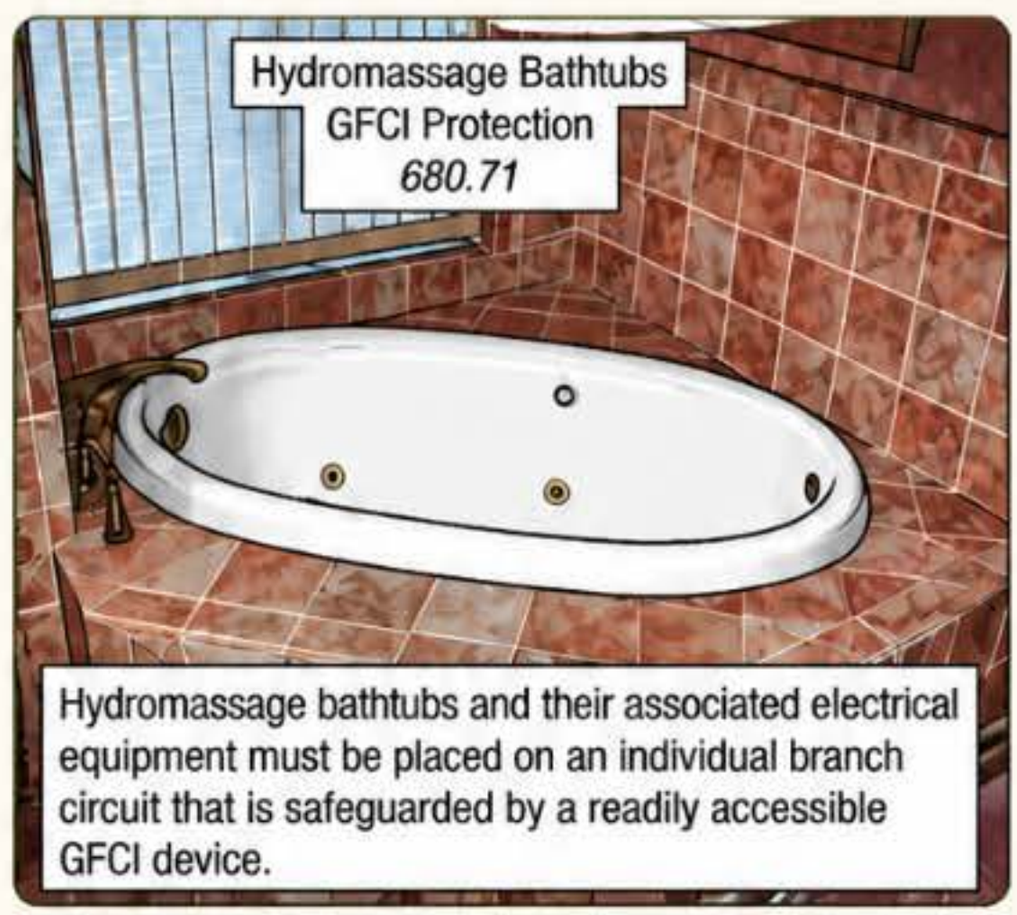
By definition in 680.2, a "hydromassage bathtub" is a permanent fixture with a recirculating piping arrangement intended to receive, circulate, and release water following each use.

— **Michael Hamilton**

680.71 GFCI Protection

Hydromassage bathtubs and their associated electrical equipment must be placed on an individual branch circuit that is safeguarded by a readily accessible GFCI device.

▸ Figure 680–88



▸ Figure 680–88

680.73 Accessibility

Electrical equipment for hydromassage bathtubs must be capable of being removed or exposed without causing damage to the building structure or finish.

▸ Figure 680–89

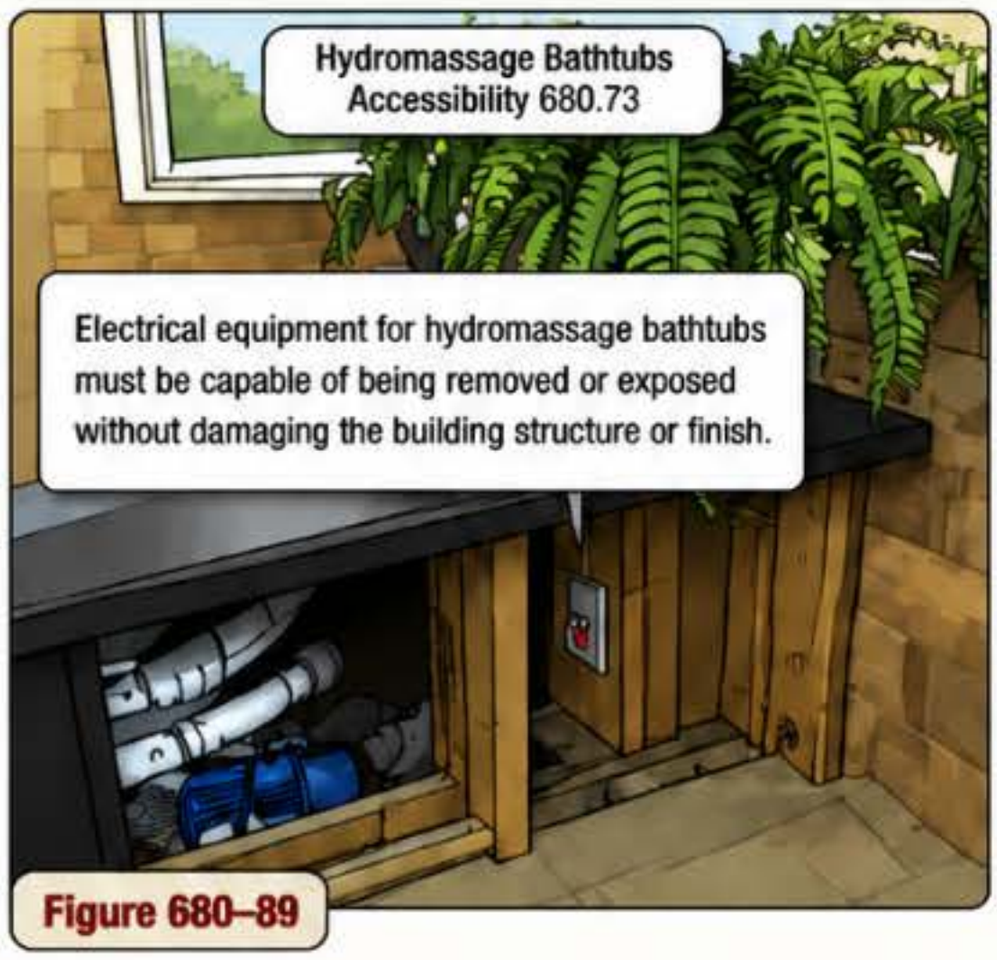


Figure 680–89

Where the hydromassage batthub is cord-and-plug-connected and the supply receptacle is only accessible through a service access opening, the receptacle must be installed so its face is in direct view and be located within 1 ft of the opening. ▶ Figure 680–90

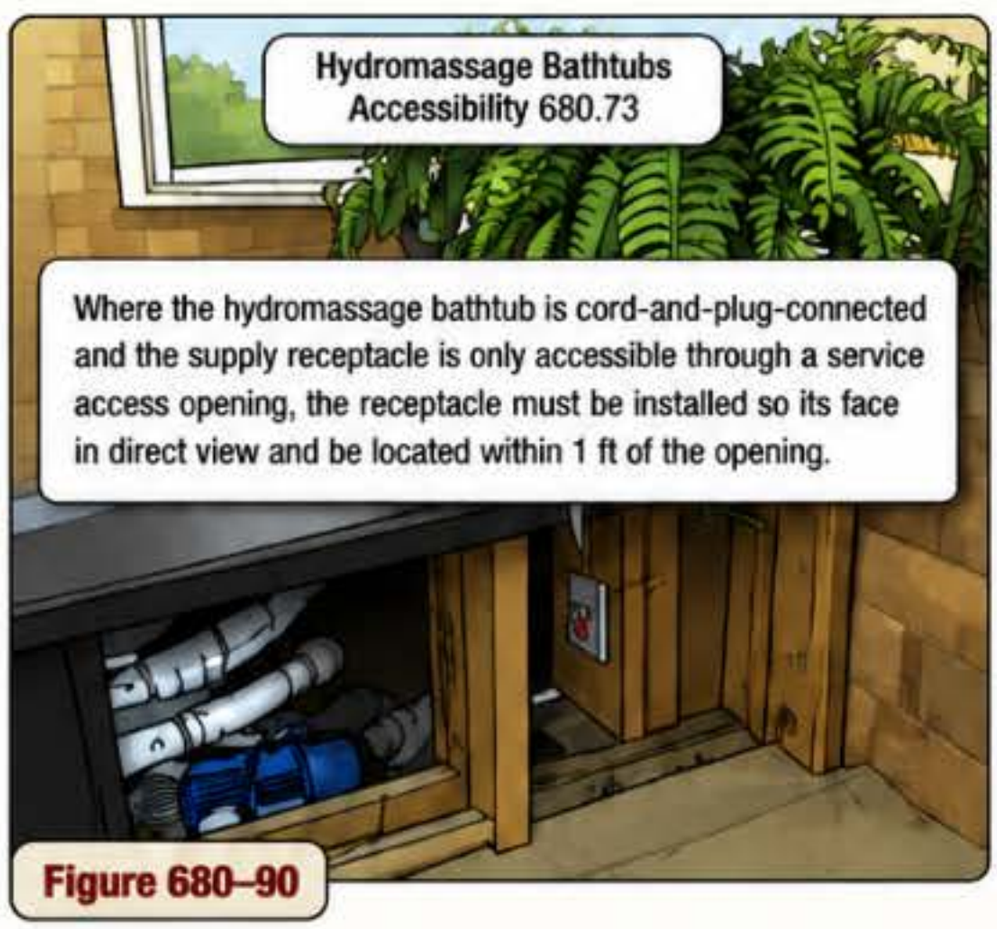


Figure 680–90

680.74 Equipotential Bonding

(A) General. The following parts must be bonded together.

(1) Metal fittings within, or attached to, the hydromassage bathtub structure that are in contact with the circulating water.

(2) Metal parts of electrical equipment associated with the hydromassage bathtub water circulating system, including pump and blower motors.

(3) Metal-sheathed cables, metal raceways, and metal piping within 5 ft of the inside walls of the hydromassage bathtub and not separated from it by a permanent barrier.

(4) Exposed metal surfaces within 5 ft of the inside walls of the hydromassage bathtub and not separated from it by a permanent barrier.

(5) Metal parts of electrical devices not associated with the hydromassage bathtub located within 5 ft from the hydromassage bathtub.

Ex 1: Small conductive surfaces not likely to become energized such as air and water jets, supply valve assemblies, drain fittings not connected to metallic piping, towel bars, mirror frames, and similar nonelectrical equipment not connected to metal framing are not required to be bonded.

Ex 2: Double-insulated motors and blowers are not required to be bonded.

(B) Bonding Conductor. Metal parts required to be bonded by 680.74(A) must be bonded together using an insulated or bare solid copper conductor not smaller than 8 AWG. Bonding jumpers are not required to be extended or attached to any remote panelboard, service disconnect, or any electrode.

A bonding jumper long enough to terminate on a replacement nondouble-insulated pump or blower motor must be provided, and it must terminate to the equipment grounding conductor of the branch circuit of the motor when a double-insulated circulating pump or blower motor is used.

Part VIII. Electrically Powered Pool Lifts

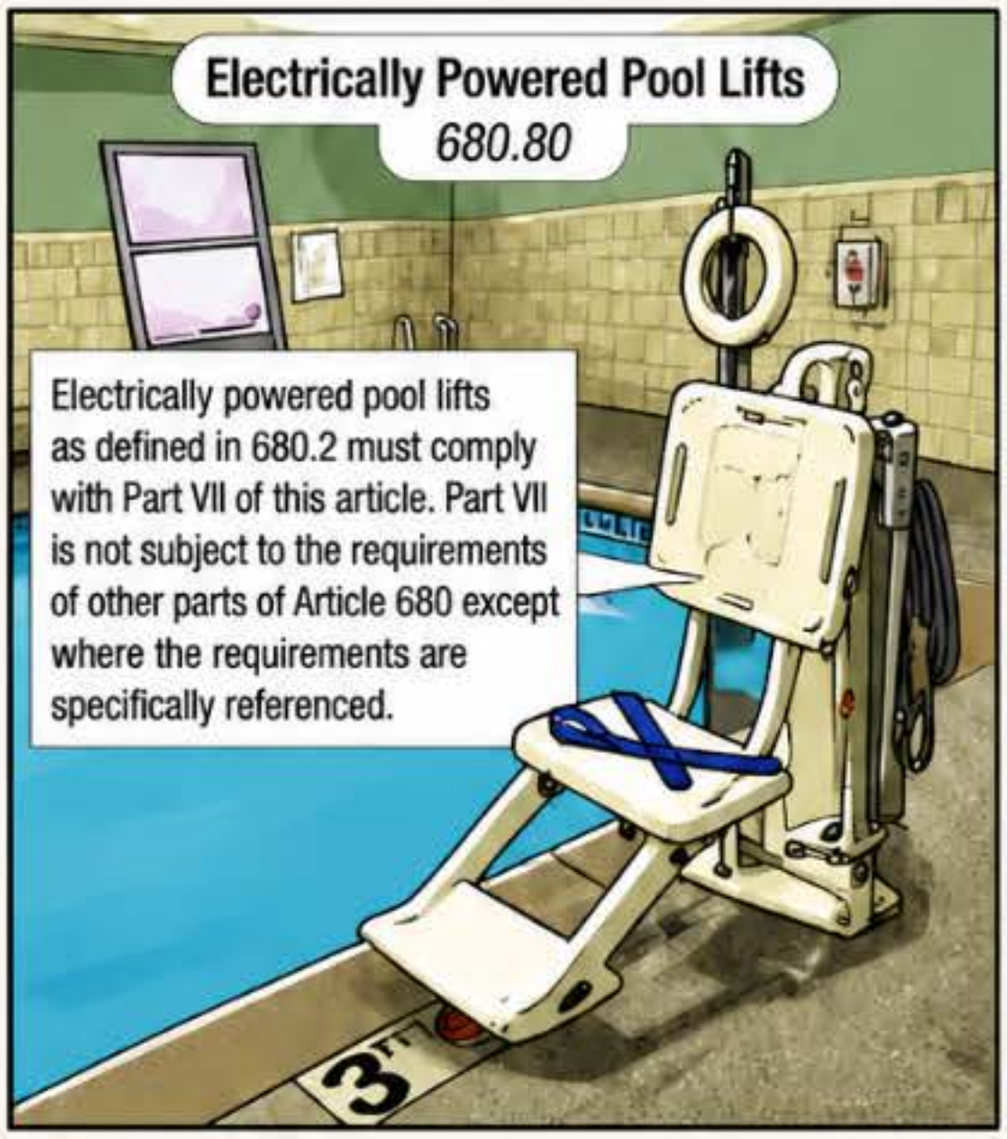
680.80 General

Electrically powered pool lifts as defined in 680.2 must comply with Part VIII of this article. Part VIII is not subject to the requirements of other parts of Article 680 except where the requirements are specifically referenced. ▶ Figure 680–91

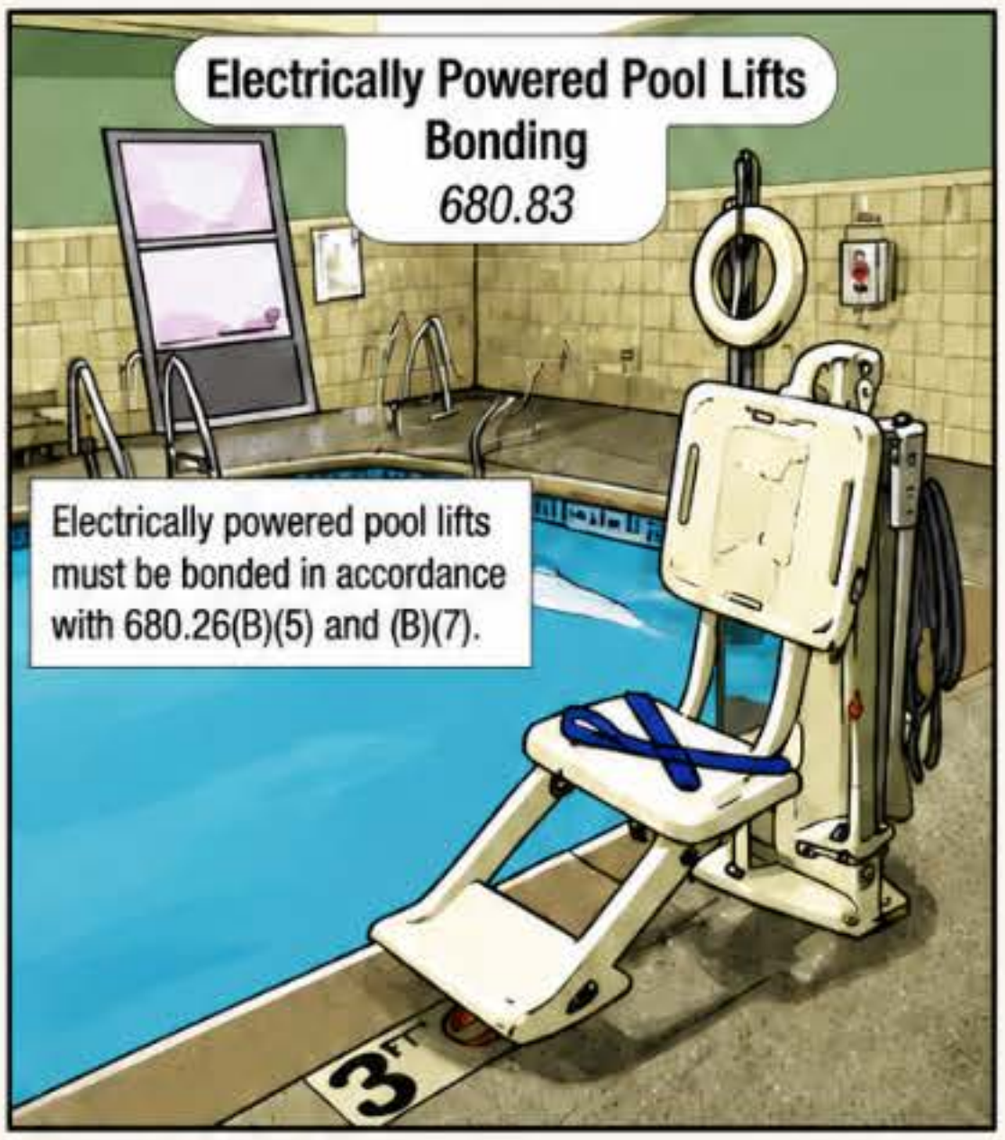
680.81 Equipment Approval

Electrically powered pool lifts must be listed, labeled, and identified for pool and spa use.

Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations | 680.84



▶ Figure 680–91



▶ Figure 680–92

680.82 Protection

Electrically powered pool lifts must be GFCI protected and comply with 680.5.

680.83 Bonding

Electrically powered pool lifts must be bonded in accordance with 680.26(B)(5) and (B)(7).

▶ Figure 680–92

680.84 Switching Devices and Receptacles

Switches and switching devices that operate above the low-voltage contact limit must comply with 680.22(C). Receptacles for electrically powered pool lifts poat are operated above the low-voltage contact limit must comply with 680.22(A)(3) and (4).

Notes

ARTICLE 690 SOLAR PHOTOVOLTAIC (PV) SYSTEMS

Introduction to Article 690—Solar Photovoltaic (PV) Systems

You might encounter devices that use photovoltaic cells to produce electricity, such as outdoor lighting, vehicle chargers, and toys. These products typically include a small solar module that generates low-voltage DC power for a compact device plus a small amount of energy. Larger PV installations supply power to buildings or other structures using the same basic principles but at a much higher scale.

PV systems that provide electrical power to a load or feed an electrical system are complex. Designers and installers must deal with many electrical, structural, and architectural challenges.

The intent of the *NEC* is to protect people and property by reducing the risks associated with electricity [90.1(A)]. Article 690 addresses safe installation and operation of PV systems and focuses on keeping people and property safe. It covers the electrical hazards that can occur during and after a PV system is installed and includes all component parts.

General *Code* rules found in Chapters 1 through 4 also apply to these installations unless a specific change is provided in this article [90.3].

Author's Commentary:

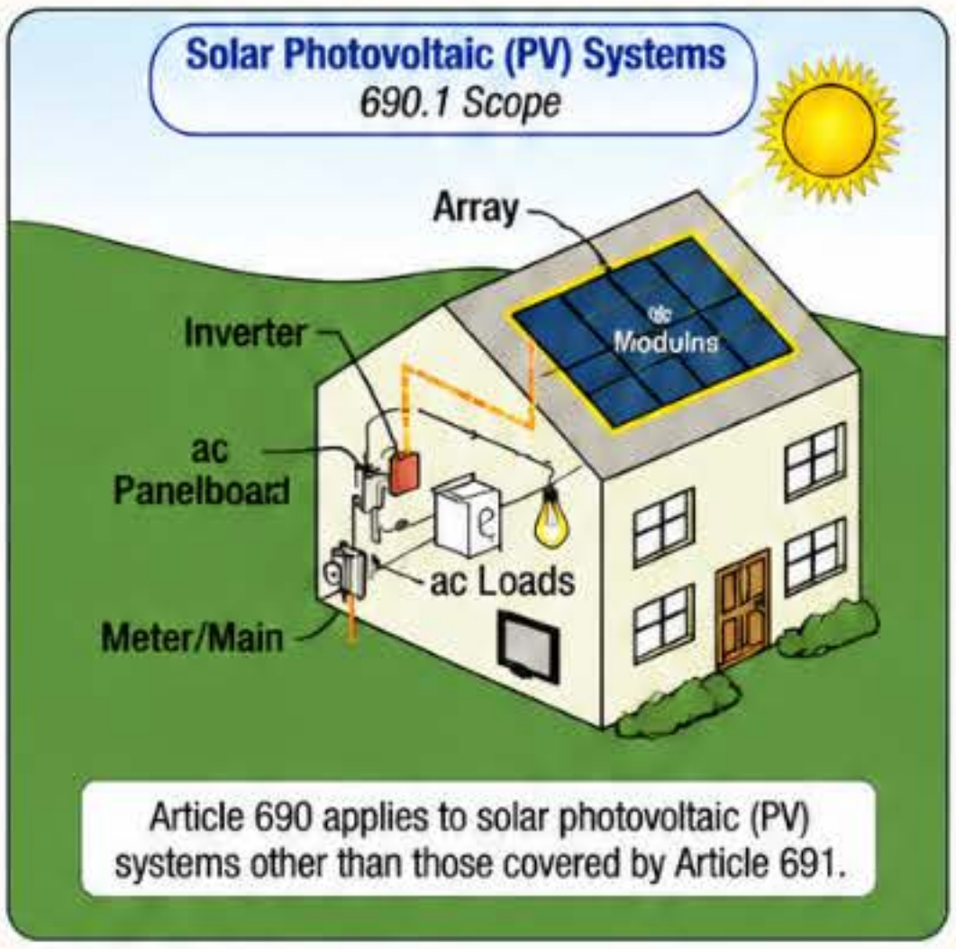
Energy storage systems appear in Article 706 and may be permitted to connect, but they are not part of PV systems.

— *Michael Hamilton*

Part I. General

690.1 Scope

Requirements in Article 690 apply to solar photovoltaic systems other than those covered in Article 691. ▸Figure 690–1

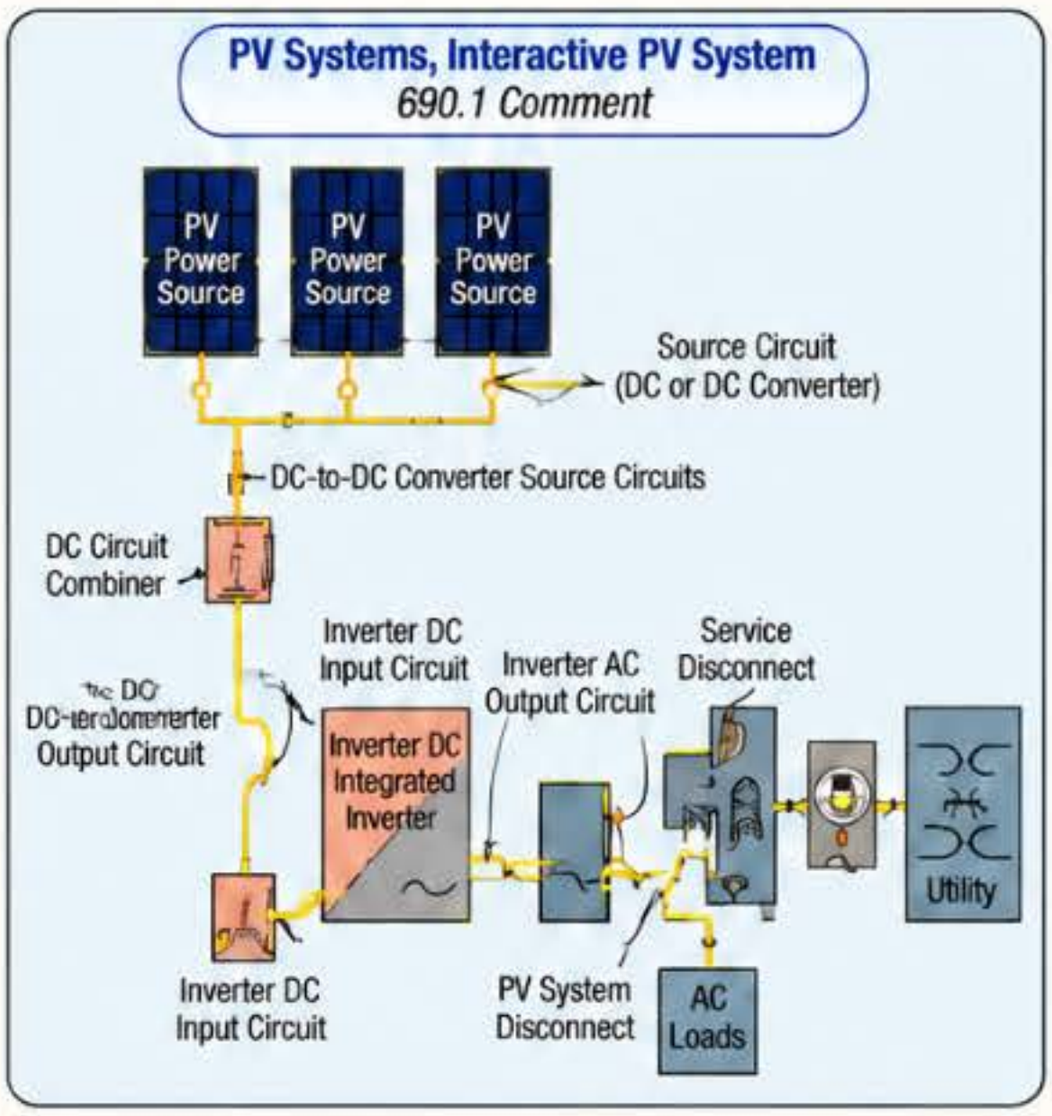


▸Figure 690–1

This article covers PV systems that operate with the utility in parallel, stand-alone installations, or any mixture of the two. PV systems can supply either alternating current (ac), direct current (dc), or both.

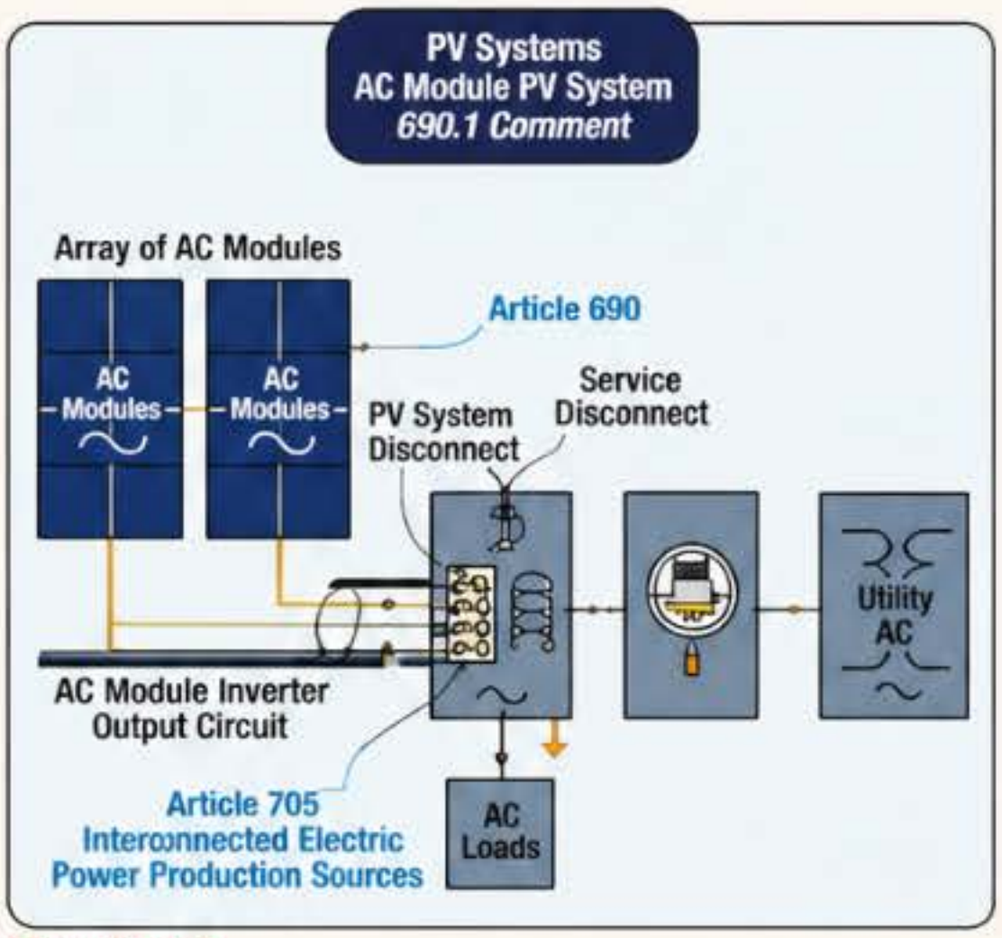
See details in ▸Figure 690–2, ▸Figure 690–3, ▸Figure 690–4, ▸Figure 690–5, and ▸Figure 690–6.

See details in ▸Figure 690–2, ▸Figure 690–3, ▸Figure 690–4, ▸Figure 690–5, and ▸Figure 690–6.

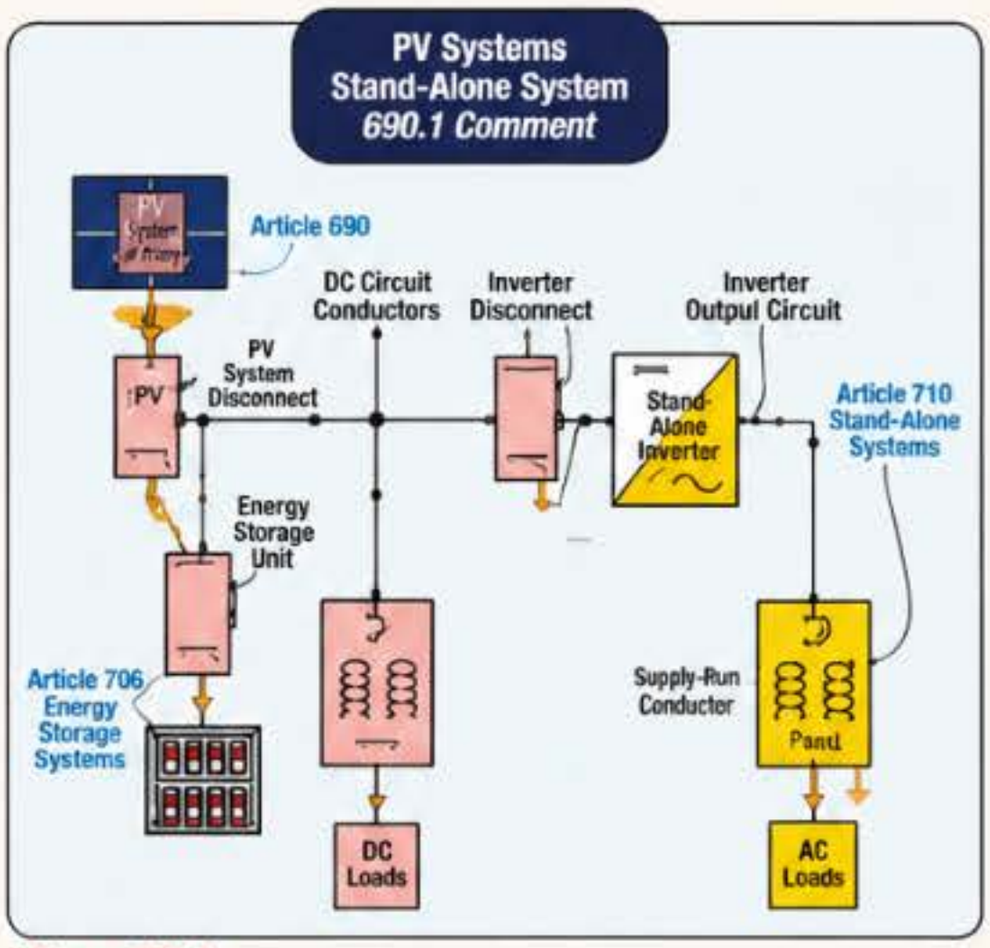


▸Figure 690–2

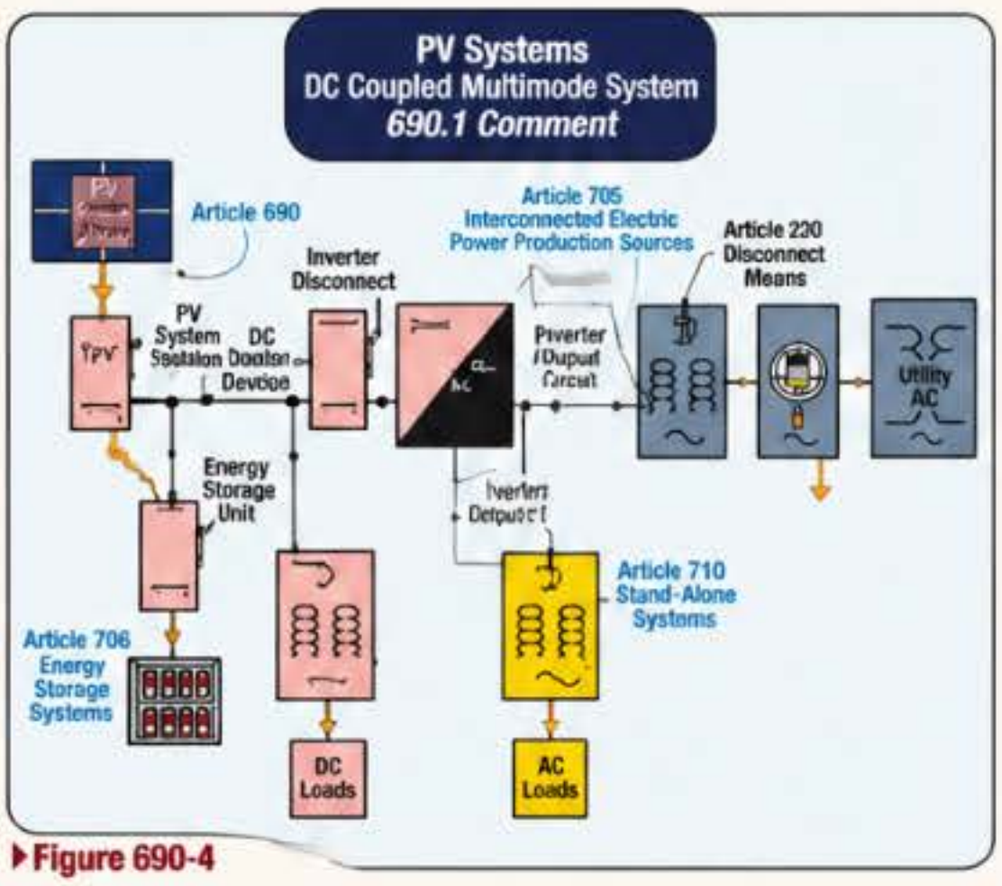
690.2 | Solar Photovoltaic (PV) Systems



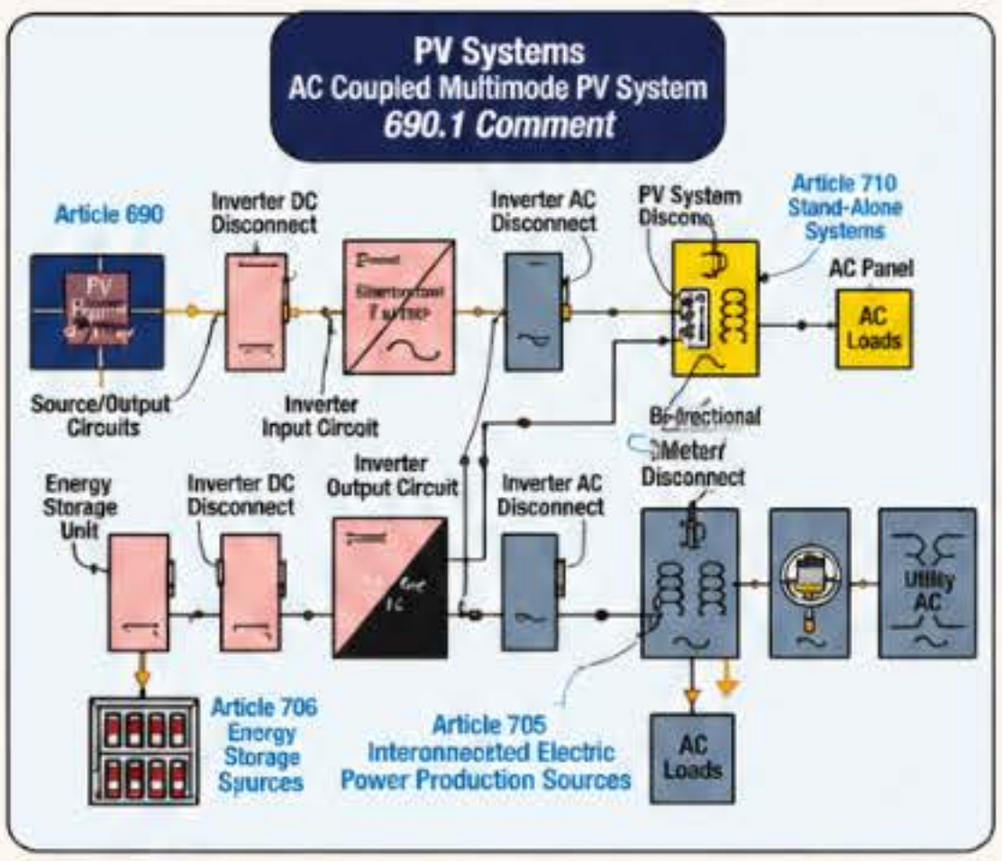
▶Figure 690-3



▶Figure 690-6

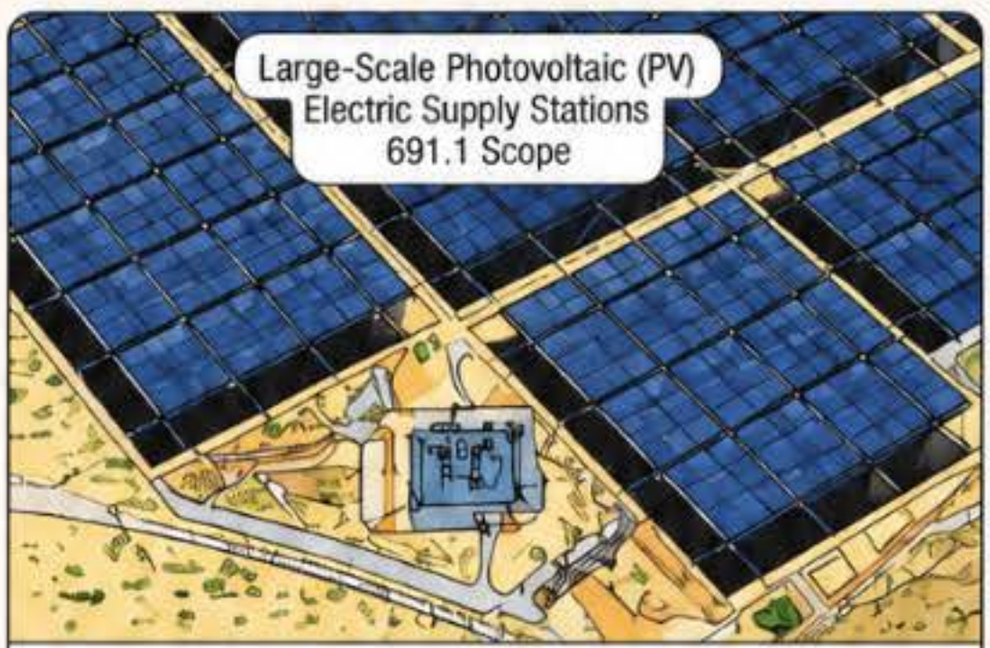


▶Figure 690-4



▶Figure 690-5

Note 2: Article 691 covers the installation of large-scale PV electric supply stations with an inverter generating capacity of not less than 5,000 kW, and not under the electric utility control. These facilities have specific design and safety features unique to large-scale PV supply stations and are for the sole purpose of providing electric supply to a system operated by a regulated utility. ▶Figure 690-7



Article 691 governs the installation of large-scale PV electric supply stations with an inverter generating capacity of not less than 5,000 kW and not under the electric utility control.

▶Figure 690-7

690.2 Definitions

The definitions in this section only apply within this article.

Alternating-Current Module System. An assembly of ac modules, wiring methods, materials, and subassemblies that are evaluated, identified, and defined as a system.

SOLAR PHOTOVOLTAIC (PV) SYSTEMS 690.2

Alternating-Current Module. An ac module is a complete, environmentally protected assembly that includes solar cells, an inverter, and other parts designed to deliver alternating-current power. **Figure 690–8**

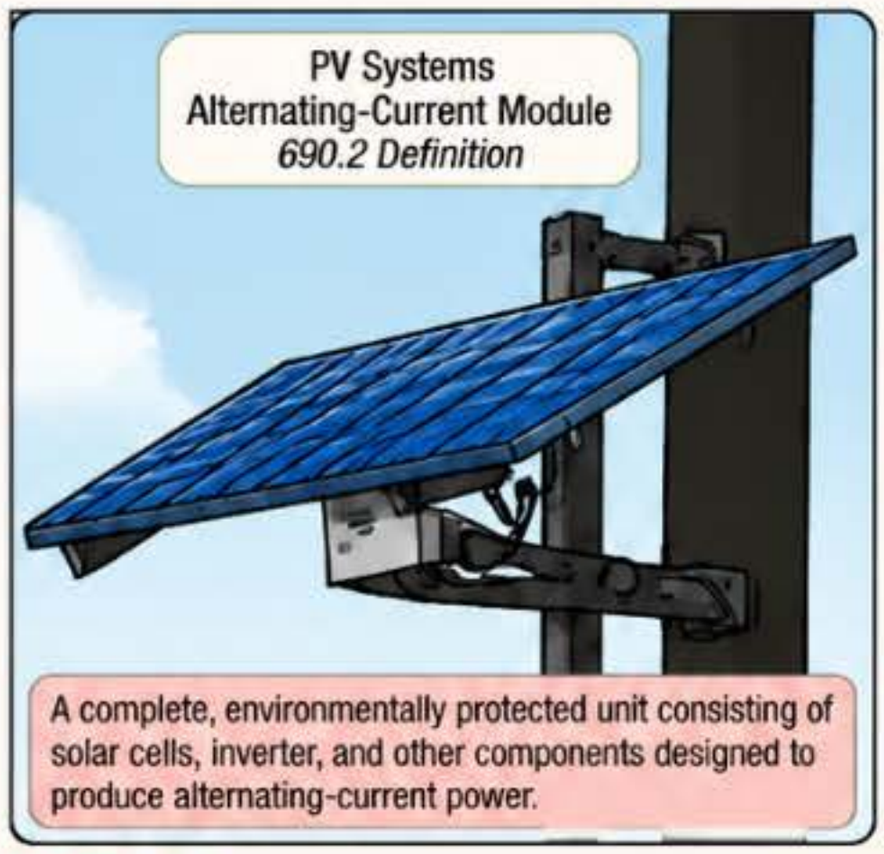


Figure 690–8

Author's Commentary:

- Alternating-current modules are connected in parallel with each other and in parallel with the utility, in an interactive mode. These modules function with the electric utility so that the ac output current from each ac module will reduce exported power upon sensing voltage loss from the electric utility.
- Manufacturers' instructions for ac modules will identify the size of the dedicated branch circuit for their connection and the maximum number of ac modules permitted on the branch circuit.

— Michael Hamilton

Array. An array is a mechanically and electrically integrated grouping of modules with a support system, including any attached system components such as inverter(s), dc-to-dc converter(s), and associated wiring. **Figure 690–9**

DC-to-DC Converter Output Circuit. A dc-to-dc converter output circuit consists of conductors of the dc circuit that are connected to the output of a dc combiner containing multiple dc-to-dc converter source circuits. **Figure 690–10**

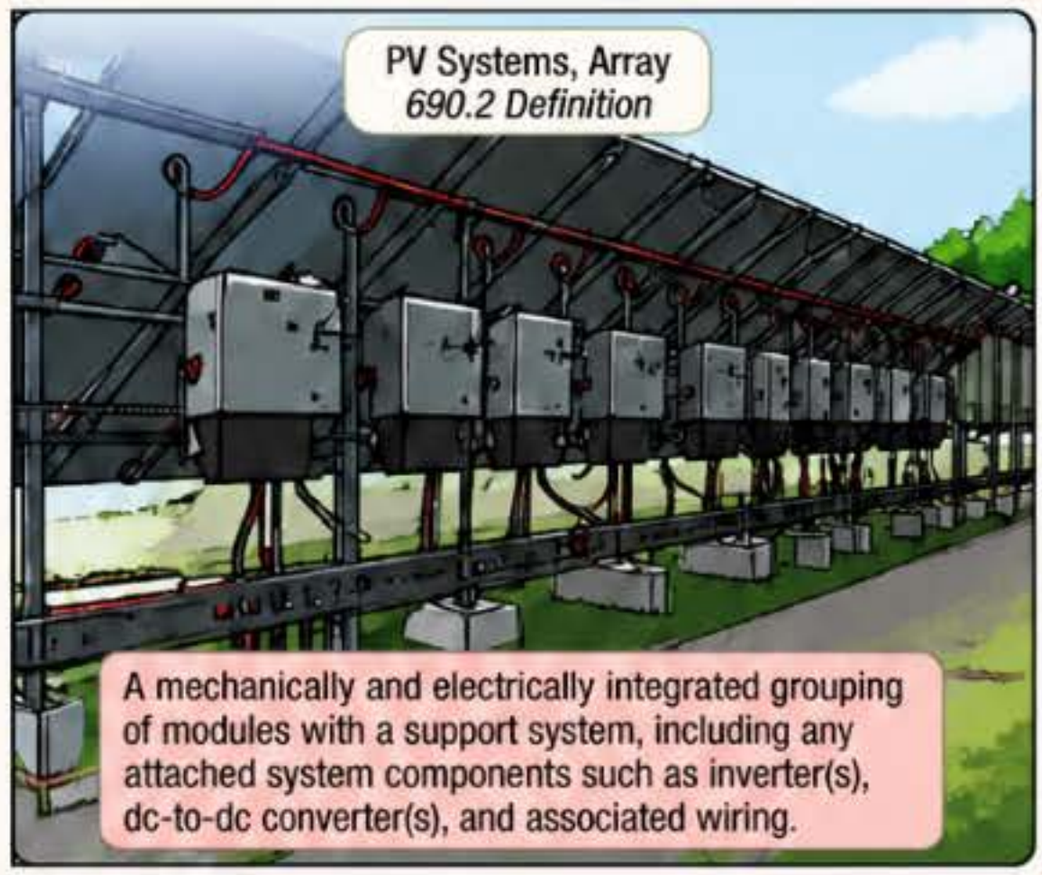


Figure 690–9

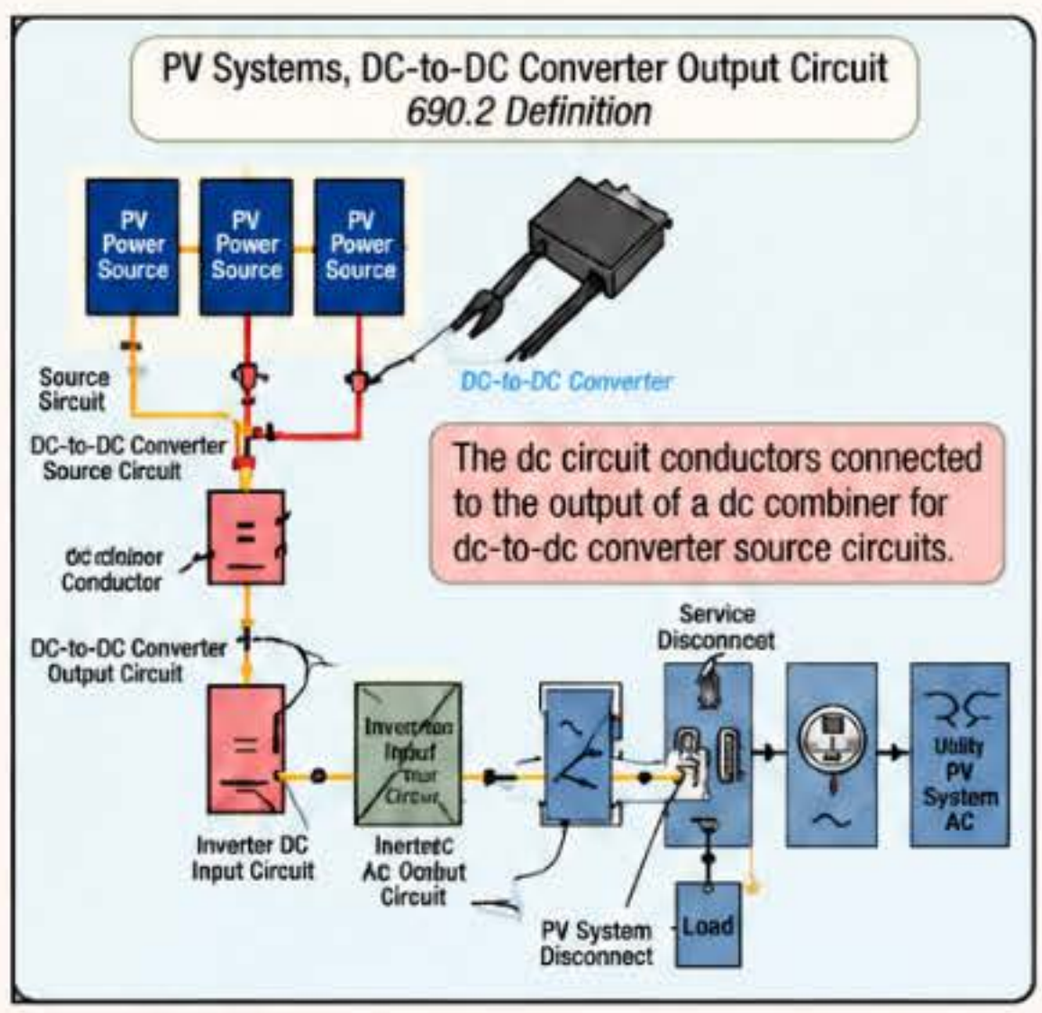


Figure 690–10

Author's Commentary:

- According to Article 100, a "DC-to-DC Converter" is a device that can provide an output dc voltage and current at a higher or lower value than the input dc voltage and current. **Figure 690–11**
- DC-to-DC converters are intended to maximize the power output of independent modules and reduce losses due to variances between the modules' outputs.

— Michael Hamilton

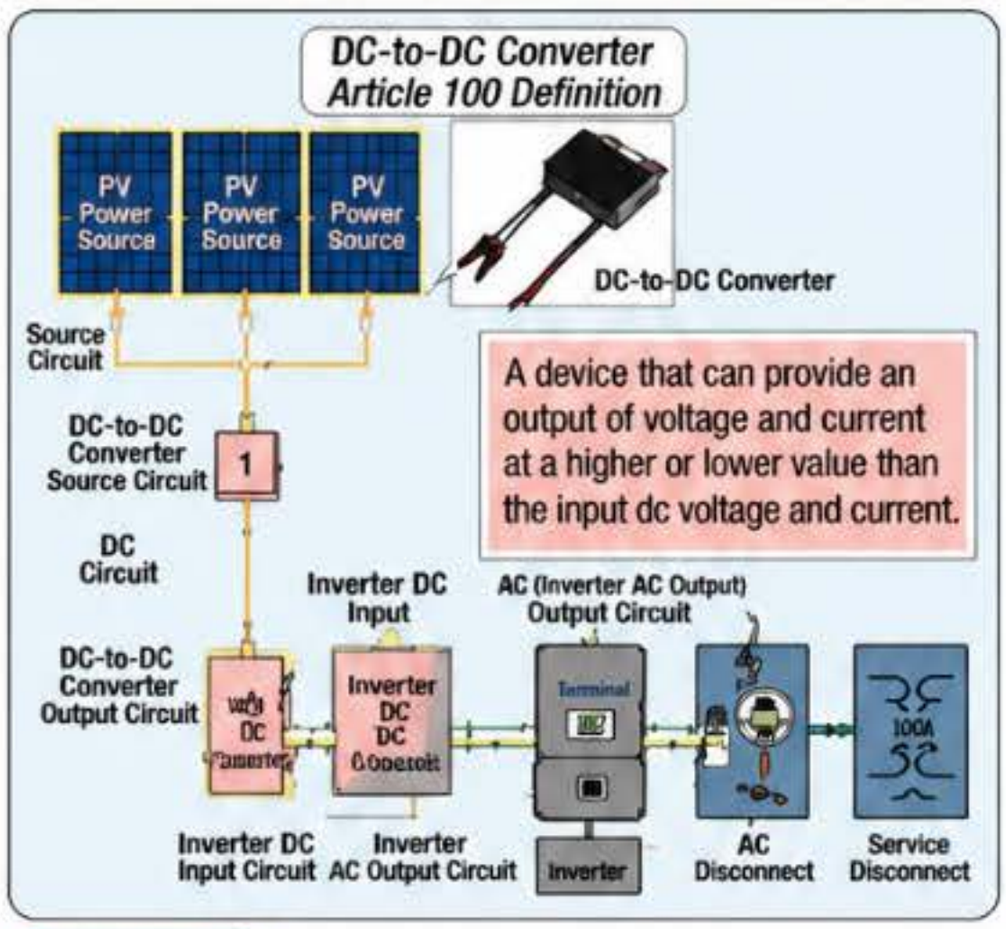


Figure 690–11

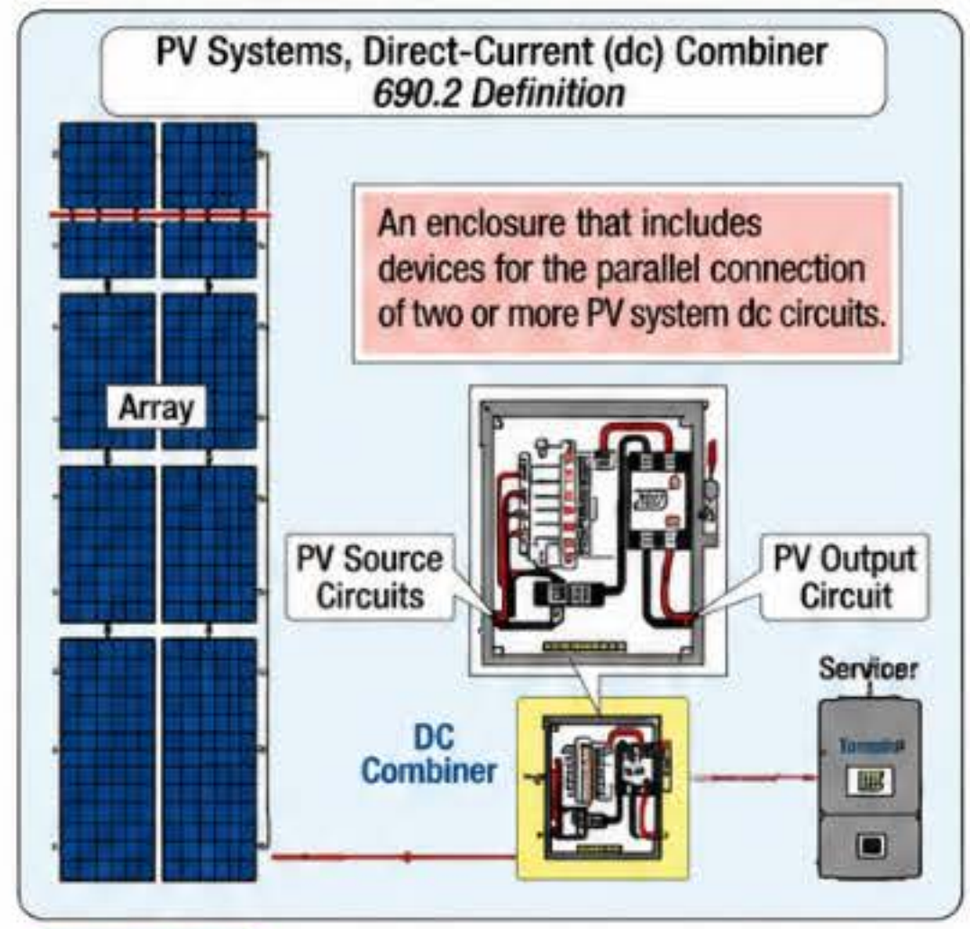


Figure 690–13

Author's Commentary:
A dc-to-dc converter allows the inverter to see the circuit voltage that is best suited for maximum direct-current and/or alternating-current power from the inverter, regardless of the source voltage, module characteristics, or minor variations in light between modules.

— Michael Hamilton

Author's Commentary:
A dc combiner brings together multiple PV source circuits and dc-to-dc converter circuits in parallel with one another to form a PV output or dc-to-dc converter output circuit. Direct-current combiners may also reorganize **multiple PV output circuits** and dc-to-dc converter output circuits into either a larger two-wire PV output or a dc-to-dc converter output circuit.

— Michael Hamilton

DC-to-DC Converter Source Circuit. A dc-to-dc converter source circuit consists of the dc circuit conductors from the output of a dc-to-dc converter. **Figure 690–12**

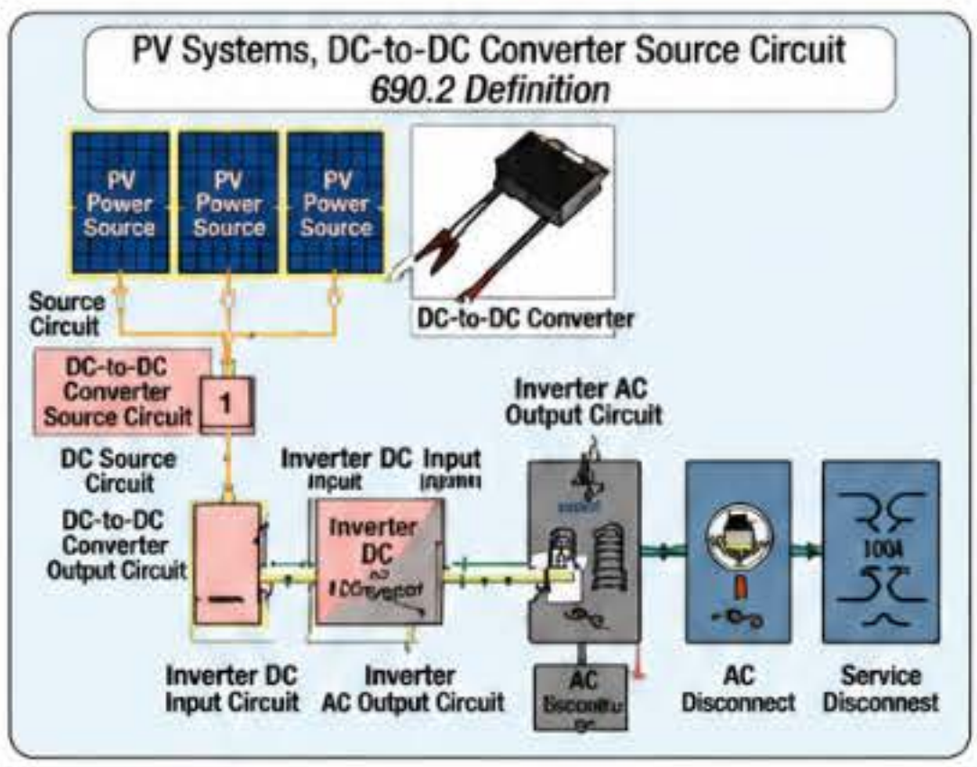


Figure 690–12

Direct-Current (dc) Combiner. A dc combiner is an enclosure that includes devices for the parallel connection of two or more PV system dc circuits. **Figure 690–13**

Electronic Power Converter. An electronic power converter is a device that uses electronics to convert one form of electrical power into another.

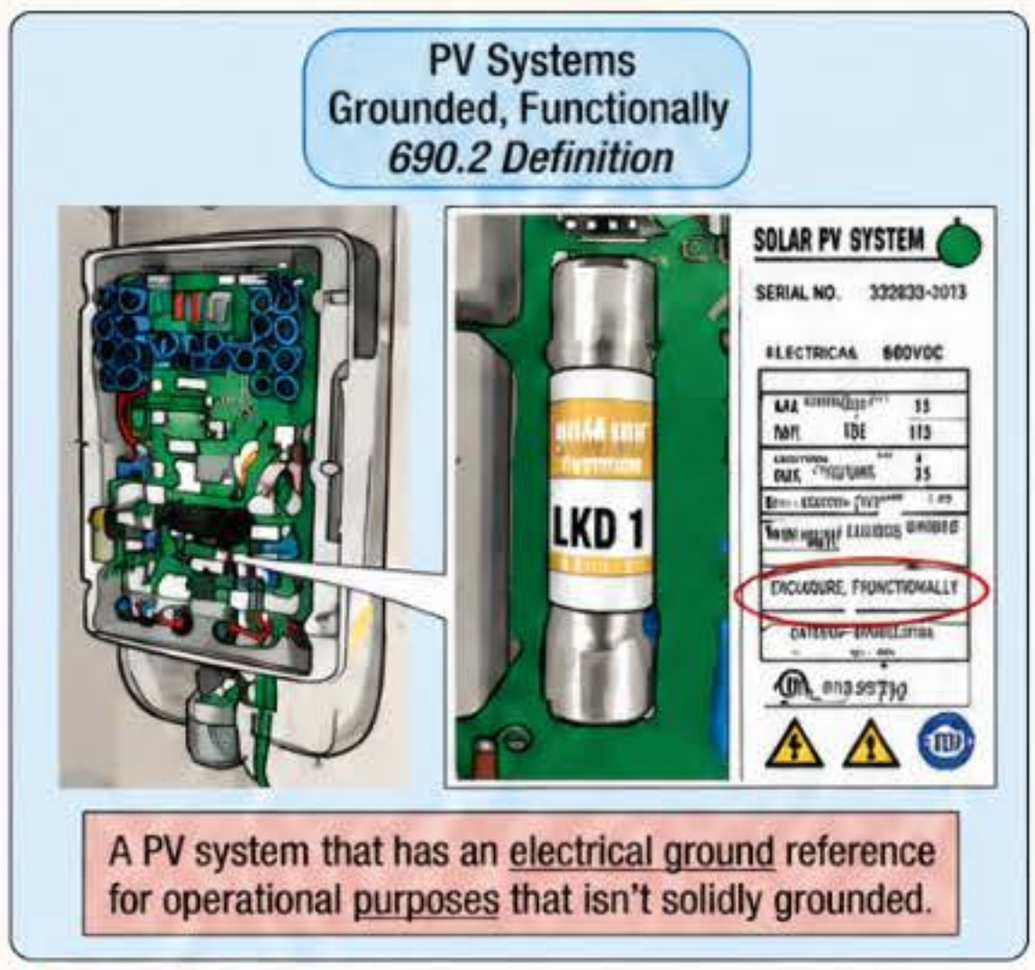
Note: Examples of electronic power converters include (but are not limited to) inverters, dc-to-dc converters, and electronic charge controllers. These devices have limited current capabilities based on the device ratings at continuous rated power.

Grounded, Functionally. A functionally grounded PV system is one that has an electrical ground reference for operationalo-purposes that is not solidly grounded. **Figure 690–14**

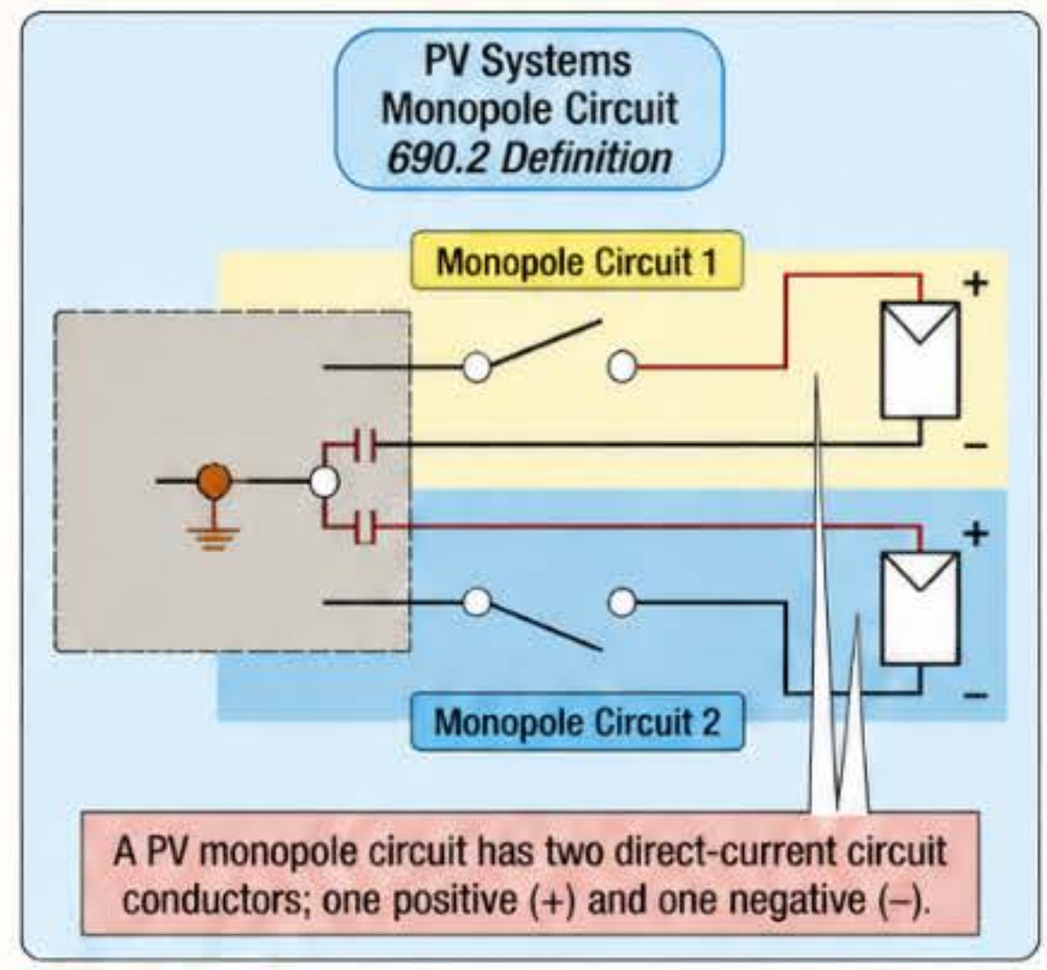
Note: A functionally grounded PV system is often connected to ground through an electronic means that is internal to an inverter or charge controller that provides ground-fault protection. Examples of operational purposes for functionally grounded systems include fault detectiton and protection, as well as performance-related issues for some power sources.

Module. A PV module is a unit of environmentally protected solar cells and components designed to produce dc power. **Figure 690–15**

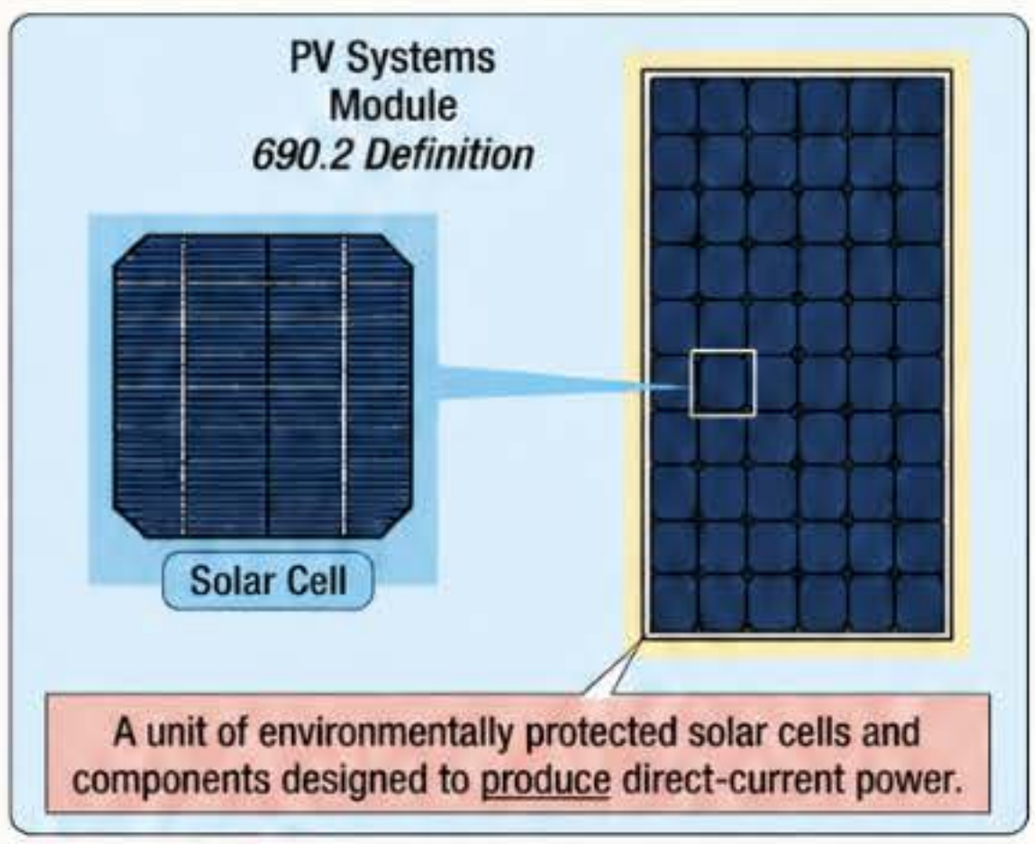
DEFINITIONS | From Michael Hamilton Publications



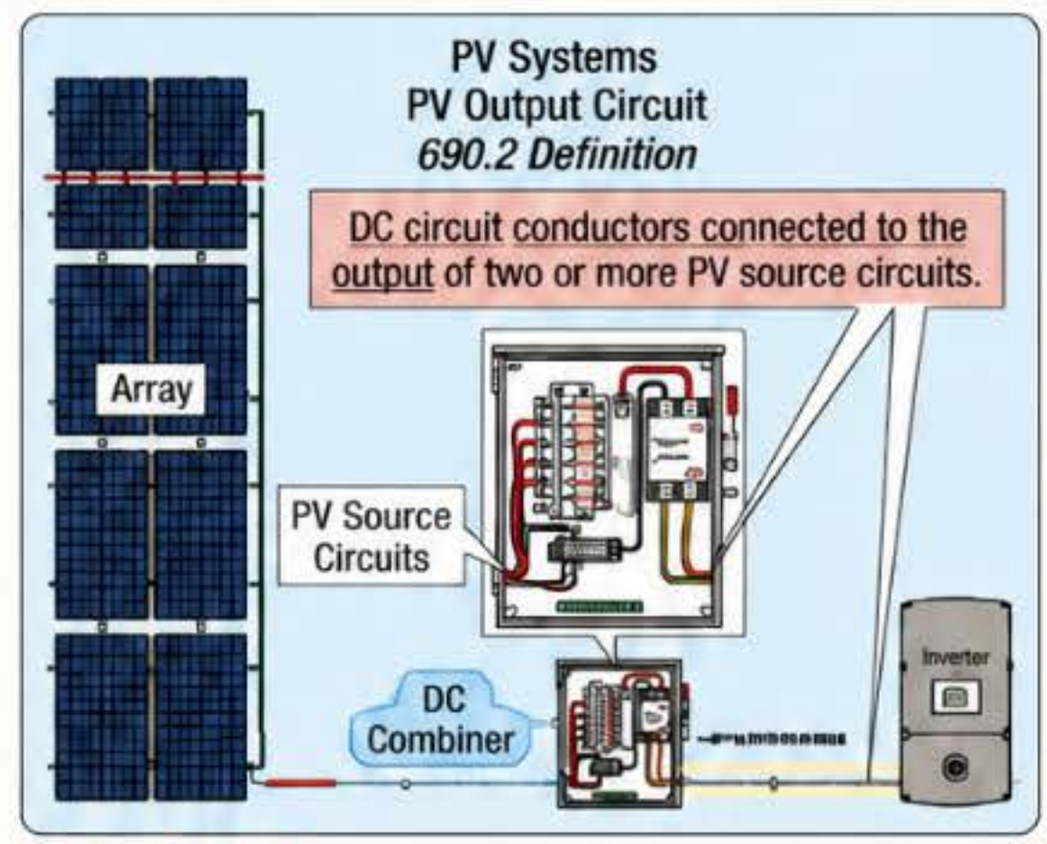
▸ Figure 690–14



▸ Figure 690–16



▸ Figure 690–15



▸ Figure 690–17

Author's Commentary:

PV modules use sunlight to transform photons into direct-current (dc) electricity via the photovoltaic effect in semiconductor materials.

— *Michael Hamilton*

Monopole Circuit. A PV monopole circuit has two dc circuit conductors; one positive (+) and one negative (–). ▸ **Figure 690–16**

PV Output Circuit. A PV output circuit consists of dc circuit conductors connected to the output of two or more PV source circuits. ▸ **Figure 690–17**

PV Source Circuit. The PV source circuit consists of the d:circuit conductors between modules and from modules to dc combiners, electronic power converters, or the PV system disconnecting means.
▸ **Figures 690–18** and **690–19**

PV System DC Circuit. The PV system dc circuit consists of any dc conductor in PV source circuits, PV output circuits, dc-to-dc converter source circuits, and dc-to-dc converter output circuits.

Solar Cell. The building block of a PV module that generates dc power when exposed to light.
▸ **Figure 690–20**

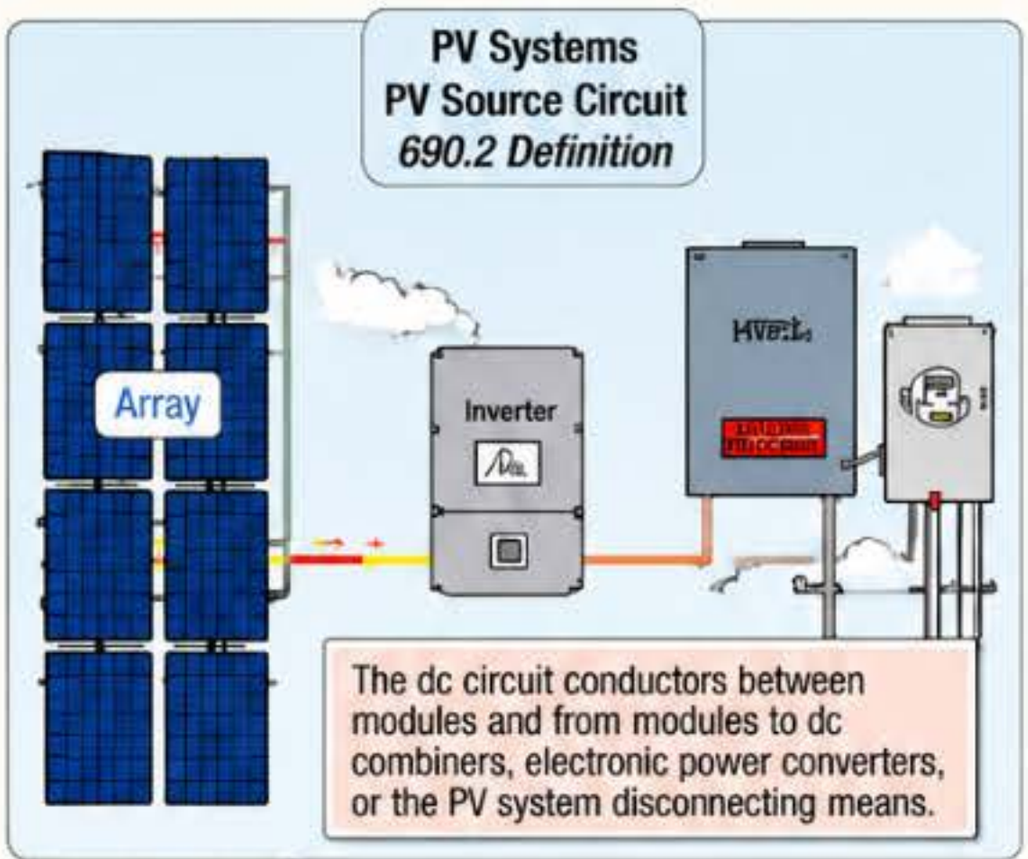


Figure 690–18

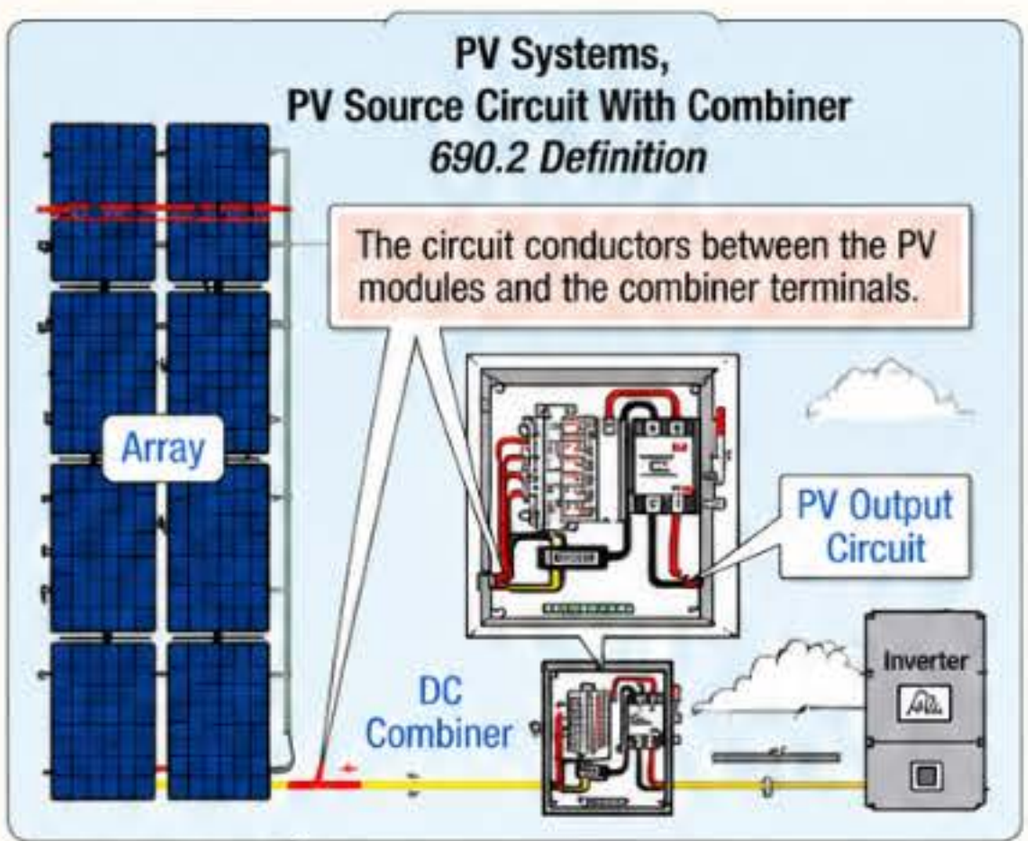


Figure 690–19

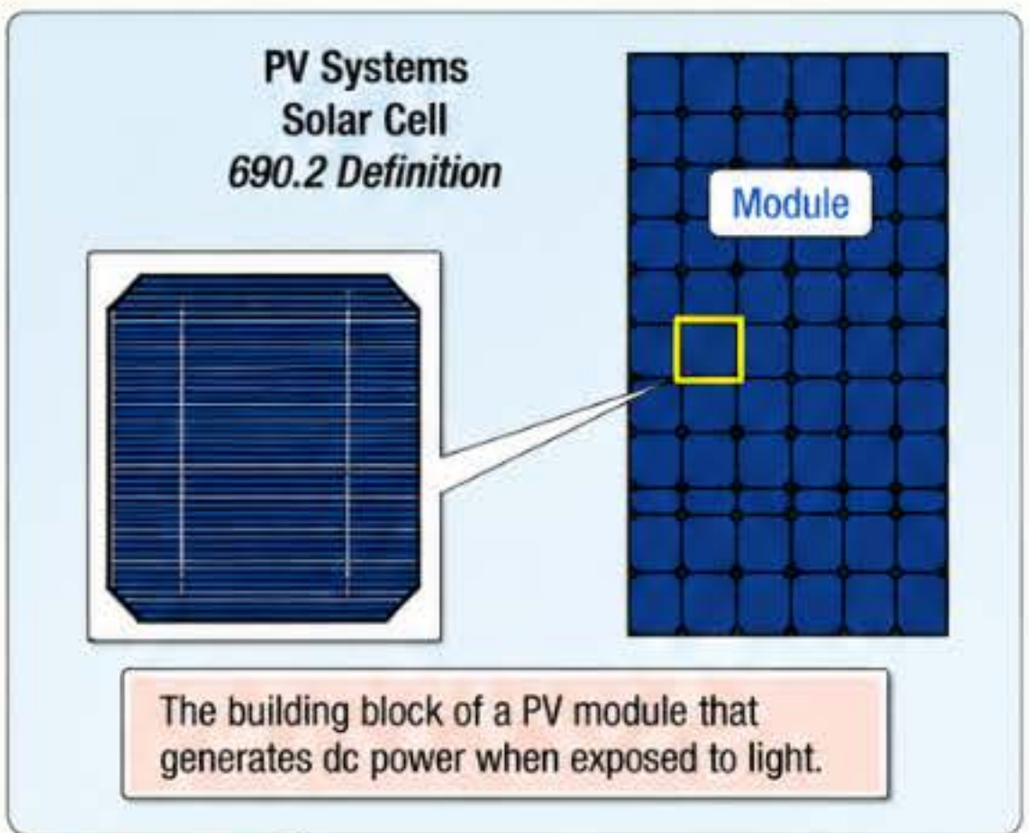


Figure 690–20

Caution

Although sunlight is the primary light source for a solar cell, other light sources such as moonlight can generate dc power.

Author's Commentary:

- Article 100 definitions are essential, yet the following terms appear frequently within PV systems. These commonly encountered components are:
  - Charge Controller
  - DC-to-DC Converter
  - DC-to-DC Output Circuit
  - Hybrid System
  - Interactive Inverter
  - Interactive System
  - Inverter, Multimode
  - Inverter Output Circuit
  - Power Production System
  - Photovoltaic (PV) System
  - Stand-Alone System

— Michael Hamilton

690.4 General Requirements

(A) PV Systems. A PV system is permitted to supply electric power to buildings or other electrical supply systems.

(B) Listed or Field Labeled Equipment. Components of the PV system—including inverters, PV modules, ac modules systems, dc combiners, dc-to-dc converters, rapid shutdown equipment, dc circuit controllers, and charge controllers—must be listed or be evaluated for the application and have a field label applied. ▸ Figure 690–21

Author's Commentary:

- "Listing" means the equipment is included in a list published by a testing laboratory acceptable to the authority having jurisdiction [Article 100].
- "Field Labeled" means the equipment or materials bearing a label, symbol, or identifying mark that a field evaluation body (FEB) indicates were evaluated and found to comply with the requirements described in the field body evaluation report [Article 100].

— Michael Hamilton

Solar Photovoltaic (PV) Systems | 690.6

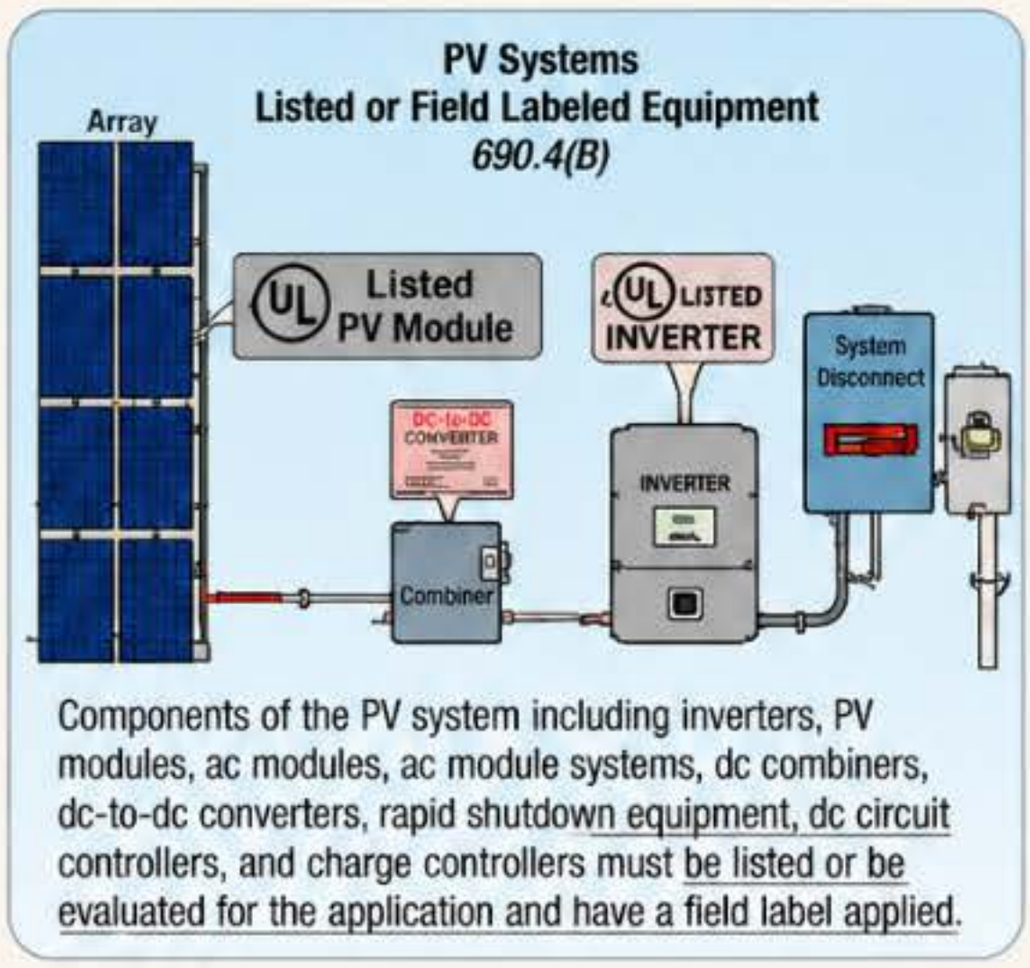


Figure 690–21

(C) Qualified Persons. The installation of PV systems must be performed by a qualified person.

Note: A qualified person has the knowledge related to the construction and operation of PV equipment and installations; along with safety training to recognize and avoid hazards to persons and property [Article 100]. Figure 690–22

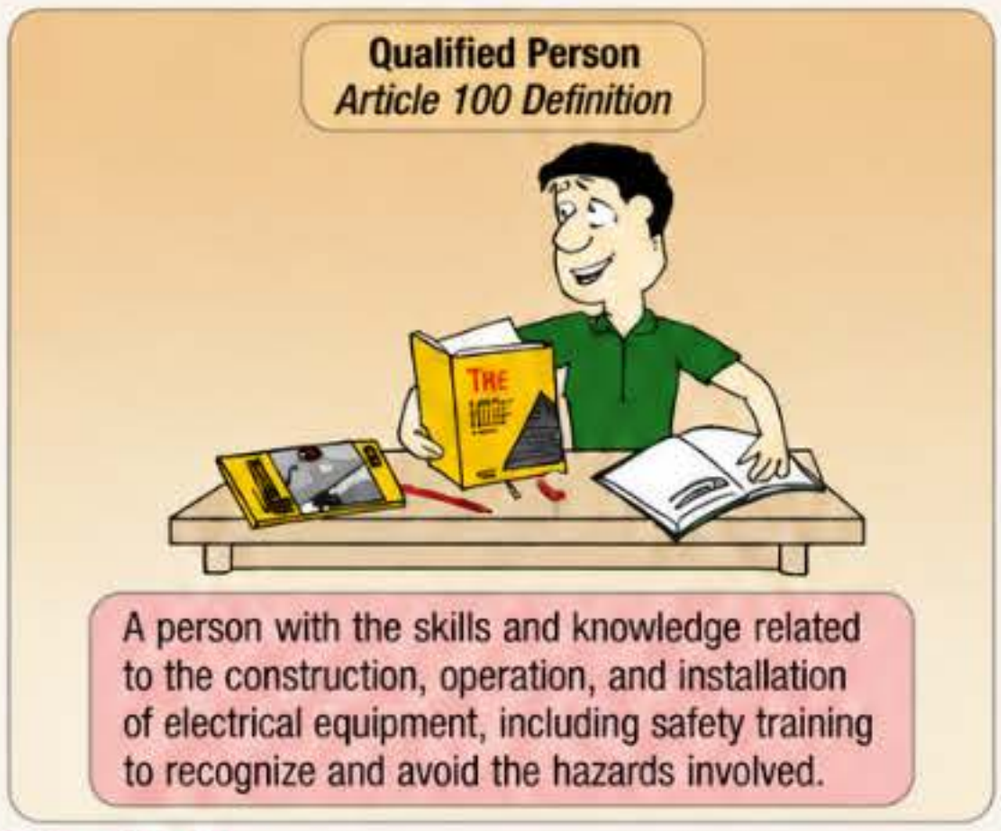


Figure 690–22

Author's Commentary:

NFPA 70E, *Standard for Electrical Safety in the Workplace*, provides information on the safety training requirements expected of a "qualified person."

— *Michael Hamilton*

- Examples of this safety training include (but are not limited to) training in the use of special precautionary techniques, personal protective equipment (PPE), insulating and shielding materials, and in the use of insulated tools and test equipment when working on or near exposed conductors or circuit parts that can become energized.
- In many parts of the United States, electricians, electrical contractors, electrical inspectors, and electrical engineers must complete an *NEC* review course each year as a requirement to maintain licensing. This, in and of itself, does not make one qualified to deal with the specific hazards involved with PV systems.

(D) Multiple PV Systems. Multiple PV systems are permitted on or in a building. Where PV systems are remotely located from each other a directory must be provided at each PV disconnect in accordance with 705.10.

(E) **Where Not Permitted.** No part of a PV system is permitted to be installed within a bathroom.

(F) Electronic Power Converters Not Readily Accessible. Electronic power converters (inverters and dc-to-dc converters) are not required to be readily accessible.

690.6 Alternating-Current Modules and Systems

(A) PV Source Circuits. The requirements of Article 690 do not apply to the source circuits for an ac module or ac module system. The source circuit, conductors, and the inverter(s) are considered internal components of a listed product. Figure 690–23

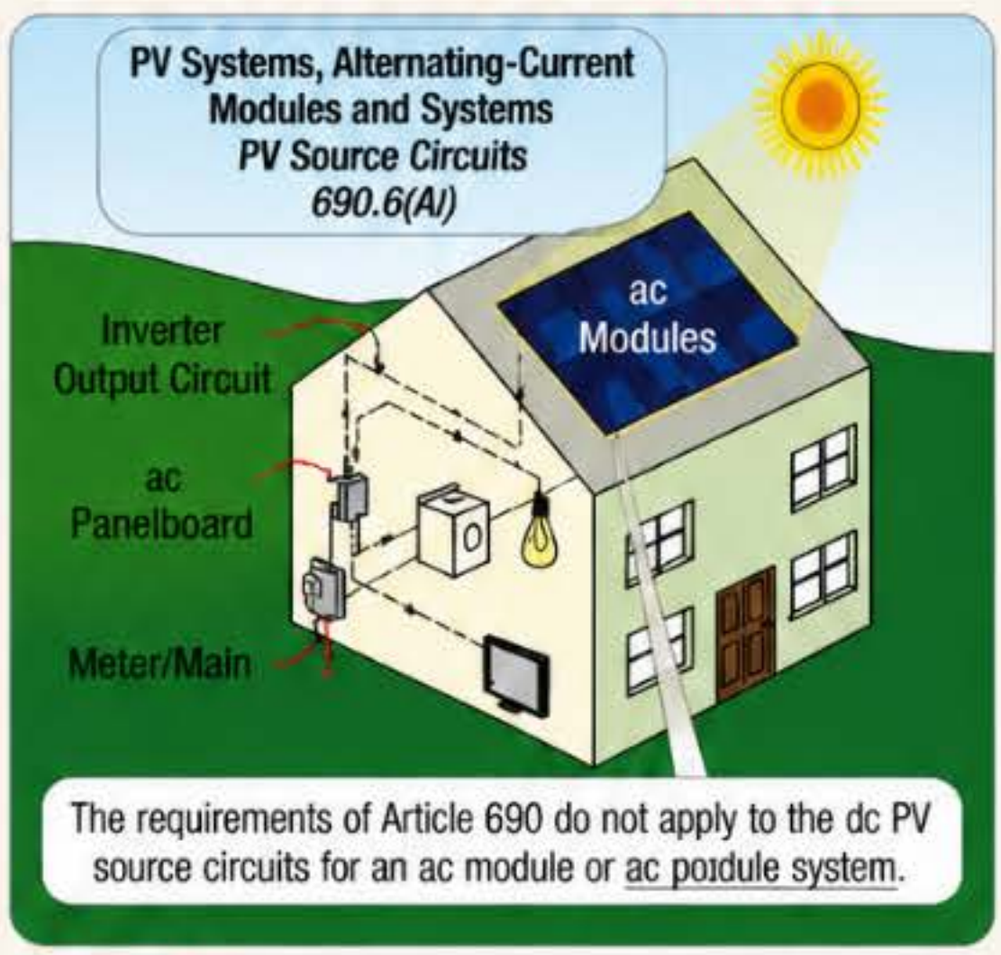


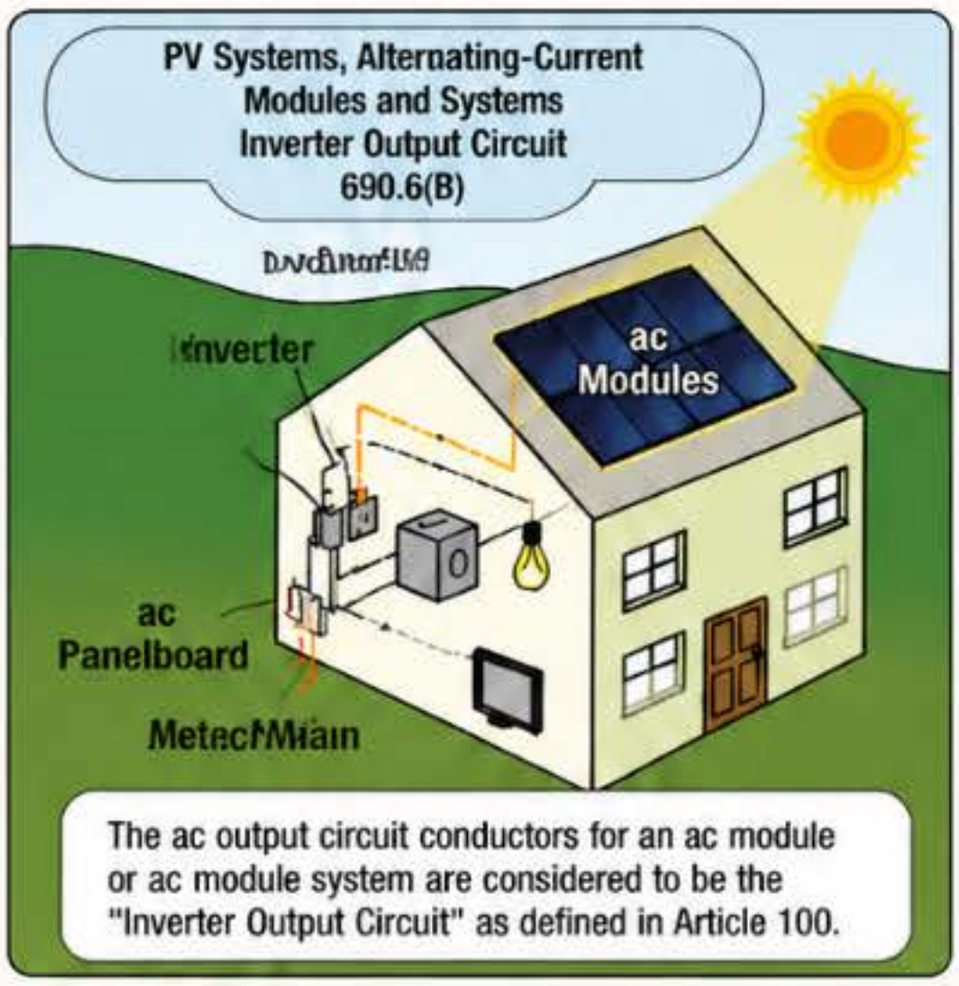
Figure 690–23

Author's Commentary:

- Electrical source circuits and inverter output circuits for ac modules or ac module systems are included in the products listed here. The equipment factory wiring that comes with those systems has already been checked by a qualified testing laboratory, so standard inspection for NEC compliance [90.7] is not required, [illegible].

— **Michael Hamilton**

(B) Output Circuit. The conductors on the output side of an ac module or ac module system are what is considered to be the "Inverter Output Circuit" as defined in Article 100. ▸**Figure 690–24**



▸**Figure 690–24**

Part II. Circuit Requirements

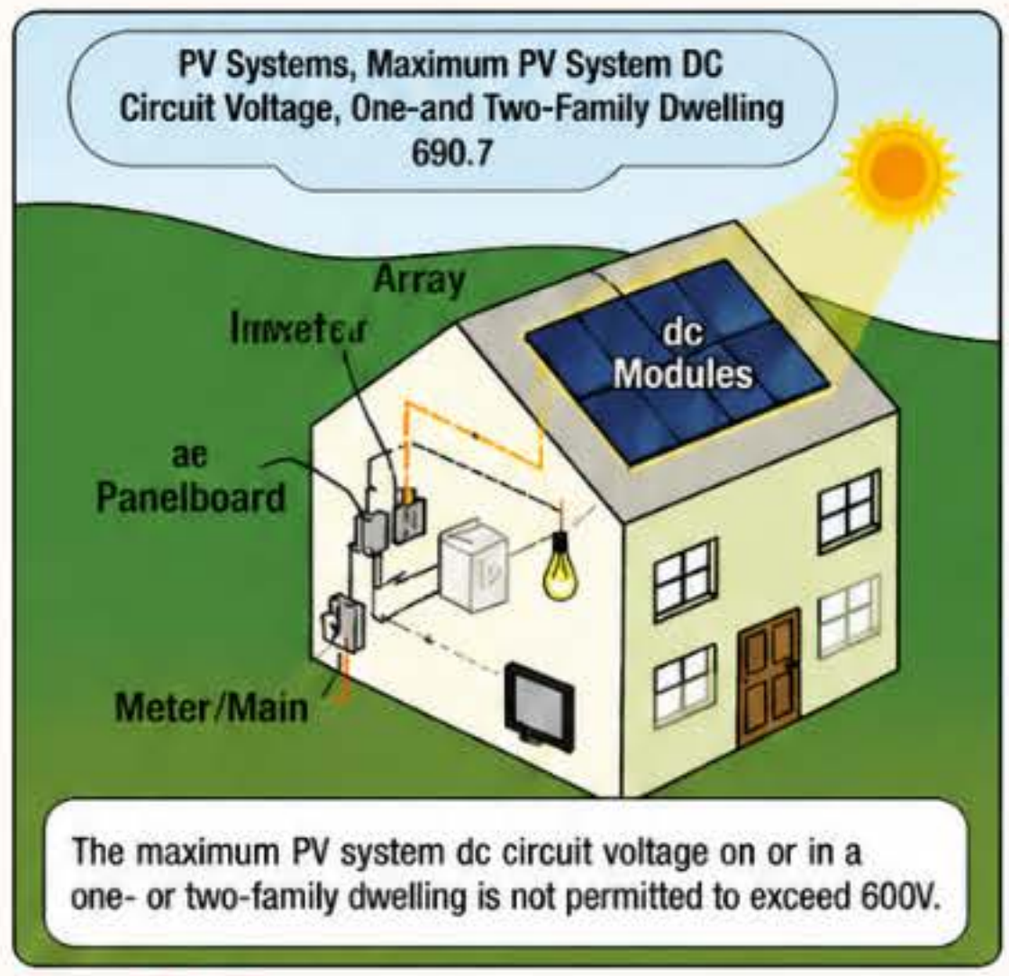
690.7 Maximum PV System Direct-Current Circuit Voltage

The goal of Article 690 is to set the upper dc voltage limit for a circuit—defined as the highest possible voltage between any two conductors of that circuit.

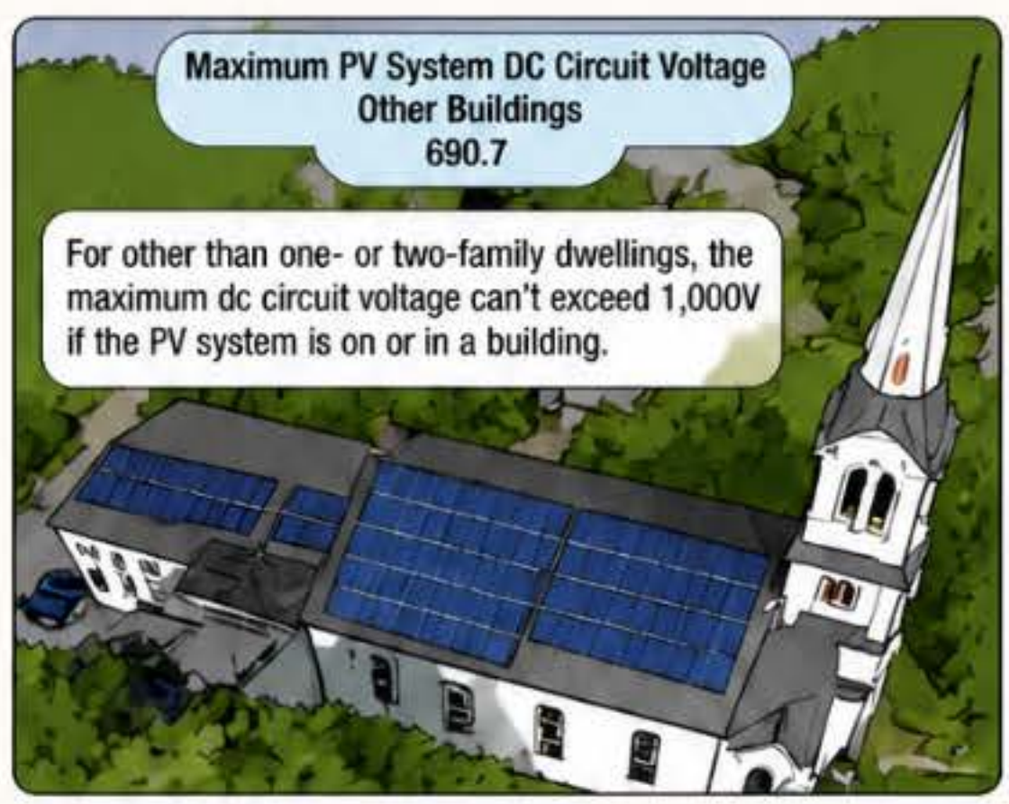
The maximum voltage of a circuit is used when selecting conductors, cables, equipment, determining working space, and for other situations where circuit voltage ratings matter.

The limit on dc circuit voltage for a PV system on or in a one- or two-family dwelling is 600V. ▸**Figure 690–25**

For buildings other than one- or two-family dwellings, the dc voltage limit is 1,000V when the PV system is installed on or in the building. ▸**Figure 690–26**



▸**Figure 690–25**



▸**Figure 690–26**

PV systems not located on or in buildings with a maximum dc circuit voltage of more than 1,500V must follow the provisions of Parts II and III of Article 490. ▸**Figure 690–27**

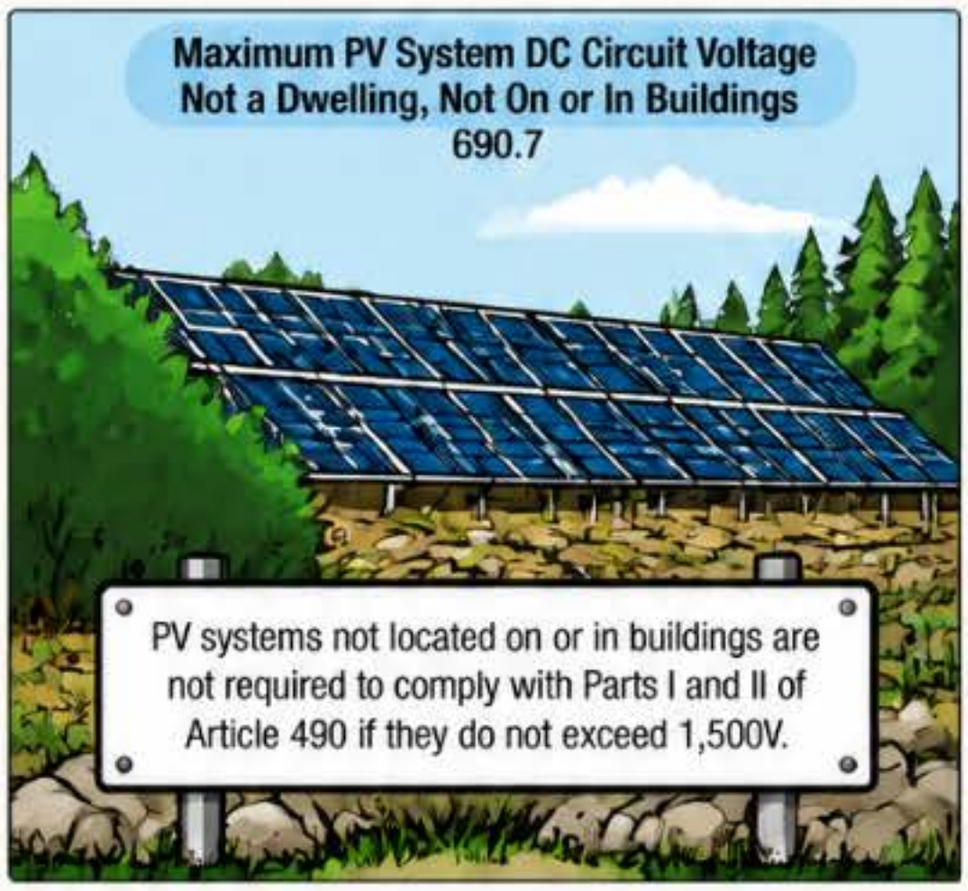
Author's Commentary:

- A PV system's dc circuit includes the PV source circuits, the PV output circuits, dc-to-dc converter source circuits, and dc-to-dc converter output circuits [690.2].

— **Michael Hamilton**

(A) PV Source and Output Circuit Volts. The maximum voltage for both source and output circuits of a PV system is determined by one of the following methods:

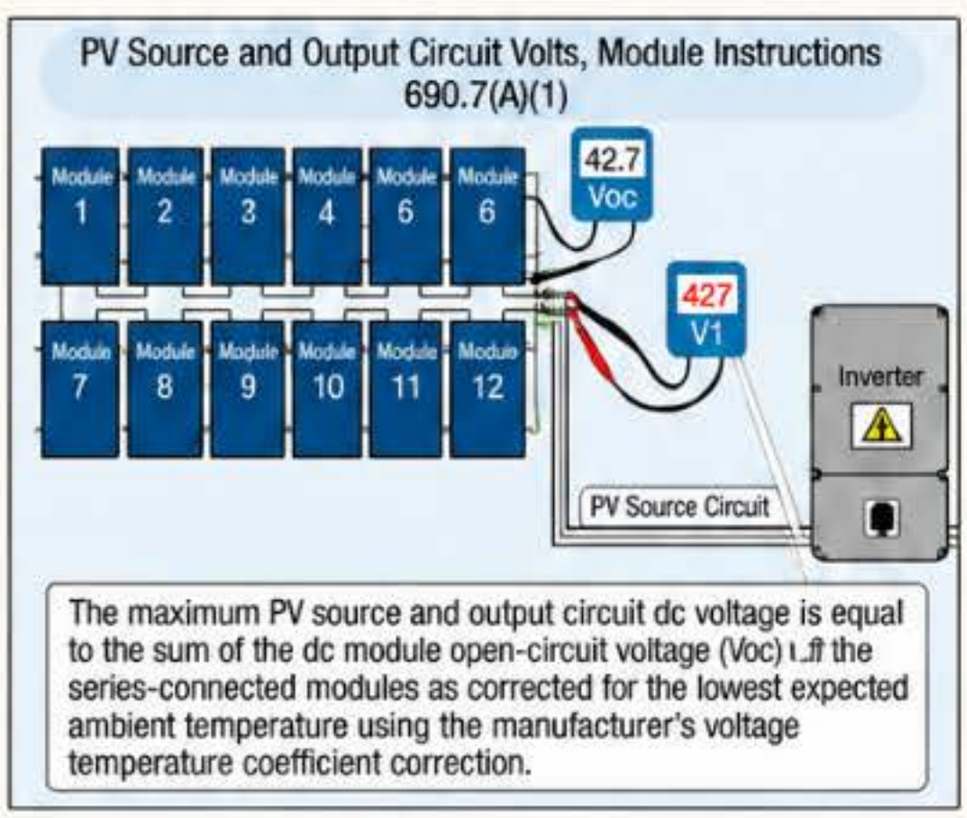
Solar Photovoltaic (PV) Systems | 690.7



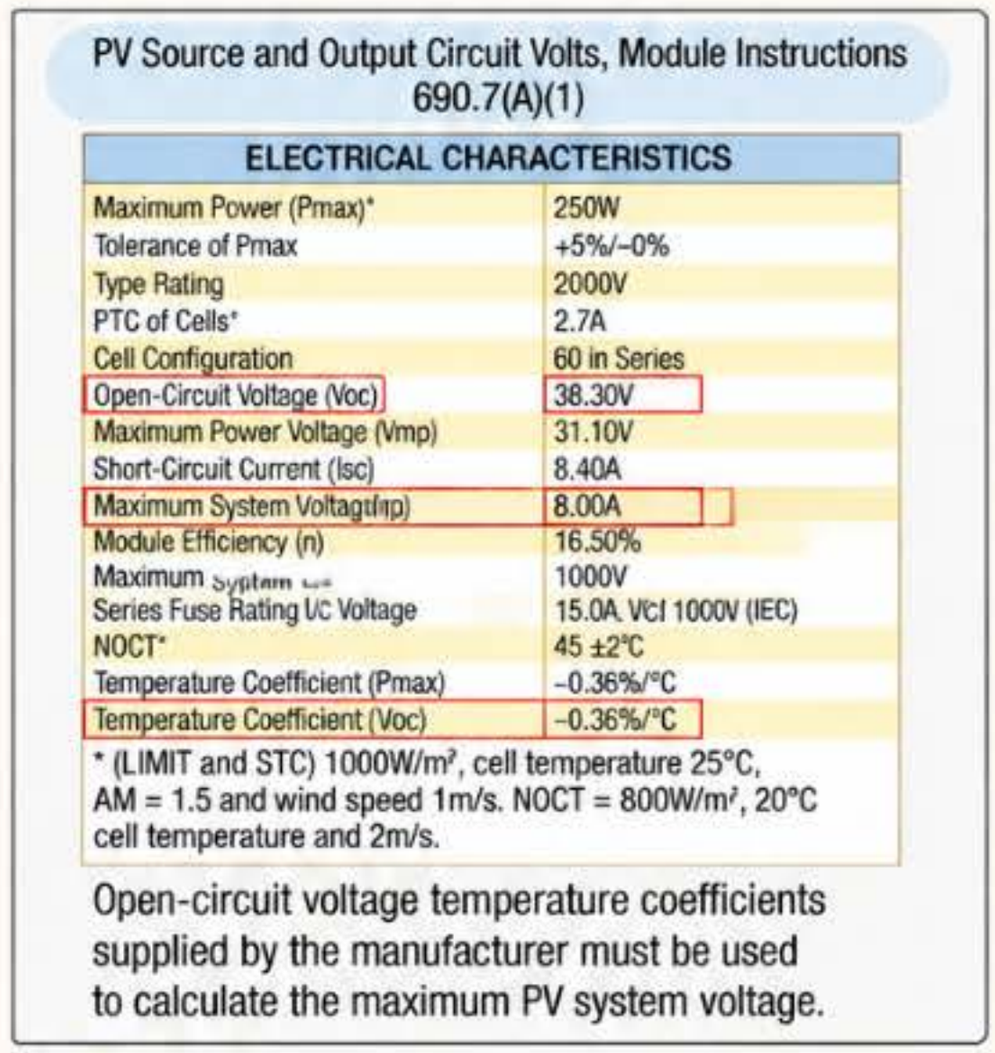
▶ Figure 690–27

(1) Module Instructions. The maximum PV source and output dc voltage is equal to the sum of the dc module open-circuit voltage (Voc) of the series-connected modules as corrected for the lowest expected ambient temperature using the manufacturer's voltage temperature coefficient correction.

▶ Figure 690–28 and ▶ Figure 690–29



▶ Figure 690–28



ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)*	250W
Tolerance of Pmax	+5%/–0%
Type Rating	2000V
PTC of Cells*	2.7A
Cell Configuration	60 in Series
Open-Circuit Voltage (Voc)	38.30V
Maximum Power Voltage (Vmp)	31.10V
Short-Circuit Current (Isc)	8.40A
Maximum System Voltage (Imp)	8.00A
Module Efficiency (n)	16.50%
Maximum System [illegible]	1000V
Series Fuse Rating UC Voltage	15.0A VCI 1000V (IEC)
NOCT*	45 ±2°C
Temperature Coefficient (Pmax)	–0.36%/°C
Temperature Coefficient (Voc)	–0.36%/°C

* (LIMIT and STC) 1000W/m², cell temperature 25°C, AM = 1.5 and wind speed 1m/s. NOCT = 800W/m², 20°C cell temperature and 2m/s.

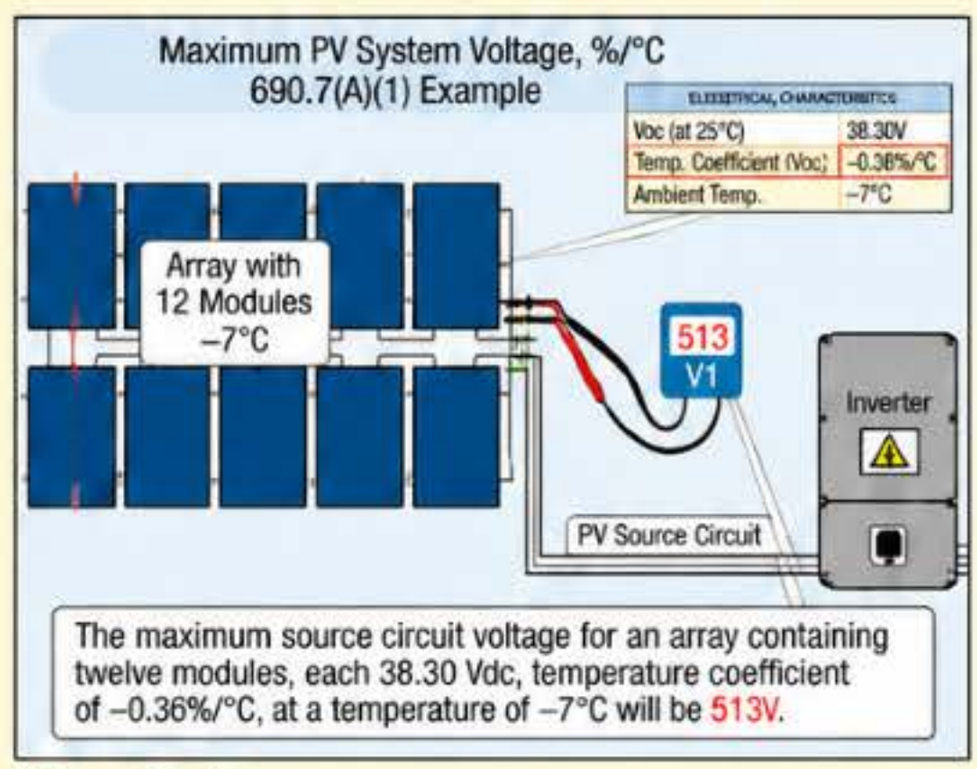
Open-circuit voltage temperature coefficients supplied by the manufacturer must be used to calculate the maximum PV system voltage.

▶ Figure 690–29

▶ Maximum PV System Voltage, Based on Manufacturer Temperature Coefficient, %/°C Example

Question: *Using the manufacturer's temperature coefficient of –0.36%/°C, what is the maximum PV system source and output circuit dc voltage for twelve modules each rated 38.30 Vdc at a temperature of –7°C?* ▶ Figure 690–30

(a) 493V (b) 513V (c) 529V (d) 541V



▶ Figure 690–30

Solution:

Four items are needed to determine the maximum PV system circuit voltage:

1. *The module Voc (open-circuit voltage) found on the manufacturer's label or datasheet.*

•••

Author's Commentary:

A PV module's dc voltage moves in the opposite direction of temperature. As temperature drops, the module's dc output rises; as temperature climbs, the module's dc output falls.

— Michael Hamilton

690.7 Solar Photovoltaic (PV) Systems

2. The manufacturer's label or datasheet lists the temperature coefficient of the open-circuit voltage (Voc).

3. Identify the lowest expected ambient temperature. Refer to local sources such as the **Solar America Board of** *Codes* and Standards or its website (*www.solarabcs.org*).

4. Count the modules wired in series within each string.

PV Voc = Rated Voc × {1 + [(Temp. °C – 25°C) × Module Coefficient %/°C]} × # Modules

Voc of Module = 38.30 Voc
Temperature Coefficient of Voc of Module = –0.36%/°C
Lowest Temperature Expected = –7°C
Number of Series-Connected Modules = 12
PV Circuit Voltage = 38.30 Voc × {1 + [(–7°C – 25°C) × –0.36%/°C]} × 12 modules
PV Circuit Voltage = 38.30 Voc × {1 + [–32°C × –0.36%/°C]]} × 12 modules
PV Circuit Voltage = 38.30 Voc × {1 + [11.52%]} × 12 modules
PV Circuit Voltage = 38.30 Voc × 11.52% × 12 modules
PV Circuit Voltage = 42.71V × 12 modules
PV Circuit Voltage = 513V

Answer: *(b) 513V*

▶ Maximum PV System Voltage, Based on Manufacturer Temperature Coefficient, V/°C Example

Question: *Using the manufacturer's temperature coefficient of –0.137V/°C, what is the maximum PV source and output circuit dc voltage for twelve modules each rated 38.30 Voc at a temperature of –7°C?* ▶ ***Figure 690–31***

(a) 493V (b) 512V (c) 524V (d) 541V

Solution:

PV Voc (V/°C) = Rated Voc + [(Temp. °C – 25°C) × Module Coefficient V/°C] × # Modules

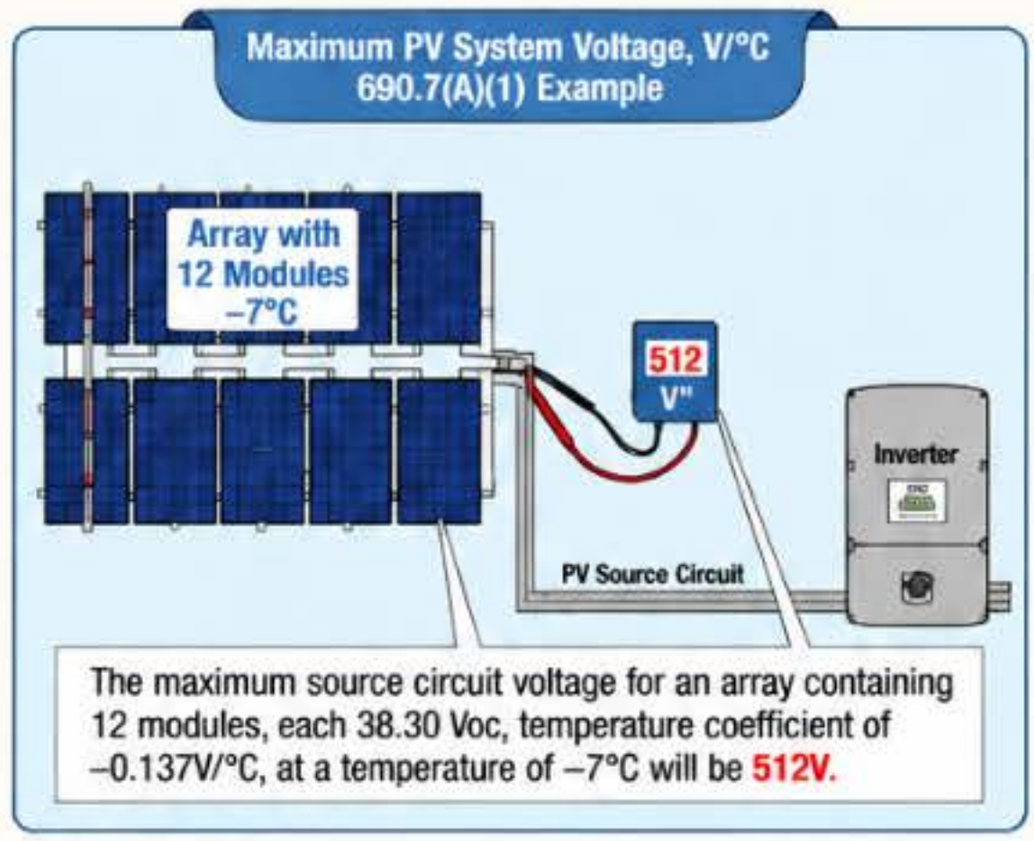
PV Circuit Voltage = [38.30V + {(–7°C – 25°C) × 0.137V/°C]} × 12 modules
PV Circuit Voltage = [38.30V + {–32°C × 0.137V/°C]} × 12 modules
PV Circuit Voltage = [38.30V + {4.384V]} × 12 modules
PV Circuit Voltage = 42.684V × 12 modules
PV Circuit Voltage = 512V

Answer: *(b) 512V*

Author's Commentary:

These calculations ensure that the PV source circuit voltage will remain within equipment voltage ratings even at the lowest temperatures.

— Michael Hamilton



▶ **Figure 690–31**

(2) Table of Crystalline and Multicrystalline Modules. The maximum PV source and output circuit voltage is equal to the sum of the dc module-rated open-circuit voltage (Voc) of the series-connected modules as corrected for the lowest expected ambient temperature in accordance with Table 690.7(A).

Table 690.7(A) Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules

Correction Factors for Ambient Temperatures Below 25°C (77°F).
(Multiply the rated open-circuit voltage by the appropriate correction factor shown below.)

Ambient Temperature (°C)	Factor	Ambient Temperature (°F)
24 to 20	1.02	76 to 68
19 to 15	1.04	67 to 59
14 to 10	1.06	58 to 50
9 to 5	1.08	49 to 41
4 to 0	1.10	40 to 32
–1 to –5	1.12	31 to 23
–6 to –10	1.14	22 to 14
–6 to –10	1.16	13 to 5
=11 to –15	1.18	4 to –4
–16 to –20	1.18	4 to –4
–21 to –25	1.20	–5 to –13
–26 to –30	1.21	–14 to –22
–31 to –35	1.23	–23 to –31
–36 to –40	1.25	–32 to –40

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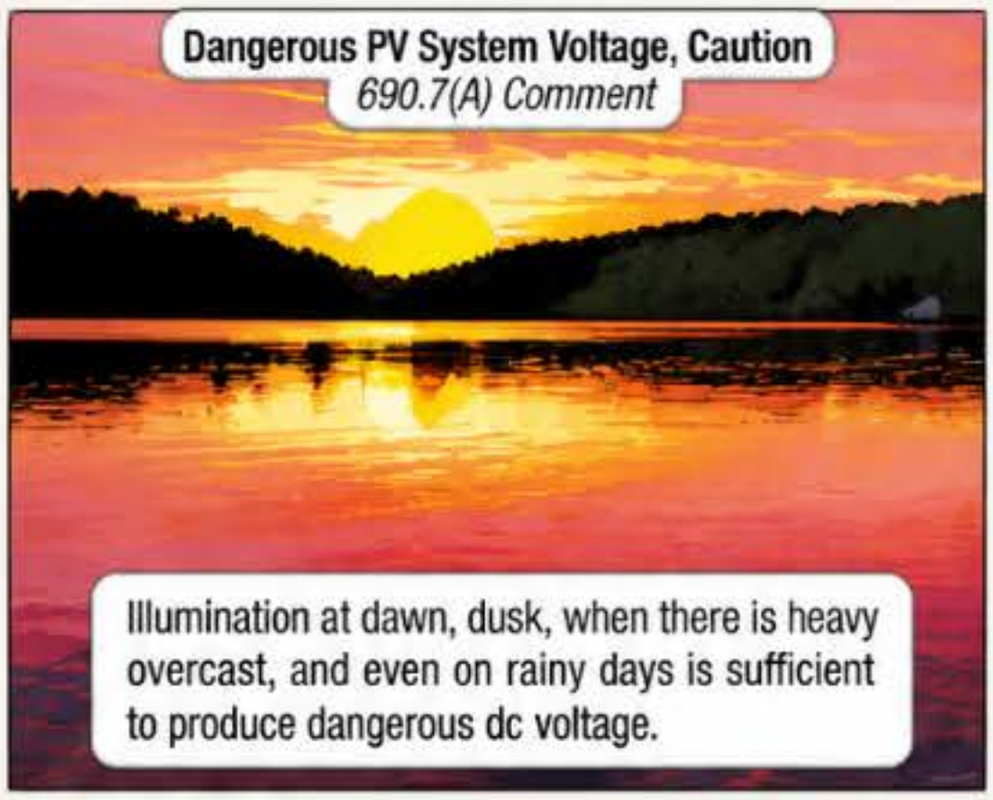
Caution

Illumination at dawn, dusk, when there is heavy overcast, and even on rainy days is sufficient to produce dangerous dc voltage.

▶ **Figure 690–32**

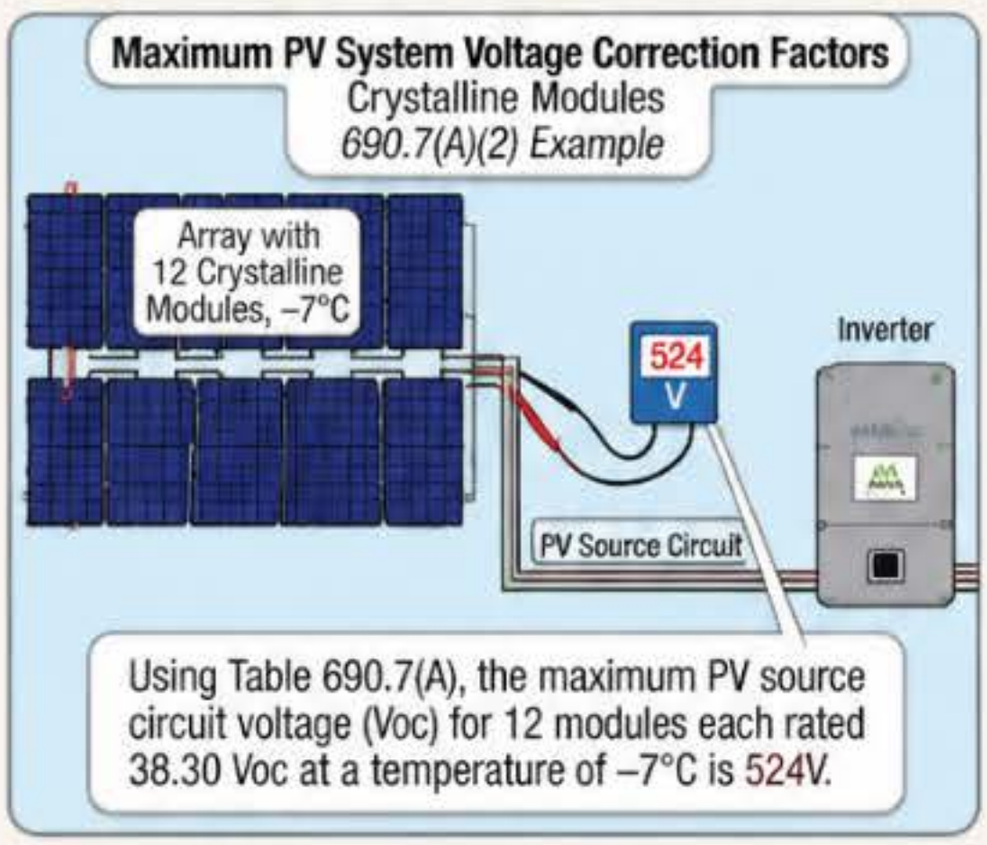


▶ **Figure 690–32**

▶ Maximum PV System Voltage, Based on Table 690.7(A) Temperature Correction [690.7(A)(2)] Example

Question: *Using Table 690.7(A), what is the maximum PV system source and output circuit dc voltage for twelve crystalline modules each rated 38.30 Voc at a temperature of –7°C?* ▶ **Figure 690–33**

(a) 493V (b) 513V (c) 524V (d) 541V



▶ **Figure 690–33**

Solution:

PV Voc = Module Voc × Table 690.7 Correction Factor × # Modules

PV Circuit Voltage = 38.30 Voc × 1.14 × 12 modules

PV Circuit Voltage = 524V

Answer: *(c) 524V*

(3) Engineered Industry Standard Method. For PV systems with an inverter, generating capacity of 100 kW or greater, the maximum PV source and output circuit dc voltage is permitted to be determined by a licensed professional electrical engineer providing documented and stamped PV system design using an industry standard method maximum dc voltage calculation.

Note 1: One source for lowest-expected, ambient temperature design data for various locations is the chapter titled "Extreme Annual Mean Minimum Design Dry Bulb Temperature" found in the *ASHRAE Handbook–Fundamentals*. This temperature data can be used to calculate maximum voltage.

Note 2: One industry standard method for calculating the maximum PV source and output circuit dc voltage is published by Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*.

(B) DC-to-DC Converter Source and Output Circuit Voltage. The maximum dc-to-dc converter dc voltage is determined by one of the following methods:

(1) Single DC-to-DC Converter. The maximum output dc voltage for a single dc-to-dc converter is based on the manufacturer's instructions for the dc-to-dc converter.

If the instructions do not provide a method to determine the maximum dc-to-dc converter output dc voltage, the maximum dc-to-dc output dc voltage will be equal to the rated output dc voltage of the dc-to-dc converter.

(2) Two or More Series-Connected DC-to-DC Converters. The maximum output circuit dc voltage for series-connected dc-to-dc converters is based on the manufacturer's instructions for the dc-to-dc converter.

If the instructions do not provide a method to determine the dc-to-dc converters' maximum output dc voltage, the maximum dc-to-dc output dc voltage for the series-connected dc-to-dc converters will be equal to the sum of the maximum rated output dc voltage of the dc-to-dc converters connected in series.

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690.8 Circuit Current and Conductor Sizing

(A) Calculation of Maximum PV Circuit Current. To determine the highest current a PV system can produce, use the method required by 690.8(A)(1) or the one in 690.8(A)(1)(a) through (e).

(1) PV System Circuit Current. The peak current for a PV system is calculated using the process in 690.8(A)(1)(a) through (e).

(a) PV Source Circuit Current Calculation.

(1) PV Systems Rated Less Than 100 kW. Find the PV source circuit dc current by taking the short-circuit current values shown on the module nameplate (*Isc*) for all modules wired in parallel and increasing that total by 125 percent.
▶ **Figure 690–34**

PV Systems Rated Less Than 100 kW
Maximum PV Source Circuit Current (Isc)
690.8(A)(1)(a)(1)

ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)	250W
Tolerance of Pmax	0/+5W
PFC Rating	2230W
Type of Cell	Polycrystalline silicon
Cell Configuration	60 in series
Short-Circuit Voltage (Voc)	38.0V
Maximum Power Voltage (Vmp)	29.8V
Short Circuit Current (Isc)	10.0A
Maximum Power Current (Imp)	8.39A
Maximum System (dc) Voltage	600V UL/1000V (IEC)
Series Fuse Rating	15A
NOCT	45±2°C
Temperature Coefficient (Pmax)	-0.45%/°C
Temperature Coefficient (Voc)	-0.36%/°C
Temperature Coefficient (Isc)	0.05%/°C

* Irradiance of 1000 W/m², cell temp. 25°C, spectrum distribution or AM 1.5 at air mass 1.5 according to standard, I_s is cell temperature of 25°C.

To calculate the maximum PV source circuit dc current, multiply the *short*-circuit current rating found *on the* modules connected in *parallel* by 125 percent.

▶ **Figure 690–34**

Author's Commentary:

- A PV source circuit is the dc circuit made by the wiring and connections between modules, between modules and dc-to-dc converters, between modules and dc combiners, and between modules and dc-to-ac inverters [690.2].
- A module can output more current than its rated value when sunlight intensifies beyond the standard test conditions used to assign its short-circuit rating. Warmer cells caused by sun angle, reflections off snow, light scattering through clouds, or low humidity can all raise the current. That's why PV system circuit current is sized at 125 percent of the module Isc. This built-in margin is commonly called the "irradiance factor."

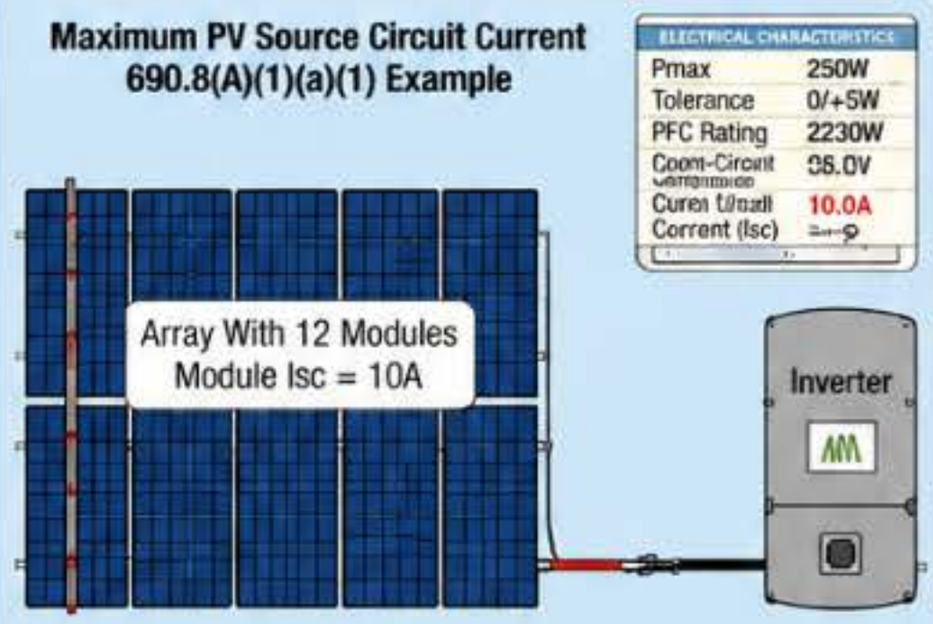
— ***Michael Hamilton***

▶ Maximum PV Source Circuit Current Example

Question: *What is the maximum PV source circuit dc current for 12 series-connected modules having a nameplate short-circuit current (Isc) of 10A?* ▶ **Figure 690–35**

(a) 12.50A *(b) 15A* *(c) 20A* *(d) 25A*

Maximum PV Source Circuit Current
690.8(A)(1)(a)(1) Example



Maximum PV Source Circuit Current = Module Isc × 125%
Maximum PV Source Circuit Current = 10A × 125%
Maximum PV Source Circuit Current = **12.50A**

▶ **Figure 690–35**

Solution:

Source Circuit Current = Module Isc × 125%

Source Circuit Current = 10A × 125%

Source Circuit Current = 12.50A

Answer: *(a) 12.50A*

(2) PV Systems Rated 100 kW or Greater. To find the highest PV source circuit dc current for systems that use inverters with an overall capacity of 100 kW or more, the value must be calculated by a qualified professional engineer who can design and stamp PV system plans using a method recognized by industry standards.

This maximum PV source circuit dc current is based on the highest 3-hour average resulting from modeled local irradiance on the array, considering both tilt and compass direction. It can never be less than 70 percent of the maximum value obtained using 690.8(A)(1)((a)(1).

Note: One industry-accepted approach for computing the maximum PV source current is available in Sandia National Laboratories reference SAND 2003-3535, *Photovoltaic Array Performance Model*. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

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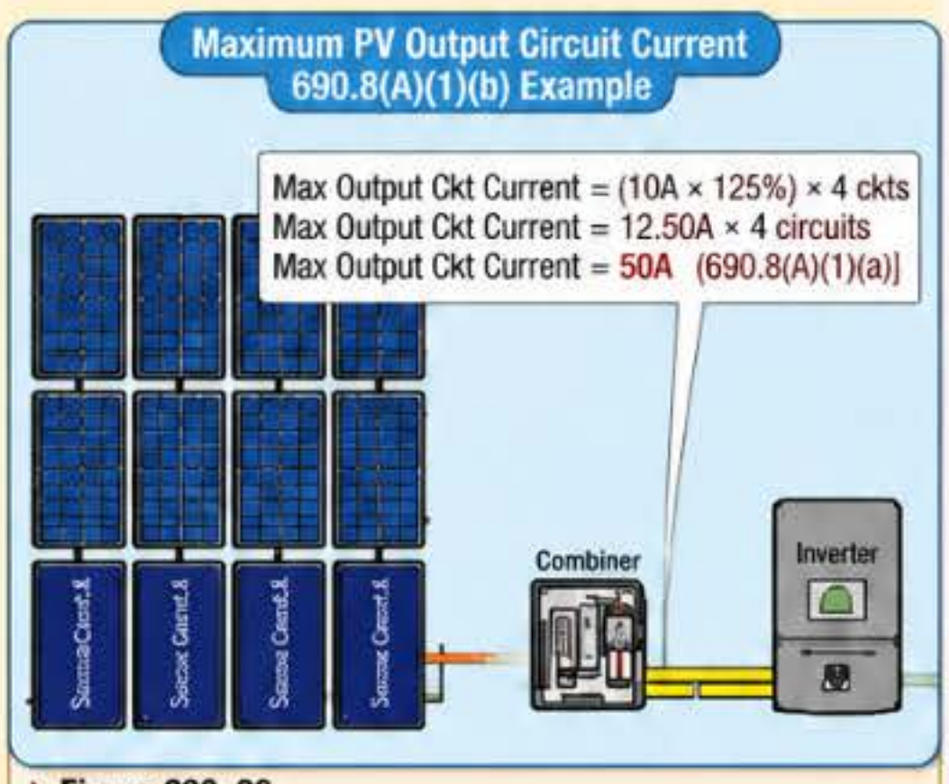
(b) PV Output Circuit Current Calculation. The highest PV output circuit dc current equals the total of the parallel PV source circuit dc currents. This total is calculated using 690.8(A)(1)(a).

> ***Author's Commentary:***
> A PV output circuit combines the two dc output conductors that run from a dc combiner to the output of a dc combiner.
> — *Michael Hamilton*

▶ Maximum PV Output Circuit Current Example

Question: *What is the maximum PV output circuit dc current for four source circuits where each source circuit contains 12 dc modules, with every module having a nameplate Isc of 10A?* ▶ **Figure 690–36**

(a) 25A (b) 35A (c) 40A (d) 50A



▶ **Figure 690–36**

Solution:

PV Output Circuit Current = (Module Isc × 125%) × Number of Source Circuits

PV Output Circuit Current = (10A × 125%) × 4 circuits

PV Output Circuit Current = 12.50A × 4 circuits

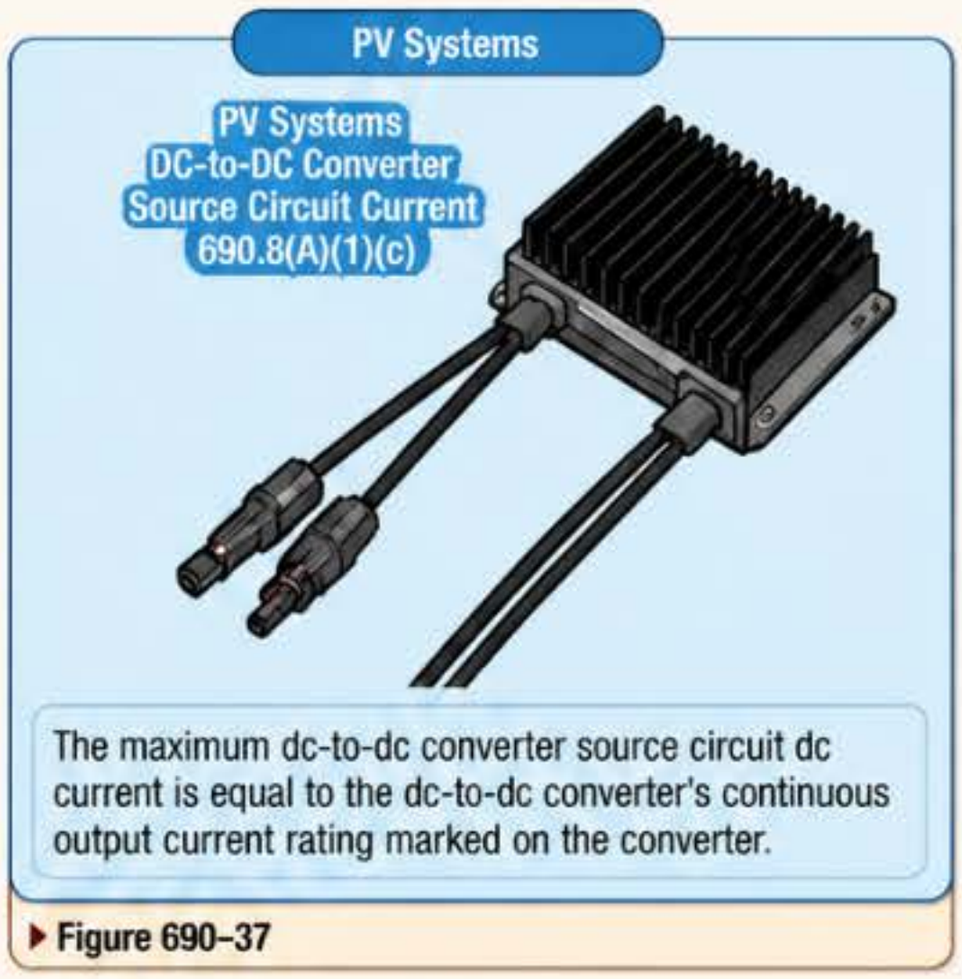
PV Output Circuit Current = 50A

**(690.8(A)(1)(a)]*

Answer: *(d) 50A*

(c) DC-to-DC Converter Source Circuit Current. The highest dc-to-dc converter source circuit dc current equals the total of the parallel-connected dc-to-dc converter source circuit dc currents as defined in 690.8(A)(1)(c).

▶ **Figure 690–37**



▶ **Figure 690–37**

> ***Author's Commentary:***
> A dc-to-dc converter source circuit is the two dc output conductors coming from the output of a dc-to-dc converter.
> — *Michael Hamilton*

(d) DC-to-DC Converter Output Circuit Current. The highest dc-to-dc converter output circuit dc current equals the total of the parallel-connected dc-to-dc converter source circuit dc currents as calculated in 690.8(A)(1)(c).

> ***Author's Commentary:***
> A dc-to-dc converter output circuit consists of the two dc conductors connected to the output of the dc combiner that contains a dc-to-dc converter source circuit.
> — *Michael Hamilton*

(e) Inverter Output Circuit Current. The highest inverter output circuit dc current equals the continuous output current rating marked on the inverter for the output ac voltage. ▶ **Figure 690–38**

> ***Author's Commentary:***
> The inverter output circuit is the circuit conductors that connect to the alternating-current output terminals of an inverter (Article 100).
> — *Michael Hamilton*

(2) Input of Electronic Power Converters. Where a circuit is protected with an overcurrent device not exceeding the conductor ampacity, the maximum current can be the rated input current of the electronic power converter.

(B) Conductor Sizing. PV circuit conductors must be sized to carry the greater value of 690.8(B)(1) or (B)(2).

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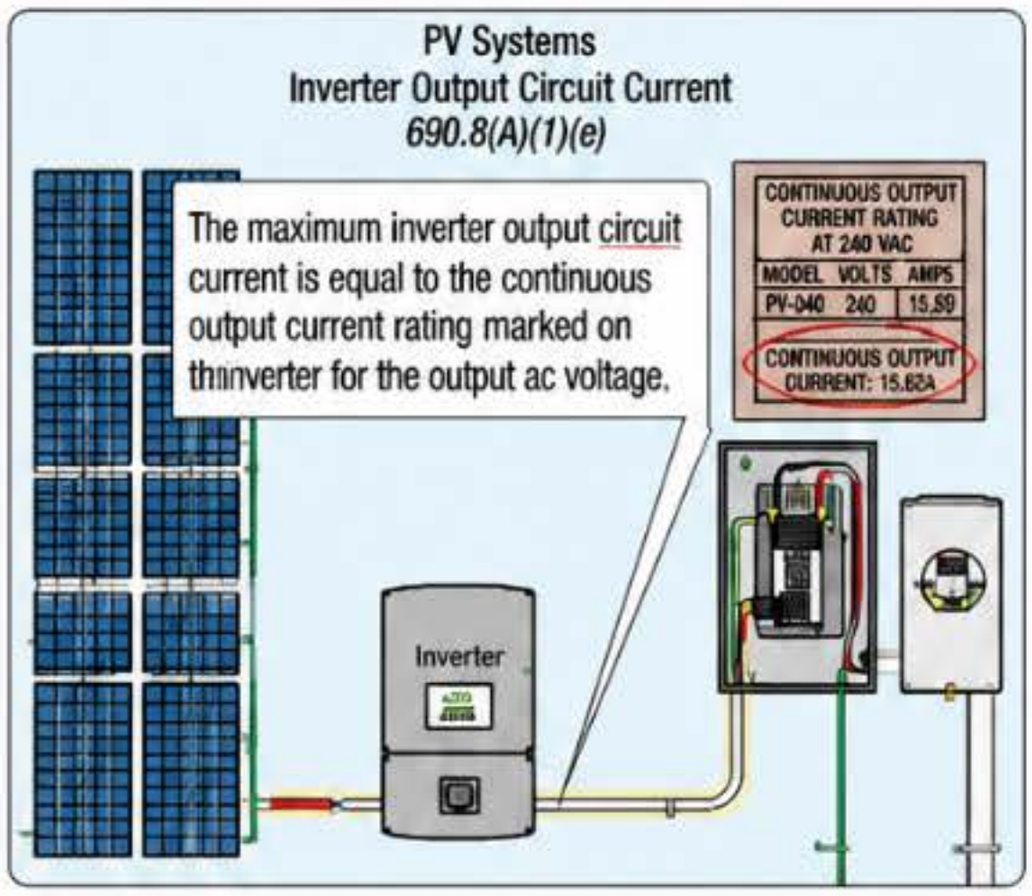

Figure 690–38

(1) Conductor Sizing, Without Ampacity Correction and/or Adjustment. PV circuit conductors within the scope of 690.8(A) must have an ampacity of not less than 125 percent of the current as determined by 690.8(A), without ampacity correction and/or adjustment.

Figure 690–39

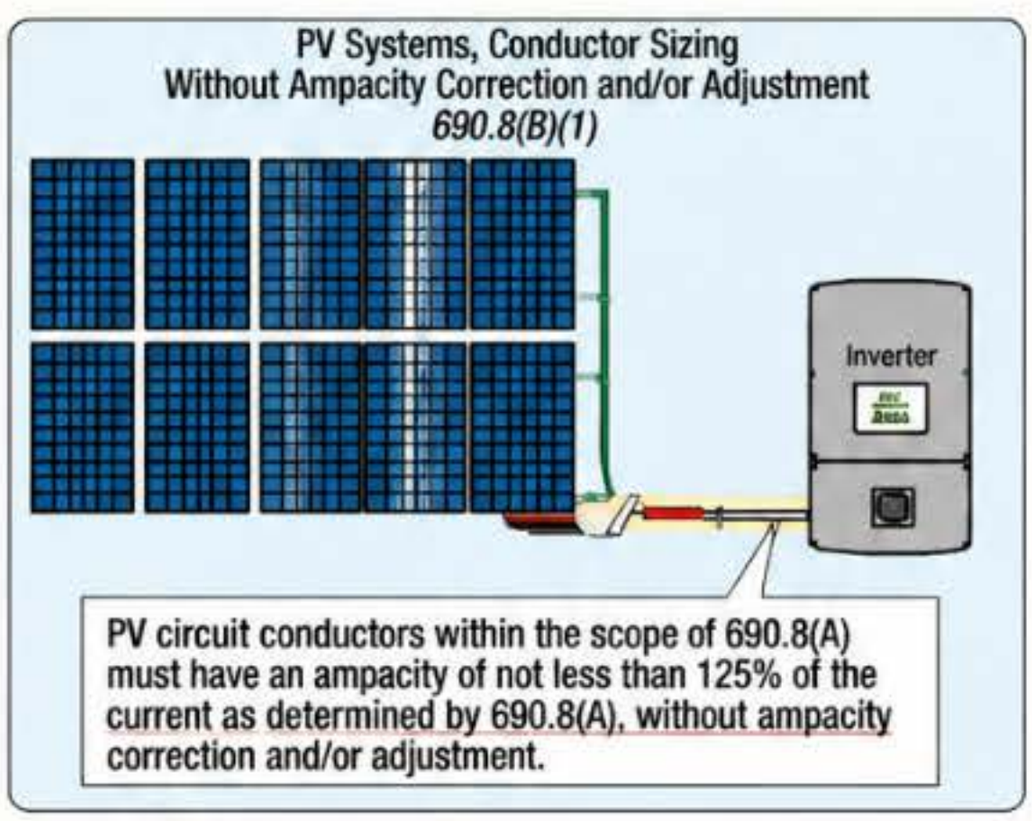

Figure 690–39

▶ PV Source Circuit Without Ampacity Correction and/or Adjustment Example

Question: *What is the minimum dc source circuit conductor ampacity, without the application of conductor correction or adjustment, for source circuit conductors having a short-circuit current rating of 10A?* **Figure 690–40**

(a) 12.50A (b) 15.62A (c) 20.41A (d) 25.56A

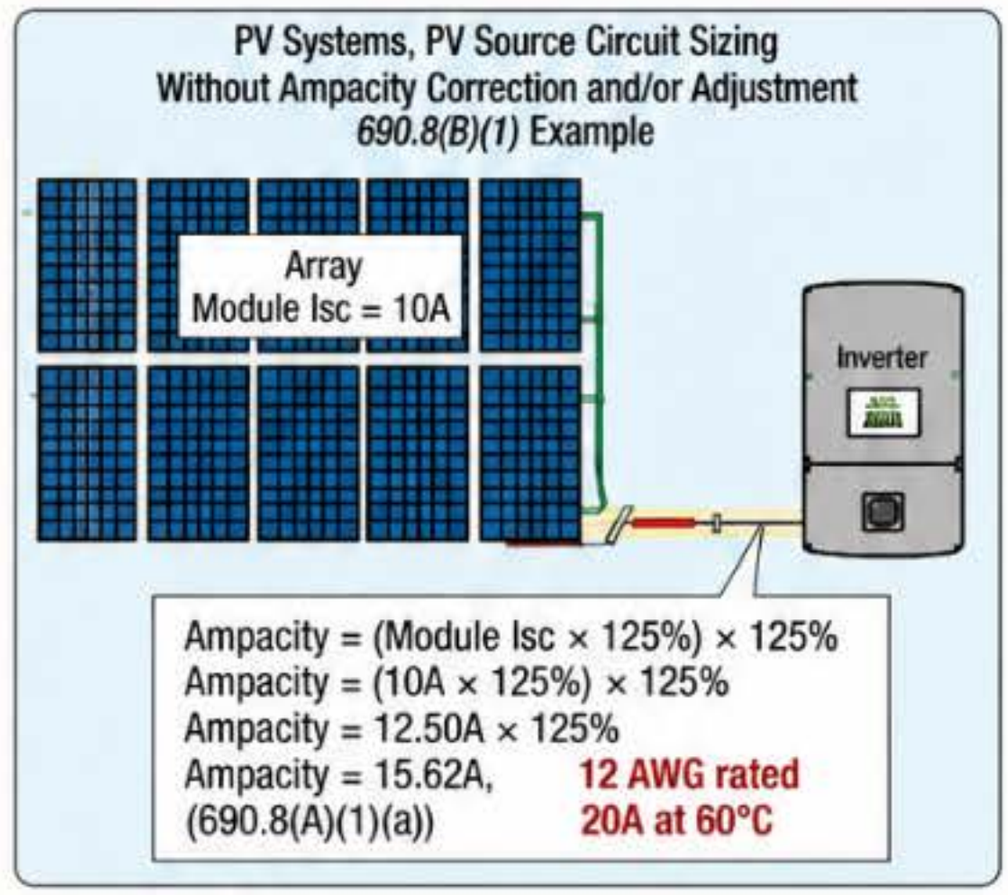

Figure 690–40

Solution:

Conductor Ampacity = (Module Isc × 125%)* × 125%

Conductor Ampacity = (10A × 125%) × 125%*

Conductor Ampacity = 12.50A × 125%

Conductor Ampacity = 15.62A

Use 12 AWG rated 20A at 60°C [110.14(C)(1)(a) and Table 310.16].

**[690.8(A)(1)(a)]*

Answer: *(b) 15.62A*

▶ PV Output Circuit Ampacity Without Correction and/or Adjustment Example

Question: *What is the minimum ac PV output circuit conductor ampacity, without the application of conductor correction or adjustment, supplied by four source circuits each with a short-circuit current rating of 10A where the terminals are rated 75°C?* **Figure 690–41**

(a) 33A (b) 32A (c) 43A (d) 63A

Solution:

Conductor Ampacity = (Module Isc × 125% × Number of Source Circuits)* × 125%

Conductor Ampacity = (10A × 125% × 4 circuits) × 125%*

Conductor Ampacity = 50A × 125%

Conductor Ampacity = 62.50A

Use 6 AWG rated 65A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].

**[690.8(A)(1)(a)]*

Answer: *(d) 63A*

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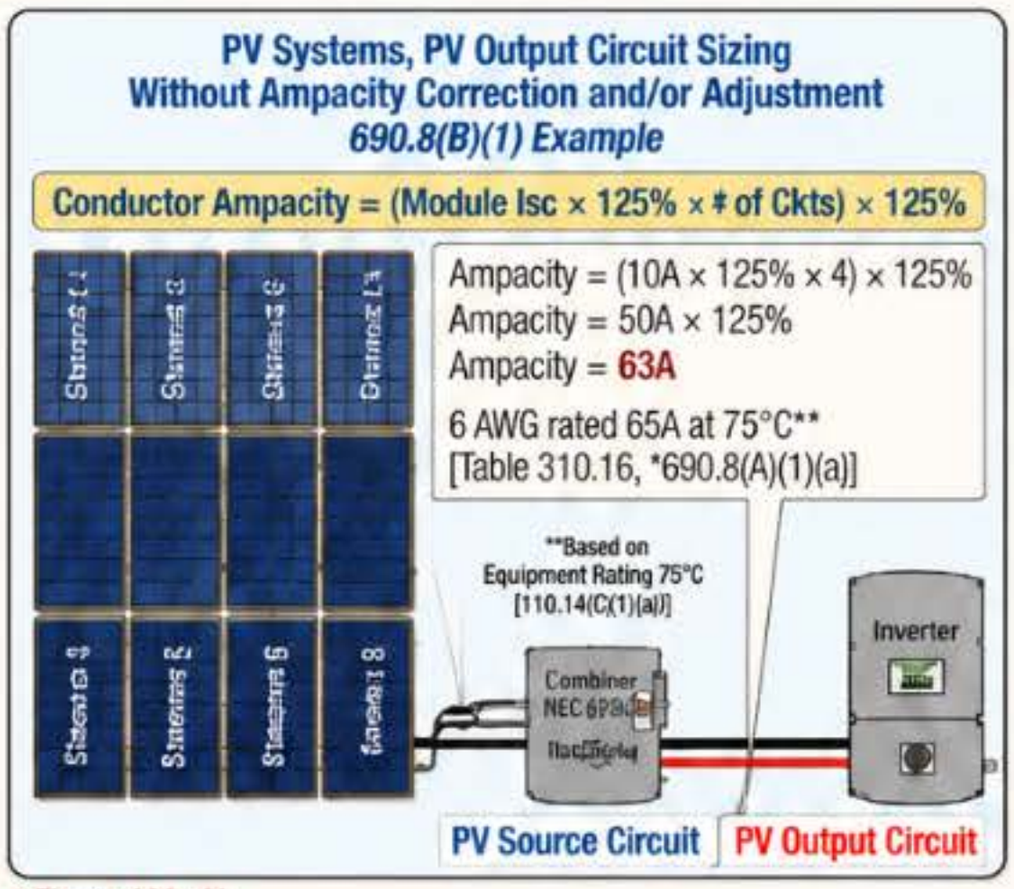
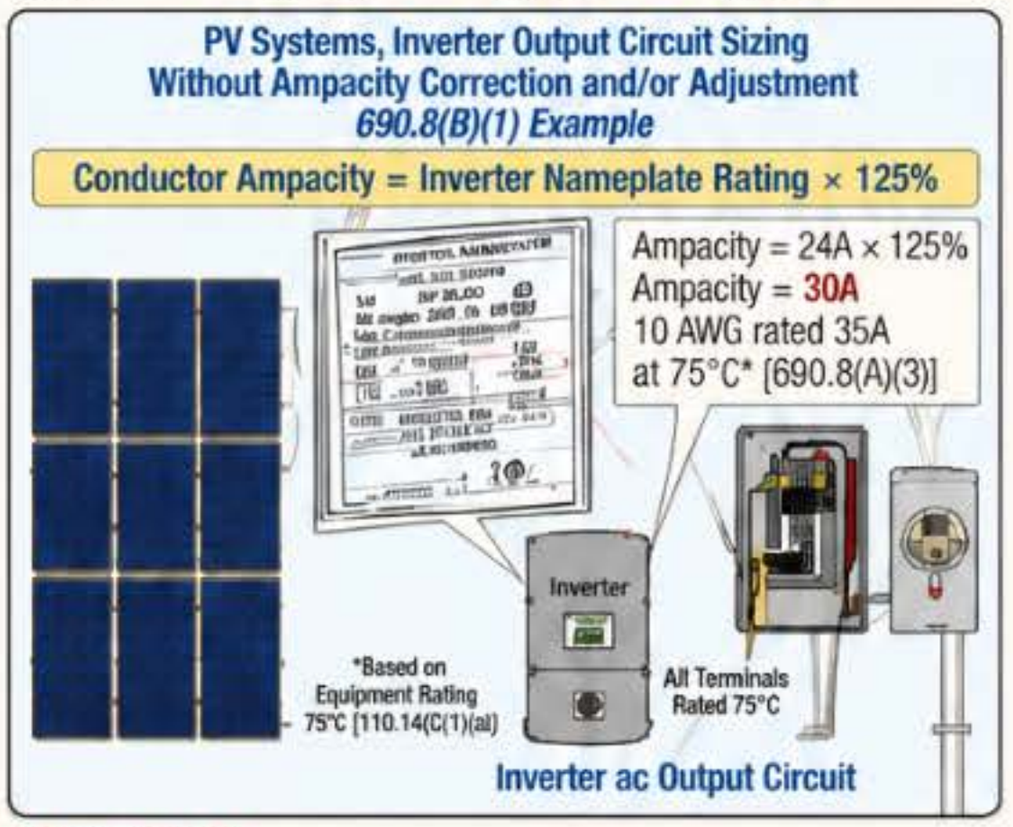


▸ Figure 690–41

▸ Inverter Output Circuit Ampacity Without Correction and/or Adjustment Example

Question: *What is the minimum inverter ac output circuit conductor ampacity, without the application of a conductor ampacity correction and/or adjustment factors, if the maximum continuous nameplate rating of the inverter is 24A where the terminals are rated 75°C?* ▸ ***Figure 690–42***

(a) 20A *(b) 25A* *(c) 30A* *(d) 35A*



▸ Figure 690–42

Solution:

Conductor Ampacity = Inverter Nameplate Rating [690.8(A)(1)(e)] × 125%

Conductor Ampacity = 24A × 125%

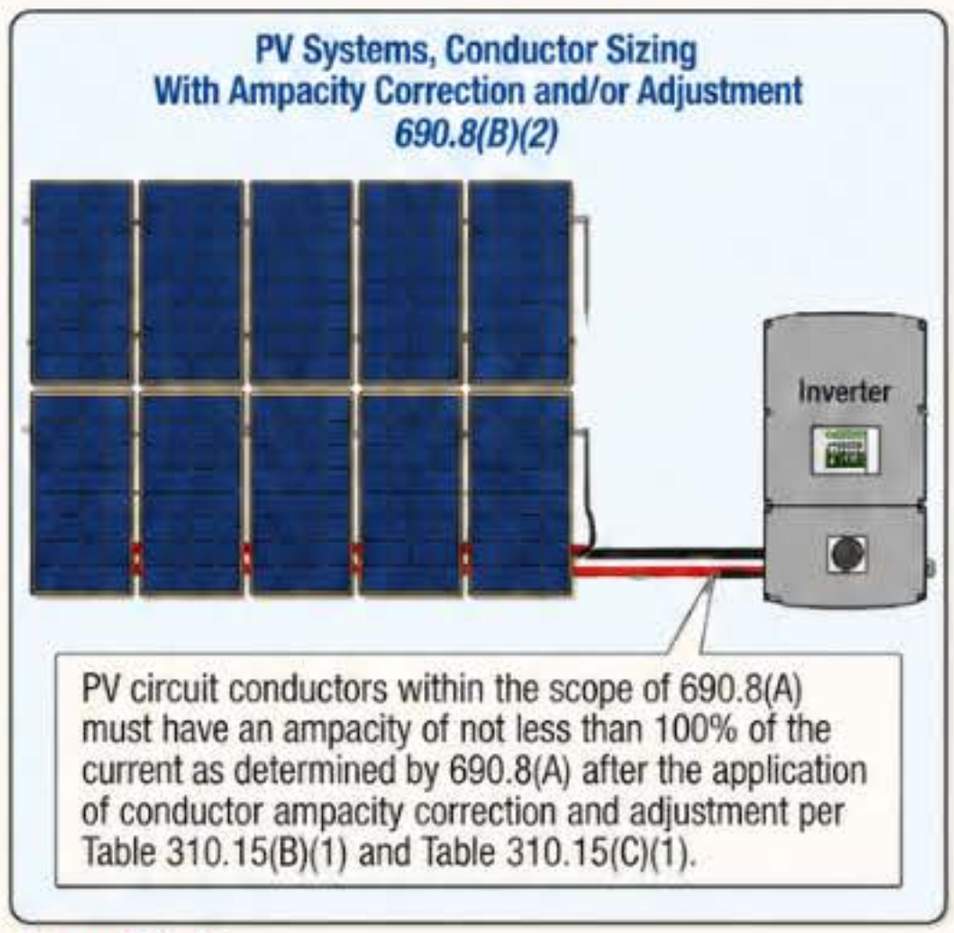
Conductor Ampacity = 30A

Use 10 AWG rated 35A at 75°C [310.16].

Answer: *(c) 30A*

Ex: *Where the assembly, including the overcurrent devices protecting the circuit(s), is listed for operation at 100 percent of its rating, the ampere rating of the overcurrent device can be sized to 100 percent of the continuous and noncontinuous loads.*

(2) Conductor Sizing, With Ampacity Correction and/or Adjustment. PV circuit conductors within the scope of 690.8(A) must have an ampacity of not less than 100 percent of the current as determined by 690.8(A) after the application of conductor ampacity correction and adjustment in accordance with Table 310.15(B)(1) and Table 310.15(C)(1). ▸ ***Figure 690–43***



▸ Figure 690–43

Author's Commentary:

The Table 310.16 ampacity must be corrected when the ambient temperature is less than 77°F or greater than 86°F and adjusted when more than three current-carrying conductors are bundled together. The temperature correction [Table 310.15(B)(1)] and conductor bundling adjustment [Table 310.15(C)(1)] are applied to the conductor ampacity based on the temperature rating of the conductor insulation as contained in Table 310.16, typically in the 90°C column [310.15].

— Michael Hamilton

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▶ PV Source Circuit Ampacity with Correction and Adjustment Example 1

Question: *A conductor has a temperature-corrected ampacity of 12 AWG USE-2 or PV wire rated for 90°C when installed in a raceway or cable located 1 in. above a roof where the air temperature is 94°F as defined by 310.15(B)(1). The array uses modules that are I_{SC}-rated at 10A. Refer to* ***Figure 690-44****.*

(a) 19A (b) 29A (c) 39A (d) 49A

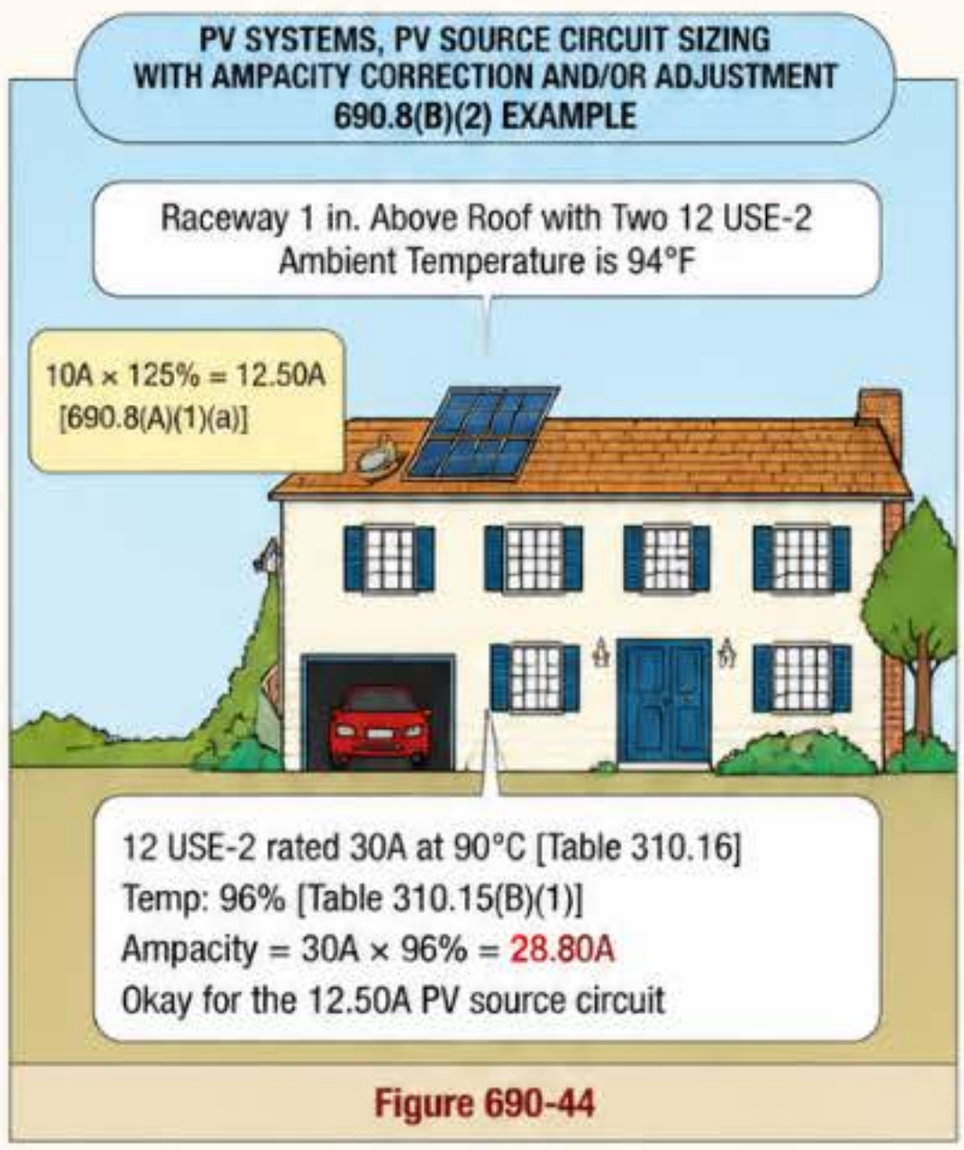


Figure 690-44

Solution:

Conductor Ampacity = Table 310.16 ampacity at 90°C column × temperature correction.

Temperature Correction = 0.96 based on a 94°F ambient temperature [Table 310.15(B)(1)].

12 AWG is rated 30A at 90°C [Table 310.16].

Conductor Corrected Ampacity = 30A × 96%

Conductor Corrected Ampacity = 28.80A

Note: *12 AWG with ampacity correction has sufficient capacity to supply the source circuit dc current of 12.50A (10A × 125%) [690.8(A)(1)(a)].*

Answer: (b) 29A

▶ PV Source Circuit Ampacity with Correction and Adjustment Example 2

Question: *For an array with modules having a nameplate I_{SC} rating of 10A for each source circuit, what is the conductor ampacity with temperature correction and adjustment for four current-carying 12 AWG USE-2 conductors located 1 in. above a roof where the ambient temperature is 94°F?* ***Refer to Figure 690-45****.*

(a) 23A (b) 24A (c) 25A (d) 26A

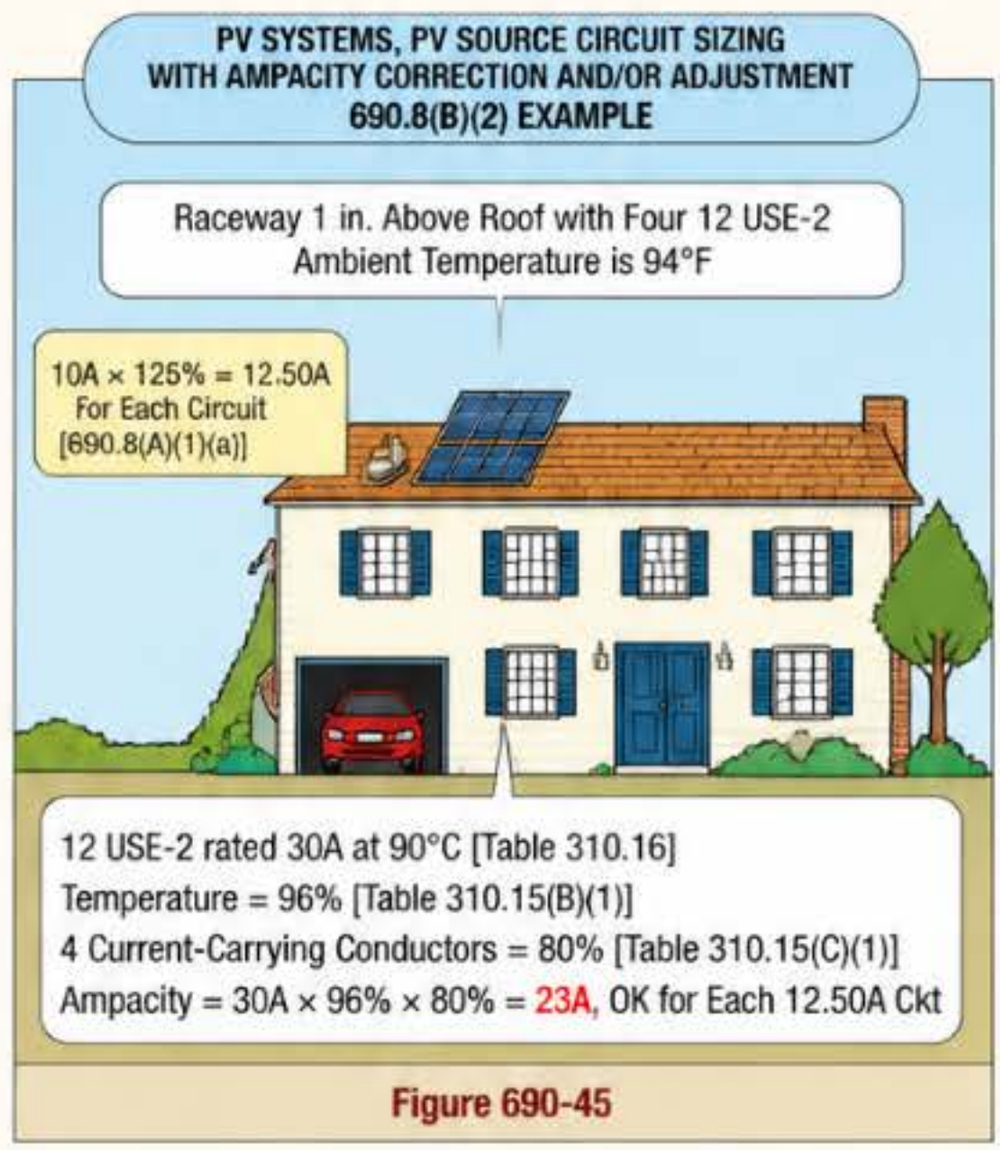


Figure 690-45

Solution:

Conductor Ampacity = Table 310.16 ampacity at 90°C column × temperature correction × bundle adjustment.

Temperature Correction = 0.96 based on a 94°F ambient temperature [Table 310.15(B)(1)].

Bundle Adjustment = 80% based on four current-carrying conductors [Table 310.15(C)(1)].

12 AWG is rated 30A at 90°C [Table 310.16].

Conductor Corrected/Adjusted Ampacity = 30A × 96% × 80%

Conductor Corrected/Adjusted Ampacity = 23A

Note: *12 AWG has sufficient ampacity with correction and adjustment to supply the dc source circuits each with a current of 12.50A (10A × 125%) [690.8(A)(1)(a)].*

Answer: (a) 23A

▶ PV Output Circuit Ampacity with Correction Example

Question: *What is the dc PV output circuit conductor ampacity with conductor temperature correction for two 6 AWG USE-2 or PV output circuit conductors located 1 in. above a roof where the PV output circuit dc current is 40A and the ambient temperature is 94°F?* **Figure 690-46**

(a) 59A (b) 69A (c) 72A (d) 89A

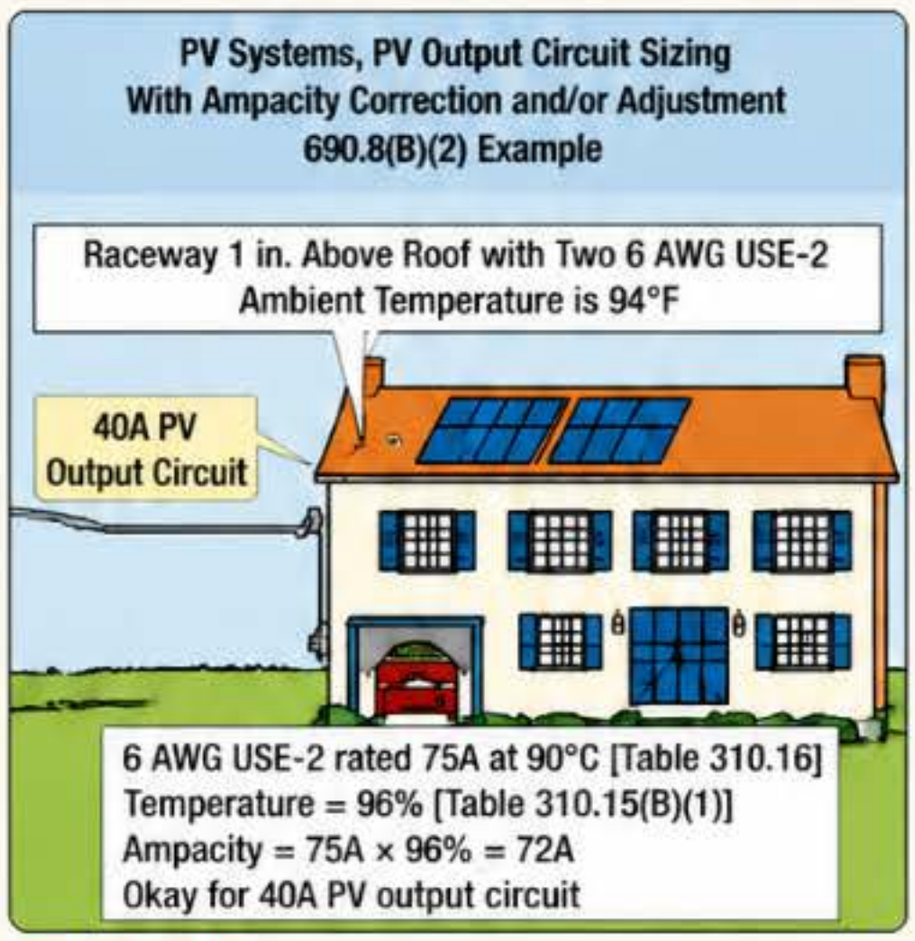


Figure 690-46

Solution:

Conductor Ampacity = Table 310.16 Ampacity at 90°C Column × Temperature Correction

Temperature Correction = 0.96 based on 94°F ambient temperature [Table 310.15(B)(1)].

6 AWG is rated 75A at 90°C [Table 310.16].

Conductor Corrected Ampacity = 75A × 96%

Conductor Corrected Ampacity = 72A

Note: *6 AWG with correction has sufficient ampacity to supply the PV output circuit dc current of 40A.*

Answer: (c) 72A

▶ Inverter Output Circuit Ampacity with Correction and Adjustment Example

Question: *What is the conductor ampacity with temperature correction for two current-carrying 10 AWG RHW-2/RHW-2/USE-2 or PV conductors rated 90°C supplying a 24A inverter output circuit and installed in a location where the ambient temperature is 94°F?* **▸Figure 690-47**

(a) 18.40A (b) 29.40A (c) 38.40A (d) 49.40A

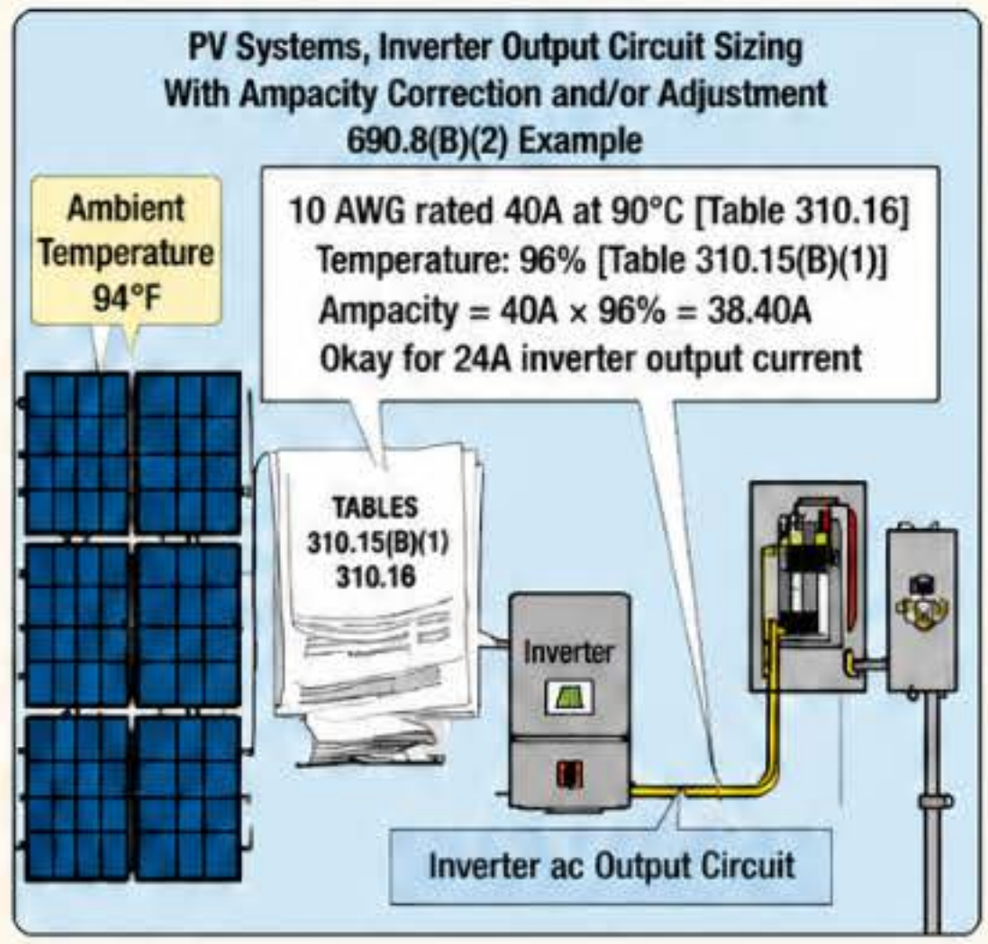


Figure 690-47

Solution:

Conductor Ampacity = Ampacity at 90°C Column [Table 310.16] × Temperature Correction.

Temperature Correction = 0.96 based on a 94°F ambient temperature [Table 310.15(B)(1)].

10 AWG is rated 40A at 90°C [Table 310.16].

Conductor Ampacity = 40A × 96%

Conductor Ampacity = 38.40A

Note: *10 AWG has sufficient ampacity with correction to supply the inverter output circuit dc current of 24A [690.8(A)(1)(e)].*

Answer: (c) 38.40A

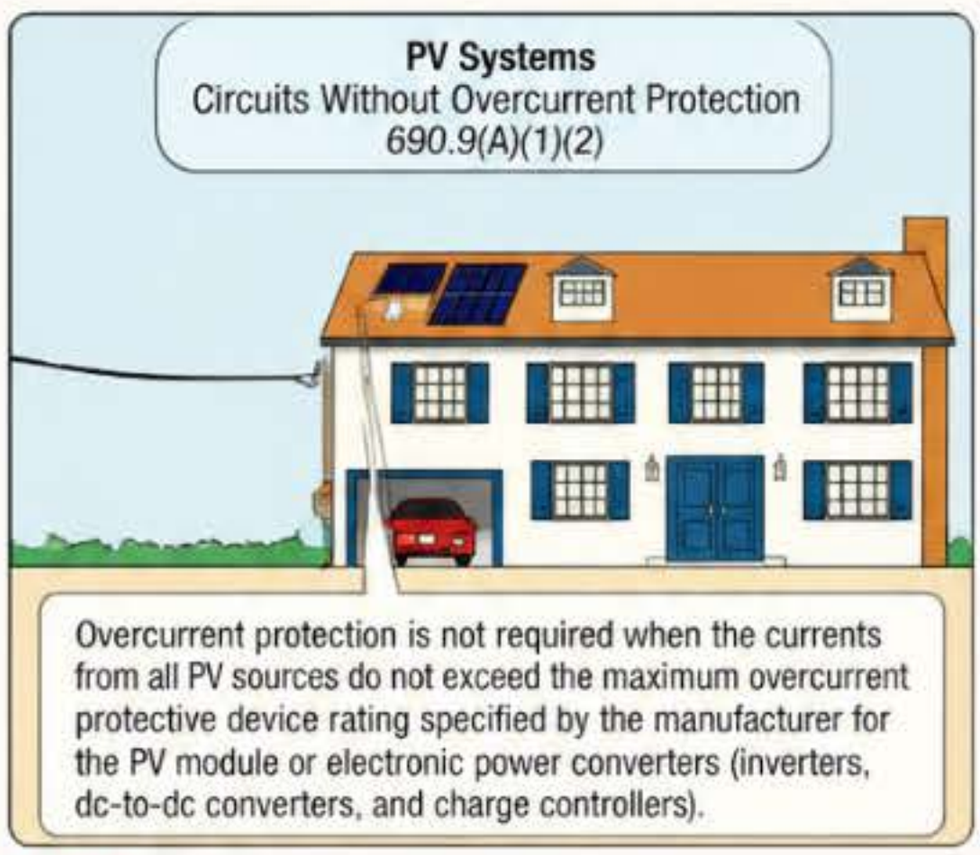
690.9 Overcurrent Protection

(A) General. PV system dc circuit and inverter output conductors and equipment must be protected against overcurrent. PV system dc circuit conductors sized in accordance with 690.8(A)(2) are required to be protected against overcurrent by one of the methods in 690.9(A)(1) through (A)(3).

(1) Circuits Without Overcurrent Protection. Overcurrent protection is not needed when both of the following conditions are satisfied:

(1) The PV system's circuit conductors have an ampacity equal to or greater than the highest current value calculated in accordance with 690.8(A).

(2) Currents from all PV sources never exceed the maximum overcurrent protective device rating provided by the manufacturer for the PV module or electronic power converters (inverters, dc-to-dc converters, and charge controllers).



▲ Figure 690–48

(2) Overcurrent Protection Required on One End. PV system circuit conductors that connect to sources with an available maximum circuit current higher than the ampacity of the conductor must have overcurrent protection at the point where they tie into the higher current source for circuit conductors connected at one end to a current-limited supply (PV modules, inverters, and dc-to-dc converters).

Note: PV system dc circuits and electronic power converter (inverters, dc-to-dc converters, and charge controllers) outputs are current-limited and in some cases do not need overcurrent protection. When these circuits are connected to higher current sources, such as parallel-connected PV system dc circuits or energy storage systems, the overcurrent device is often installed at the higher current source end of the circuit conductor.

(3) Other Circuits. PV circuit conductors that do not comply with 690.9(A)(1) or (A)(2) must be protected by one of the following methods:

(1) PV circuit conductors on (but not within) a building must not be longer than 10 ft in length and must have overcurrent protection at one end of the circuit.

(2) PV system circuit conductors within a building must not be longer than 10 ft in length, be within a raceway or metal-clad cable, and have overcurrent protection on one end of the circuit.

(3) PV circuit conductors protected from overcurrent on both ends.

(4) PV circuit conductors not installed on or within buildings having overcurrent protection at one end of the circuit must comply with all of the following conditions:

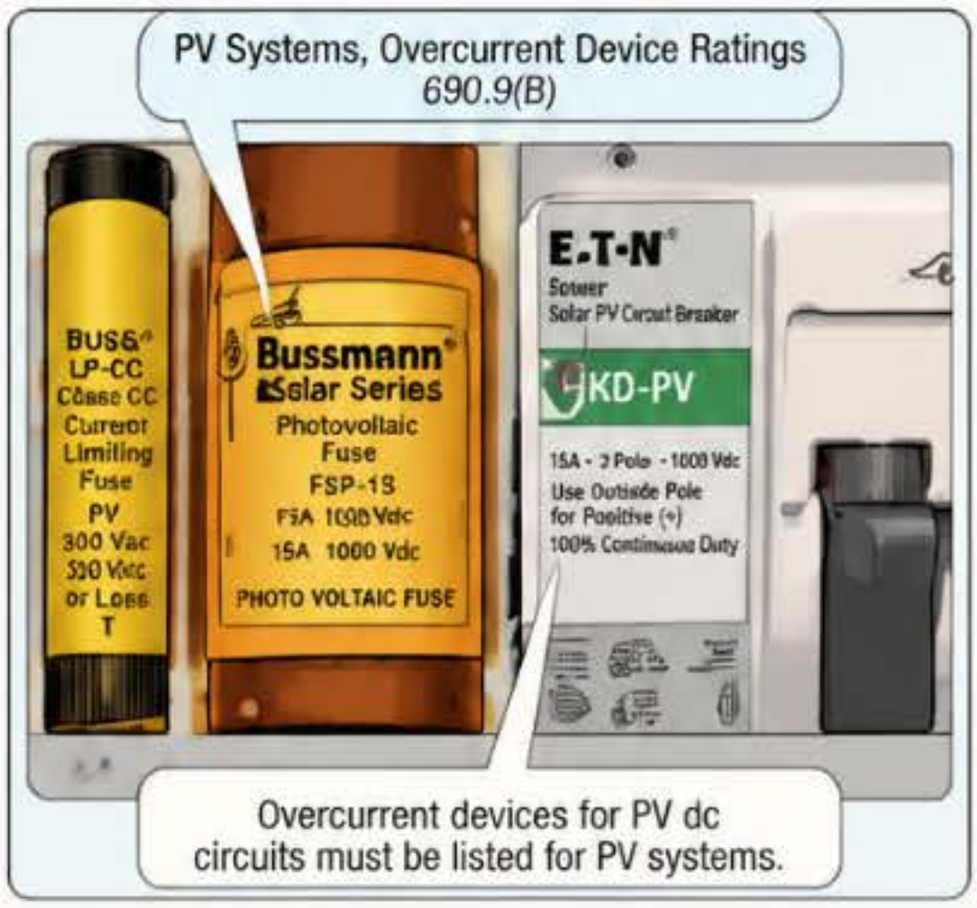
a. The PV system circuit conductors are in metal raceways, metal-clad cables, enclosed metal cable trays, underground, or in pad-mounted enclosures.

b. The PV system circuit conductors terminate to a single circuit breaker or a single set of fuses that limit the current to the ampacity of the conductors.

c. The overcurrent device for the conductors is integral with the disconnecting means or located within 10 ft (conductor length) of the disconnecting means.

d. The disconnecting means is located outside the building or at a readily accessible location nearest the point of entrance of the conductors inside the building. PV circuit conductors are considered outside of a building where they are encased or installed under not less than 2 in. of concrete or brick in accordance with 230.8.

(B) Overcurrent Device Ratings. Overcurrent devices for PV dc circuits must be listed for PV systems. Figure 690–49



▲ Figure 690–49

Electronic devices listed to prevent backfeed in PV dc circuits are permitted to prevent overcurrent of conductors on the PV array side of the electronic device.

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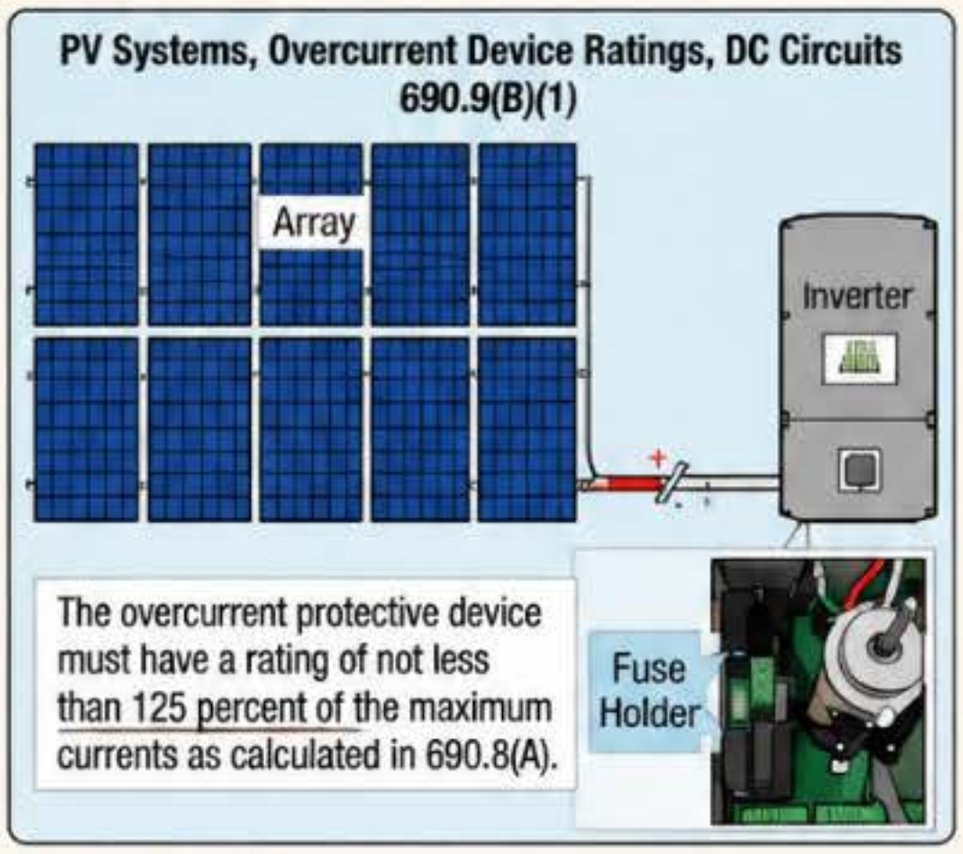
Overcurrent protective devices required by 690.9(A)(2) must comply with one of the following. The next higher standard size overcurrent device is permitted if it meets 240.4(B).

(1) The overcurrent protective device must have a rating that does not exceed 125 percent of the maximum current determined in 690.8(A).

▸ **Figure 690–50**



▸ **Figure 690–50**

(2) Where the assembly, together with its overcurrent device(s), is listed for continuous operation at 100 percent of its rating, the overcurrent protective device can be sized at 100 percent of the maximum currents as calculated in 690.8(A).

Note: Some electronic devices prevent backfeed current, which in some cases is the only source of overcurrent in PV system dc circuits.

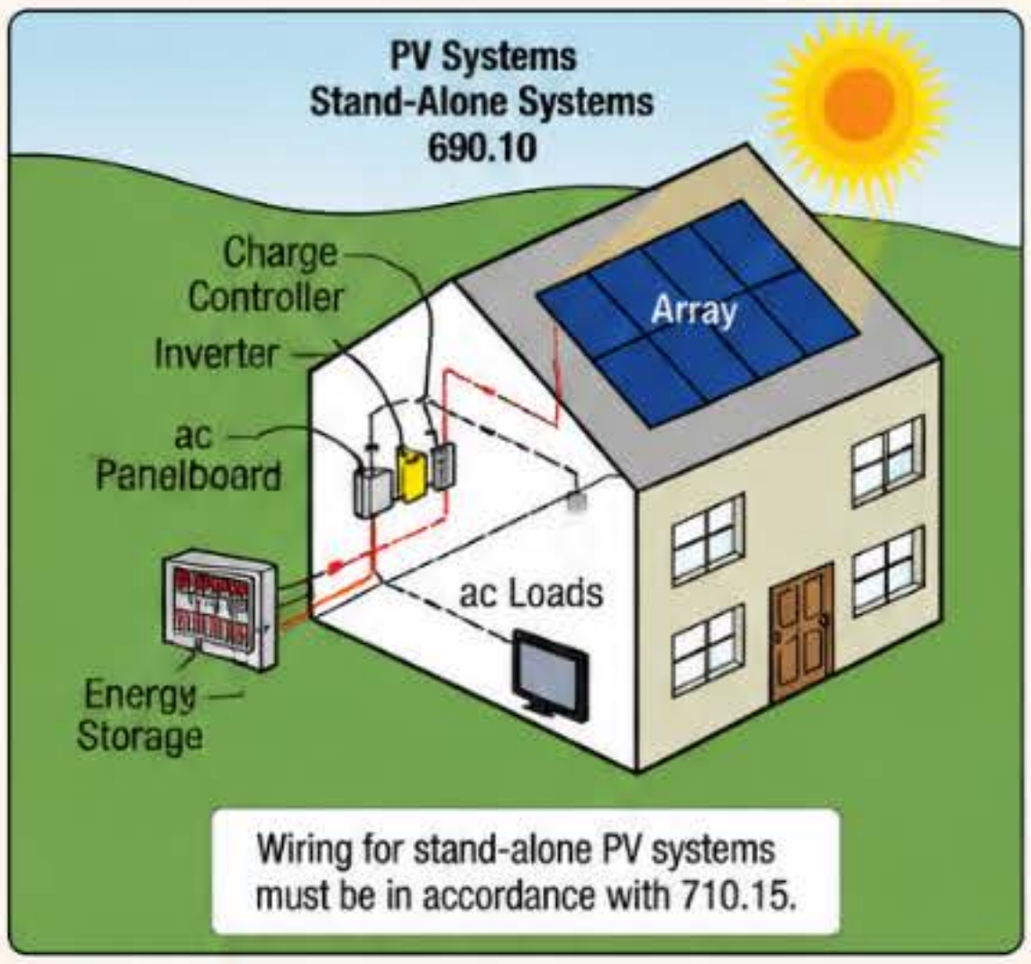
(C) Source and Output Circuits. A single overcurrent protective device can be used to protect PV modules, dc-to-dc converters, and source circuit and output circuit conductors. Where a single overcurrent protective device is used to protect source circuits or output circuits, it must be placed in the same polarity for all circuits within the PV system.

Note: A single overcurrent protective device in either the positive or negative conductors of a functionally grounded PV system provides adequate overcurrent protection.

690.10 Stand-Alone Systems

Wiring for stand-alone PV systems must be in accordance with 710.15.

▸ **Figure 690–51**



▸ **Figure 690–51**

690.11 Arc-Fault Circuit Protection

PV system dc circuits operating at 80V dc or greater must be protected by a listed PV arc-fault circuit interrupter or other component listed to provide equivalent protection.

Ex: PV dc AFCI protection is not required for PV circuits not installed on or in buildings if the circuits are within metal raceways, metal-cables, enclosed cable trays, or underground. PV dc AFCI protection is not required for PV circuits installed in a detached building whose sole purpose is to house PV system equipment.

690.12 Rapid Shutdown

PV system conductors on or in a building must be controlled by a rapid shutdown system to reduce shock hazard for firefighters in accordance with 690.12(A) through (D).

Ex: A rapid shutdown system is not required for ground-mounted PV system conductors that enter buildings whose sole purpose is to house PV system equipment.

(A) Controlled Conductors. PV system conductors controlled by the rapid shutdown system include:

(1) PV system dc circuit conductors.

(2) Inverter output ac circuits originating from inverters located within the array boundary.

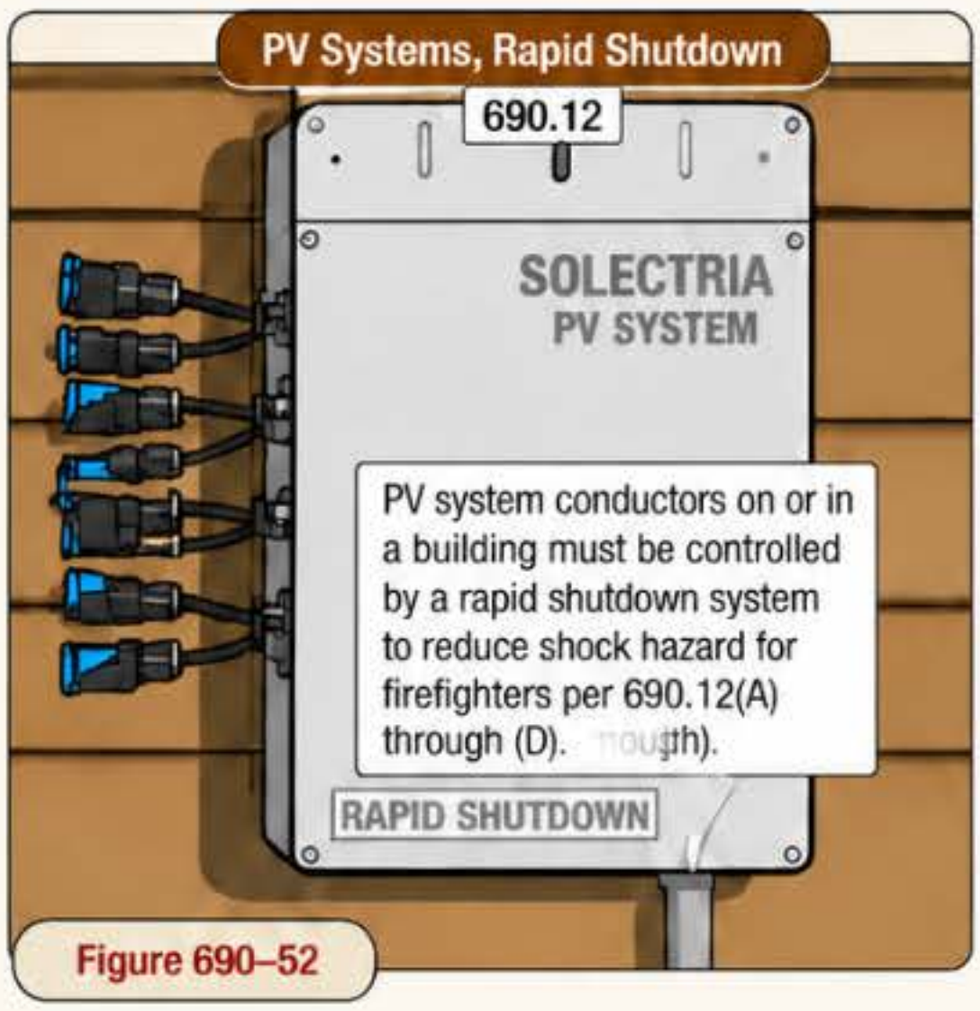


Figure 690–52

Note: The ac output conductors from PV systems will either be de-energized after shutdown initiation or remain energized if by a utility service. To prevent PV systems with ac output conductors from remaining energized, they must be controlled by the rapid shutdown system after shutdown initiation.

(B) Controlled Limits. To accomplish rapid shutdown, the array boundary is the area 1 ft outside the perimeter of the PV array.

(1) Outside the Array Boundary. PV system circuit conductors located outside the PV array boundary or more than 3 ft from the point of entry inside a building must be limited to 30V within 30 seconds of rapid shutdown initiation.

(2) Inside the Array Boundary. The PV system rapid shutdown system must meet one of these conditions:

(1) PV hazard control system listed for the purpose must be installed in compliance with the manufacturer's instructions. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device (690.12(C)) must perform this initiation.

> ***Author's Commentary:*** *A listed or field-labeled hazard PV control system includes either a single component of equipment that carries out all required functions or a group of components that work together as specified in the manufacturer's installation instructions.*
>
> *— Michael Hamilton*

(2) PV system circuit conductors located inside the PV array boundary must be limited to 80V within 30 seconds of rapid shutdown initiation.

(3) PV arrays must not use exposed wiring methods or exposed conductive parts and must be installed more than 8 ft from exposed conductive parts.

(C) Initiation Device. A rapid shutdown initiation device is used to start the rapid shutdown function of the PV system. When the initiation device is switched to the "off" position, that indicates the rapid shutdown function has been activated.

In one- and two-family dwellings, the initiation device must be installed outside the building in a spot that can be reached without obstacles.

For an individual PV system, the initiation device must be operated by any one of these types of equipment:

(1) The service disconnect. ▸**Figure 690–53**

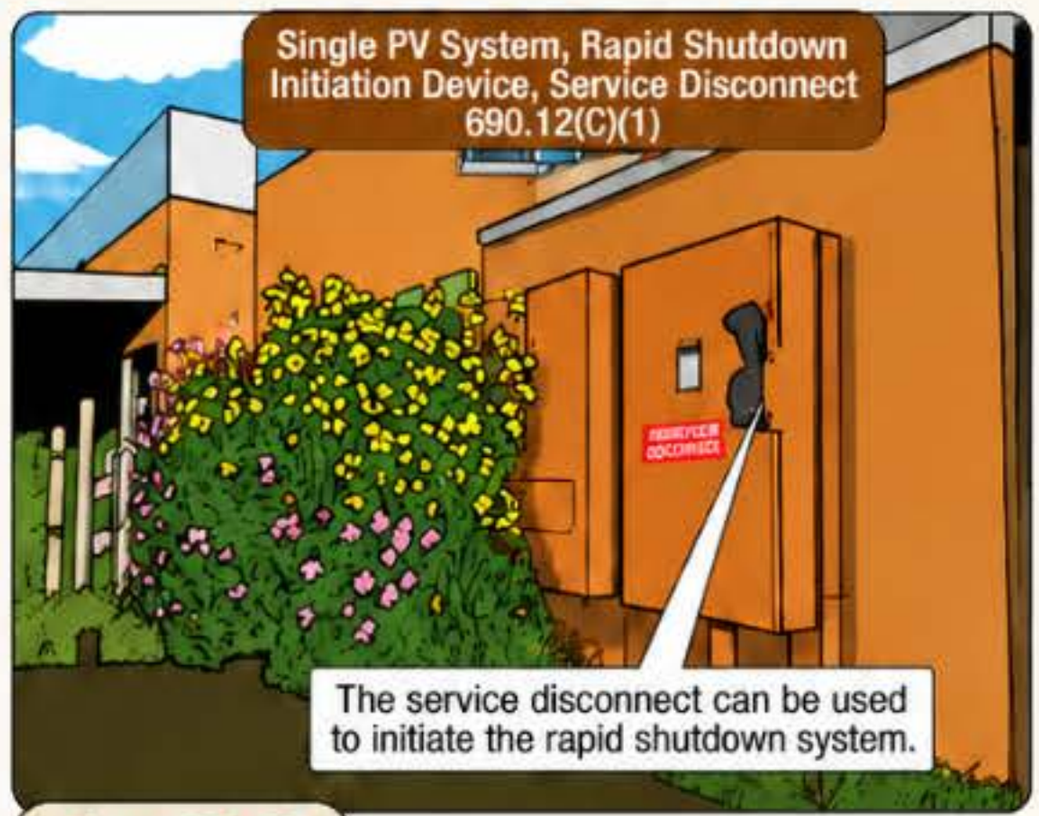


Figure 690–53

(2) The PV system disconnect. ▸**Figure 690–54**

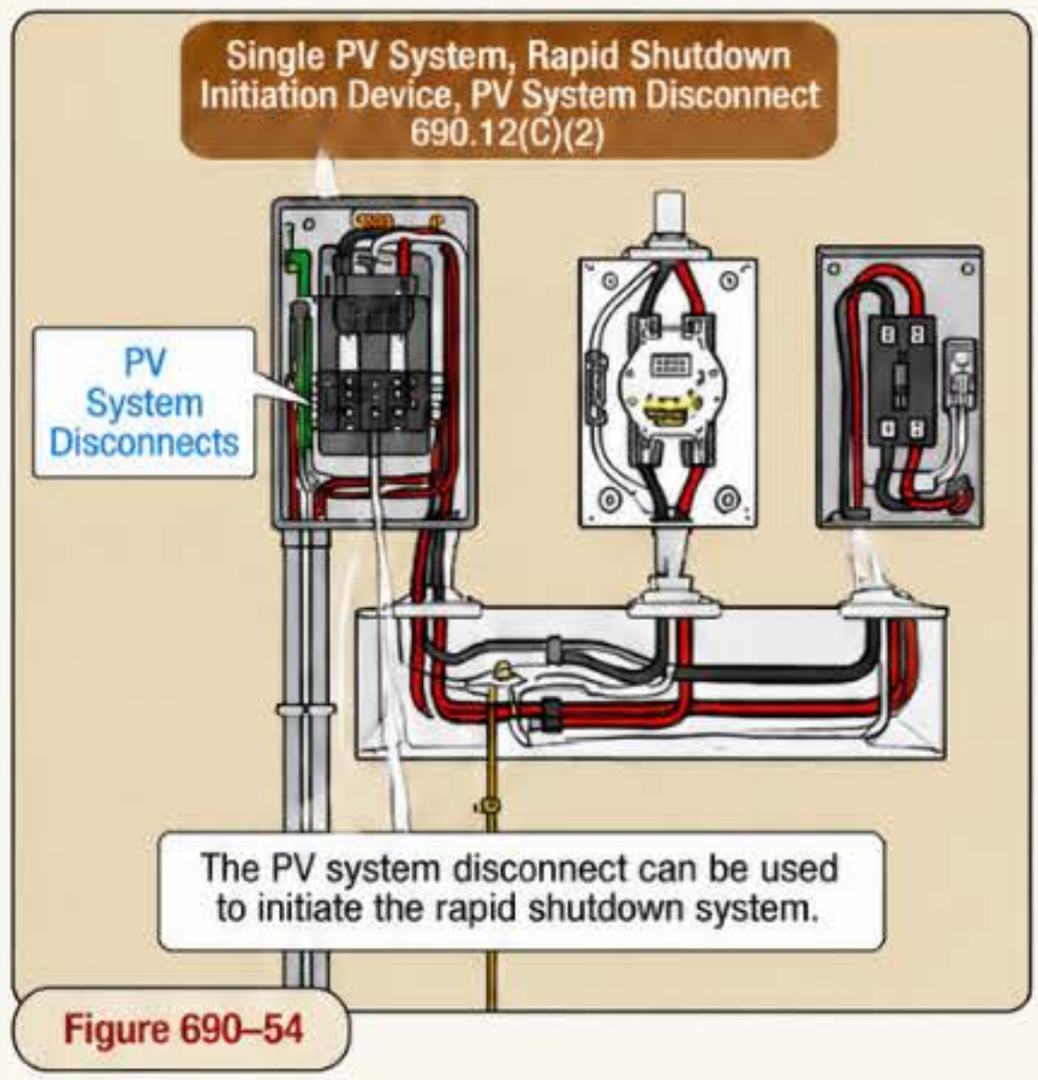


Figure 690–54

(3) Install a plainly visible toggle or rocker switch that shows whether it is in the "off" or "on" position.

Note: A typical example of a fast shutdown initiation device that follows 690.12(C(3) is used when the PV system connects to an optional standby or standalone arrangement.

If several PV systems serve one location, the rapid shutdown initiation device must open no more than six switch pairs or six circuit breaker interrupting positions, or a mix of up to six switches plus some circuit breakers as well.

(D) Equipment. List equipment that performs the rapid **shutdown function** (other than the initiation device itself) and that supplies **rapid shutdown protection.**

Part III. Disconnect

690.13 PV System Disconnect

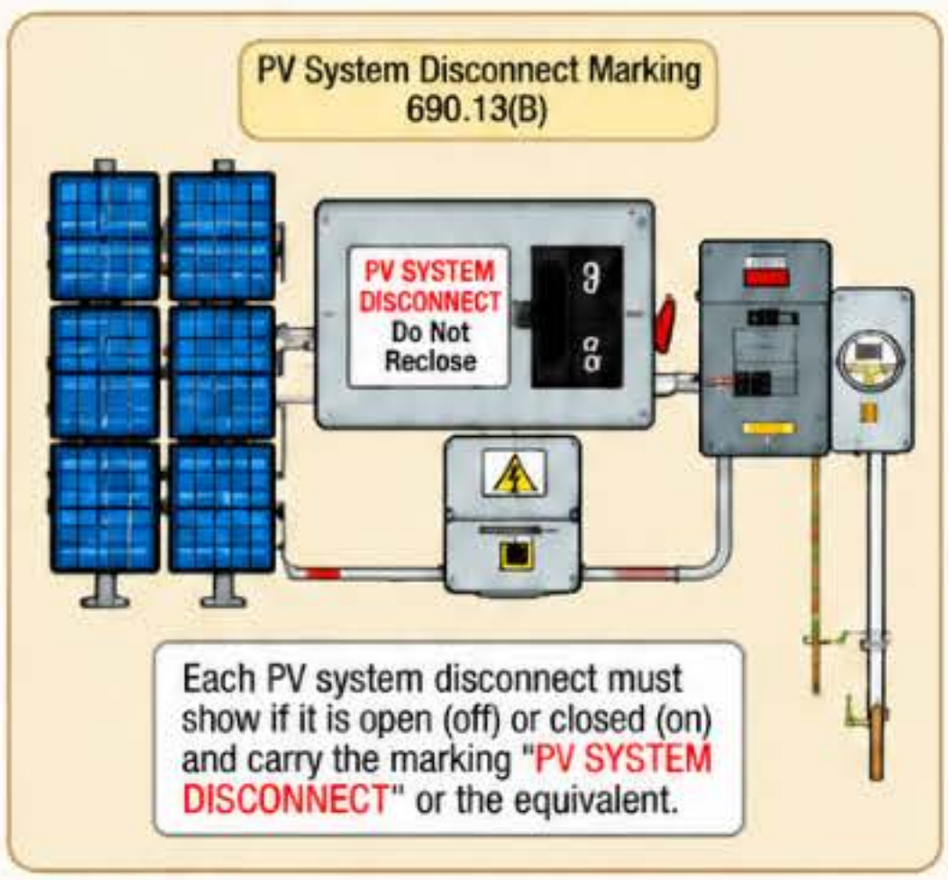
Provide means to disconnect PV system conductors from power sources, energy storage, utilization equipment, and associated building wiring.

(A) Location. Install the PV system disconnect where it can be reached easily.

Keep the access door or hinged cover for the PV disconnect locked or furnish a tool to open it.

Note: Rapid shutdown systems that comply with 690.12 address issues related to live conductors inside buildings.

(B) Marking. Put a clear, durable label on the disconnect. If it is in the open (off) or closed (on) position, mark it "PV SYSTEM DISCONNECT" or the equivalent.



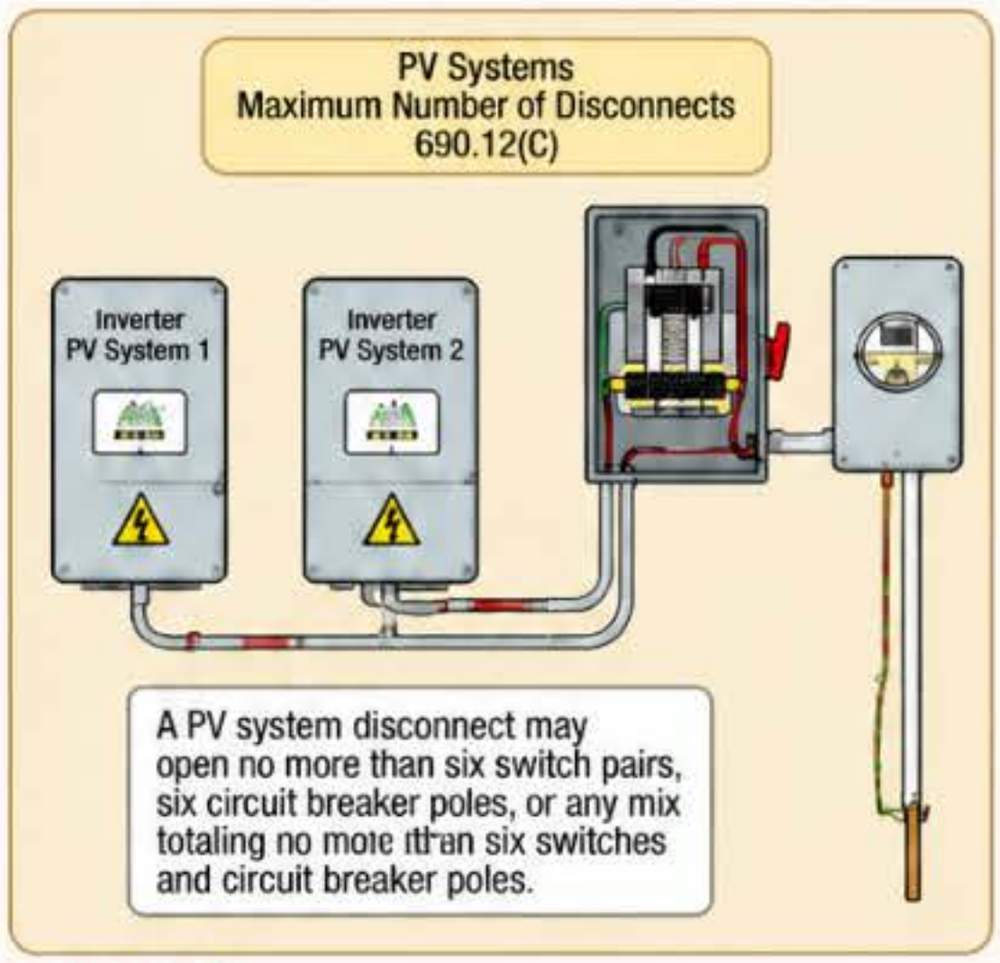
▸ Figure 690–55

When the line and load terminals of a PV system disconnect might be energized while open (off), attach this or an equivalent warning at the point of disconnect:

WARNING—ELECTRIC SHOCK KAZARD
TERMINALS ON THE LINE AND LOAD SIDES
MAY BE ENERGIZED IN THE OPEN POSITION

Make the warning on the disconnect permanent and durable so it remains legible despite the environment involved [110.21(B)].

(C) Maximum Number of Disconnects. A PV system disconnect may open no more than six switch pairs, six circuit breaker poles, or any mix totaling no more than six switches and circuit breaker poles. ▸ Figure 690–56



▸ Figure 690–56

You may use a single PV system disconnect for the combined output of one or more inverters or AC modules in an interactive system.

Note: The requirement for a maximum of six PV system disconnects does not cap the number of PV systems at a location [690.4(D)]. A dedicated circuit breaker for an interactive inverter follows 705.12(A) as an example of one PV system disconnect.

(D) Ratings. Ensure the PV system disconnect has **adequate ratings for the system's maximum short-circuit current, the available fault current, and the DC voltage at the PV system disconnect terminals.**

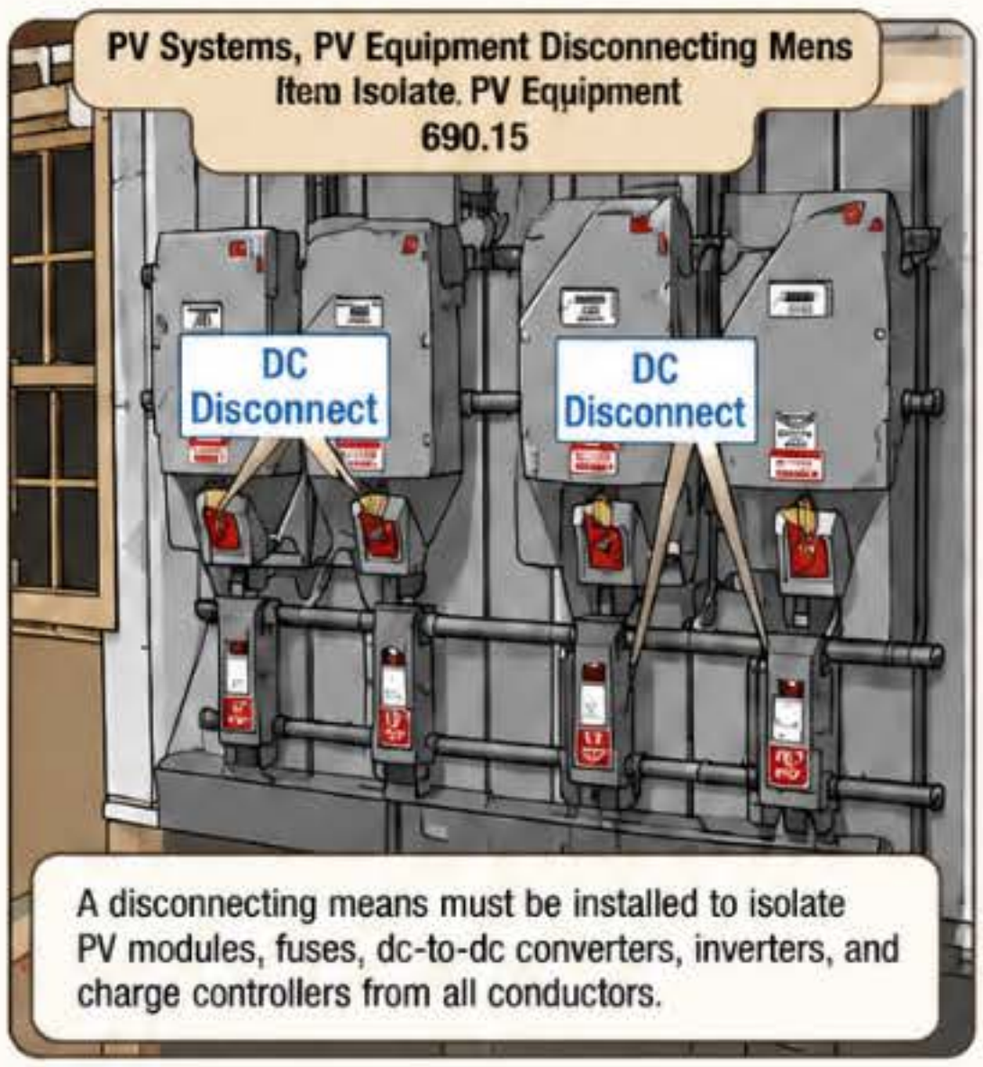
(E) Type of Disconnect. A PV system disconnect must open all ungrounded PV circuit conductors at once. It must be accessible to the operator, and the enclosure or access location must be capable of being locked in the open position as required by 110.25. Acceptable PV disconnects include one of the following:

1. A manually operated switch or circuit breaker.
2. A connector that mates in accordance with 690.33(D)(1) or (D)(3).
3. A pull-out switch with adequate interrupting capacity.
4. A remote-controlled switch or circuit breaker that can be operated by hand and that opens automatically when the control power is lost.
5. A device approved for the specific use.

Note: Circuit breakers labeled "line" and "load" may not be appropriate for reverse power flow; therefore, they are not permitted to serve as the PV system disconnect.

690.15 PV Equipment Disconnecting Means to Isolate PV Equipment

A disconnecting means of the required type [690.15(D)] must be provided to isolate PV modules, fuses, dc-to-dc converters, inverters, and charge controllers from all conductors. ▸Figure 690–57



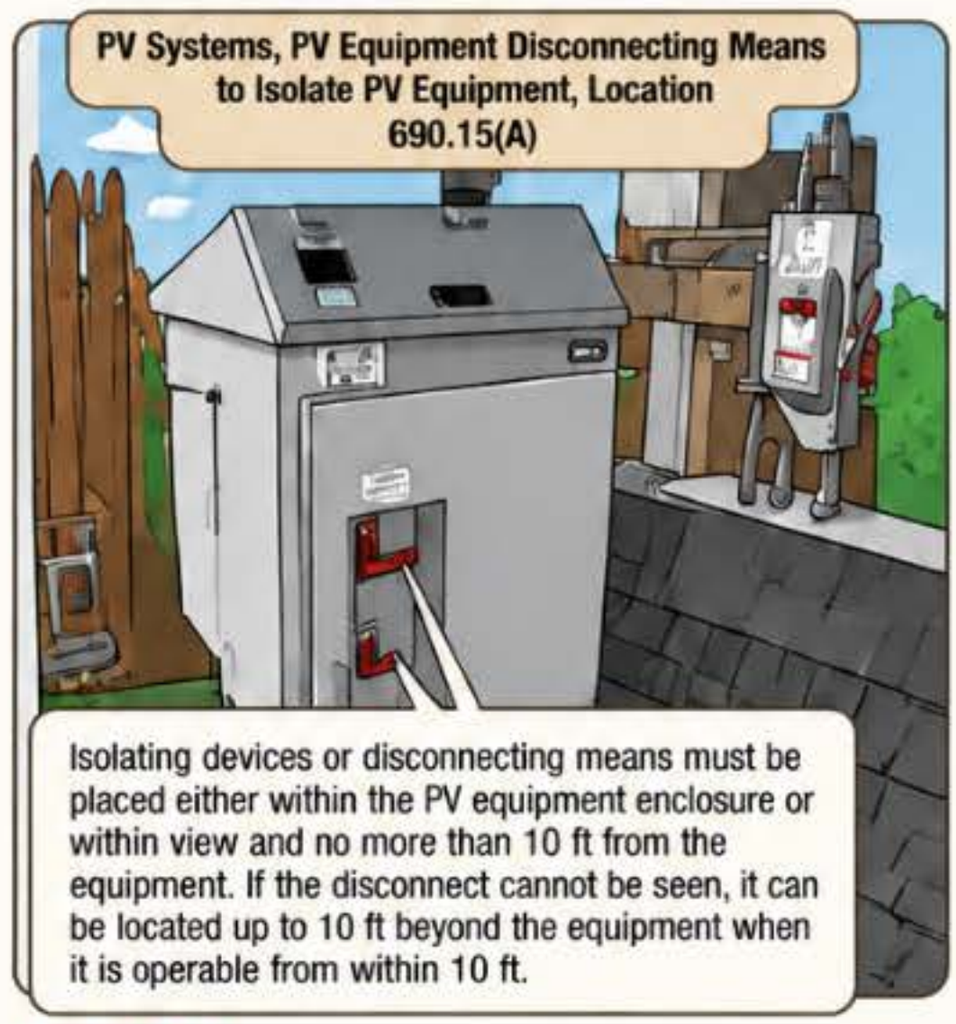
▸Figure 690–57

Author's Commentary:

The goal of the PV disconnect is to allow safe and easy replacement or servicing of PV equipment without exposing qualified persons to energized conductors.

— Michael Hamilton

(A) Location. Isolating devices or disconnecting means must be located either within the PV equipment enclosure or within view and no more than 10 ft from the equipment. If the disconnect cannot be seen, it may be installed up to 10 ft beyond the equipment when it can be operated from within 10 ft. ▸Figure 690–58



▸Figure 690–58

The door or hinged cover for the PV equipment disconnect must be capable of being locked or must require a tool to open.

(B) Isolating Device. An isolating device does not need to have an interrupting rating and, where not rated to open current, it must be marked "Do Not Disconnect Under Load" or "Not for Current Interrupting." Acceptable isolating devices include:

1. A mating connector that complies with 690.33 and is identified for use with the specific equipment. ▸Figure 690–86
2. A fuse holder designed so that a finger cannot touch live parts. ▸Figure 690–60
3. An isolating device that requires a tool to place in the open (off) position.
4. An isolating device intended for the specific application.

PV Systems, PV Equipment Disconnecting Means to Isolate PV Equipment, Isolating Device *690.15*(B)(1)

An isolating device can be a mating connector meeting the requirements of 690.33 and listed and identified for use with specific equipment.

Figure 690–59

PV Systems, PV Equipment Disconnecting Means to Isolate PV Equipment, Finger-Safe Fuse Holder *690.15*(B)(2)

A finger-safe fuse holder is permitted to be used as an isolating device.

Figure 690–60

(C) Equipment Disconnecting Means. The PV equipment disconnecting means must have a rating sufficient for the maximum circuit current, available fault current, and the voltage at the terminals of the disconnect.

The PV equipment disconnecting means must simultaneously disconnect all current-carrying circuit conductors to which it is connected, must be externally operable without exposing the operator to contact with energized parts, and indicate whether it is in the open (off) or closed (on) position. **Figure 690–61**

Where the PV equipment disconnect is not within sight and within 10 ft of the equipment, the PV equipment disconnect must be capable of being locked in the open position in accordance with 110.25.

The equipment disconnecting means must be of the same type as required in 690.13(E).

PV Systems, PV Equipment Disconnecting Means *690.15*(C)

PV equipment disconnecting means must simultaneously disconnect all current-carrying conductors to which it is connected, be externally operable without exposing the operator to contact with energized parts, and indicate whether in the open (off) or closed (on) position.

Figure 690–61

An equipment disconnecting means, other than those complying with 690.33, must be marked in accordance with the warning in 690.13(B) if the line and load terminals can be energized in the open position.

Author's Commentary:

- According to 690.13(B), each PV system disconnect must indicate if it is in the open (off) or closed (on) position and the disconnect must be permanently marked "PV SYSTEM DISCONNECT" or equivalent. Where the line and load terminals of the PV system disconnect may be energized when the disconnect is in the open (off) position, the disconnect must be marked with the following words or equivalent:

— Michael Hamilton

WARNING—ELECTRIC SHOCK HAZARD
TERMINALS ON THE LINE AND LOAD SIDES
MAY BE ENERGIZED IN THE OPEN POSITION

The warning markings on the disconnect must be permanently affixed and have sufficient durability to withstand the environment involved [110.21(B)].

Note: A common installation practice is to terminate circuit conductors on the line side of a disconnect which will de-energize load-side terminals, blades, and fuses when the disconnect is in the open position.

(D) Type of Disconnecting Means. Where disconnects are required to isolate equipment, the disconnecting means must be one of the following types:

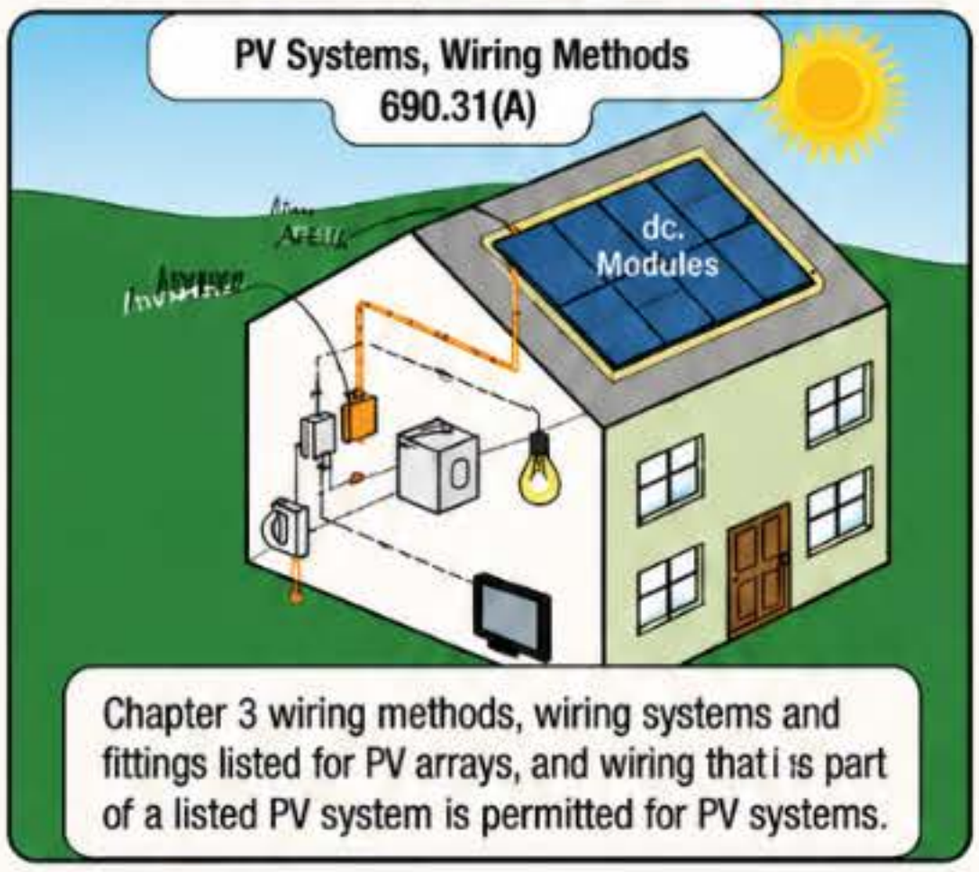
(1) Over 30A Circuit. A disconnecting means is required in accordance with 690.15(C).

(2) Not over 30A Circuit. An isolating device is required in accordance with 690.15(B).

Part IV. Wiring Methods

690.31 Wiring Methods

(A) Wiring Systems. Acceptable wiring approaches include Chapter 3 methods, the recognized wiring systems, and the component wiring options listed for PV arrays. Wiring that is part of a listed PV system is allowed. ▶Figure 690–62



▶Figure 690–62

PV system dc circuit conductors operating at over 30V installed in a readily accessible location must be guarded or installed within a raceway or Type MC cable. ▶Figure 690–63 and ▶Figure 690–64

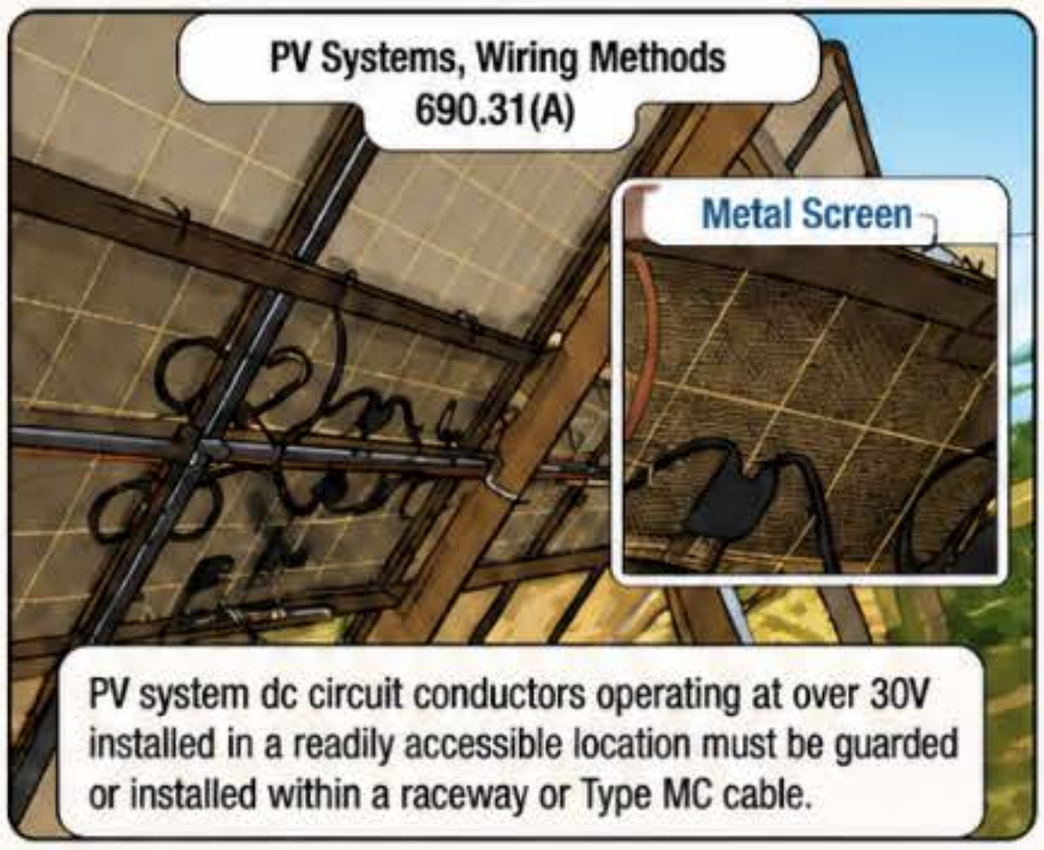
PV circuit conductors with insulation rated at 105°C and 125°C must have their ampacity [690.31(A)(b)] corrected by Table 690.31(A)(a).

Note: See 110.14(C) for conductor temperature limitations due to termination provisions.

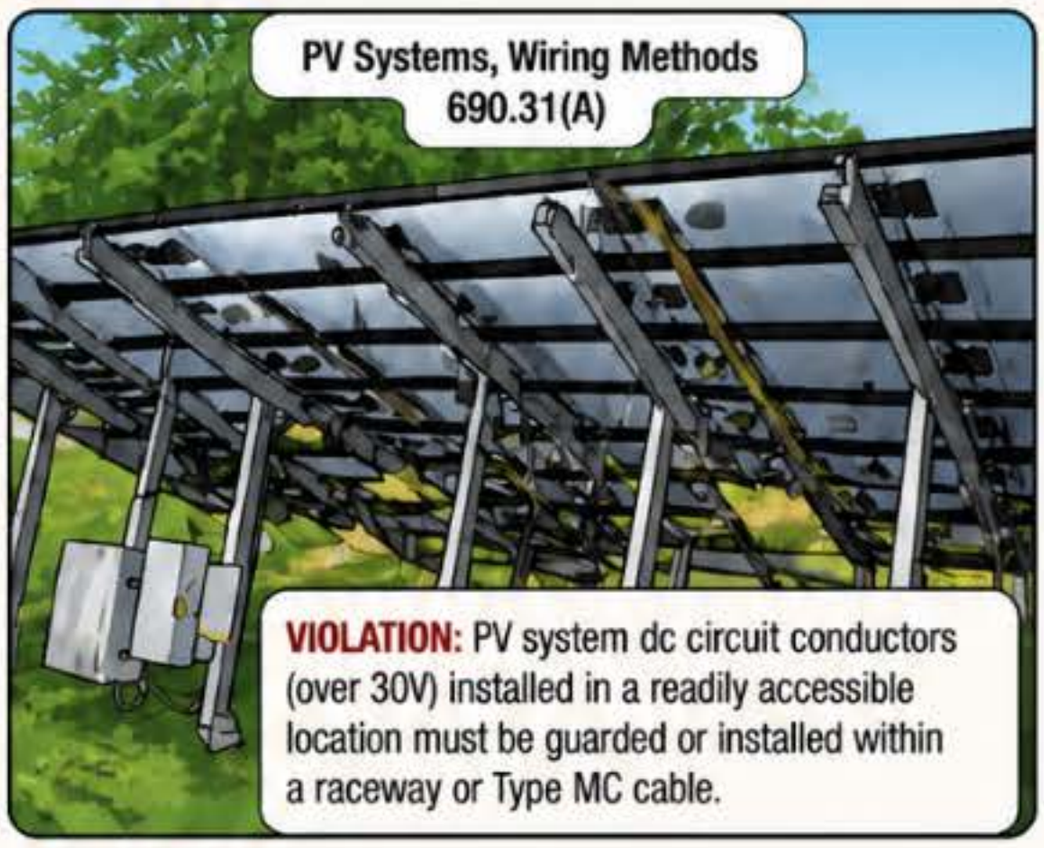
(B) Identification and Grouping. PV system circuits are permitted in the same enclosure, cable, or raceway with each other and with Class 1 circuits associated with the PV system [725.48(B)(1)].

Author's Commentary:
Guard exposed DC wiring above 30 volts or run it in conduit or Type MC. Use the table to adjust ampacity when insulation is rated above 90°C.

— Michael Hamilton



▶Figure 690–63



▶Figure 690–64

Table 690.31(A)(a) Correction Factors

Ambient Temperature (°C)	Temperature Rating of Conductor 105°C (221°F)	Temperature Rating of Conductor 125°C (257°F)	Ambient Temperature (°F)
31–35	0.97	0.97	87–95
36–40	0.93	0.95	96–104
41–45	0.89	0.92	105–113
46–50	0.86	0.89	114–122
51–55	0.82	0.86	123–131

Table 690.31(A)(a) Correction Factors (continued)

Ambient Temperature (°C)	Temperature Rating of Conductor 105°C (221°F)	Temperature Rating of Conductor 125°C (257°F)	Ambient Temperature (°F)
56–60	0.77	0.83	132–140
61–65	0.73	0.79	141–149
66–70	0.68	0.76	150–158
71–75	0.63	0.73	159–167
76–80	0.58	0.69	168–176
81–85	0.52	0.65	177–185
86–90	0.45	0.61	186–194
91–95	0.37	0.56	195–203
96–100	0.26	0.51	204–212
101–105	–	0.46	213–221
106–110	–	0.40	222–230
111–115	–	0.32	231–239
116–120	–	0.23	240–248

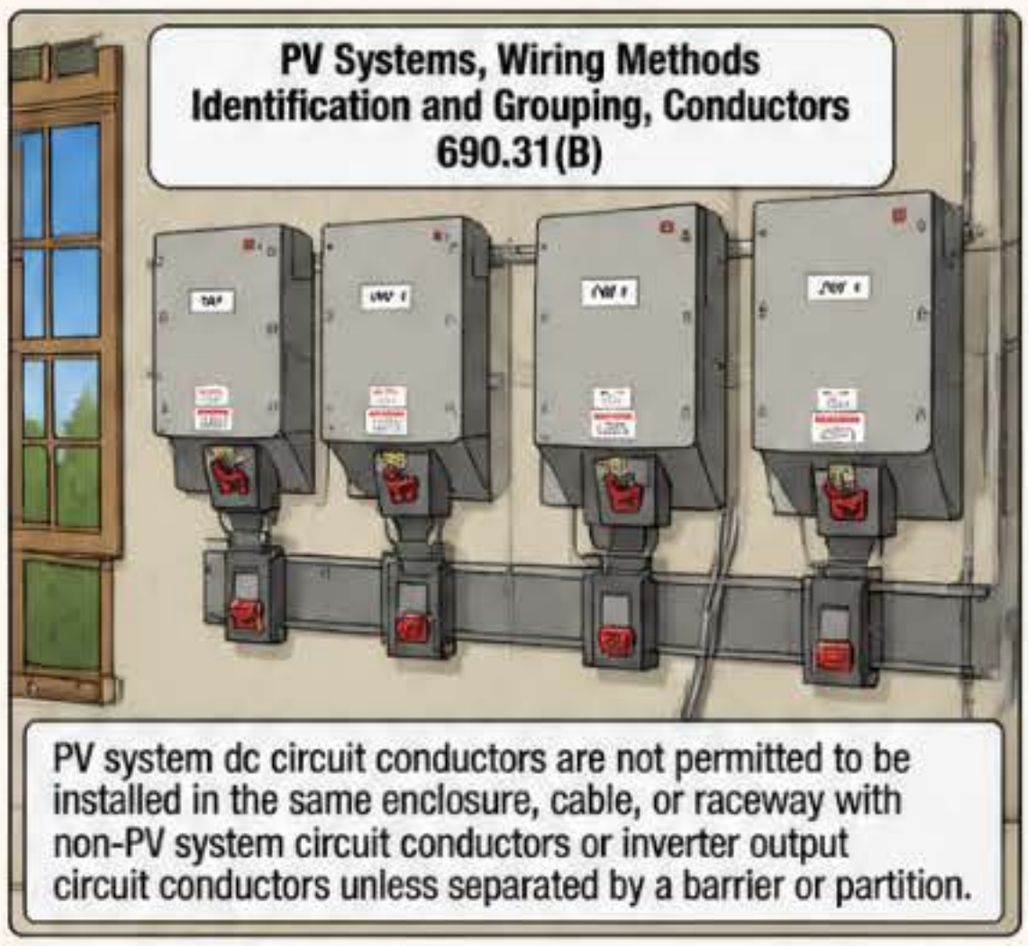
Table 690.31(A)(b) Conductor Ampacity, Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth, with Ambient Temperature of 30°C (86°F)

Wire Size AWG	PVC, CPE, XLPE 105°C	XLPE, EPDM 125°C
18	15	16
16	19	20
14	29	31
12	36	39
10	46	50
8	64	69
6	81	87
4	109	118
3	129	139
2	143	154

Table 690.31(A)(b) Conductor Ampacity, Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth, with Ambient Temperature of 30°C (86°F) (continued)

Wire Size AWG	PVC, CPE, XLPE 105°C	XLPE, EPDM 125°C
1	168	181
1/0	193	208
2/0	229	247
3/0	263	284
4/0	301	325

PV system dc circuit conductors are not permitted to be installed in the same enclosure, cable, or raceway with non-PV system circuit conductors or inverter output circuit conductors unless separated by a barrier or partition. ▶ **Figure 690–65**



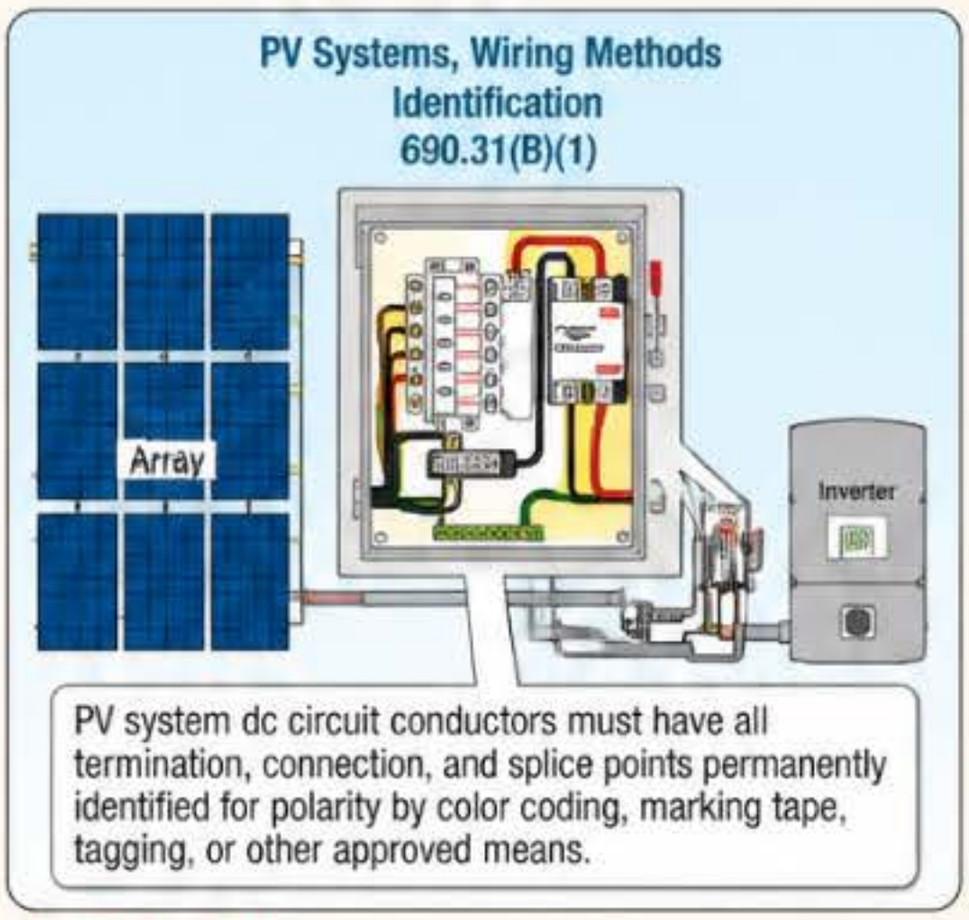
▶ **Figure 690–65**

Ex: *PV system dc circuits within multiconductor jacketed cable, Type MC cable, or listed wiring harnesses identified for the application can be installed in the same enclosure, cable, or raceway with non-PV system circuits. All conductors, harnesses, or assemblies must have an insulation rating equal to at least the maximum circuit dc voltage applied to any conductor within the enclosure, cable, or raceway.*

PV system dc circuits must be identified and grouped as required by 690.31(B)(1) and (B)(2).

690.31 | Solar Photovoltaic (PV) Systems

(1) Identification. Every PV system conductor must have all terminations, connections, and splice locations clearly and permanently identified for polarity using an approved method such as color coding, marking tape, tags, or other listed means. ▸Figure 690–66



▸Figure 690–66

Conductors that depend on marking tape, tagging, or any other approved identification method for polarity must be permanently marked with an approved means such as labeling, sleeving, or shrink-tubing that fits the conductor's outer diameter.

The marking tape, tag, or other approved polarity identifier must include a positive sign (+) or the word "POSITIVE" or "POS" for the positive conductor, and a negative sign (–) or the word "NEGATIVE" or "NEG" for the negative conductor. The markings must be long-lasting and in a color other than green, white, gray, or red.

Example: *Identification is not necessary when the arrangement or spacing of the conductors clearly shows which conductor is which.*

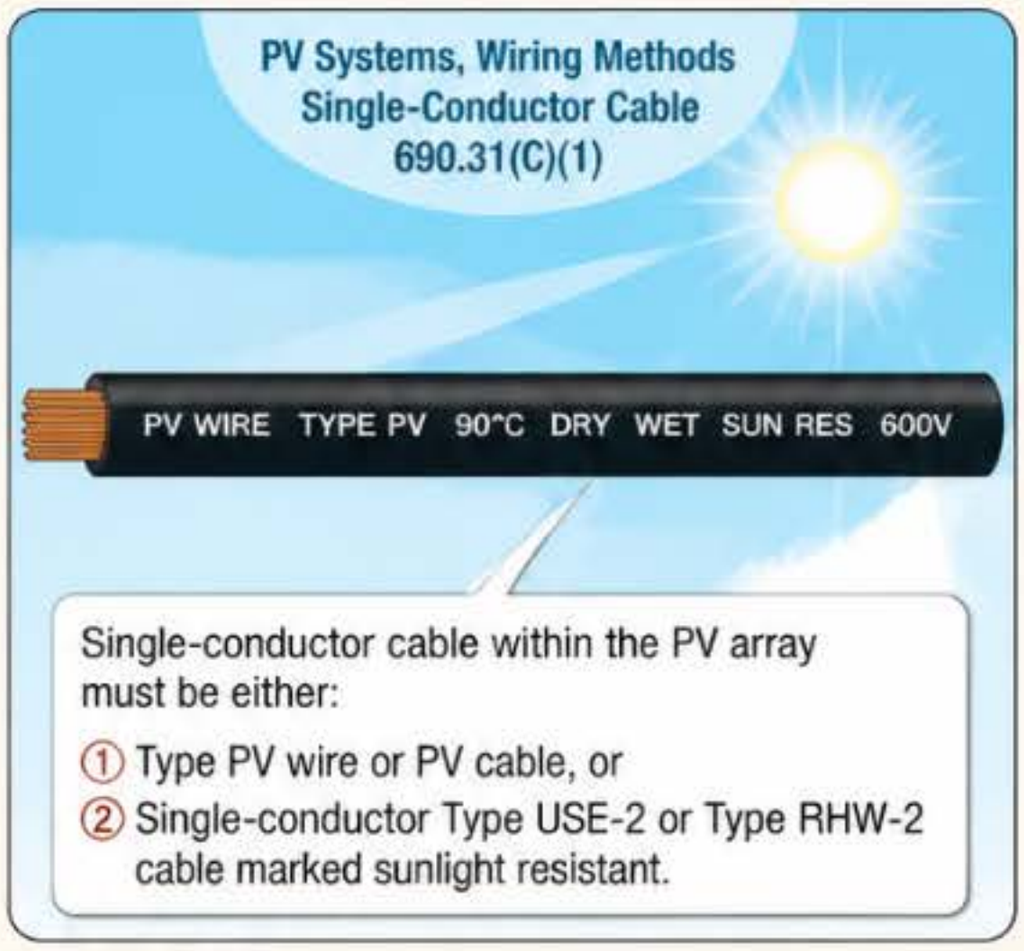
(2) Grouping. Within the same raceway or enclosure that carries PV system dc circuit conductors, the dc circuit conductors of each system must be tied together using cable ties or a comparable supporting method at least once, and at intervals no greater than 6 ft.

Example: *Grouping is not required when dc circuit conductors enter from a cable or raceway unique to the circuit that makes the grouping obvious.*

(C) Cables. The following cable types are permitted.

(1) Single-Conductor Cable. A single-conductor cable placed within the PV array may be either of these types: ▸Figure 690–67

① Type PV wire or Type PV cable.



▸Figure 690–67

② Single-conductor Type USE-2 or Type RHW-2 cable that is identified as sunlight resistant.

Exposed single-conductor cables must be supported and secured at intervals not to exceed 24 in. by cable ties, straps, hangers, or similar approved fasteners designed for outdoor use.

Type PV wire or Type PV cable is permitted for installation in all locations where RHW-2 is allowed.

(2) Cable Tray. Single-conductor Type PV wire, Type PV cable, or Type DG cable may be installed in cable trays in outdoor locations, provided the cables are supported at intervals not to exceed 12 in. and secured at intervals not to exceed 4½ ft.

Note: Type PV wire, Type PV cable, and Type DG cable are nonstandard outside diameters. Chapter 9, Table 1 specifies the allowable percent of cross section of conduit and tubing for conductors and cables. ▸Figure 690–68

(3) Multiconductor Jacketed Cable. Where a multiconductor jacketed cable is included in a listed PV assembly, it must be installed strictly in accordance with the manufacturer's instructions.

A multiconductor jacketed cable not included in a listed assembly or not covered by this *Code* must be installed in accordance with the product listing instructions.

A multiconductor jacketed cable must be installed in accordance with all of the following requirements:

(1) In Raceways. A multiconductor jacketed cable on or in buildings must be installed in a raceway, except for rooftop installations.

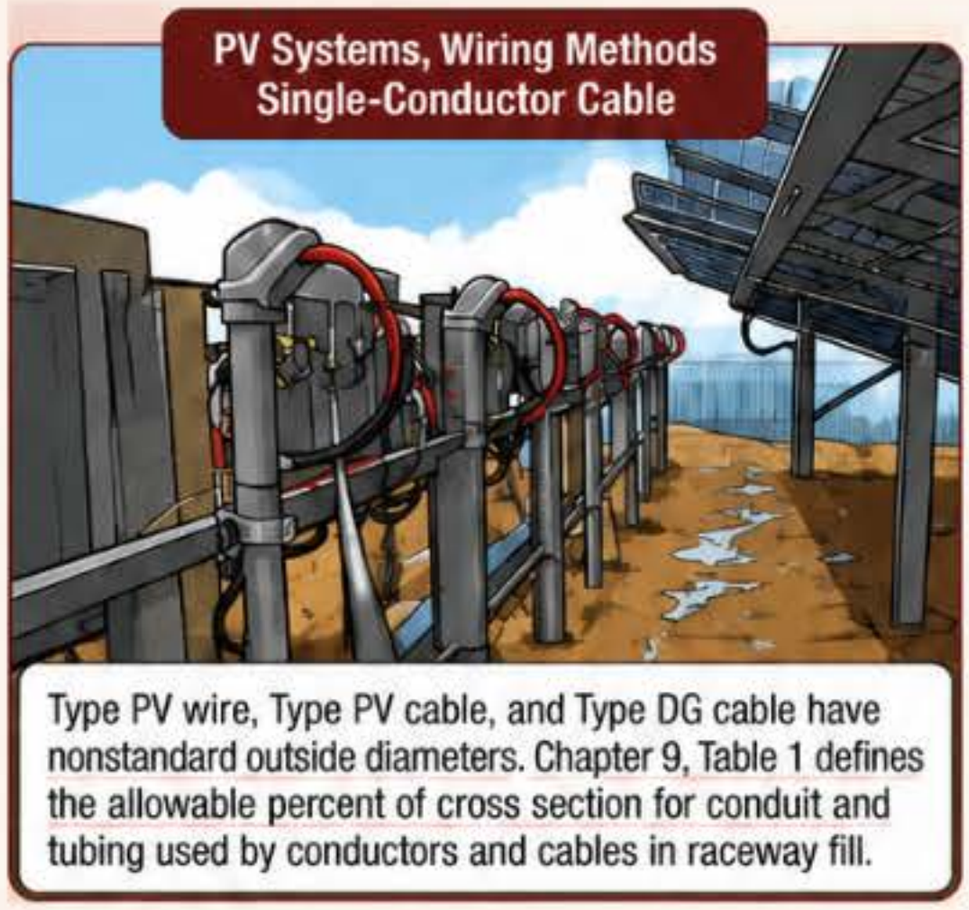


Figure 690–68

(2) Not Within Raceway. Multiconductor jacketed cable is not permitted outside of a raceway. However, it must:

a. Be marked "Sunlight Resistant" for outdoor exposure.

b. Be protected or guarded when subject to physical harm. Figure 690–69

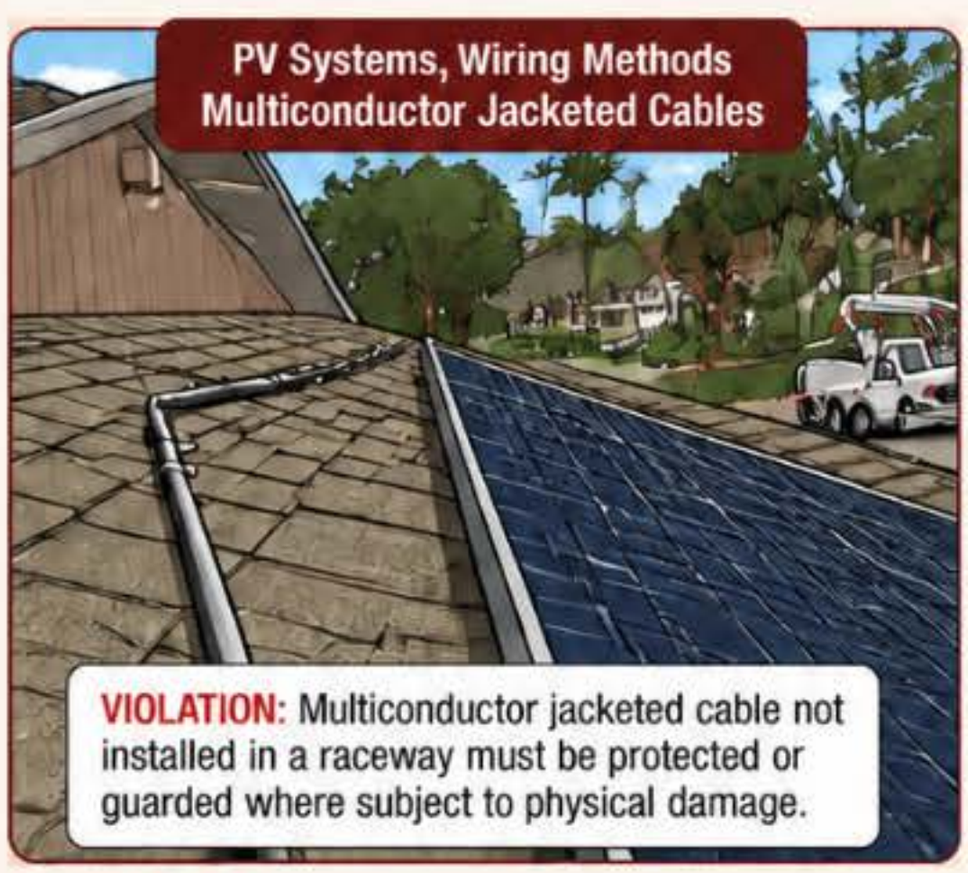


Figure 690–69

c. Follow closely along the surface of support members.

d. Be secured at spaced intervals not greater than 6 ft.

e. Be fastened within 24 in. of mating connectors or entering enclosures.

f. Be marked "Direct Burial" when buried underground.

(4) Flexible Cords and Cables for Tracking PV Arrays. Flexible cords used to connect moving parts of tracking PV systems must be installed in accordance with Article 400, be identified as hard-service or portable power cable, and be suitable for extra-hard usage. They must also be listed for outdoor applications, resist water, and withstand sunlight.

Type PV wire used for moving portions of tracking PV arrays must have a minimum number of strands specified in Table 690.31(C)(4).

Table 690.31(C)(4) Minimum PV Wire Strands for Moving Parts of Tracking PV Arrays

PV Wire AWG	Minimum Strands
18	17
16–10	19
8–4	49
2	130
1 AWG–1,000 MCM	259

(5) Flexible, Fine-Stranded Cables. Flexible, fine-stranded cables must terminate on terminals, lugs, devices, or connectors identified for the use of finely stranded conductors in accordance with 110.14. Figure 690–70

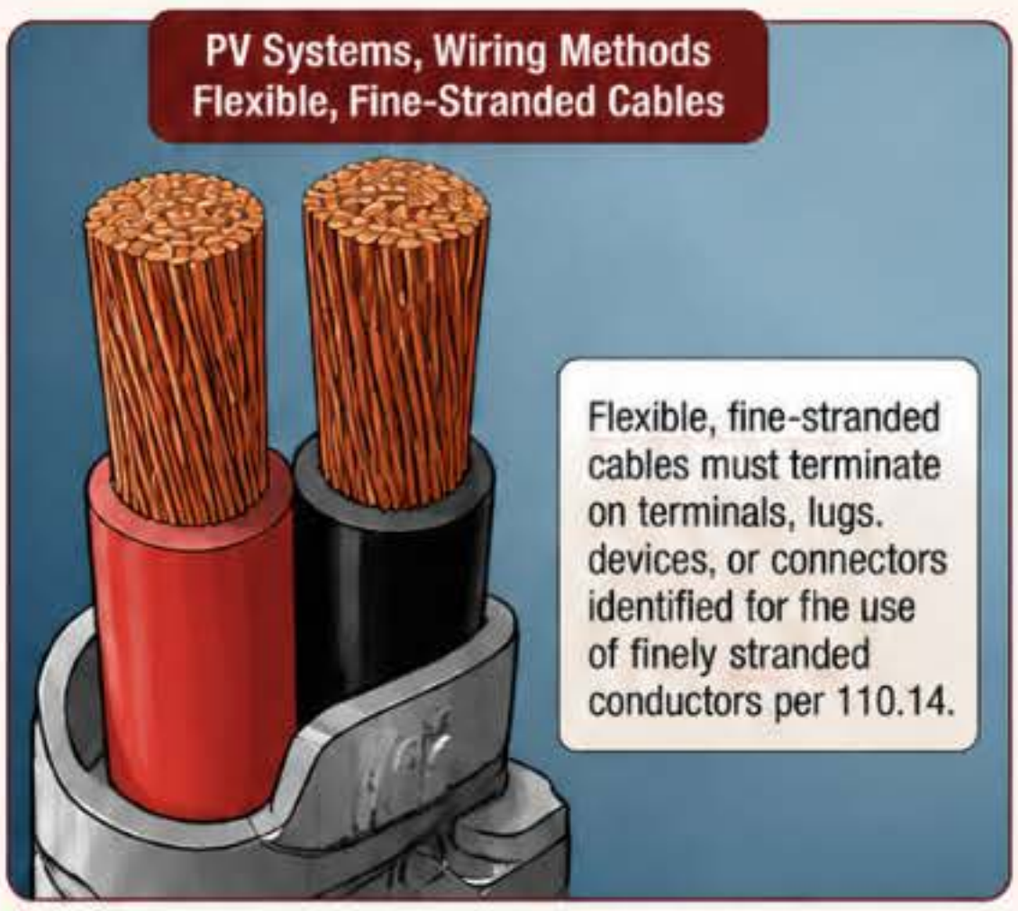


Figure 690–70

(D) PV System Direct-Current Circuits On or In Buildings. When the PV system DC circuit is located inside a building, the circuit conductors must be installed in a metal raceway, Type MC cable, or a metal enclosure. Figure 690–71

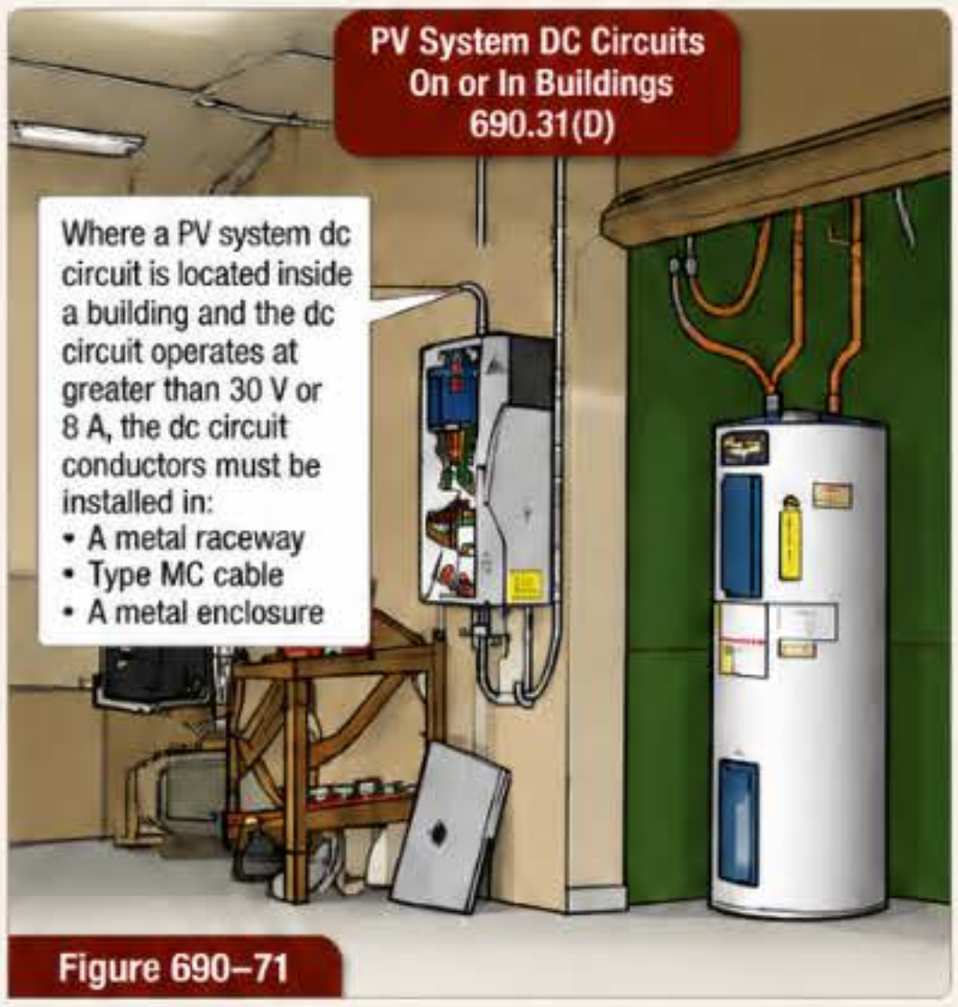


Figure 690–71

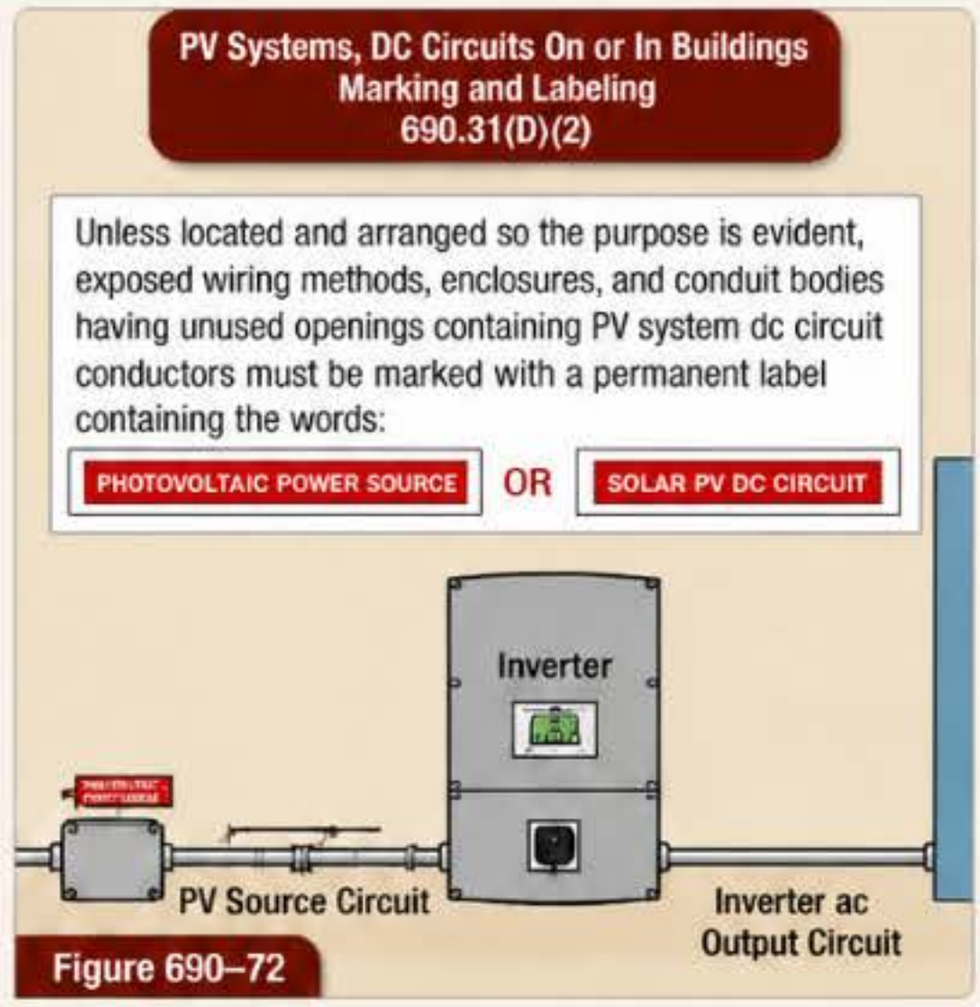


Figure 690–72

Ex: PV hazard control system conductors that are installed for a rapid shutdown application in accordance with 690.12(B)(2)(1) can be provided with (or listed for use with) nonmetallic enclosures, nonmetallic raceways, and permitted cable types other than Type MC cable, at the point of penetration of the building to the PV hazard control actuator.

Wiring methods for PV system dc circuits on or in buildings must comply with the following additional requirements:

(1) Flexible Wiring Methods. Where flexible metal conduit smaller than trade size ¾ or Type MC cable smaller than 1 in. in diameter containing PV system dc circuit conductors is run across ceilings or floor joists, the flexible metal conduit or Type MC cable must be protected by substantial guard strips that are at least as high as the flexible metal conduit or Type MC cable.

Where flexible metal conduit or Type MC cable containing PV system dc circuit conductors is run exposed further than 6 ft from their connection to equipment, the flexible metal conduit or Type MC cable must closely follow the building surface or be protected from physical damage by an approved means.

(2) Marking and Labeling. Unless located and arranged so the purpose is evident, the following wiring methods and enclosures containing PV system dc circuit conductors must be marked with a permanent label containing the words "PHOTOVOLTAIC POWER SOURCE" or "SOLAR PV DC CIRCUIT":

(1) Exposed raceways, cable trays, and other wiring methods.

(2) Covers or enclosures of pull boxes and junction boxes.

(3) Conduit bodies having unused openings.

The label must be visible after installation. The letters must be capitalized and be a minimum height of ⅜ in. in white on a red background. ▼ Figure 690–73

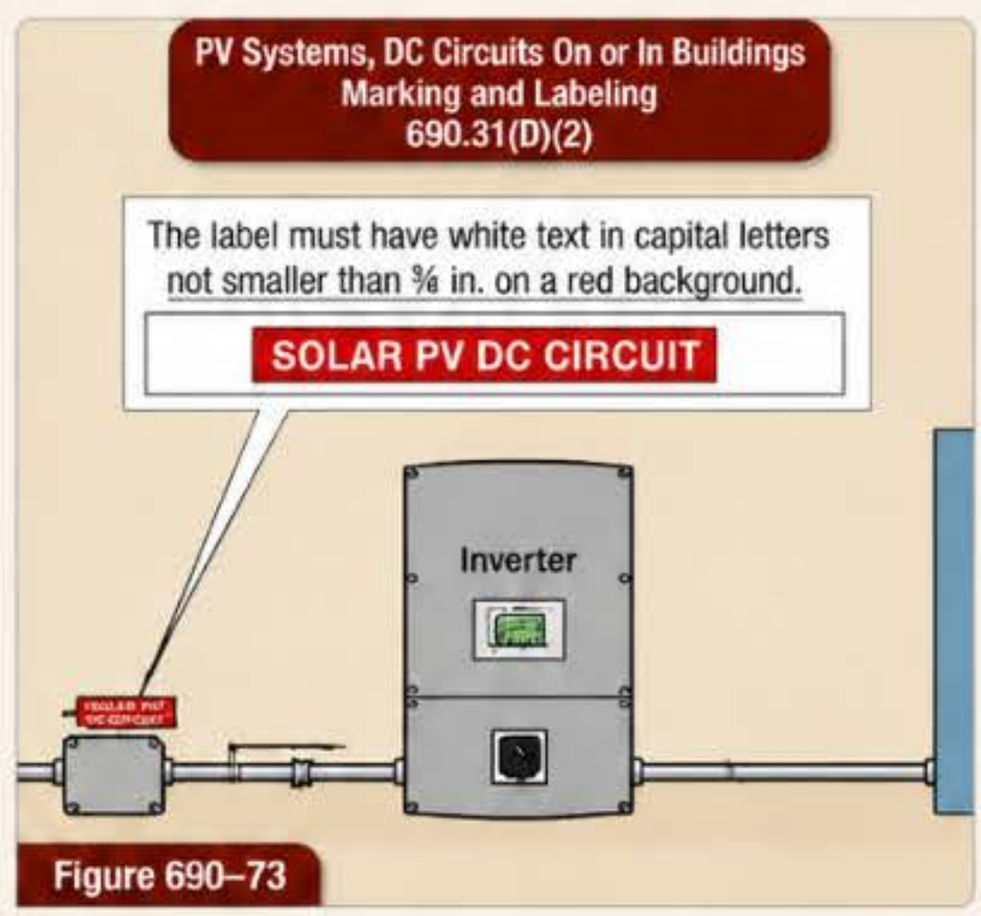


Figure 690–73

Labels must appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels must not be more than 10 ft, and the label must be suitable for the environment. ▼ Figure 690–74

(F) Wiring Methods and Mounting Systems. Roof-mounted PV array mounting systems are permitted to be held in place with an approved means other than those required by 110.13. The wiring methods must allow any expected movement of the array.

Note: Expected movement of unattached PV arrays is often included in structural calculations.

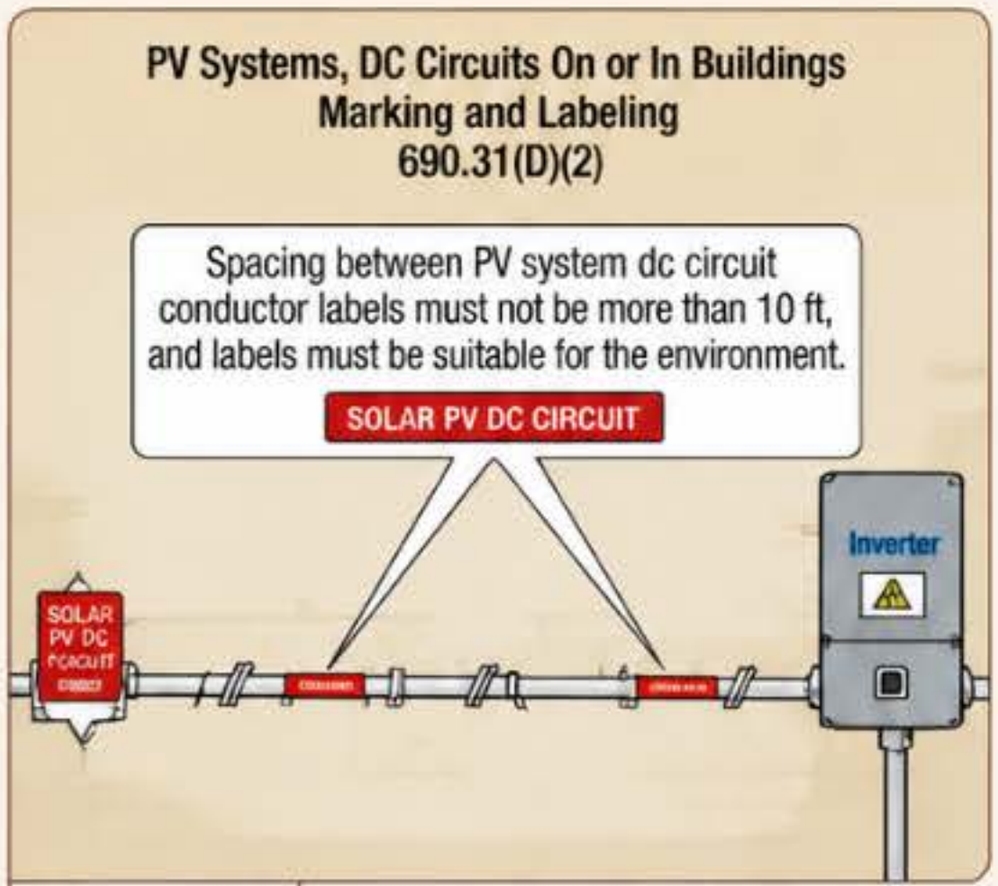


Figure 690-74

690.32 Component Interconnections

Fittings and connectors that are intended to be concealed at the time of on-site use for building-integrated PV systems must be listed for on-site interconnection of modules or other array components.

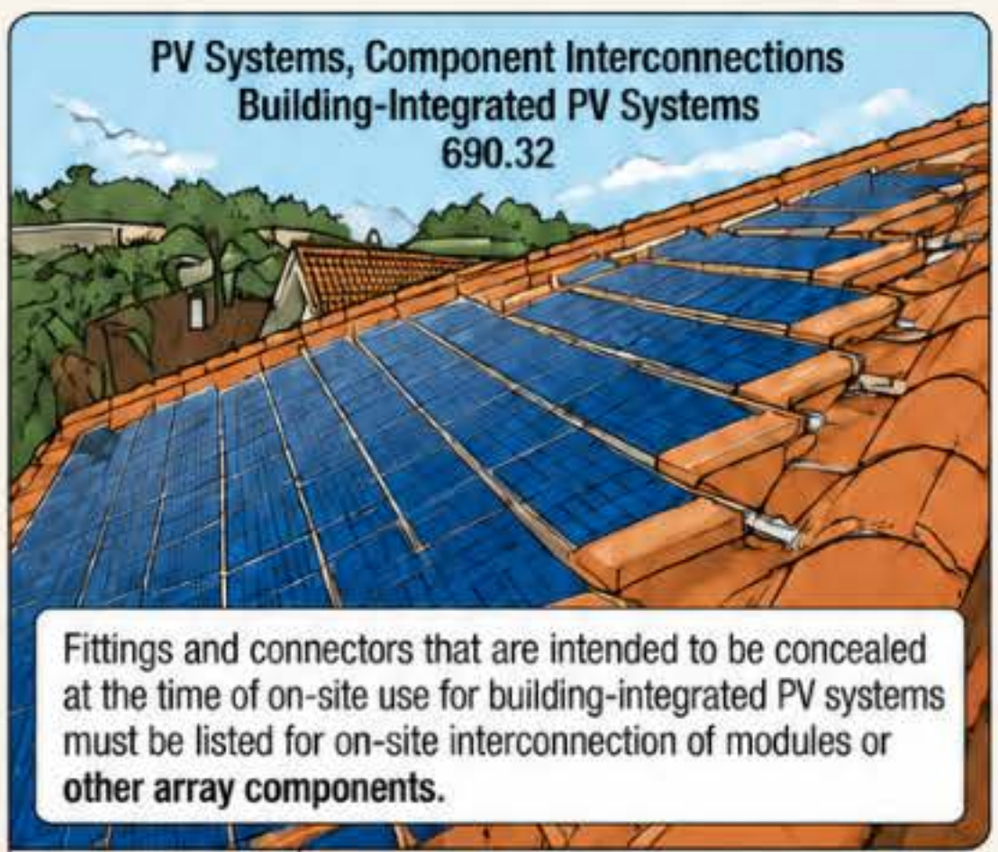


Figure 690-75

Author's Commentary:

- Building-integrated PV systems have PV system dc circuit conductors embedded in built-up, laminate, or membrane roofing materials on roofs.

— **Michael Hamilton**

690.33 Connectors (Mating)

Mating connectors, other than listed connectors for building-integrated PV systems as covered in 690.32, must comply with the following:

▸ **Figure 690-76**

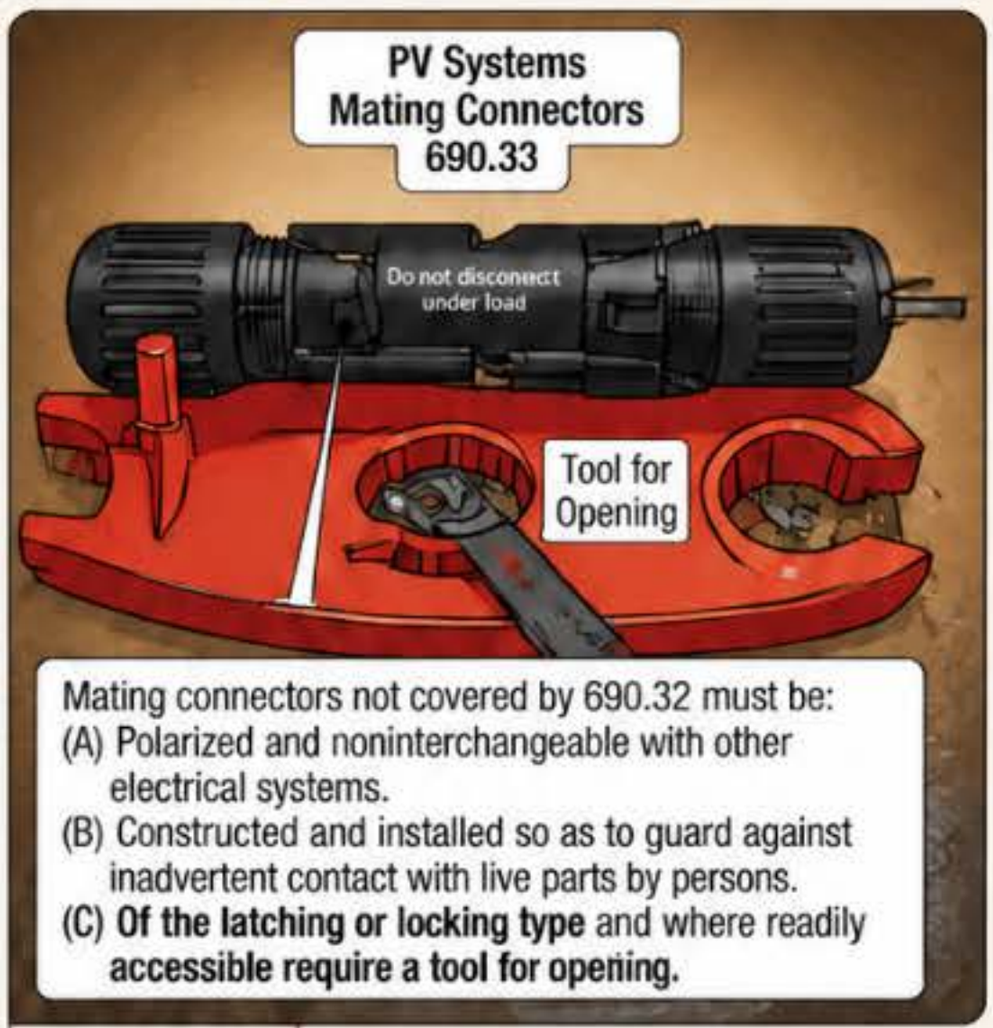


Figure 690-76

(A) Configuration. The mating connectors must be polarized and be noninterchangeable with other electrical systems on the premises.

(B) Guarding. The mating connectors must be constructed and installed so as to guard against inadvertent contact with live parts by persons.

(C) Type. Mating connectors must be of the latching or locking type and where readily accessible require a tool for opening. Where mating connectors are not of the identical type and brand, they must be listed and identified for intermatability as described in the manufacturer's instructions.

(D) Interruption of Circuit. Mating connectors must comply with one of the following requirements. **Figure 690-77**

(1) Mating connectors must be rated to interrupt current without hazard to the operator.

(2) A tool must be required to open the mating connector and the mating connectors must be marked "Do Not Disconnect Under Load" or "Not for Current Interrupting."

(3) Mating connectors supplied as part of listed equipment must be used in accordance with instructions provided with the listed connected equipment.

PV Systems, Mating Connectors
Interruption of Circuit
690.33(D)

Mating connectors can be used to interrupt circuits if they:
(1) Are rated for interrupting current without hazard to the operator, or
(2) Require a tool to open and marked "Do Not Disconnect Under Load" or "Not for Current Interrupting," or
(3) Are supplied as part of listed equipment that must be used per provided instructions.

▸ Figure 690–77

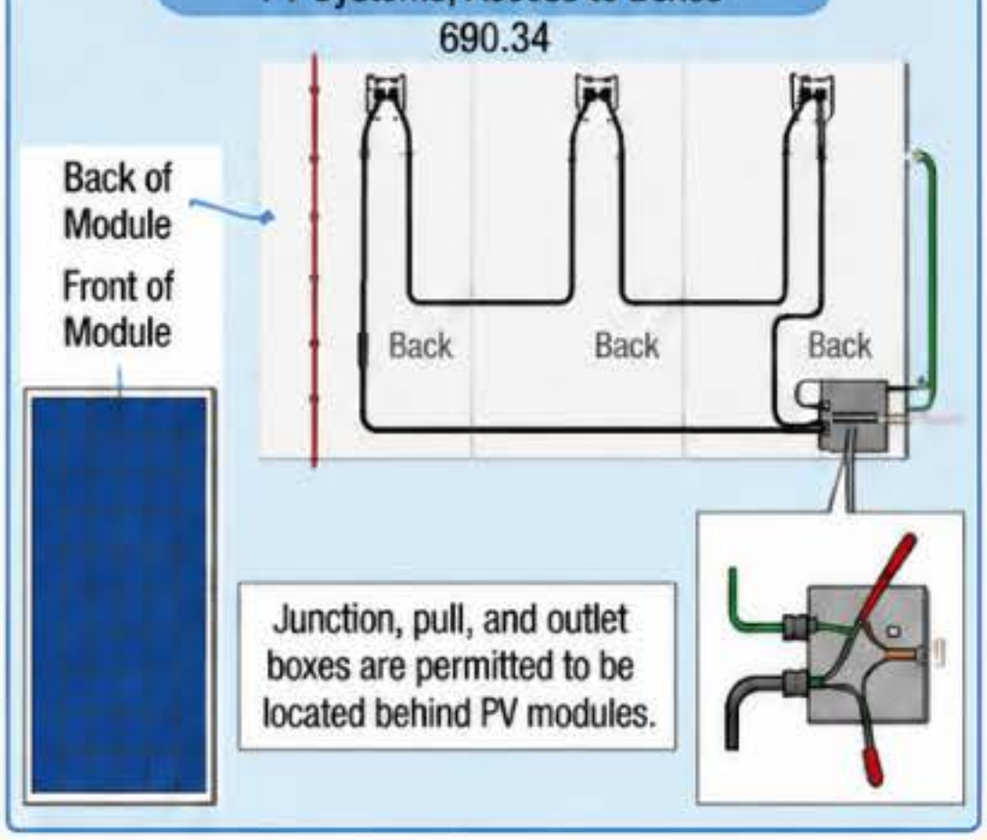
Note: Some listed equipment, such as micro inverters, are evaluated to allow use of mating connectors as disconnect devices even though the connectors themselves are labeled "Do Not Disconnect Under Load" or "Not for Current Interrupting."

690.34 Access to Boxes

Junction, pull, and outlet boxes are permitted to be located behind PV modules.

▸ Figure 690–78

PV Systems, Access to Boxes
690.34



▸ Figure 690–78

Part V. Grounding and Bonding

690.43 Equipment Grounding and Bonding

Exposed metal parts of PV module frames, electrical equipment, and enclosures containing PV system conductors must be connected to the PV system circuit equipment grounding conductor complying with 690.43(A) through (D) and in accordance with 250.134 or 250.136.

▸ Figure 690–79

PV Systems
Equipment Grounding and Bonding
690.43

Exposed metal parts of PV module frames, electrical equipment, and enclosure containing PV system conductors must be connected to the PV system circuit EGC complying with 690.43(A) through (D) and per 250.134, or 250.136.

▸ Figure 690–79

Author's Commentary:

▸ Pursuant to 250.134, any exposed metal parts of equipment, raceways, and enclosures must be bonded to at least one equipment grounding conductor type identified in 250.118. An equipment grounding conductor of a different category may be run separately from the circuit conductors if it is contained within the array [250.134 Ex 2].

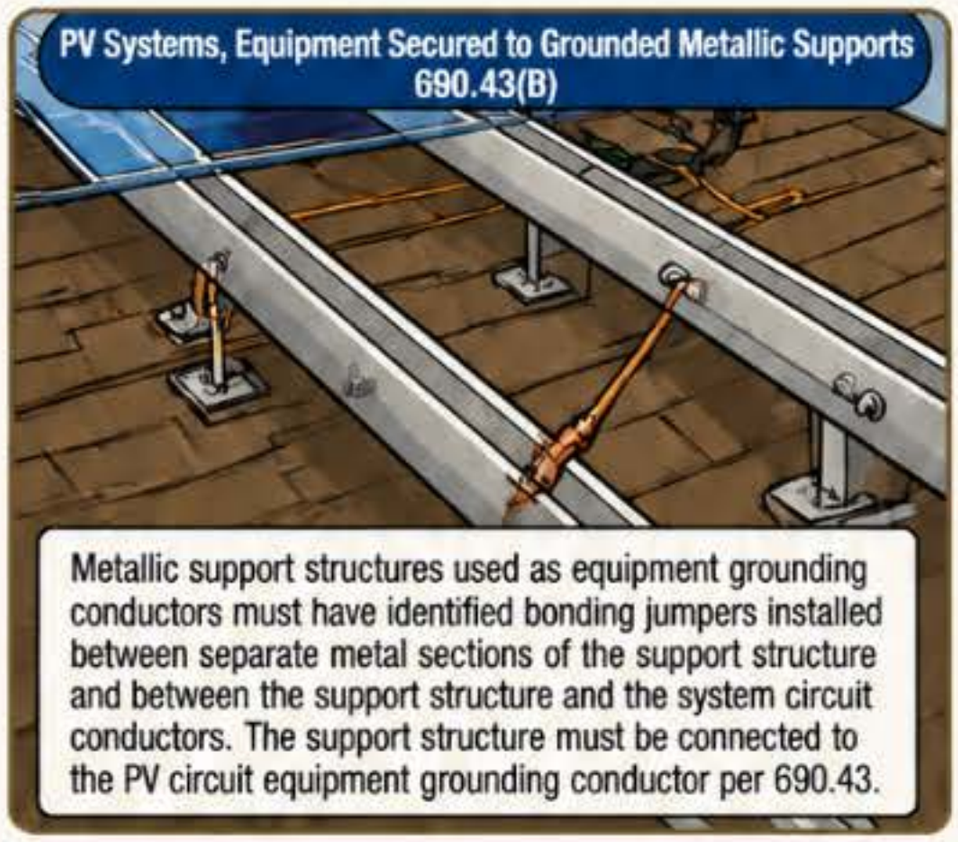
— Michael Hamilton

(A) Photovoltaic Module Mounting Systems and Devices. Devices used to secure and support PV module frames to metal support structures and adjacent PV modules must be listed, labeled, and identified for bonding, Devices that mount adjacent PV modules are permitted to bond adjacent PV modules.

(B) Equipment Secured to Grounded Metal Support Structure. Metallic support structures that are listed, labeled, and identified for bonding and grounding metal parts of PV systems can serve to bond PV equipment to the metal support structure.

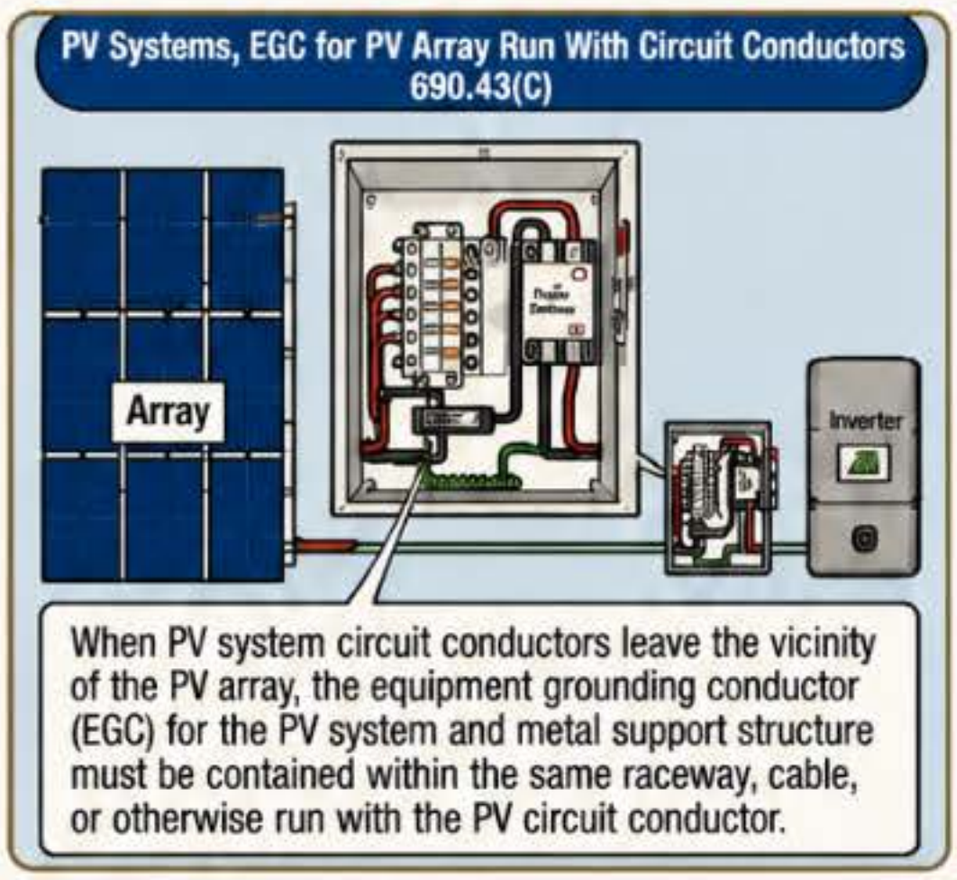
Solar Photovoltaic (PV) Systems 690.43

Metal structures that serve as equipment grounding conductors must be bonded with jumpers between separate metal sections of the support framework and between the support structure and the system circuit conductors. This bonding is required so the metal framework can be used for equipment bonding as specified in 690.43. ▸ Figure 690–80

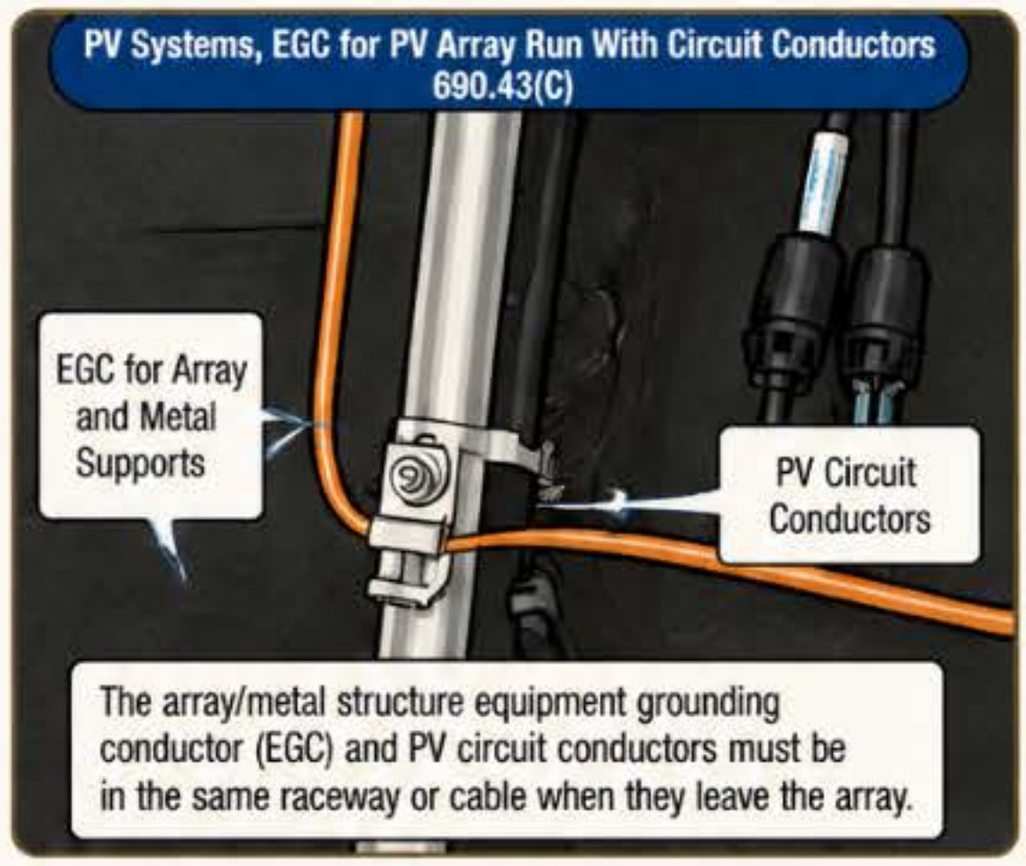


▸ Figure 690–80

(C) With Circuit Conductors. When PV system circuit conductors leave the vicinity of the PV array, the equipment grounding conductors for the PV system and metal support structure must be contained within the same raceway, cable, or otherwise run with the PV circuit conductor.
▸ Figure 690–81 and ▸ Figure 690–82



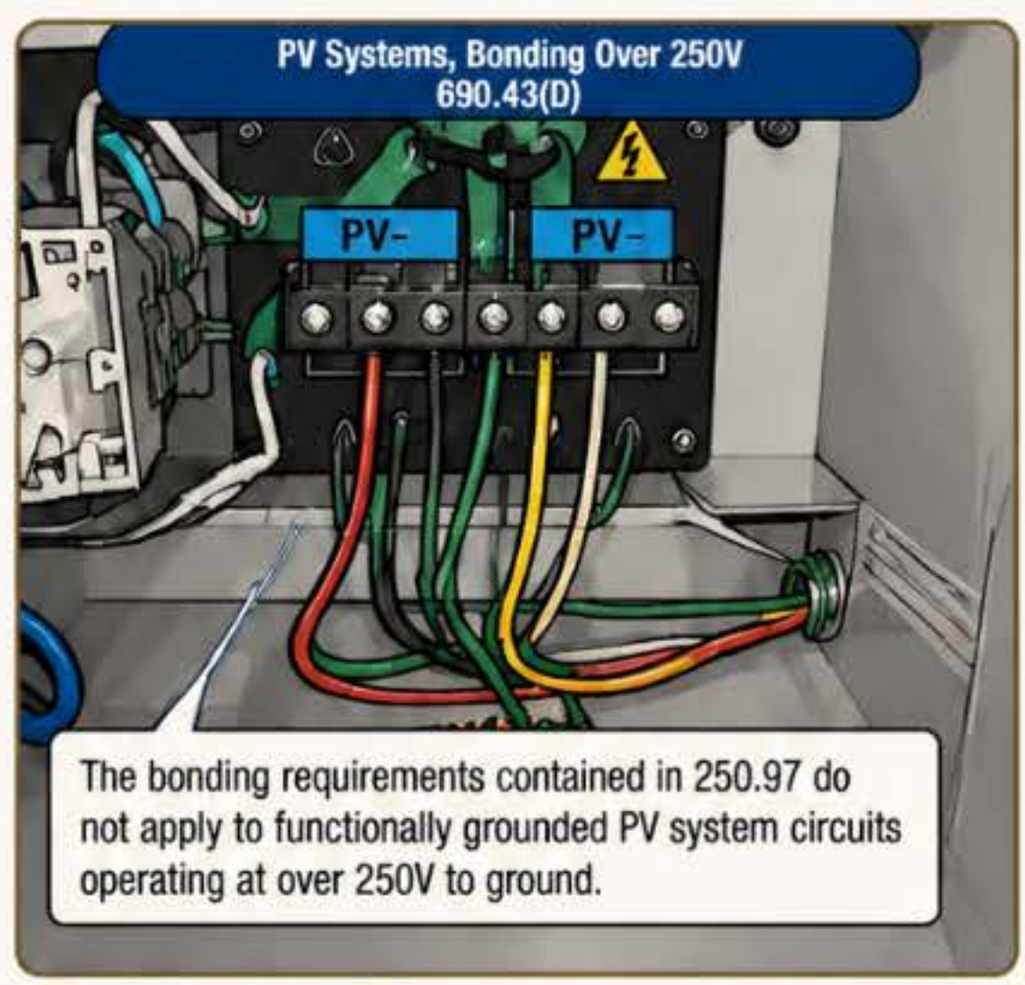
▸ Figure 690–81



▸ Figure 690–82

> ***Author's Commentary:***
> - Exposed equipment grounding conductors 8 AWG and smaller for dc circuits [250.134 Ex 2] may be allowed to terminate separately from the circuit conductors when not subject to physical damage [250.120(C)].
>
> — *Michael Hamilton*

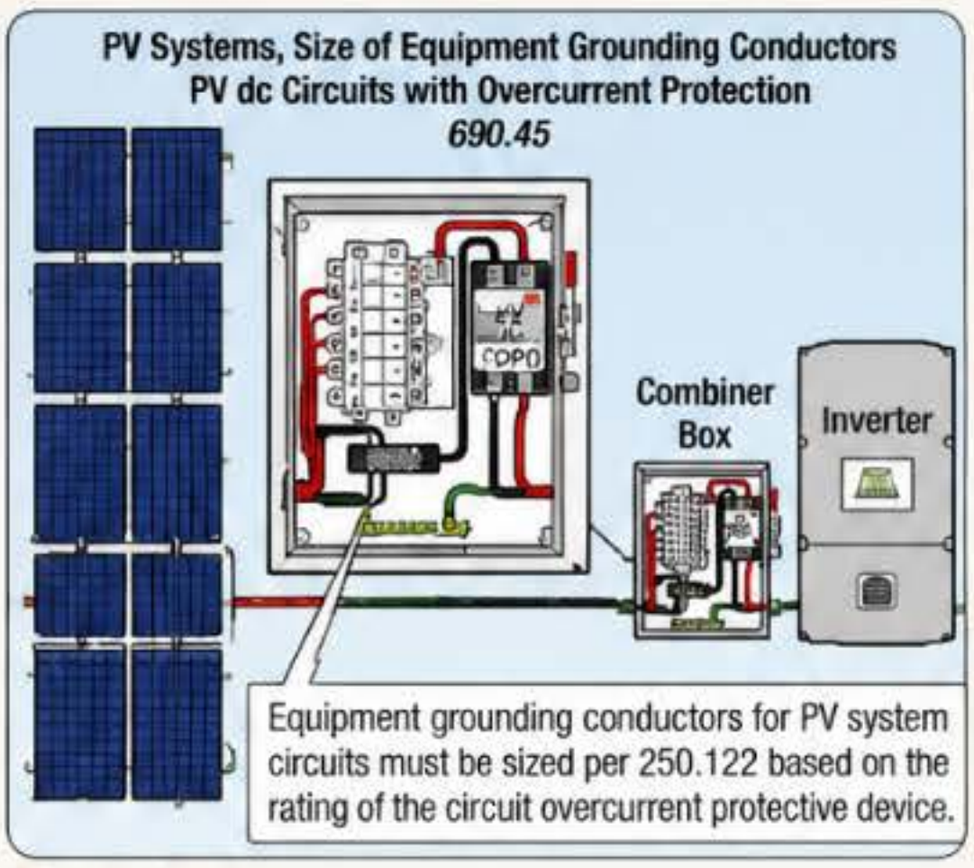
(D) Bonding Over 250V. The bonding requirements contained in 250.97 do not apply to functionally grounded PV system circuits operating at over 250V to ground.
▸ Figure 690–83



▸ Figure 690–83

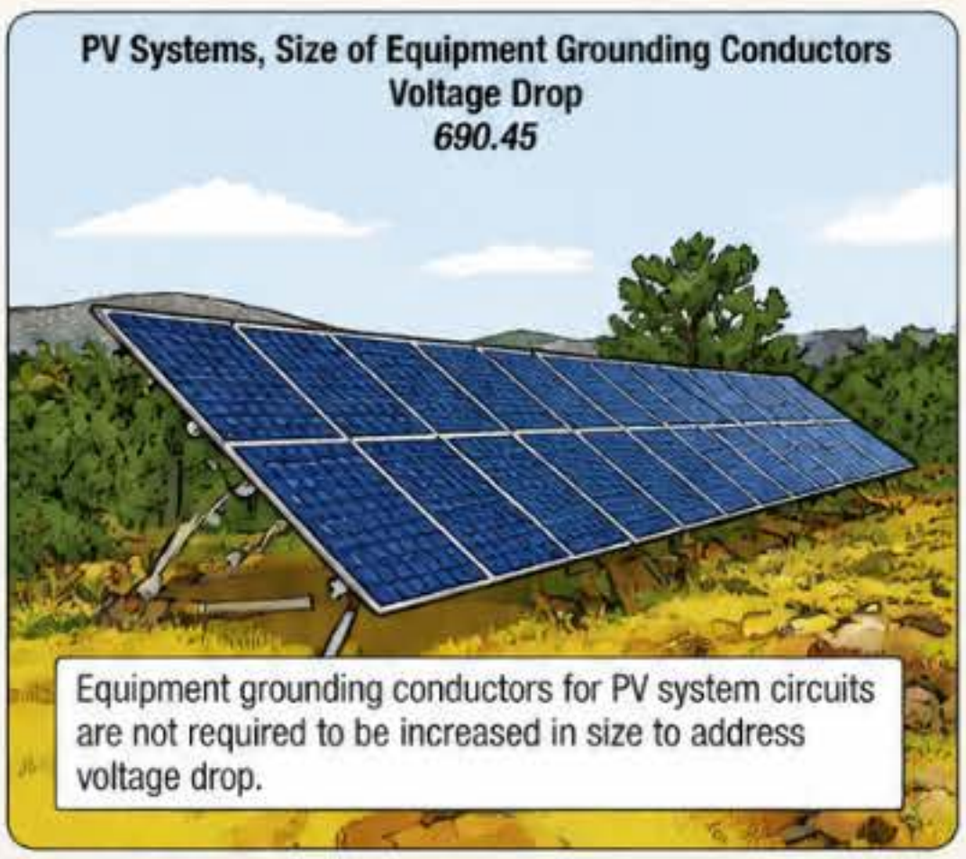
690.45 Size of Equipment Grounding Conductors

Equipment grounding conductors for PV system circuits must be sized in accordance with 250.122 based on the rating of the circuit overcurrent protective device.
▸ Figure 690–84



▸ Figure 690–84

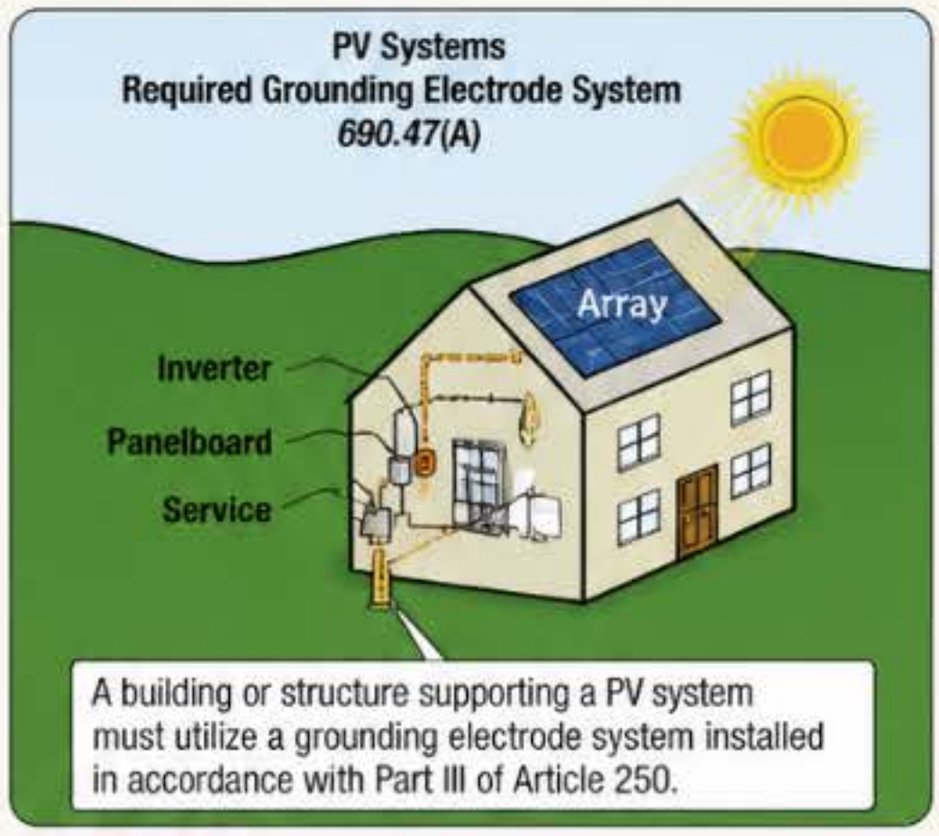
Where no overcurrent protective device is required [690.9(A)(1)], the equipment grounding conductor for the PV system dc circuit must be sized in accordance with Table 250.122 based on an assumed overcurrent device for the circuit sized in accordance with 690.9(B). Equipment grounding conductors are not required to be increased in size to address voltage-drop considerations.
▸ Figure 690–85



▸ Figure 690–85

690.47 Grounding Electrode System

(A) Required Grounding Electrode System. A building or structure supporting a PV system must utilize a grounding electrode system installed in accordance with Part III of Article 250.
▸ Figure 690–86



▸ Figure 690–86

Author's Commentary:

- Part III of Article 250 addresses the grounding electrode system, the grounding electrode types, and the grounding electrode installation requirements.

— Michael Hamilton

(1) Functionally Grounded PV Systems. Functionally grounded PV systems are grounded to the building grounding electrode system when the PV output ac circuit equipment grounding conductor terminates to distribution equipment. ▸ Figure 690–87

The use of the PV output circuit equipment grounding conductor to serve as the required PV equipment grounding conductor connection to ground is the **only connection to ground** required for the functionally grounded PV system. ▸ Figure 690–88

Note. Most PV systems are functionally grounded rather than solidly grounded. For functionally grounded systems, the inverter equipment grounding conductor is connected to the grounded distribution equipment. This connection is used for the ground-fault protection and equipment grounding of the PV array.

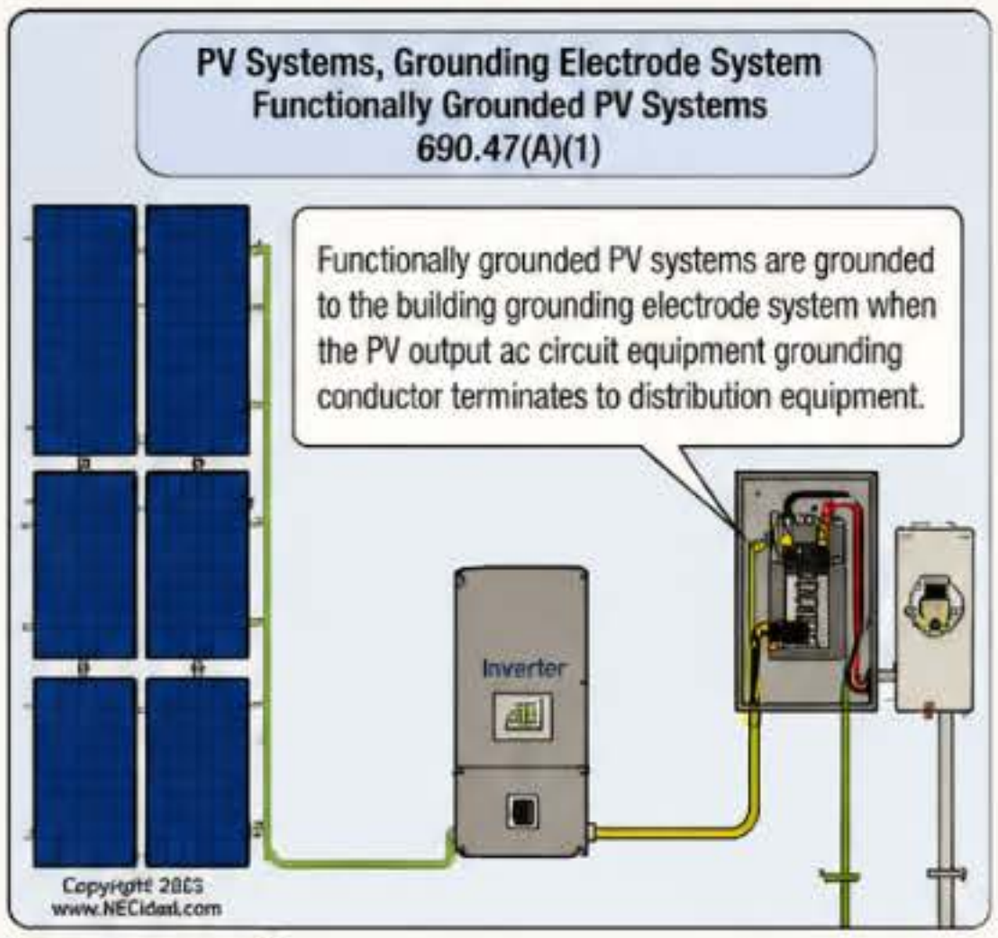


Figure 690–87

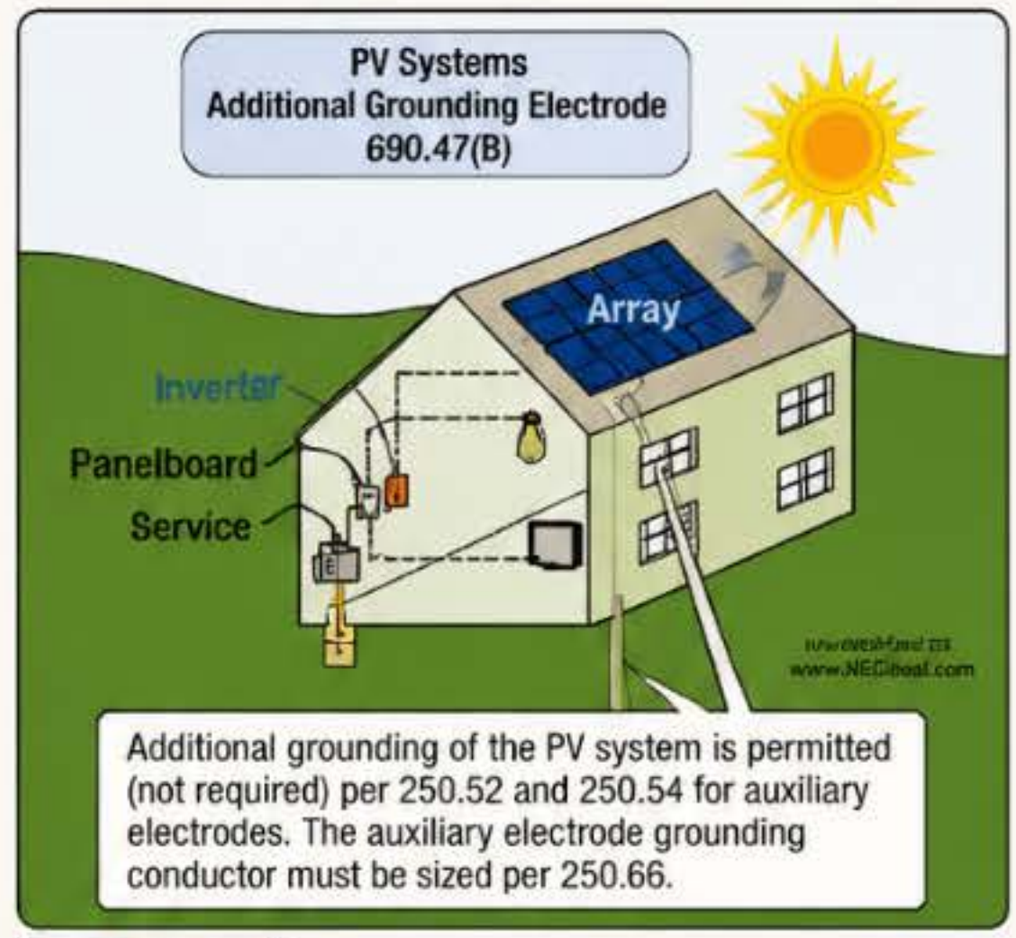


Figure 690–89

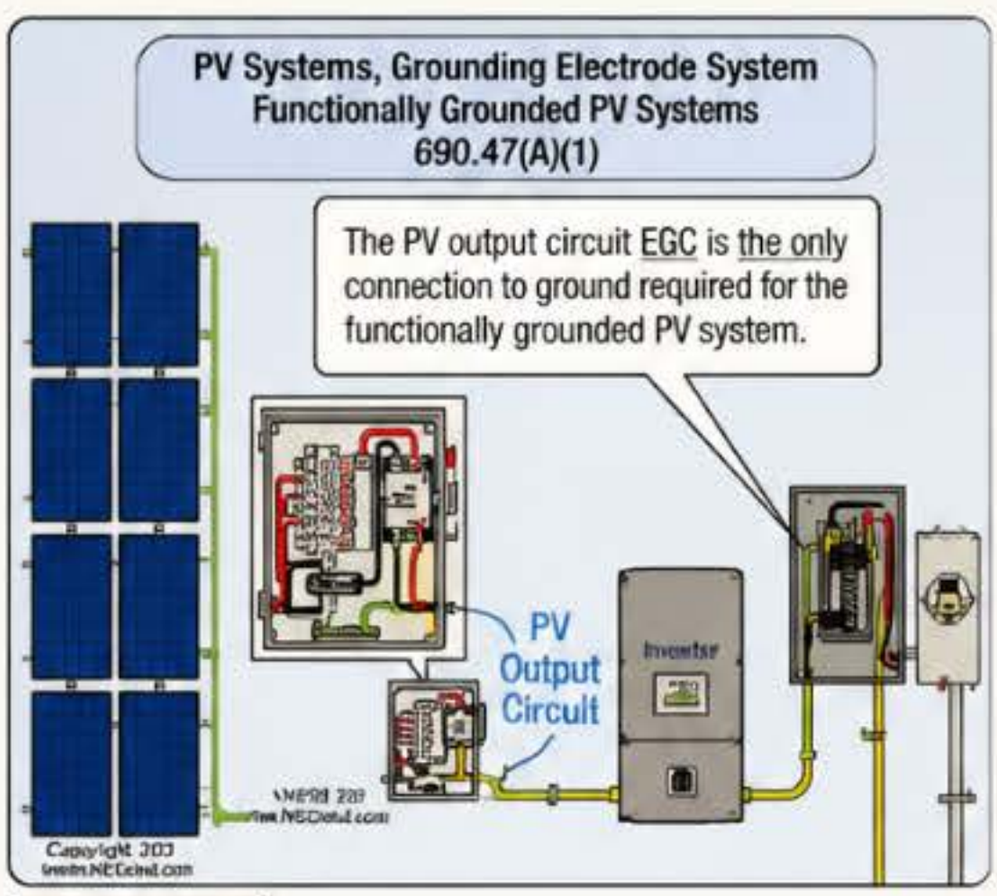


Figure 690–88

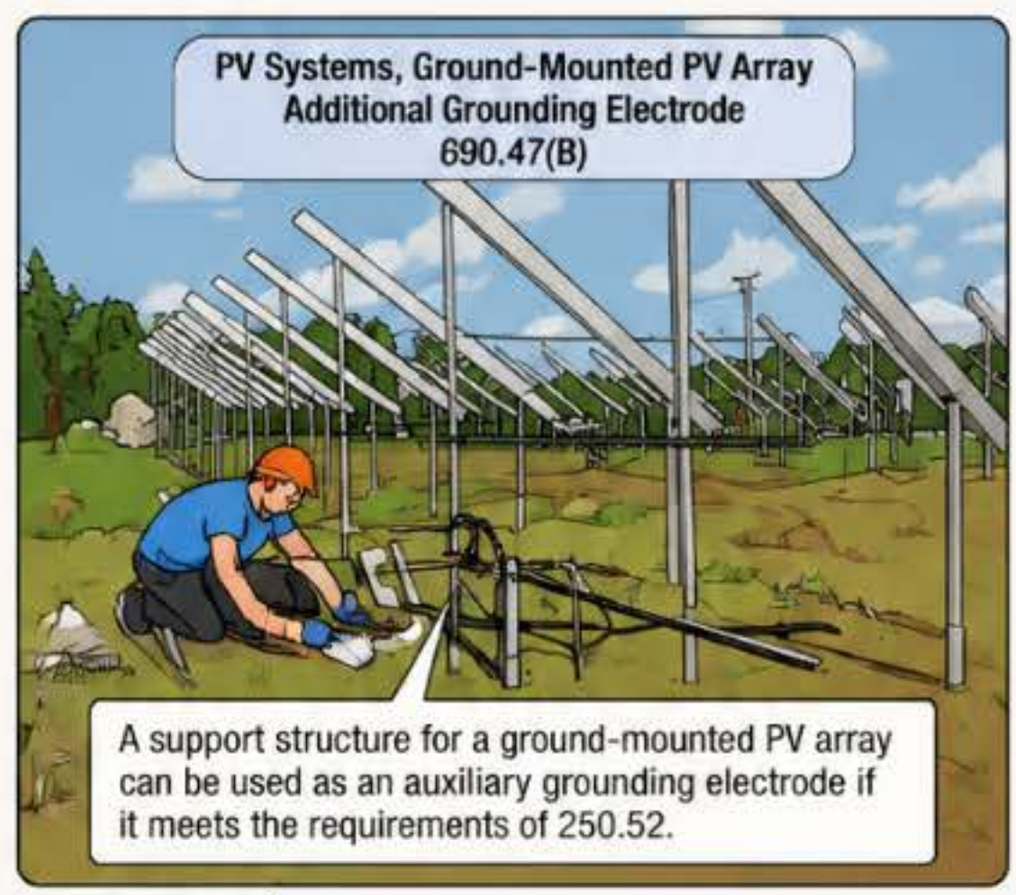


Figure 690–90

(B) Additional Grounding Electrode. Additional grounding of the PV system is permitted (but not required) in accordance with 250.52 and 250.54 for auxiliary electrodes. The auxiliary electrode grounding conductor must be sized in accordance with 250.66. ▸ Figure 690–89

Author's Commentary: A ground-mounted PV array support frame may serve as an auxiliary grounding electrode when it satisfies the conditions of 250.52. ▸ Figure 690–90 Many PV arrays attached to buildings can use the building's metal structure as the grounding electrode conductor when the criteria of 250.68(C)(2) are fulfilled.

— ***Michael Hamilton***

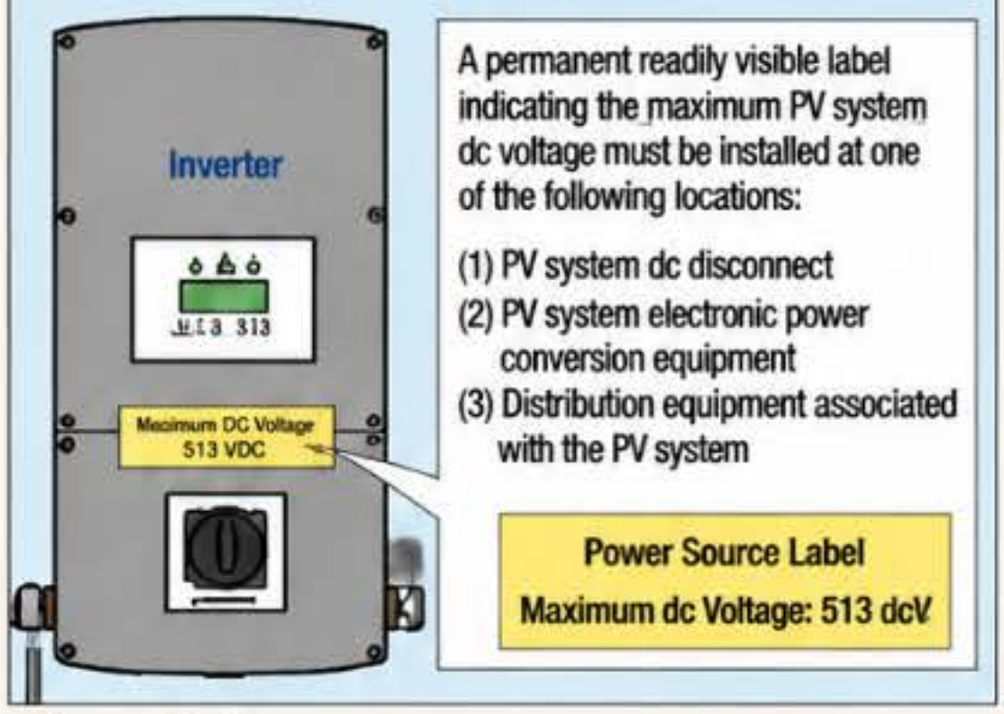
Part VI. Markings and Labels

690.53 Direct-Current PV Circuit Label

A permanent readily visible label indicating the maximum PV system dc voltage as calculated in accordance with 690.7 must be installed at one of the following locations: ▸ Figure 690–91

1. PV system dc disconnect
2. PV system electronic power conversion equipment
3. Distribution equipment associated with the PV system

PV Systems, Direct-Current PV Circuit Label
690.53

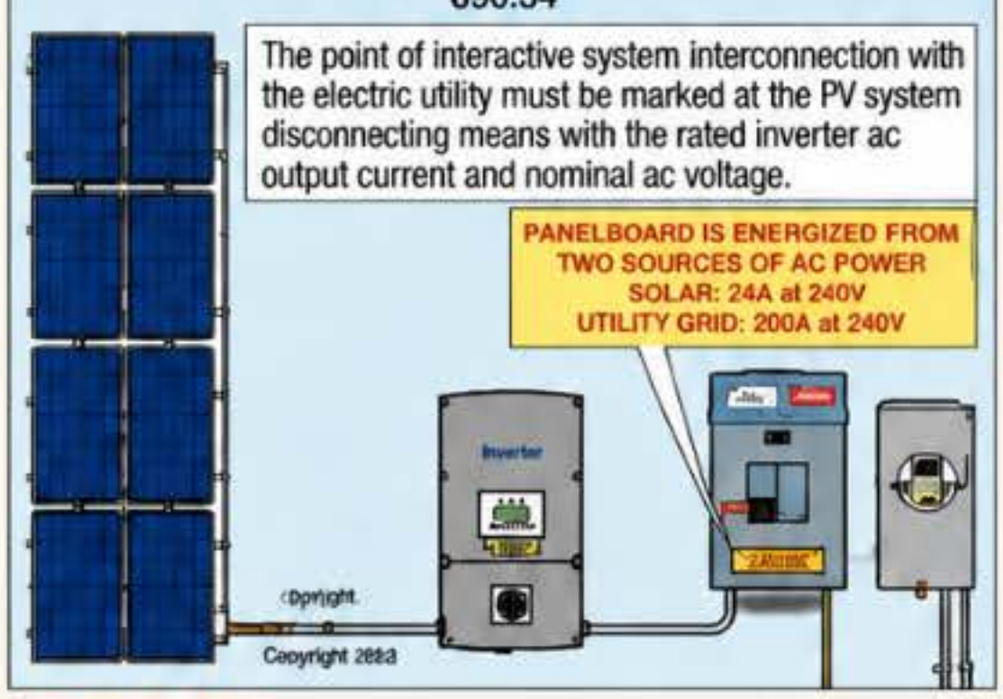


▸Figure 690–91

690.54 Interactive System Point of Interconnection

The point of interactive system interconnection with the electric utility must be marked at the PV system disconnecting means with the rated inverter ac output current and nominal ac voltage. ▸Figure 690–92

PV Systems
Interactive System Point of Interconnection, Marking
690.54



▸Figure 690–92

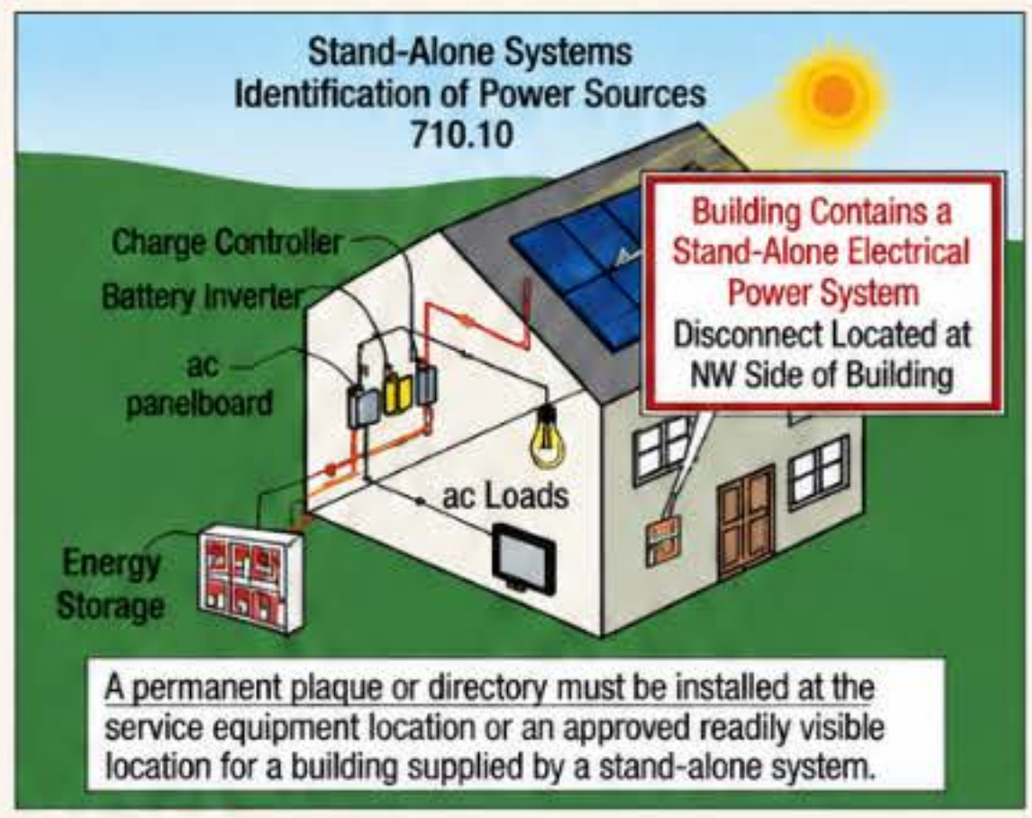
690.55 Energy Storage

PV system dc circuit conductors connected to energy storage systems must be marked for polarity in accordance with 690.31(B)(1).

Author's Commentary:
Polarity markings help ensure the battery system is wired correctly, which protects equipment and supports safe operation.
— Michael Hamilton

690.56 Identification of Power Sources

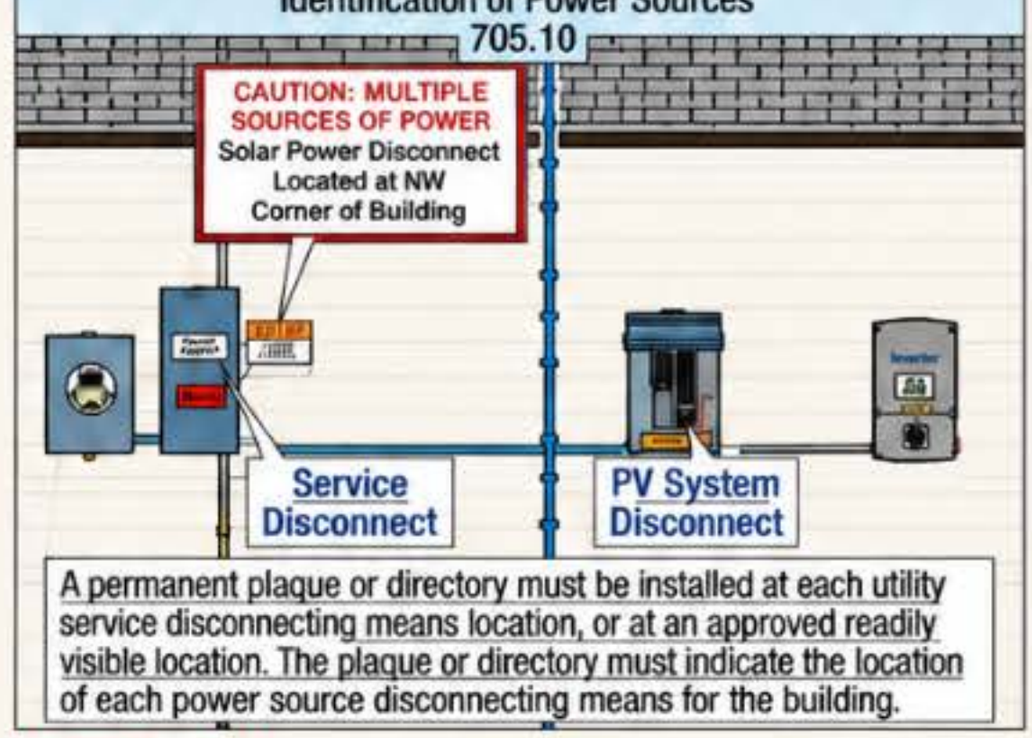
(A) Stand-Alone Systems. Any building with a stand-alone PV system must have a permanent plaque or directory in accordance with 710.10. ▸Figure 690–93



▸Figure 690–93

(B) Building with Utility Power and PV Systems. A building having both utility power and an interactive PV system(s) must have a plaque or directory installed in accordance with 705.10. ▸Figure 690–94

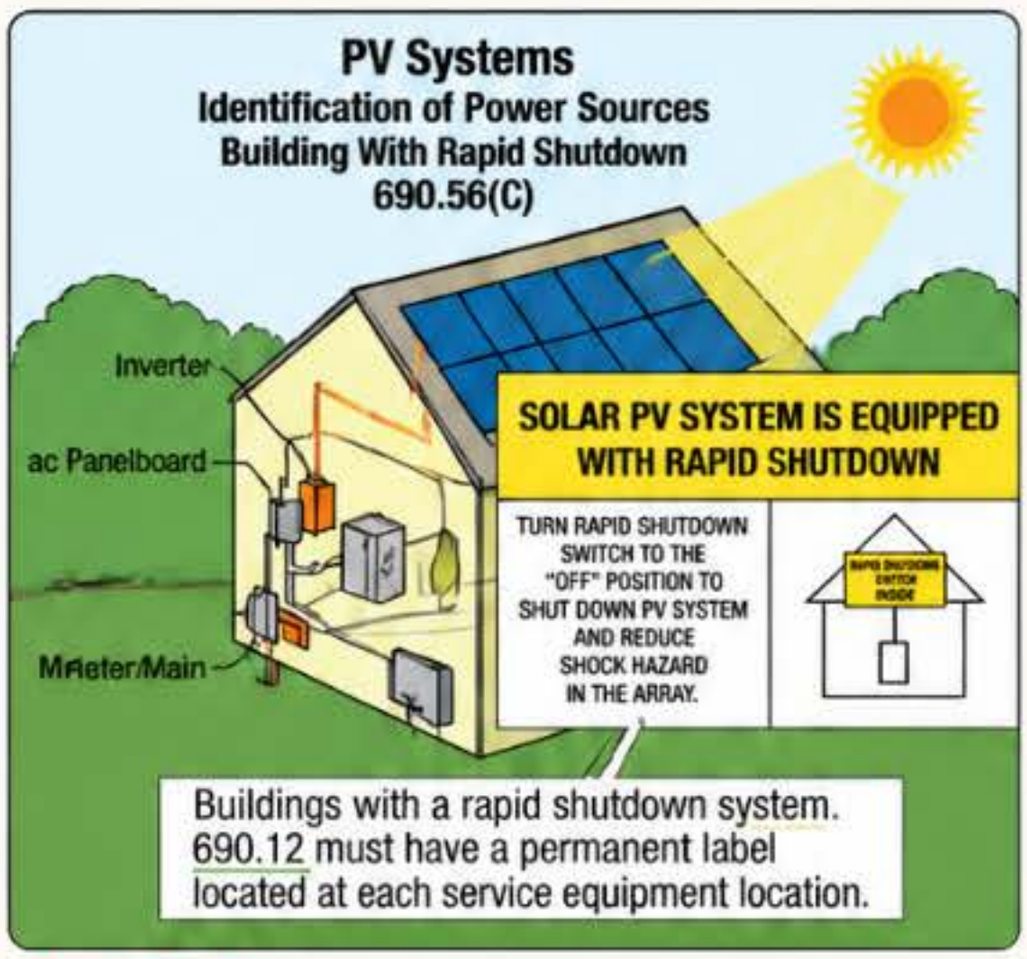
Interconnected Electric Power Production Sources
Identification of Power Sources
705.10



▸Figure 690–94

(C) Building with Rapid Shutdown System(s). A building with a rapid shutdown system [690.12] must have a permanent label indicating the location of all rapid shutdown initiation devices. The label must be located at each service equipment location or at an approved readily visible location and the label must include a diagram of a building with a roof with the following words: ▸Figure 690–95

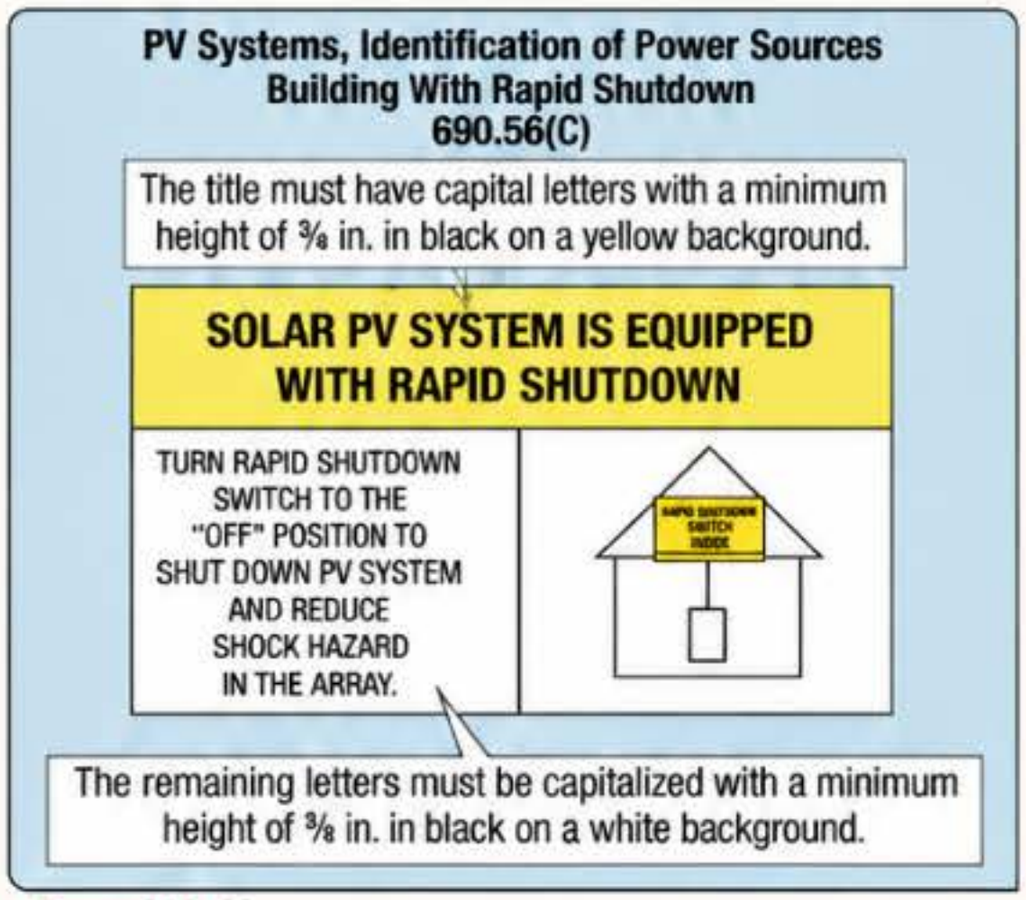
Author's Commentary:
During an emergency, responders must know where rapid shutdown controls are located to cut power quickly and safely.
— Michael Hamilton



▸Figure 690–95

SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN
TURN RAPID SHUTDOWN SWITCH TO THE "OFF" POSITION TO SHUT DOWN PV SYSTEM AND REDUCE SHOCK HAZARD IN THE ARRAY

The label "SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN" must be in all capital letters and be at least ⅜ in. high in white on a black background. All other characters also must be in all capital letters with a minimum height of ⅜ in. in black on a white background. ▸Figure 690–96

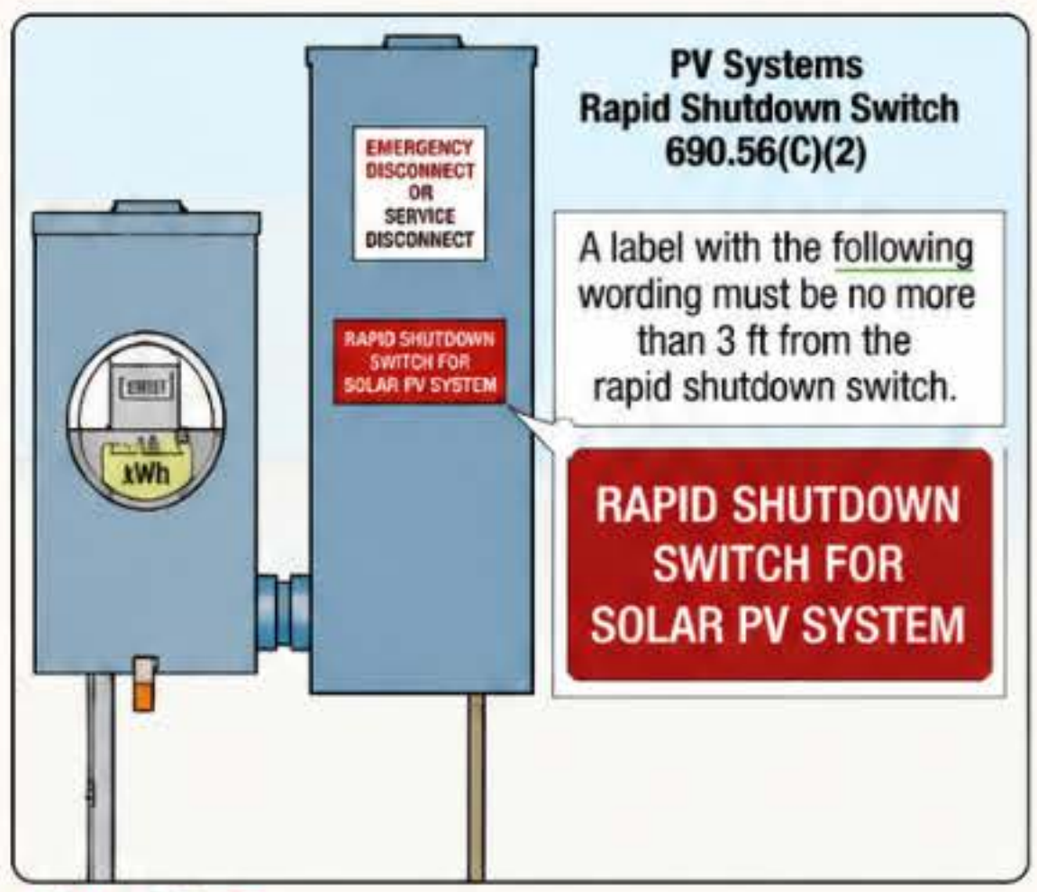


▸Figure 690–96

Note: See Note Figure 690.56(C) in the *NEC* for an example.

(1) Buildings with More Than One Rapid Shutdown Type. A structure that contains either multiple rapid shutdown systems or one that does not require rapid shutdown must carry a floor plan schematic of the rooftop area. The plan must mark every area that stays energized once an initiation device for rapid shutdown has been activated.

(2) Rapid Shutdown Switch. A rapid shutdown control switch needs a label with this wording when it is located more than 3 ft from the switch: "RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM." The rapid shutdown label must use capital letters, have lettering no less than ⅜ in. (9.5 mm) high in white on a red background. ▸Figure 690–97



▸Figure 690–97

Part VII. Connections to Other Sources

690.59 Connection to Other Power Sources

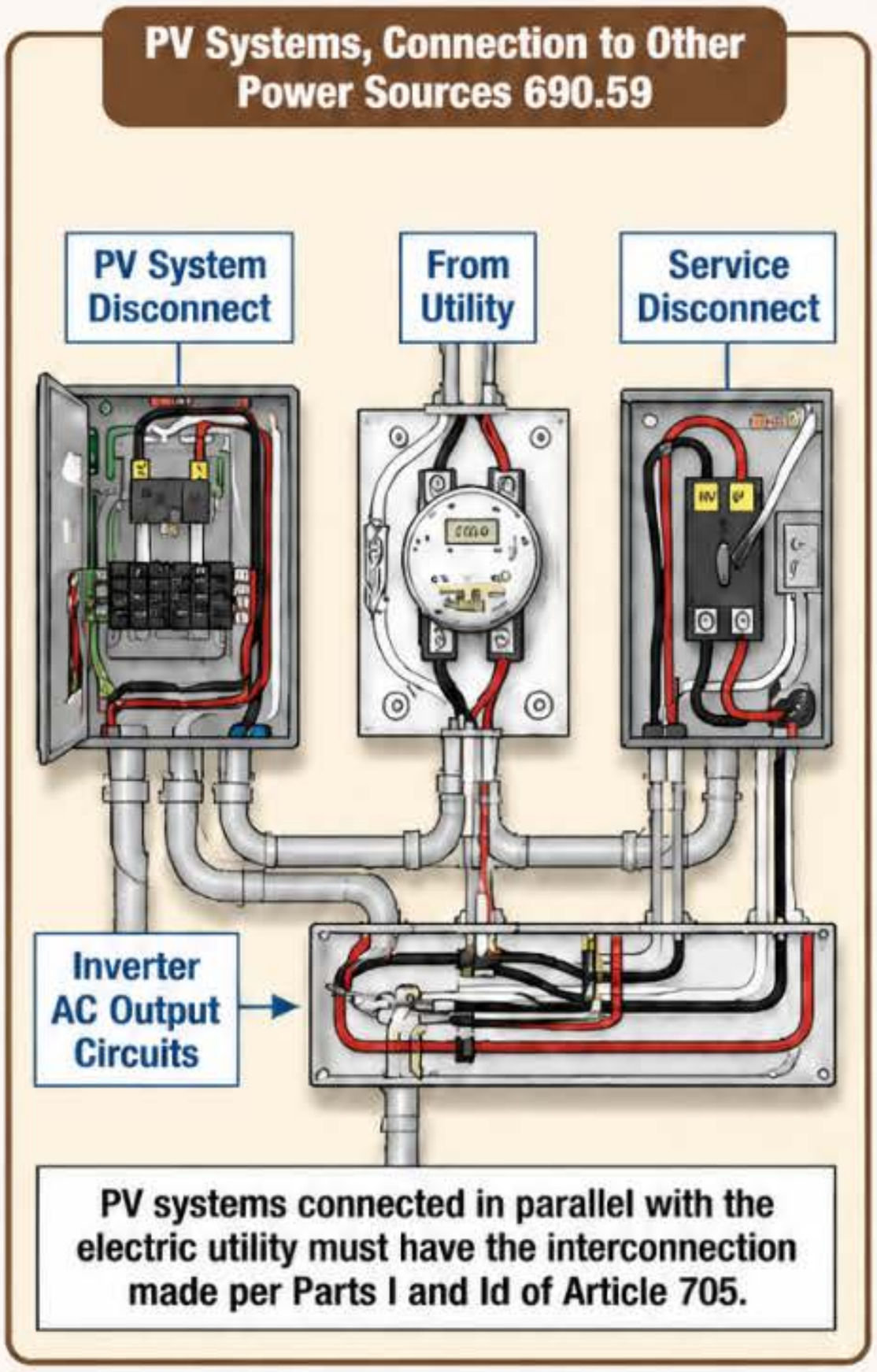
Photovoltaic systems connected in parallel with the utility electrical system must use an interconnection that complies with Parts I and II of Article 705 for utility and PV system interconnections. ▸Figure 690–98

Part VIII. Energy Storage Systems

690.71 Energy Storage Systems

Energy storage systems that are tied to a PV system must be installed according to Article 706.

690.72 | Solar Photovoltaic (PV) Systems



▶ Figure 690-98

690.72 Self-Regulated PV Charge Control

The PV dc charge controller source circuit is considered to comply with 706.33 if:

(1) The PV source circuit is matched to the dc voltage rating and charge current requirements of the interconnected battery cells, and

(2) The maximum charging current multiplied by one hour is less than three percent of the rated battery capacity expressed in ampere-hours or as recommended by the battery manufacturer.

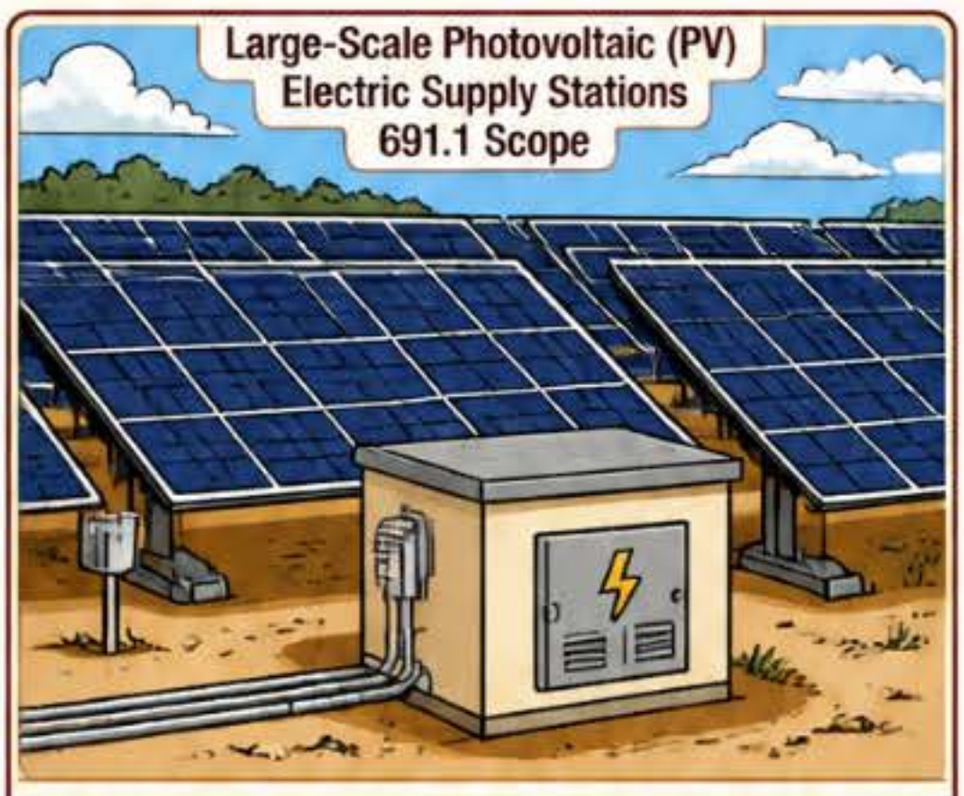
ARTICLE 691 LARGE-SCALE PHOTOVOLTAIC (PV) ELECTRIC SUPPLY STATIONS

Introduction to Article 691—Large-Scale Photovoltaic (PV) Electric Supply Stations

The general requirements for solar photovoltaic (PV) systems are addressed in Article 690. When a system is 5,000 kW or larger, it is classified as a large-scale PV electric supply station and must comply with Article 691. This article specifies what constitutes a large-scale photovoltaic system and sets out additional rules that must be followed instead of the alternative design and safety provisions unique to smaller systems. These stations, which are privately owned PV systems, operate under the regulations of a utility in a manner similar to those in Article 690, as they can deliver power to serve end users, utilities, or both. The design must undergo a detailed review by a qualified engineer to verify safe operation and adherence to applicable electrical standards and industry best practices.

691.1 Scope

Article 691 covers the installation of large-scale PV electric supply stations with an inverter generating capacity of more than 5,000 kW and not under the electric utility control.
→ Figure 691-1



Article 691 covers the installation of large-scale PV electric supply stations with an inverter generating capacity of more than 5,000 kW and not under the electric utility control.
Figure 691-1

Author's Commentary:

These facilities are purpose-built for large PV installations and are run exclusively to deliver electricity to a utility that then distributes it to consumers under regulation.

— Michael Hamilton

691.4 Special Requirements for Large-Scale PV Electric Supply Stations

Large-scale PV electric supply stations are permitted only for access by authorized personnel and must comply with the following requirements:

1. Electrical circuits and equipment shall be kept in good condition and handled only by qualified personnel.
2. PV electric supply stations must be enclosed by fencing or other means in accordance with 110.31, and hazard signage meeting 110.21(B)(1) and (B)(3) must be permanently attached and remain highly visible in all conditions.
3. The connection between the PV electric supply system and the utility system must be made through medium- or high-voltage equipment such as a switchgear, substation, switchyard, or other comparable methods intended for reliable interconnection of the two systems.
4. Loads at the PV electric supply station are allowed only to support auxiliary equipment used in producing the PV power.
5. Large-scale PV electric supply stations are not permitted inside buildings.

Author's Commentary:

These safeguards protect personnel, ensure clear hazard communication, and promote dependable operation of the facility while maintaining a safe tie-in with the utility grid.

— Michael Hamilton

691.5 Equipment

All electrical equipment must be approved for installation by one of the following:

① Listing and labeling.

② Be evaluated for the application and have a field label applied.

③ Where products complying with 691.5(1) or (2) are not available, by engineering review validating that the electrical equipment is evaluated and tested to relevant standards or industry practice.

691.6 Engineered Design

Technical documents for the electric supply station must be prepared by a licensed professional electrical engineer and submitted at the request of the authority having jurisdiction. Stamped independent engineering reports from a licensed professional electrical engineer detailing compliance with the design using applicable electrical standards and industry practice must also be provided when requested by the authority having jurisdiction.

The documentation must describe how the design complies with Article 690 and any alternative methods in Article 690, or other provisions of the *NEC*.

691.7 Conformance of Construction to Engineered Design

Documents from a licensed professional electrical engineer confirming that construction of the electric supply station follows the electrical engineered design must be submitted to the authority having jurisdiction. Stamped independent engineering reports from a licensed professional engineer explaining that construction meets the *Code*, applicable standards, and industry practice must be provided upon request of the authority having jurisdiction. This independent engineer must be retained by the system owner or installer.

691.8 Direct-Current Operating Voltage

Large-scale PV electric supply station calculations must be included in the documentation required in 691.6.

691.9 Disconnect for Isolating Photovoltaic Equipment

Isolating devices are not required to be located within sight of equipment and may be located remotely from the equipment.

The engineered design required by 691.6 must document disconnection procedures and means of isolating equipment.

Note: For information on electrical system maintenance, see NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance.*

For information on written procedures and conditions of maintenance, including lockout/tagout procedures, see NFPA 70E, *Standard for Electrical Safety in the Workplace.*

Buildings whose sole purpose is to house and protect supply station equipment are not required to include a rapid shutdown function to reduce shock hazard for firefighters [690.12]. Written standard operating procedures must be available at the site detailing necessary shutdown procedures in the event of an emergency.

691.10 Arc-Fault Mitigation

PV systems that do not provide arc-fault protection as required by 690.11 must include details of fire mitigation plans to address dc arc faults in the documentation required in 691.6.

691.11 Fence Bonding and Grounding

Fence grounding requirements and details must be included in the documentation required in 691.6.

Note: See 250.194 for fence bonding and grounding requirements for PV systems that operate at more than 1,000V between conductors. Grounding requirements for other portions of electric supply station fencing are assessed based on the presence of overhead conductors, proximity to generation and distribution equipment, and potential for step and touch potential.

ARTICLE 695 FIRE PUMPS

Introduction to Article 695—Fire Pumps

The fundamental goal behind most Code requirements is to ensure that circuit overcurrent protection is in place to shut down equipment before the supply conductors overheat or suffer damage from overload. Article 695 follows a different mindset. It starts from the belief that a fire pump motor must always keep running, no matter what. Because of this, the water that feeds the building's fire protection piping—like sprinklers and standpipes—must stay available. To achieve that goal, some equipment may need to be sacrificed, but the pump must never be taken out of service.

A portion of the requirements may already seem self-evident. For instance, the pump should be located where its exposure to fire is minimal, typically in a separate fire-rated space. It's also important that the power source feed both the fire pump and its jockey (pressure maintenance) pump, and that the pump has independent wiring from other loads. At first glance, some of Article 695's rules might appear straightforward—until you think about what happens if the pump is located at the very front of the building. For example, if the disconnect is lockable only in the closed position, other items required for upkeep could be locked open to protect the maintenance staff. That instantly conflicts with the need to keep the pump operating. But the goal is clear: protect the safety of the whole structure and everyone inside.

Keep in mind, the fire pump must remain in service even while it's being tested or if it sustains damage. In many cases, that means sacrificing a component rather than the pump itself. The purpose of Article 695 is to give building occupants enough time to evacuate—and when possible—to save the facility.

695.1 Scope

(A) Covered. Article 695 covers the installation of: ▶ Figure 695-1

(1) Electric power sources and interconnecting circuits.

(2) Switching and control equipment dedicated to fire pump drivers.

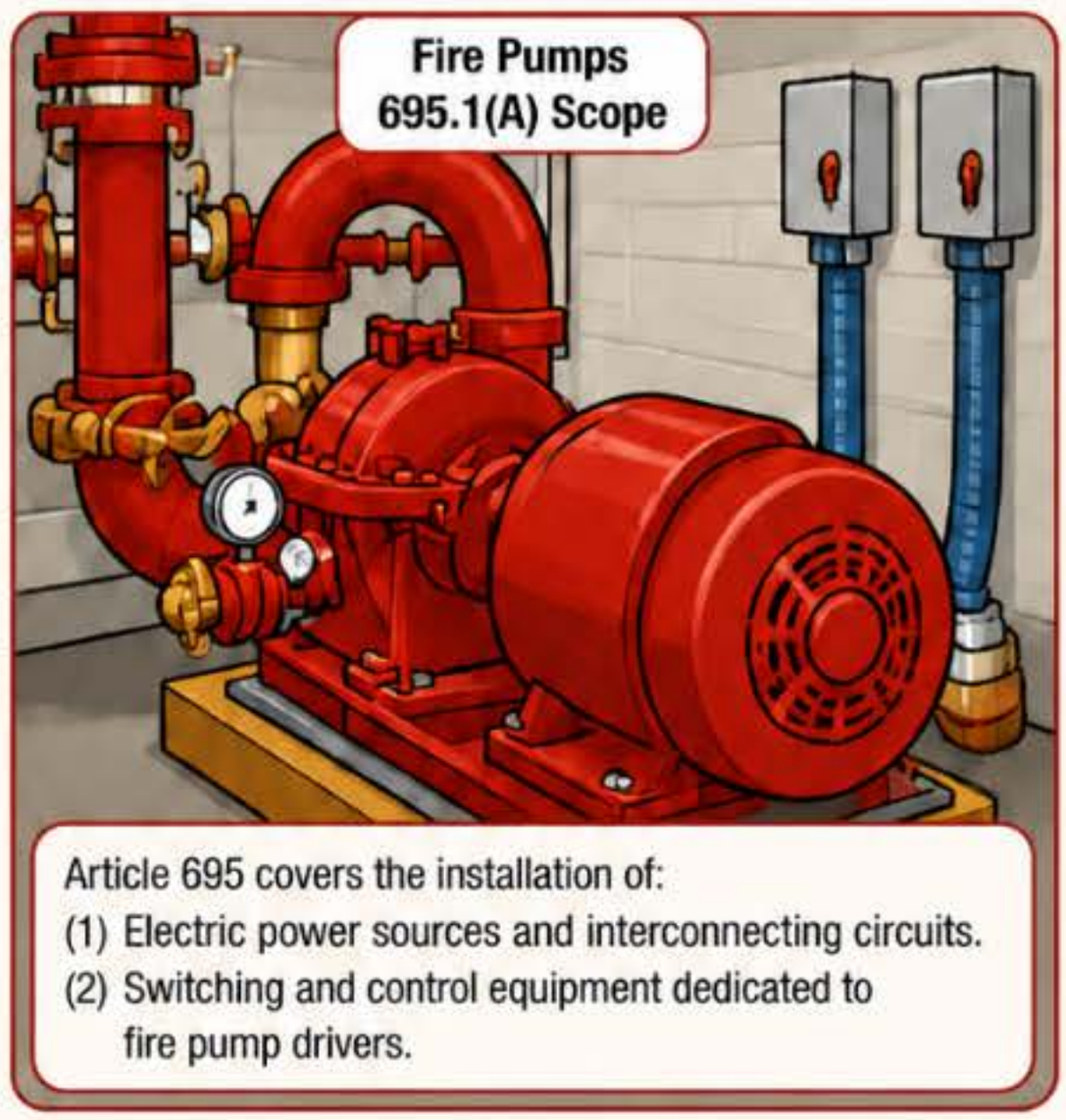
(B) Not Covered. Article 695 does not cover:

(1) Performance, maintenance, testing, and the internal wiring of the components of the system.

(2) The installation of pressure maintenance (jockey or makeup) pumps.

Note: Article 430 governs the installation of pressure maintenance (jockey or makeup) pumps, whether or not they are supplied by the fire pump.

(3) Transfer equipment upstream of the fire pump transfer switch(es).



▶ Figure 695-1

Author's Commentary:

Fire pump systems are life-safety critical, so their power connections must be installed with care by experienced professionals who understand the system. These installations often need to tie into other power equipment like backup sources and motor controllers. Always follow a clear set of job-specific requirements.

— Michael Hamilton

Author's Commentary:

Keep the service disconnect for the fire pump system in a spot away from other power disconnects to reduce the chance of an accidental shutdown [230.72(B)]. In most cases, place it upstream of the main disconnect but downstream of the generator disconnect. The fire pump disconnect needs to be easy to see.

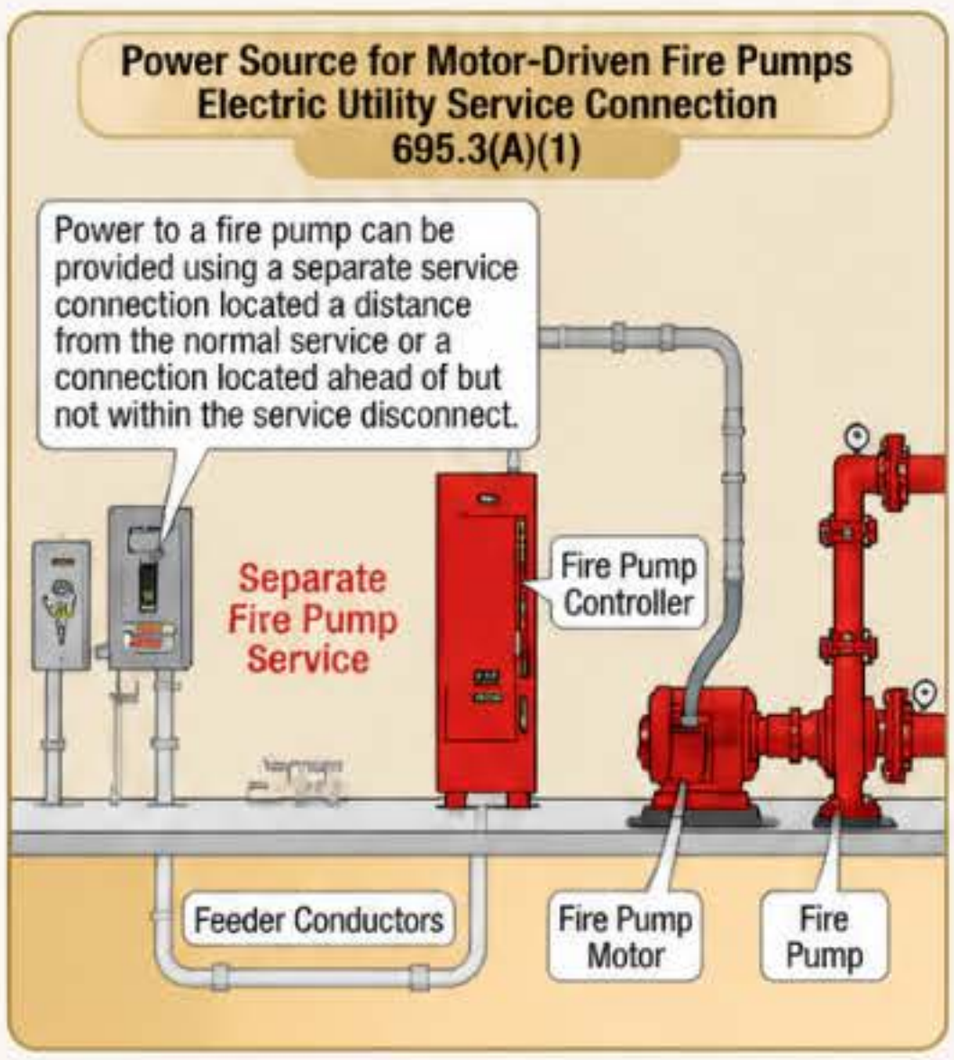
— Michael Hamilton

695.3 Electric Power Source(s)

(A) Individual Sources. Electric power for the motors that drive fire pumps must come from a dependable source that can handle the locked-rotor current of the pump motor(s), the maintenance service loads for the pump motors, and the full-load current of any associated equipment. The code requires that acceptable power sources be identified.

Note: See 9.3.2 and A 9.3.2 from NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* for help in deciding which electric power source is suitable.

(1) Electric Utility Service Connection. A separate service connection located a distance from normal power service is used to reduce the chance of an unintentional outage [230.72(B)] or a disconnection that could leave both services without power [230.82(5)]. ▸ **Figure 695–2**



▸ **Figure 695–2**

(2) On-Site Power. An on-site generator, installed and guarded from fire damage, is permitted to reduce harm from fire.

(B) Multiple Sources. When one source may fail, power must be fed to the fire pump system from any of the following options from 695.3(A).

(1) Individual Sources. Any combination of two or more individual sources allowed by the authority having jurisdiction.

(2) Individual Source and On-Site Standby Generator. A mix of one of the options in 695.3(A) and a generator that complies with 695.3(D) approved by the authority having jurisdiction.

Examples 1 and 2: An alternate source of power is not required when a backup, engine, steam turbine, or electric motor driven fire pump uses an independent power source in accordance with 695.3(A) or (C).

(F) Transfer of Power. Place the power transfer equipment for the fire pump controller inside the pump room.

695.4 Continuity of Power

(B) Connection Through Disconnect and Overcurrent Device.

(1) Number of Disconnecting Means.

(a) One disconnecting means may be installed between the following items in the fire pump electrical supply:

(1) An approved fire pump controller,

(2) A listed fire pump power transfer switch, or

(3) A listed combination fire pump controller/power transfer switch.

(2) Overcurrent Device Selection.

(a) Individual Sources. Overcurrent protection for individual sources must follow these requirements:

(1) Facilities must select or configure overcurrent protective devices that can carry without interruption the total of the locked-rotor current of the largest fire pump motor plus 100 percent of the full-load currents of all other pump motors and accessories for the fire pump system. • **Figure 695–3**

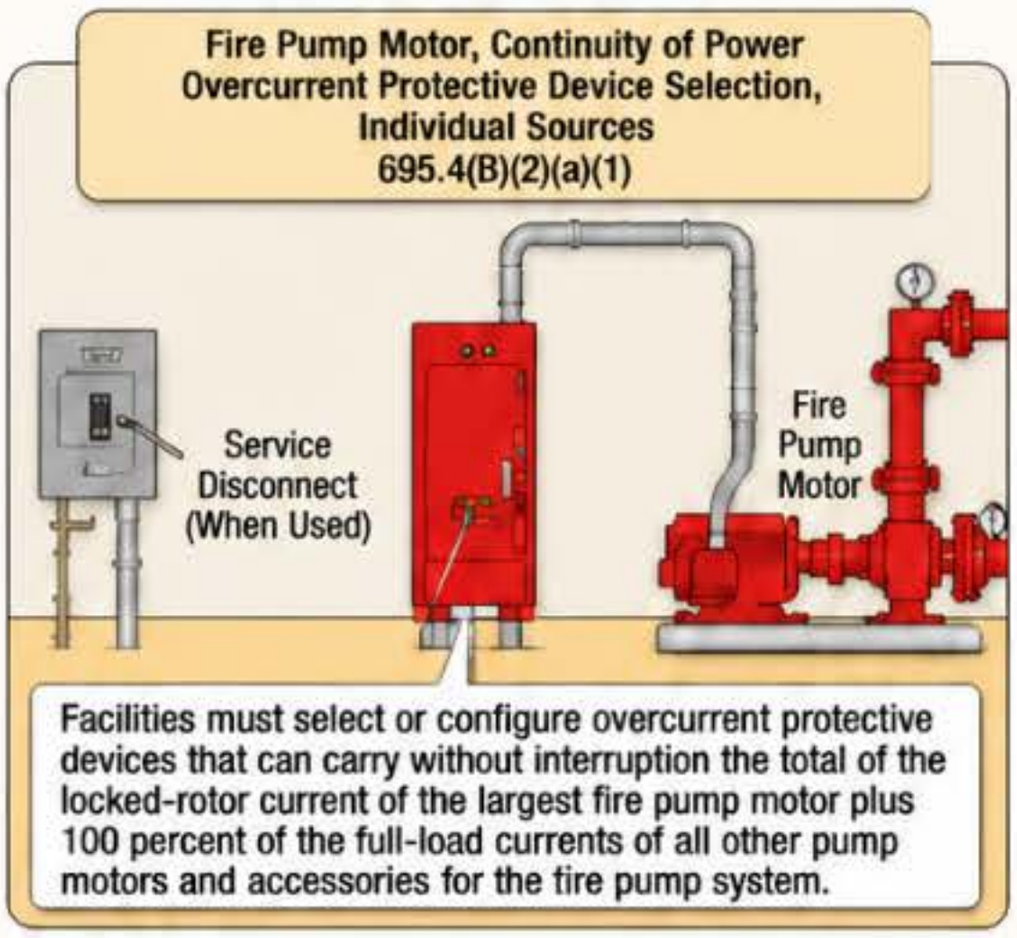


Figure 695–3

► Fire Pump Overcurrent Size Example

Question: *What size overcurrent protective device and conductor is required for a 25 hp, 460V, three-phase fire pump motor that has a locked-rotor current rating of 183A?* • **Figure 695–4**

(a) 100A, 8 AWG *(b) 200A, 8 AWG*
(c) 400A, 8 AWG *(d) 450A, 8 AWG*

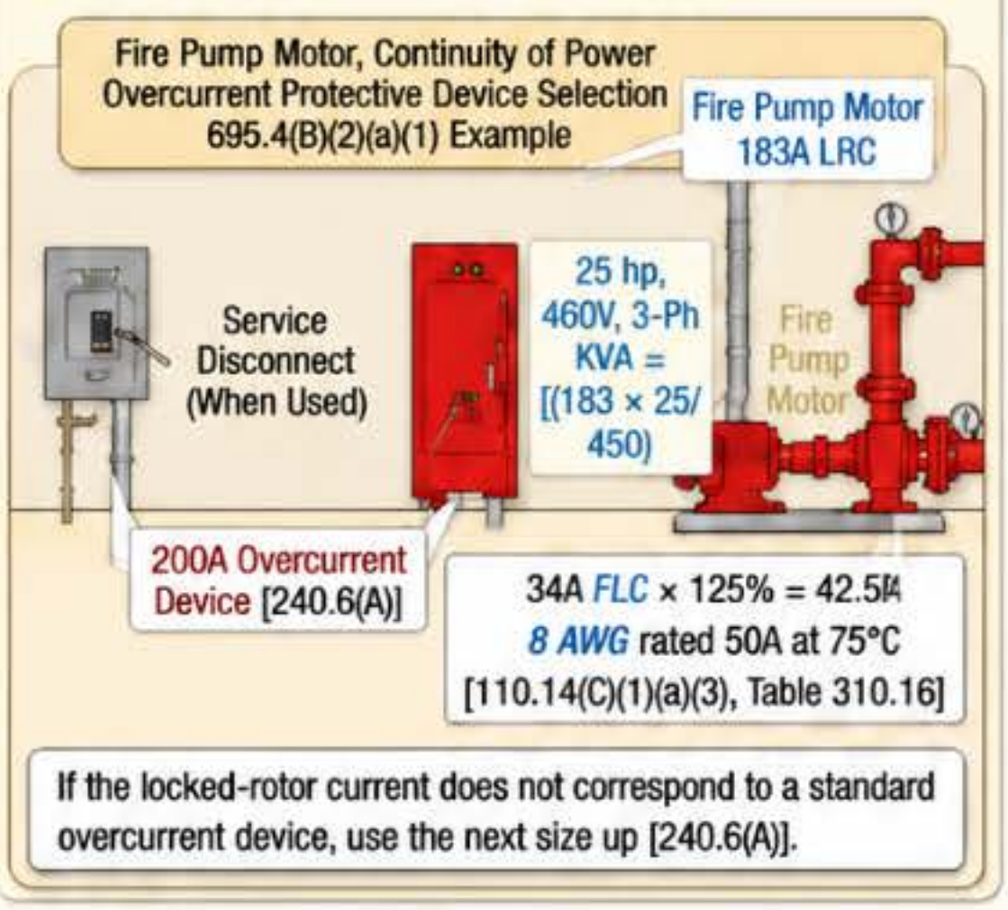


Figure 695–4

Solution:

Locked-Rotor Current = 183A

Protection Size = 200A [240.6(A) and 695.4(B)(2)(a)(1)]

Determine the branch-circuit conductor at 125 percent of the motor's FLC [Table 310.16, 430.22, and Table 430.250].

Branch-Circuit Conductor = 34A × 125%

= 42.50A

Use an 8 AWG conductor rated 50A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].

Answer: *(b) 200A, 8 AWG*

If the locked-rotor current value does not correspond to a standard overcurrent device size, the next larger standard overcurrent device size must be used in accordance with 240.6.

(2) Overcurrent protection must be listed for fire pump service and must not:

a. open within 2 minutes at 600 percent of the full-load current of the pump motor(s).

b. open with a re-start locked-rotor current of 24 times the full-load current of the pump motor(s).

c. open within 10 minutes at 300 percent of the full-load current of the pump motor(s).

d. have a field adjustable trip setting.

(b) On-Site Standby Generators. Overcurrent protective devices between an on-site standby generator and a fire pump rotar bt bnt e de,aized in accordance with 430.62, based on the largest rating or setting of the short-circuit and ground-fault device for the largest motor FLC and the sum of other motors on the feeder.

695.5 Transformers

(A) Size. When a transformer supplies power to an electric fire pump motor, its capacity must be at least 125 percent of the total of the fire pump motor(s) and pressure maintenance pump(s) motor loads, plus 100 percent of the ampere rating of the fire pump's accessory equipment.

(B) Overcurrent Protection. The main overcurrent protective device(s) must be sized so it can handle, for an unlimited duration, the total of the locked-rotor current of the fire pump motor(s) plus the current needed for the pressure maintenance pump motor(s), and 100 percent of the nameplate current of any accessory equipment. Secondary overcurrent protection is not allowed. The rule requiring the overcurrent device to tolerate locked-rotor current without tripping does not apply to fire pump motor conductors.

695.6 Power Wiring

(A) Supply Conductors.

(1) Services and On-Site Power Production Facilities. Service conductors and conductors supplied by on-site power production facilities must be physically routed outdoors. When installed underground, they must be encased in at least 2 in. of concrete or brick [230.6].

Example: Supplying conductors within the fire pump room do not have to be encased in 2 in. of concrete or brick as required by 230.6(1) or (2).

Note: Refer to 250.24(C) for instructions on routing the grounded conductor to the service equipment.

(2) Feeder Conductors. Fire pump supply conductors must satisfy all of the following:

(1) Independent Routing. Route these conductors separately from all other wiring.

(2) Associated Fire Pump Loads. The conductors must serve only loads that are directly connected to the fire pump system.

(3) Protection from Potential Damage. Provide physical protection against possible harm due to fire, structural failure, or other operational hazards.

(4) Inside a Building. When routed through a building, the fire pump conductors must get 2-hour fire protection using any of these methods:

(a) Run the cable or raceway within at least 2 in. of concrete.

(b) Use a fire-resistive cable or a listed fire-resistive cable system.

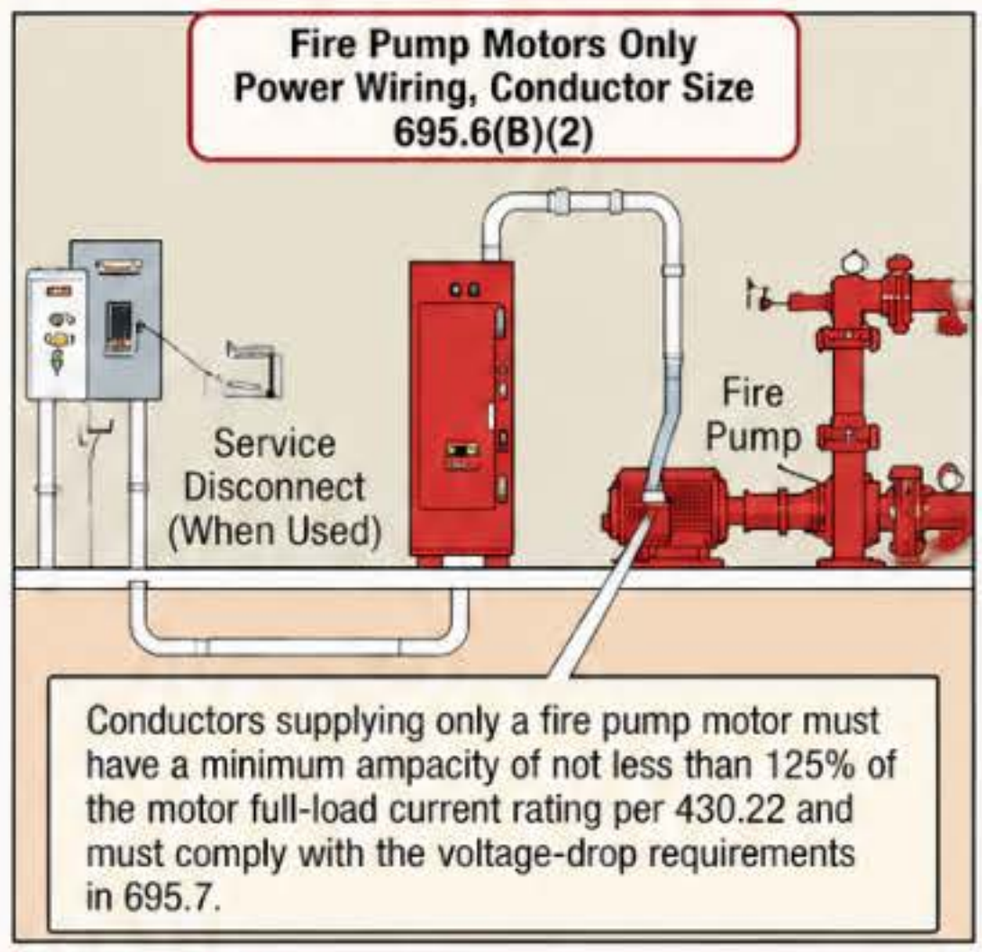
(c) Employ a cable or raceway belonging to a listed electrical circuit protective system.

Example: Conductors located between an electrical equipment room and the fire pump room are not required to have 2-hour fire protection unless otherwise required in 700.10(D).

(B) Conductor Size.

(1) Fire Pump Motors and Other Equipment. Conductors supplying a fire pump motor(s), pressure **maintenance** pumps, and associated equipment must have an ampacity of not less than 125 percent of the sum of the fire pump motor(s) **and pressure maintenance motor(s) full-load** current(s), and 100 percent of the associated fire pump accessory equipment.

(2) Fire Pump Motors Only. Conductors supplying only a fire pump motor must have an ampacity of not less than 125 percent of the motor full-load current rating in accordance with 430.22 and must comply with the voltage-drop requirements in 695.7. ▶ Figure 695–5



▶ Figure 695–5

▶ Fire Pump Conductor Size Example

Question: *What size conductor is required for a 25 hp, 460V, three-phase fire pump motor with terminals rated 75°C?* ▶ Figure 695–6

(a) 8 AWG *(b) 6 AWG* *(c) 4 AWG* *(d) 3 AWG*

Solution:

25 hp, 460V, Three-Phase Motor FLC = 34A [Table 430.250]

Determine the branch-circuit conductor at 125 percent of the motor's FLC [Table 310.16, 430.22, and Table 430.250].

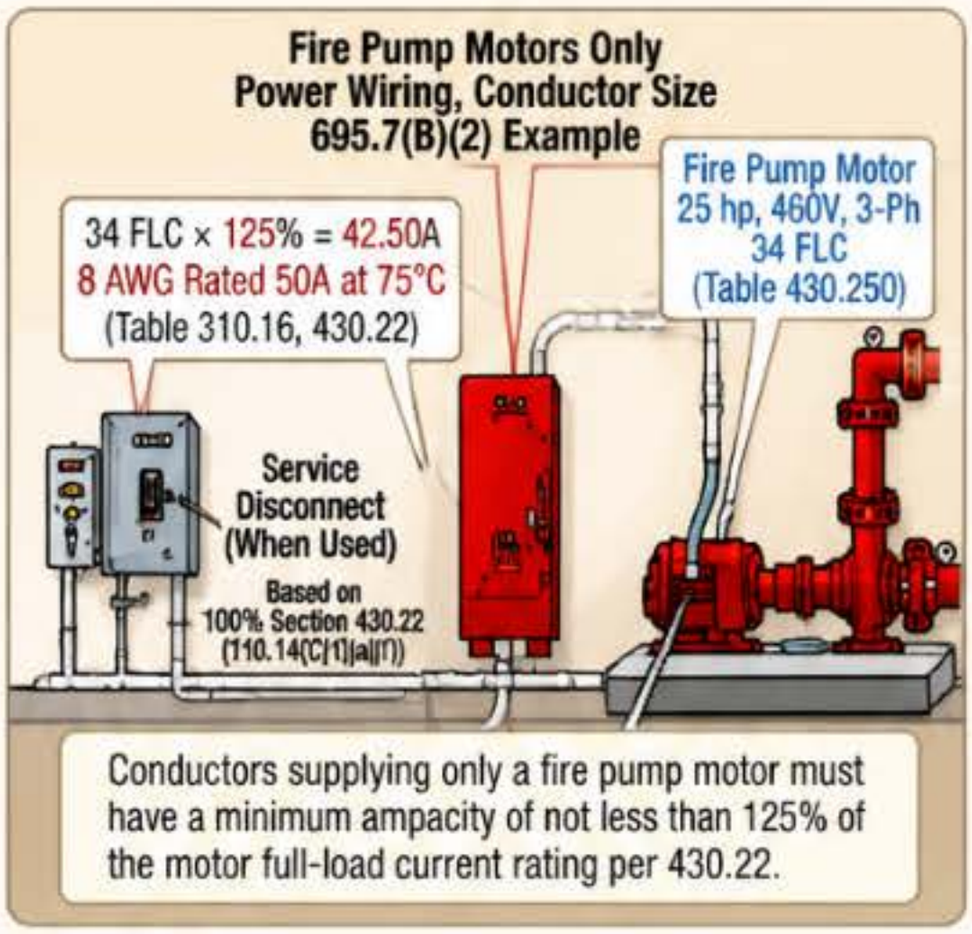
Branch-Circuit Conductor = 34A × 125%

Branch-Circuit Conductor = 42.50A

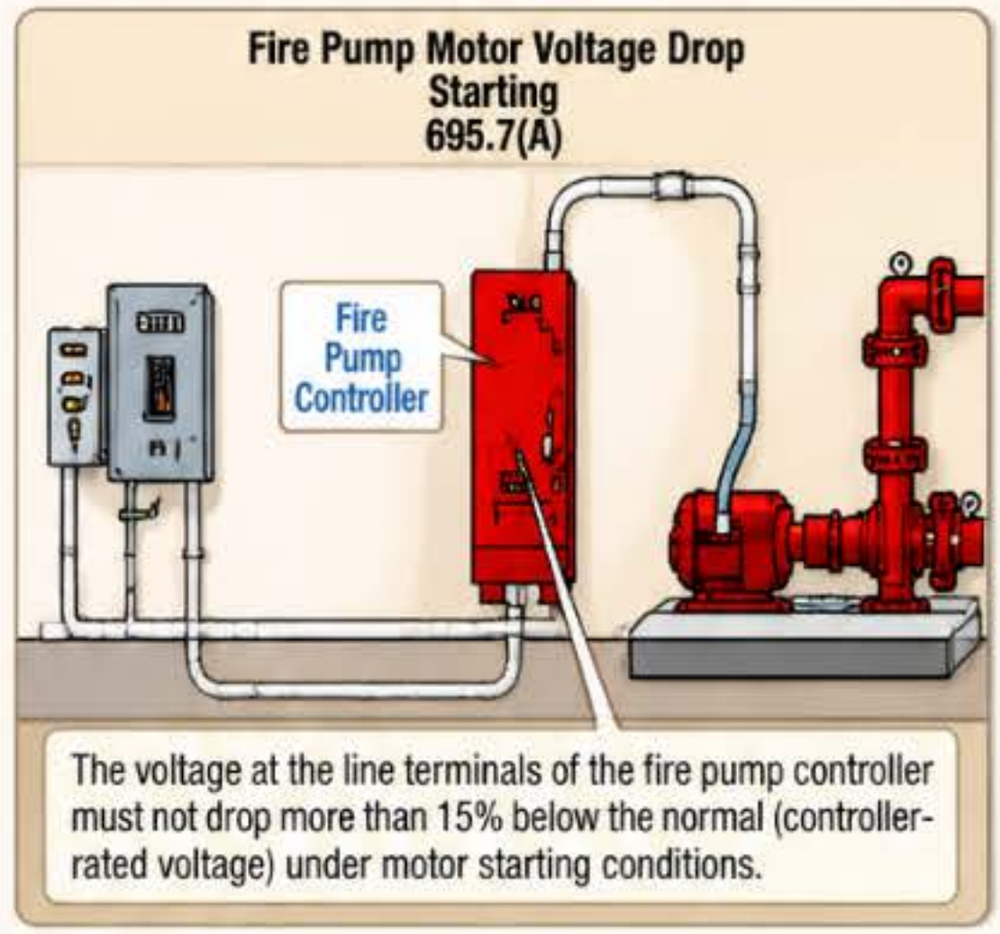
Use an 8 AWG conductor rated 50A at 75°C [110.14(C)(1)(a)(3) and Table 310.16].

Answer: *(a) 8 AWG*

Fire Pumps | 695.7



▸ Figure 695–6



▸ Figure 695–7

(D) Pump Wiring. Wiring from the fire pump controllers to the fire pump motors must be in rigid metal conduit, intermediate metal conduit, electrical metallic tubing, liquidtight flexible metal conduit, liquidtight flexible nonmetallic conduit, listed Type MC cable with an impervious covering, or Type MI cable. The connections in the motor terminal box must be made with a listed device. Twist-on, insulation-piercing type.

(G) Ground-Fault Protection of Equipment. Ground-fault protection of equipment (GFPE) is not permitted in the fire pump power circuit.

(J) Terminations. Where raceways or cables terminated at a fire pump controller, the following requirements apply:

(1) Raceway or cable fittings must be listed and identified for use in wet locations.

(2) The enclosure type rating of the raceway or cable fittings must be at least equal to that of the fire pump controller.

(3) The installation instructions of the manufacturer of the fire pump controller must be followed.

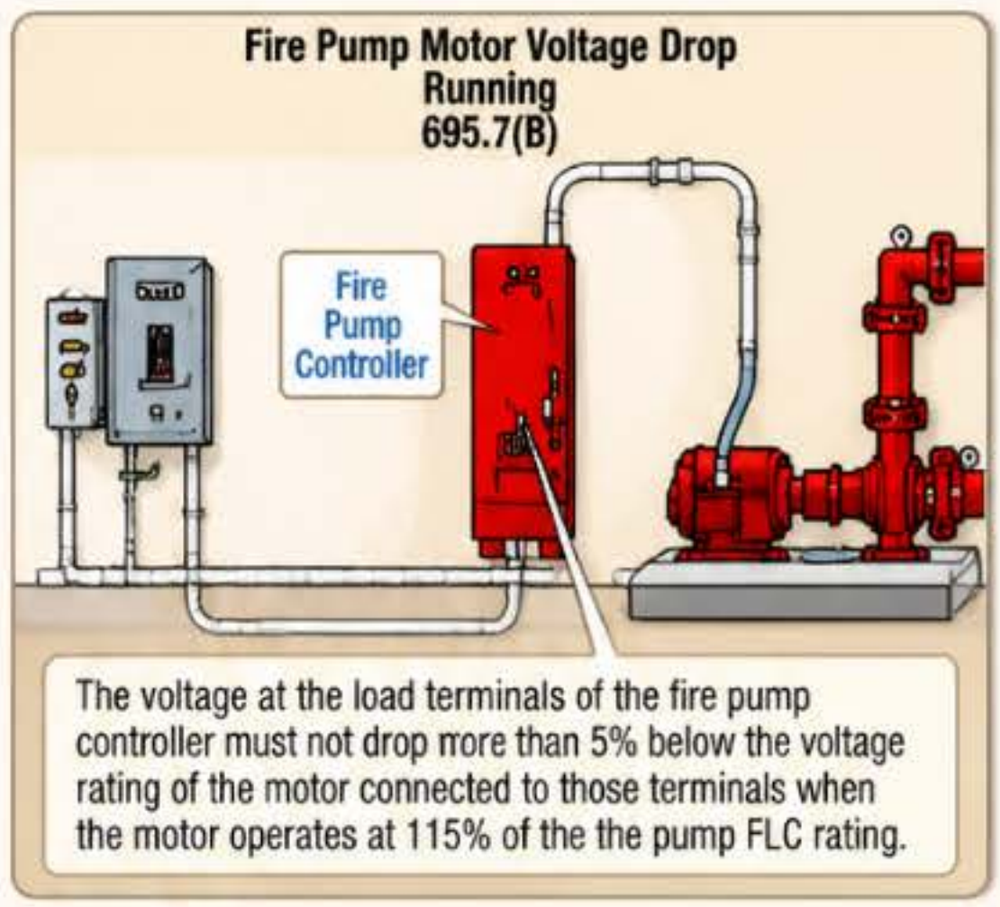
(4) Alterations to the fire pump controller, other than raceway or cable terminations, must be approved by the authority having jurisdiction.

695.7 Voltage Drop

(A) Starting. The voltage at the line terminals of the fire pump controller is not permitted to drop more than 15 percent below the normal (controller-rated voltage) under motor starting conditions. ▸ Figure 695–7

(B) Running. The voltage at the load terminals of the fire pump controller is not permitted to drop more than 5 percent below the voltage rating of the motor connected to those terminals when the motor operates at 115 percent of the fire pump motor full-load current rating.

▸ Figure 695–8



▸ Figure 695–8

Author's Commentary:

Sizing conductors for fire pump circuits to account for start-up and running voltage drop because of low power factor during start-up must be performed by a qualified person; typically an electrical engineer.

— Michael Hamilton

695.10 | Fire Pumps

695.10 Listed Equipment

Diesel engine fire pump controllers, electric fire pump controllers, electric motors, fire pump power transfer switches, foam pump controllers, and limited service controllers must all carry a listing for their intended use in fire pump service.

Fire pump controllers and transfer switches are not allowed to be field reconditioned.

695.14 Control Wiring

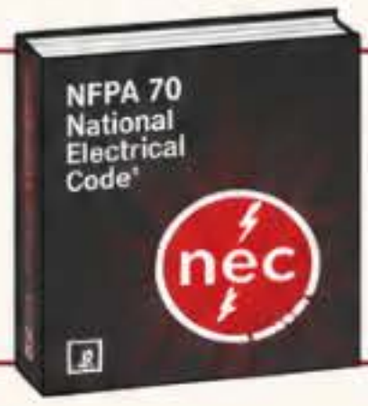
(E) Wiring Methods. Control wiring must be installed in rigid metal conduit, intermediate metal conduit, liquidtight flexible metal conduit, electrical metallic tubing, liquidtight flexible nonmetallic conduit, Type MC cable with an impervious covering, or Type MI cable.

695.15 Surge Protection

A listed surge protective device must be installed in or on the fire pump controller.

CHAPTER 6

PRACTICE QUESTIONS



Please use the *2023 Code* book to answer the following questions.

CHAPTER 6—SPECIAL EQUIPMENT

Article 600—Electric Signs and Outline Lighting

1. Article 600 covers the installation of conductors, equipment, and field wiring for _____, retrofit kits, and outline lighting, regardless of voltage.

(a) electric signs
(b) outline lighting
(c) neon tubing
(d) all of these

2. A kit consisting of primary parts, which does not include all the parts for a complete subassembly but includes a list of required parts and installation instructions to complete the subassembly in the field for a sign is called a "_____.".

(a) general use retrofit kit
(b) reconditioning kit
(c) maintenance kit
(d) sign specific retrofit kit

3. A "section sign" is a sign or _____, shipped as subassemblies, that requires field-installed wiring between the subassemblies to complete the overall sign.

(a) outline lighting system
(b) skeleton tubing system
(c) neon system
(d) sign body

4. Fixed, mobile, or portable electric signs, section signs, outline lighting, photovoltaic (PV) powered signs, and retrofit kits shall be _____, unless otherwise approved by special permission.

(a) marked
(b) approved
(c) identified for the location
(d) listed and labeled

5. Field-installed skeleton tubing shall not be required to be _____ where installed in conformance with the *Code*.

(a) listed
(b) identified for the purpose
(c) marked
(d) approved

6. Signs and outline lighting systems shall be listed and labeled, and marked with the _____.

(a) manufacturer's name, trademark, or other means of identification
(b) input voltage
(c) current rating
(d) all of these

7. For signs with a retrofitted illumination system, the sign shall be marked that the Illumination system has been _____.

(a) replaced
(b) modified
(c) refurbished
(d) updated

8. Signs with a retrofitted illumination system equipped with tubular light-emitting diode lamps powered by the existing sign sockets shall include a label meeting the requirements of 110.21(B), includes a warning not to install _____ lamps, and be visible during relamping.

(a) incandescent
(b) fluorescent
(c) LED
(d) all of these

9. The markings required on signs and outline lighting systems in 600.4(A) shall be permanent, durable, and _____ when installed in wet locations.

(a) weatherproof
(b) laminated
(c) rainproof
(d) indelible

10. Each commercial occupancy accessible to pedestrians shall have at least one sign outlet in an accessible location at each entrance to each tenant space supplied by a branch circuit rated at least _____.

(a) 15A
(b) 20A
(c) 30A
(d) 40A

11. A sign or outline lighting outlet shall not be required at commercial occupancy entrances for _____ that are intended to be used only by service personnel or employees.

(a) deliveries
(b) service corridors
(c) service hallways
(d) any of these

12. A disconnecting means for a sign, outline lighting system, or controller shall be marked to identify the _____, outline lighting system, or controller it controls.

(a) branch circuit
(b) feeder
(c) sign
(d) all of these

13. Branch circuits that supply signs shall be considered to be _____ loads for the purposes of calculations.

(a) continuous
(b) separate
(c) combined
(d) dynamic

14. Each sign and outline lighting system, feeder conductor(s), or branch circuit(s) supplying a sign, outline lighting system, or skeleton tubing shall be controlled by an externally operable switch or circuit breaker that opens all _____ conductors and controls no other load.

(a) ungrounded
(b) grounded
(c) equipment grounding
(d) all of these

15. Each sign and outline lighting system shall be controlled by an externally operable switch or circuit breaker that opens all ungrounded conductors simultaneously on _____ branch circuits.

(a) 15A
(b) 20A
(c) multiwire
(d) outdoor

16. The location of the sign and outline lighting system feeder or branch-circuit disconnect is intended to allow service or maintenance personnel and _____ complete and local control of the disconnecting means.

(a) security
(b) emergency
(c) first responders
(d) local jurisdictional

17. The disconnecting means for a sign or outline lighting system shall be permitted to be located at the point of entry to a sign and the disconnect shall be located at the point the feeder circuit or branch circuit(s) supplying a sign or outline lighting system enters a _____.

(a) sign enclosure
(b) sign body
(c) pole in accordance with 600.5(D)(3)
(d) any of these

18. A disconnect is not necessary for branch circuit(s) or feeder conductor(s) that pass through a sign when the sign is enclosed in a Chapter 3 raceway or in identified metal-jacketed cable for the location.

(a) listed
(b) labeled
(c) identified
(d) approved

19. A disconnect is not required at the entrance of a sign cabinet or sign body for branch circuit(s) or feeder conductor(s) that supply an internal _____ in a sign enclosure or sign body.

(a) switchboard(s)
(b) switchgear(s)
(c) panelboard(s)
(d) any of these

20. Where the disconnecting means is out of sight from any section of a sign or outline lighting able to be energized, the disconnecting means must be _____ in the open position in accordance with 110.25.

(a) secured
(b) bolted
(c) lockable
(d) visible when open

21. A permanent field-applied marking that identifies the location of the disconnecting means must be attached to the sign in a location visible during _____, and the warning label shall comply with 110.21(B).

(a) installation
(b) repair
(c) retrofitting
(d) servicing

22. If the disconnecting means for a sign or outline lighting is not within sight of the _____, a permanent field-applied marking showing its location must be fastened to the controller in a location visible during servicing, and the warning label shall comply with 110.21(B).

(a) controller
(b) branch circuit
(c) feeder
(d) photocell

23. Metal equipment of signs, outline lighting, and skeleton tubing systems shall be grounded by connection to the _____ of the supply branch circuit(s) or feeder using the types of equipment grounding conductors specified in 250.118.

(a) grounding electrode conductor
(b) equipment grounding conductor
(c) neutral conductor
(d) ground rod

24. Listed flexible metal conduit or listed liquidtight flexible metal conduit enclosing the secondary circuit conductor from a transformer or power supply for use with neon tubing may be used as a bonding means if the total accumulated length of the conduit in the secondary circuit does not exceed _____ ft.

(a) 6
(b) 25
(c) 50
(d) 100

25. Bonding conductors for the bonding connections of the noncurrent-carrying metal parts of signs must not be smaller than _____ AWG.

(a) 14
(b) 12
(c) 8
(d) 6

26. The bottom of sign and outline lighting system equipment shall be at least _____ ft above areas accessible to vehicles unless protected from physical damage.

(a) 12
(b) 14
(c) 16
(d) 18

27. Neon tubing, other than _____, must be easily accessible to pedestrians unless guarded against physical damage.

(a) Class I, Division 1 locations
(b) listed dry-location, portable signs
(c) fixed equipment
(d) wet-location portable signs

28. Signs and outline lighting systems must be installed so that nearby combustible materials are not exposed to temperatures higher than _____.

(a) 60°C
(b) 75°C
(c) 90°C
(d) 105°C

29. A workspace not less than 3 ft high by 3 ft wide by _____ ft deep is required for each ballast, transformer, electronic power supply, and Class 2 power source, or at any enclosure that won't be installed in a sign.

(a) 2
(b) 3
(c) 4
(d) 6

30. At least one lighting outlet with a switch or controller by a wall switch must be installed in attic areas that contain ballasts for electric signs. At least one _____ shall be provided near the normal point of entry to these spaces. The lighting outlet must be at or close to the equipment that needs service.

(a) receptacle
(b) switch
(c) point of control
(d) luminaire

31. Ballasts, transformers, electronic power supplies, and Class 2 power sources for signs must be secured in located above suspended ceilings, provided those enclosures are firmly attached in place and _____.

(a) are effectively bonded
(b) not dependent on the suspended-ceiling grid for support
(c) are rated at not more than 300V
(d) effectively grounded

Article 604—Manufactured Wiring Systems

1. A manufactured wiring system is an assembly built by a manufacturer, which cannot be examined at the building site without _____.

(a) a permit
(b) a manufacturer's representative present
(c) damage or destruction to the assembly
(d) an engineer's supervision

2. Manufactured wiring systems and associated components shall be _____.

(a) listed
(b) labeled
(c) identified
(d) approved

3. Manufactured wiring systems shall be _____ in accordance with the applicable cable or conduit article for the cable or conduit type employed.

(a) inspected and tested
(b) relocated
(c) secured and supported
(d) reassembled

Article 620—Elevators, Escalators, and Moving Walks

1. Article 620 covers the installation of electrical equipment and wiring used in connection with elevators, dumbwaiters, escalators, moving walks, platform lifts, and _____.

(a) stairway chairlifts
(b) pool lifts
(c) boat hoists
(d) all of these

2. Each 15A and 20A, 125V, single-phase receptacle installed in pits, in hoistways, on the cars of elevators and dumbwaiters associated with wind turbine tower elevators, on the platforms or in the runways and machinery spaces of platform lifts and stairway chairlifts, and in escalator and moving walk wellways shall be _____.

(a) on a GFCI-protected circuit
(b) of the GFCI type
(c) provided with GFPE protection
(d) current-limiting

3. All 15A and 20A, 125V, single-phase receptacles installed in _____, for elevators, dumbwaiters, escalators, moving walks, lifts, and chairlifts shall have ground-fault circuit-interrupter protection for personnel.

(a) machine rooms
(b) control spaces and machine spaces
(c) control rooms
(d) all of these

4. A(an) _____ branch circuit shall supply the elevator car lights and shall be permitted to supply receptacles, accessory equipment (alarm devices, alarm bells, monitoring devices not part of the control system), auxiliary lighting power source, and ventilation on each elevator car or inside the operation controller.

(a) GFCI-protected
(b) AFCI-protected
(c) multiwire
(d) separate

5. The branch circuit(s) supplying the lighting for an elevator machine room/machinery space shall be separate from the branch circuit(s) supplying the receptacle(s). The required lighting shall not be connected to the load side of a(an) _____.

(a) local subpanel
(b) SWD-type circuit breaker
(c) HID-type circuit breaker
(d) GFCI

6. A(an) _____ shall be located at the point of entry to an elevator machine room.

(a) directory
(b) lighting switch
(c) control circuit disconnecting means
(d) emergency exit map

7. At least _____ 125V, single-phase, 15A or 20A, duplex receptacle(s) shall be provided in each elevator machine room and elevator machinery space.

(a) one
(b) two
(c) three
(d) four

8. Separate _____ shall supply the elevator hoistway pit lighting and receptacles and the required lighting shall not be connected to the load side of a ground-fault circuit interrupter.

(a) feeders
(b) subpanels
(c) emergency systems
(d) branch circuits

9. The lighting switch for hoistway pits shall be readily accessible from the _____.

(a) pit access door
(b) elevator car
(c) floor of the pit
(d) machinery room

10. At least _____ 125V, single-phase, 15A or 20A, duplex receptacle(s) shall be provided in the elevator hoistway pit.

(a) one
(b) two
(c) three
(d) four

11. Only wiring, raceways, and cables used directly in connection with an elevator shall be permitted inside the hoistway and the machine room.

(a) True
(b) False

12. A single means for disconnecting all ungrounded main power supply conductors for each _____ shall be provided and be designed so that no pole can be operated independently.

(a) elevator or dumbwaiter
(b) escalator or moving walk
(c) platform lift or stairway chairlift
(d) any of these

13. The disconnecting means for an elevator or escalator shall be an enclosed externally operable circuit breaker or fused motor circuit switch that is _____.

(a) capable of interrupting six times the locked-rotor current
(b) lockable
(c) inherently protected
(d) suitable for use as service equipment

14. The location of the disconnecting means for an elevator shall be located where it is _____ to qualified persons.

(a) accessible
(b) readily accessible
(c) disclosed only
(d) accessible only with a key

Author's Commentary:

These questions focus on Article 620 requirements for elevator electrical installations, including branch circuits, lighting, receptacles, disconnecting means, and accessibility.

— Michael Hamilton

Article 625—Electric Vehicle Power Transfer System

1. Article 625 governs the electrical conductors and related components that connect an electric vehicle to premises wiring for the following objectives:

   (a) charging
   (b) power export
   (c) bidirectional current flow
   (d) all of these

2. "Electric vehicle supply equipment" denotes the conductors and electric vehicle connectors, installed specifically for the intended purpose of transferring energy between the premises wiring system and the electric vehicle.

   (a) attachment plugs
   (b) fittings
   (c) power outlets
   (d) all of these

3. Electric vehicle power export equipment and electric vehicle supply equipment are sometimes combined in a single assembly, referred to as a "_____ EVSE."

   (a) directional
   (b) supplemental
   (c) bi-directional
   (d) integrated

4. "Wireless power transfer equipment" (WPTE) refers to a system that includes a charger power converter and a primary pad that are _____.

   (a) integrated
   (b) contained within one enclosure
   (c) separate units or contained within one enclosure
   (d) bidirectional

5. All equipment that falls under the scope of Article 625 shall be _____.

   (a) listed
   (b) labeled
   (c) identified
   (d) all of these

6. Each outlet installed for the purpose of charging electric vehicles shall be supplied by a dedicated _____ circuit that shall have no other outlets.

   (a) parallel branch
   (b) feeder
   (c) branch
   (d) GFCI-protected

7. Conductors that supply electric vehicle supply equipment shall be sized for continuous duty and have an ampacity of not less than 125 percent of the maximum load of the electric vehicle supply equipment.

   (a) True
   (d) False

8. For electric vehicle equipment rated more than _____ or more than 150 volts-to-ground, the disconnecting means shall be provided and installed in a readily accessible location.

   (a) 20A
   (b) 30A
   (c) 50A
   (d) 60A

9. The electric vehicle supply equipment located outdoors shall be situated to permit direct electrical coupling of the EV connector (conductor or inductive) to the electric vehicle.

   (a) True
   (b) False

10. The _____ of electric vehicle supply equipment located indoors shall be positioned not less than 18 in. above the floor level.

    (a) attachment plugs
    (b) fittings
    (c) power outlets
    (d) coupling means

11. Where electric vehicle storage batteries are used or electric vehicle supply equipment is _____ for charging electric vehicles indoors without ventilation, mechanical ventilation shall not be required.

    (a) listed
    (b) labeled
    (c) identified
    (d) all of these

ARTICLE 630—ELECTRIC WELDERS

12. Where the electric vehicles supply equipment is listed for charging electric vehicles that require ventilation for indoor charging, mechanical ventilation shall include permanently installed supply and exhaust equipment located to intake from inside the building and vent outdoors.

(a) True
(b) False

13. In addition to the requirements in 210.8, all receptacles installed for the connection of electric vehicle charging shall have arc-fault circuit-interrupter protection.

(a) True
(b) False

Article 630—Electric Welders

1. Article ____ covers apparatus for electric arc welding, resistance welding, plasma cutting, and other similar welding and cutting process equipment that is connected to an electrical supply system.

(a) 600
(b) 620
(c) 630
(d) 680

2. All welding and cutting power equipment under the scope of Article 630 shall be ____.

(a) identified
(b) labeled
(c) listed
(d) approved

3. The ampacity of the supply conductors to an individual electric arc welder shall not be less than the effective current value on the rating plate.

(a) True
(b) False

4. Minimum conductor ampacity feeding a group of welders shall be based on the individual currents determined in 630.11(A) as the sum of ____ percent of the two largest welders, plus 85 percent of the third largest welder, plus 70 percent of the fourth largest welder, plus 60 percent of all remaining welders.

(a) 100
(b) 115
(c) 125
(d) 175

5. An arc welder shall have overcurrent protection rated or set at not more than ____ percent of the rated primary current of the welder.

(a) 100
(b) 125
(c) 150
(d) 200

6. A disconnecting means shall be provided in the supply circuit for each arc welder not equipped with ____, and the identity shall be marked in accordance with 110.22(A).

(a) a governor
(b) a shunt-trip device
(c) an integral disconnect
(d) GFCI protection

7. The required ampacity for the supply conductors for a resistance welder with a duty cycle of 15 percent and a primary current of 21A is ____.

(a) 5.67A
(b) 6.72A
(c) 8.19A
(d) 9.45A

8. Each resistance welder shall have an overcurrent device rated or set at not more than ____ percent of the rated primary current of the welder.

(a) 80
(b) 100
(c) 125
(d) 300

Article 640 | Practice Questions

9. Conductors that supply one or more resistance welders must be guarded by an overcurrent device rated at or configured for no more than _____ percent of the conductor ampacity.

(a) 80
(b) 100
(c) 125
(d) 300

10. A _____ is required to interrupt power to each resistance welder and isolate its control apparatus from the supply circuit.

(a) contactor
(b) relay
(c) magnetic starter
(d) switch or circuit breaker

Article 640—Audio Signal Amplification and Reproduction Equipment

1. Electronic musical instruments and electronic organs are covered by the provisions of Article 640.

(a) True
(b) False

2. If an audio distribution cable is not terminated at a device and is not labeled for later use, it is treated as abandoned.

(a) True
(b) False

3. Audio signal processing, amplification, and reproduction equipment described in 300.22(B) shall only be installed in ducts that are manufactured specifically for environmental air.

(a) speakers
(b) Class 3 circuits
(c) equipment and circuits
(d) only power-limited circuits

4. Class 2 and Class 3 cables for audio signal processing, amplification, and reproduction equipment may be installed in ducts built for environmental air in accordance with 725.135(B) and Table 725.154.

(a) True
(d) False

5. Class 2 and Class 3 cables for audio signal processing, amplification, and reproduction equipment installed in accordance with 725.135(C) and Table 725.154 shall not be permitted to be installed in other spaces used for environmental air (plenums).

(a) True
(b) False

6. Amplifiers, loudspeakers, and similar equipment shall be situated or shielded so they are protected from exposure or physical damage that could result in _____.

(a) a fire
(b) shock
(c) personal hazard
(d) any of these

7. Exposed audio cables must be secured using _____ or comparable fittings that are designed and installed so they will not damage the cable.

(a) straps
(b) staples
(c) hangers
(d) any of these

8. The reachable portion of abandoned audio distribution cables shall be removed.

(a) True
(b) False

9. Audio cables intended for future use must be identified with a tag that is durable enough to resist _____.

(a) moisture
(b) humidity
(c) the environment involved
(d) temperature fluctuations

10. Audio system equipment that is fed by branch-circuit power shall not be mounted horizontally within _____. of the inside wall of a pool, spa, hot tub, fountain, or the prevailing or tidal high water mark.

(a) 18 in.
(b) 2 ft
(c) 5 ft
(d) 10 ft

Article 645—Information Technology Equipment (ITE)

1. Article 645 governs the installation of information technology equipment and the systems within IT equipment rooms that must comply with the requirements of 645.4.

(a) equipment
(b) power-supply wiring
(c) interconnecting wiring
(d) all of these

2. Supply conductors and interconnecting cables serving information technology equipment are not terminated on the equipment and do not have a tag for future use if the equipment is considered to be ____.

(a) abandoned
(b) unused
(c) for future use
(d) removed from service

3. Section(s) _____ shall apply to penetrations of the fire-resistant information technology room boundary.

(a) 300.21
(b) 770.26
(c) 800.26
(d) all of these

4. Which of the following sections and tables apply to wiring and cabling in other spaces used for environmental air (plenums) above an information technology equipment room?

(a) Wiring methods: 300.22(C)(1)
(b) Class 2, Class 3, and PLTC cables: 725.135(C) and Table 725.154
(c) Fire alarm systems: 760.53(B)(2), 760.135(C), and Table 760.154
(d) all of these

5. Which of the following sections and tables apply to wiring and cabling in other spaces used for environmental air (plenums) above an information technology equipment room?

(a) Optical fiber cables: 770.113(C) and Table 770.154(a)
(b) Communications circuits: 800.113 and Table 800.154(a)
(c) CATV and radio distribution systems: 820.113 and Table 800.154(a)
(d) all of these

6. Article 645 does not apply unless an information technology equipment room contains ____.

(a) a disconnecting means complying with 645.10
(b) a separate heating/ventilating/air-conditioning (HVAC) system
(c) separation by fire-resistance-rated walls, floors, and ceilings
(d) all of these

7. Ventilation in the underfloor area of an information technology equipment room shall be used in that room only, unless provided with fire/smoke dampers at the point of penetration of the room boundary.

(a) True
(b) False

8. Only electrical equipment and wiring associated with the operation of the information technology room is allowed to be installed in the room. Examples include HVAC systems, communications systems, telephone, fire alarm systems, security systems, water detection systems, and other related protective equipment.

(a) True
(b) False

9. Branch-circuit conductors for data processing equipment in information technology equipment rooms shall have an ampacity not less than ____ of the total connected load.

(a) 80 percent
(b) 100 percent
(c) 125 percent
(d) the sum

10. Where supply cords of listed information technology equipment are installed under a raised floor, they shall not be longer than _____ ft.

(a) 10
(b) 12
(c) 15
(d) 16

11. Separate information technology equipment units shall be permitted to be interconnected by means of listed cables and cable assemblies. Where exposed to physical damage, supply circuits and interconnecting cables shall be protected.

(a) True
(b) False

Article 645 | Practice Questions

12. Where the area under the floor is accessible and openings minimize the entrance of debris beneath the floor, _____, and receptacles associated with the information technology equipment shall be permitted.

    (a) power and communication cables
    (b) connecting and interconnecting cables
    (c) cord-and-plug connections
    (d) all of these

13. Information technology equipment branch circuit supply conductorinder a raised floor shall be permitted to be installed only in an electrical metallic tubing (EMT) raceway.

    (a) True
    (b) False

14. Nonmetallic raceways for branch circuit supply conductors can be installed in the area under raised floors of approved construction of information technology equipment rooms.

    (a) True
    (b) False

15. Which of the following are permitted under raised floors of information technology equipment rooms for information technology equipment?

    (a) supply cords of listed information technology equipment in accordance with 645.5(B)
    (b) interconnecting cables enclosed in a raceway
    (c) equipment grounding conductors
    (d) all of these

16. Types CL2, CM, and CMG cables are permitted within the raised floor area of an information technology equipment room if installed in accordance with 725.154(A).

    (a) True
    (b) False

17. Interconnecting cables under raised floors that support information technology equipment shall be permitted to be listed Type _____ cable having adequate fire-resistant characteristics suitable for use under raised floors of an information technology equipment room.

    (a) RF
    (b) UF
    (c) LS
    (d) DP

18. In addition to optical fiber cables installed in accordance with 770.113(C), Types OFNR, OFCR, OFN, and OFC shall be permitted under raised floors of an information technology equipment room.

    (a) True
    (b) False

19. Power cables, communications cables, connecting cables, interconnecting cables, and associated boxes, connectors, plugs, and receptacles that are listed as part of, or for, information technology equipment shall not be required to be secured in place where installed _____..

    (a) above suspended ceilings
    (b) exposed on interior walls
    (c) under raised floors
    (d) exposed on exterior walls

20. The accessible portion of abandoned interconnecting cables under an information technology room raised floor shall be removed unless the cables are contained within a _____.

    (a) raceway
    (b) restricted area
    (c) junction box
    (d) cable tray

21. Installed supply circuits and interconnecting cables identified for future use in information technology equipment rooms shall be marked with a tag of sufficient durability to withstand the environment involved which shall include the _____.

    (a) date the cable was identified for future use
    (b) date of intended use
    (c) intended future use of the cable
    (d) all of these

22. An approved means shall be provided to disconnect power to all electronic equipment in the information technology equipment room or in designated zones within the room. There shall also be a similar approved means to disconnect the power to all _____ serving the room or designated zones.

    (a) dedicated HVAC systems
    (b) lighting circuits
    (c) audio systems
    (d) all of these

23. Remote disconnect controls that shut off power to any electronic equipment in an information technology equipment room must be placed at an approved _____. location.

(a) accessible
(b) readily accessible
(c) secured
(d) restricted

24. A single control is allowed for the remote disconnection of both electronic equipment power and HVAC systems when both are grouped and identifie.

(a) True
(b) False

25. All noncurrent-carrying metal parts of an information technology system must be _____.

(a) GFPE protected
(b) inaccessible to non-qualified personnel
(c) GFCI protected
(d) bonded to an equipment grounding conductor or double insulated

Article 680—Swimming Pools, Spas, Hot Tubs, Fountains, and Similar Installations

1. Electrical wiring for, and equipment in or near, all swimming pools, wading pools, therapeutic pools, and decorative pools is covered in Article _____.

(a) 555
(b) 600
(c) 680
(d) 690

2. An electrically powered lift that allows access to and from a pool or spa for people with disabilities is known as an "electrically powered _____. lift."

(a) spa
(b) disability
(c) pool
(d) tub

3. Per Article 680, the definition of a "fountain" includes drinking water coolers.

(a) True
(b) False

4. For pools, fountains, and similar installations, the low-voltage contact limit is not to exceed _____.

(a) 15V (RMS) for sinusoidal ac or 21.20V peak for nonsinusoidal ac
(b) 30V for continuous dc
(c) 12.40V peak for dc that is interrupted at a rate of 1 to 200Hz
(d) all of these

5. A "spa" or "hot tub" is a hydromassage pool or tub that is designed to have the contents drained or discharged after each use.

(a) True
(b) False

6. A "wet-niche luminaire" is intended to be installed in a _____.

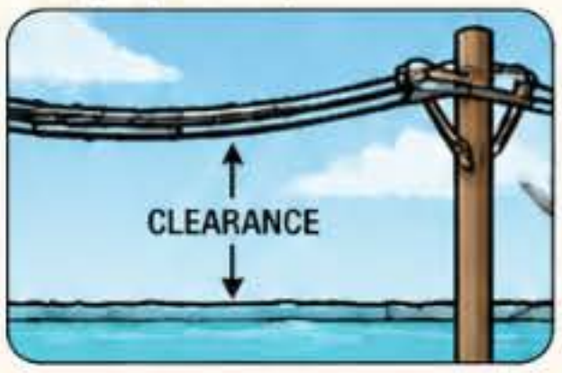
(a) transformer
(b) forming shell
(c) hydromassage bathtub
(d) all of these

7. After permanently installed swimming pools are completed, the authority having jurisdiction must allow for inspection and testing to be conducted _____.

(a) seasonal
(b) monthly
(c) periodic
(d) annual

8. Insulated overhead service conductors that are bundled together with a bare messenger and are used at not over 750 volts to ground shall maintain a _____. ft clearance in any direction to the water level of pools, fountains, and similar installations.

(a) 14
(b) 16
(c) 20
(d) 22½



9. Heating elements in electric pool water heaters must be subdivided into loads not exceeding _____.

(a) 20A
(b) 35A
(c) 48A
(d) 60A

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10. Underground wiring must not be installed without a conduit when such wiring is required to energize pool equipment allowed by Article 680, and the _____ cover depth values must be as listed in Table 300.5.

(a) maximum
(b) permissible
(c) minimum
(d) any of these

11. The disconnect serving pool equipment must be locatable _____ and at least 5 ft from the water's edge, unless a permanent barrier separates it.

(a) secured
(b) at least 24 in. higher than the highest water level
(c) capable of being locked in the open position
(d) readily accessible and within sight of the equipment

12. Wiring approaches outlined in 680.14 may be _____ for use in corrosive environments.

(a) listed
(b) labeled
(c) identified
(d) listed and identified

13. Wiring methods for pool motors in corrosive locations that are permanently installed and fully comply with 680.14 or insulated copper conductors sized to Table 250.122, but not smaller than _____ AWG.

(a) 18
(b) 16
(c) 14
(d) 12

14. Receptacles supplying pool motors by branch circuits rated 150V or less to ground and _____ or less, single- or three-phase, shall have Class A GFCI protection.

(a) 20A
(b) 30A
(c) 50A
(d) 60A

15. GFCI-protected receptacles that energize water-pump motors for the pool's circulation and sanitation must be located no closer than _____ ft from the pool's interior surface.

(a) 3
(b) 6
(c) 8
(d) 12

16. All receptacles on branch circuits rated _____ or less to ground within a pool equipment room must have GFCI protection.

(a) 110V
(b) 125V
(c) 150V
(d) 250V

17. New luminaires installed above outdoor pools or adjacent areas extending _____ ft horizontally from the pool's interior must be mounted no lower than 12 ft above the highest water level.

(a) 3
(b) 5
(c) 10
(d) 12

18. Low-voltage gas-discharge luminaires, decorative fireplaces, fire pits, and similar items placed in permanent installations may be installed in these locations when they comply with 680.26(B).

(a) True
(b) False

19. Receptacles inside or surrounding pool areas must be mounted no nearer than _____ ft to the pool walls.

(a) 5
(b) 8
(c) 10
(d) 20

20. Wet-location luminaires must be positioned with the top of the lens no less than _____ in. beneath the normal water line of the pool.

(a) 6
(b) 12
(c) 18
(d) 24

21. Wet-niche luminaires shall be connected to an equipment grounding conductor not smaller than ____ AWG.

(a) 12
(b) 10
(c) 8
(d) 6

22. The junction box connected to a conduit that extends to the forming shell of a luminaire that operates at over 15V shall be located not less than ____ in. above the ground level or pool deck.

(a) 4
(b) 6
(c) 8
(d) 12

23. Junction boxes for pool lighting shall be located not less than ____ ft from the inside wall of a pool unless separated by a fence or wall.

(a) 3
(b) 4
(c) 6
(d) 8

24. The ____ terminals of a junction box, transformer enclosure, or other enclosure in the supply circuit to a wet-niche or no-niche luminaire and the field-wiring chamber of a dry-niche luminaire shall be connected to the equipment grounding terminal of the panelboard.

(a) equipment grounding
(b) grounded
(c) grounding terminals
(d) ungrounded

25. An 8 AWG or larger solid copper equipotential bonding conductor shall be extended to service equipment to eliminate voltage gradients in the pool area.

(a) True
(b) False

26. For equipotential bonding, the perimeter surface to be bonded shall be considered to extend for ____ ft horizontally beyond the inside walls of the pool and shall include unpaved surfaces and other types of paving.

(a) 3
(b) 5
(c) 10
(d) 12

27. Metallic pool cover anchors intended for insertion in a concrete or masonry deck surface, 1 in. or less in any dimension and 2 in. or less in length shall require bonding.

(a) True
(b) False

28. Where a double-insulated water pool pump motor is installed where there is no connection between the swimming pool equipotential bondingmeans and the equipment grounding system for the premises, a solid 8 AWG copper bonding conductor shall be connected to ____.

(a) a ground rod
(b) the equipment grounding conductor of the motor circuit
(c) an 8 AWG bonding grid
(d) any of these

29. The electric motors, controllers, and wiring for an electrically operated pool cover shall be located at least ____ ft from the inside wall of the pool or separated from the pool by a permanent barrier.

(a) 5
(b) 6
(c) 10
(d) 20

30. Circuits serving gas-fired swimming pool and spa water heaters operating at voltages above the low-voltage contact limit shall be provided with ____ protection for personnel.

(a) GFCI
(b) AFCI
(c) combined AFCI/GFCI
(d) a gas valve emergency shut-off

31. All 15A and 20A, 125V receptacles located within _____ ft of the inside walls of a storable pool, storable spa, or storable hot tub shall be GFCI protect-. ected.

(a) 8
(b) 10
(c) 15
(d) 20

32. In spas or hot tubs, a clearly labeled emergency shutoff or control switch shall be _____, not less than 5 ft away, adjacent to, and within sight of the spa or hot tub.

(a) accessible
(b) readily accessible
(c) available
(d) of the pneumatic type

33. The equipotential bonding requirements for perimeter surfaces contained in 680.26(B)(2) do not apply to a listed self-contained spa or hot tub installed above a finished floor.

(a) True
(b) False

34. Receptacles rated 30A or less, 125V located within 10 ft of the inside walls of an indoor spa or hot tub, shall be _____.

(a) GFCI protected
(b) AFCI protected
(c) of the twist-locking type
(d) readily accessible

35. The branch circuit supplying submersible fountain equipment shall be _____ unless the equipment is listed for operation at not more than 15V.

(a) not greater than 240V nominal
(b) GFCI protected
(c) not less than 20A
(d) rated at least 30V

36. Metal piping systems associated with a fountain shall be bonded to the equipment grounding conductor of the _____.

(a) branch circuit supplying the fountain
(b) bonding grid
(c) equipotential plane
(d) grounding electrode system

37. Fountain electrical equipment that is supplied by a flexible cord shall have all exposed noncurrent-carrying metal parts grounded by an insulated copper equipment grounding conductor that is an integral part of this _____.

(a) cord
(b) feeder circuit
(c) branch circuit
(d) fountain

38. Electric signs installed within a fountain or within _____ ft of the fountain edge, shall have ground-fault circuit-interrupter protection for personnel.

(a) 2
(b) 5
(c) 6
(d) 10

39. Outlets supplying all permanently installed nonsubmersible fountain pump motors rated 250V or less and _____ or less, single- or three-phase, shall be provided with ground-fault circuit-interrupter protection.

(a) 20A
(b) 30A
(c) 50A
(d) 60A

40. Where installed for hydromassage bathtubs, double-insulated _____ shall not be bonded.

(a) motors and blowers
(b) cords
(c) cables
(d) fittings

Article 690—Solar Photovoltaic (PV) Systems

1. Article 690 applies to solar PV systems, including _____.

(a) array circuit(s), inverter(s), and controller(s) for such PV systems
(b) those interactive with other electrical power production sources or stand-alone, or both
(c) PV systems with ac or dc output for utilization
(d) all of these

2. In accordance with Article 690, an "ac module system" is an assembly or subassembly of _____ that are evaluated, identified, and defined as a system.

(a) ac modules
(b) wiring methods
(c) material
(d) all of these

3. In accordance with Article 690, a "dc-to-dc ____ circuit" is the dc circuit conductors connected to the output of a dc combiner for dc-to-dc converter source circuits.

(a) converter output
(b) converter control
(c) inverter output
(d) inverter control

4. In accordance with Article 690, a "dc combiner" is an enclosure that includes devices used to connect two or more PV system dc circuits in ____.

(a) series
(b) series-parallel
(c) parallel
(d) parallel-series

5. In accordance with Article 690, a solidly grounded PV system is often connected to ground through an electronic means internal to an inverter or charge controller that provides ground-fault protection.

(a) True
(b) False

6. In PV systems, a "_____ circuit" is an electrical subset of a PV system that has two conductors in the output circuit, one positive (+) and one negative (–).

(a) bipolar
(b) monopole
(c) double-pole
(d) module

7. In accordance with Article 690, a "PV system dc circuit" includes any dc conductor(s) in PV source circuits, PV output circuits, _____ converter source circuits, and dc-to-dc converter output circuits.

(a) ac-to-dc
(b) dc-to-ac
(c) dc-to-dc
(d) any of these

8. PV systems are permitted to supply a building or other structure in addition to any other _____ supply system(s).

(a) electrical
(b) telephone
(c) data
(d) communications

9. The installation of PV equipment and all associated wiring and interconnections shall be performed only by _____.

(a) licensed electricians
(b) qualified personnel
(c) master electricians
(d) journeyman electricians

10. PV system equipment and disconnecting means are permitted to be installed in a bathroom when listed for the application.

(a) True
(b) False

11. Article 690 requirements pertaining to dc PV source circuits do not apply to ac PV modules since the PV source circuit, conductors, and inverters are considered as internal wiring of the ac module.

(a) True
(b) False

12. For one- and two-family dwellings, the maximum voltage for PV system dc circuits is limited to ____.

(a) 30V
(b) 50V
(c) 600V
(d) 1,000V

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13. In a dc PV source circuit or output circuit, the highest voltage that is allowed after adjustment for the coolest expected ambient temperature, which is used for that circuit, can be calculated in accordance with the instructions provided on the equipment.

(a) True
(b) False

14. For PV systems source circuits or output circuits that have a generating capacity of _____ kW or more, the maximum voltage may be determined using an undocumented and stamped PV system design, based on an industry standard approach. This calculation must be done by a qualified, licensed electrical professional.

(a) 25
(b) 50
(c) 75
(d) 100

15. For PV dc circuits connected to the output of a single dc-to-dc converter, the _____ is established according to the directions listed on or with the converter.

(a) minimum voltage
(b) minimum current
(c) maximum voltage
(d) maximum current

16. To stop PV system overvoltage on bipolar circuits during a ground fault or an arc fault, each monopole subarray circuit shall be _____ from ground.

(a) grounded
(b) connected to earth
(c) isolated
(d) shielded

17. The allowable maximum output current of the PV system shall equal the total of the maximum currents from all parallel PV source circuits, as calculated in _____.

(a) 690.8(A)(1)(a)
(b) 690.8(A)(2)
(c) 690.8(A)(3)
(d) Article 220

18. In PV systems, where a single overcurrent device is used to protect two or more parallel-connected module circuits, the ampacity of each intermodule interconnection conductors shall not be less than the sum of the rating of the single overcurrent device plus _____ percent of the short-circuit current from the other parallel-connected modules.

(a) 100
(b) 115
(c) 125
(d) 150

19. In PV systems, when a circuit conductor is connected to a current-limited supply at one end, and also connected to a source having an available maximum current greater than the ampacity of the circuit conductor, the circuit conductors shall be protected from overcurrent at the point of connection to _____ current source(s).

(a) the lower
(b) the higher
(c) either
(d) both

20. Fuses or circuit breakers for PV dc circuits shall be _____ for use in PV systems.

(a) identified
(b) approved
(c) recognized
(d) listed

21. Overcurrent devices for PV source and output circuits shall be readily accessible.

(a) True
(b) False

22. Ground mounted PV system circuits that enter buildings, of which the sole purpose is to house PV system equipment, shall include a rapid shutdown function to reduce shock hazard for firefighters.

(a) True
(b) False

Author's Commentary:

These practice questions focus on key requirements for PV source and output circuits found in Article 690. Understanding these principles helps ensure safe and code-compliant PV system installations.

— Michael Hamilton

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Article 690

23. PV system circuits that are installed on or in buildings must be equipped with a rapid shutdown feature to lower the chance of electrical shock for _____.

(a) personnel
(b) employees
(c) firefighters
(d) installers

24. For PV system rapid shutdown setups, controlled conductors found outside the array boundary by more than 3 ft from the nearest array part inside a building are limited to not more than _____ within 30 seconds of rapid shutdown initiation.

(a) 15V
(b) 30V
(c) 50V
(d) 80V

25. In a single PV system, rapid shutdown initiation must happen when at least one of the following devices is operated:

(a) service disconnecting means
(b) PV system disconnecting means
(c) a readably accessible switch that indicates whether it is in the "off" or "on" position
(d) any of these

26. A means is required to disconnect the PV system from all wiring systems. This includes power systems, energy storage systems, utilization equipment, and the wiring that connects to the premises.

(a) True
(b) False

27. PV system disconnecting means on systems above _____ must be easy for unqualified people to reach, any enclosure door or hinged cover exposing live parts when open must be lockable or must provide for tool use to open.

(a) 30V
(b) 120V
(c) 240V
(d) 600V

28. The maximum count of disconnects for each PV system shall include no more than _____ switches or _____ sets of circuit breakers, or any mix of not more than _____ switches and sets of circuit breakers in one enclosure or in several separate enclosures.

(a) one
(b) six
(c) no limit
(d) a total of twelve

29. The PV system disconnecting means must have ratings that are sufficient for the _____ available at the terminals of the PV system disconnect.

(a) maximum circuit current
(b) available fault current
(c) voltage
(d) all of these

30. For PV system equipment, isolating means must be installed within the equipment or within sight and within _____ ft of the equipment.

(a) 3
(b) 10
(c) 25
(d) 50

31. Which of the following is an isolating device for PV system equipment?

(a) A mating connector that meets the criteria of 690.33 and is listed for use with specific PV equipment.
(b) A finger-safe fuse holder that needs a tool to move the device to the open (off) position.
(c) An isolating device referenced for the intended application.
(d) any of these

32. All points of termination, connections, and splices of the conductors in PV output circuits and inverter input and output circuits must be identifiable.

(a) True
(d) False

Article 690 Practice Questions

33. Where the conductors of more than one PV system occupy the same junction box or raceway with removable cover(s), the ac and dc conductors of each system shall be grouped separately by cable ties or similar means at least once, and then shall tie grouped at intervals not to exceed ____ ft.

(a) 1
(b) 3
(c) 6
(d) 10

34. Single-conductor cable ____ sunlight resistant and Type USE-2 and RHW-2 cable can be run exposed at outdoor locations for PV source circuits within the PV array.

(a) approved
(b) listed or labeled
(c) marked
(d) manufacturer certified

35. Where inside buildings, PV system dc circuits that exceed 30V or 8A installed where Type MC cable smaller than ____ in. in diameter containing PV power circuit conductors is installed across ceilings or floor joists, the raceway or cable shall be protected by substantial guard strips that are at least as high as the raceway or cable.

(a) ⅜
(b) ½
(c) ¾
(d) 1

36. Labels or markings of PV system raceways and enclosures shall be suitable for the environment and be placed with a maximum of ____ ft of spacing.

(a) 5
(b) 10
(c) 20
(d) 25

37. Fittings and connectors that are intended to be concealed at the time of on-site assembly, where ____ for such use, shall be permitted for on-site interconnection of modules or other array components.

(a) approved
(b) identified
(c) marked
(d) listed

38. PV systems that exceed 30V or 8A shall be provided with direct-current ____ to reduce fire hazards.

(a) arc-fault protection
(b) rectifier protection
(c) ground-fault monitors
(d) ground-fault protection

39. Ground-fault protection of PV system equipment shall provide indication of ground faults at a readily accessible location. Examples of indication include but are not limited to ____.

(a) a remote indicator light
(b) alarm system monitoring
(c) web-based services
(d) any of these

40. Devices and systems used for mounting PV modules that are also used for bonding module frames shall be ____ for bonding PV modules. Devices that mount adjacent PV modules shall be permitted for bonding adjacent PV modules.

(a) listed
(b) labeled
(c) identified
(d) all of these

41. Where no overcurrent protection is provided for the PV circuit, an assumed overcurrent device rated in accordance with 690.9(B) shall be used to size the equipment grounding conductor in accordance with ____.

(a) 250.66
(b) 250.102(C)(1)
(c) 250.122
(d) Table 250.122

42. For PV systems that are not solidly grounded, the equipment grounding conductor for the output of the PV system, where connected to associated distribution equipment connected to a grounding electrode system, shall be permitted to be the only connection to ground for the system.

(a) True
(b) False

43. Facilities with stand-alone systems shall have ____ installed in accordance with 710.10.

(a) plaques
(b) directories
(c) plaques and directories
(d) plaques or directories

44. Buildings with PV systems shall have a permanent label located at each ____ location to which the PV systems are connected or at an approved readily visible location and shall indicate the location of rapid shutdown initiation devices.

(a) service equipment
(b) PV system disconnect
(c) PV equipment disconnect
(d) all of these

45. For buildings with rapid shutdown, the rapid shutdown switch shall have a label that reads "RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM" installed within ____ ft of the switch.

(a) 3
(b) 6
(c) 10
(d) 25

Article 691—Large-Scale Photovoltaic (PV) Electric Supply Stations

1. Article ____ covers the installation of large-scale PV electric supply stations with a generating capacity of not less than 5,000 kW and not under the electric utility control.

(a) 690
(b) 691
(c) 705
(d) 711

2. Facilities covered by Article 681 have specific design and safety features unique to large-scale ____ facilities and are operated for the sole purpose of providing electric supply to a system operated by a regulated utility for the transfer of electric energy.

(a) industrial
(b) electrical
(c) distribution
(d) PV

3. Large-scale PV electric supply stations are only permitted to be accessible to authorized personnel and, electrical circuits and equipment shall be maintained and operated by qualified personnel.

(a) True
(b) False

4. Electrical equipment for large-scale PV electric supply stations shall only be approved for installation by ____.

(a) listing and labeling
(b) being evaluated for the application and having a field label applied
(c) qualified personnel
(d) listing and labeling, or being evaluated for the application and having a field label applied

5. Engineering documentation of large-scale electric supply stations shall include details of conformance of the design with Article ____.

(a) 250
(b) 690
(c) 702
(d) 710

Article 695—Fire Pumps

1. Article 695 covers the installation of the electric power sources and interconnecting circuits, and the switching and control equipment dedicated to drivers for ____.

(a) generators
(b) fire pumps
(c) alarm systems
(d) large scale solar arrays

2. Power to fire pump motors shall be supplied by a reliable source of power that has the capacity to carry the ____.

(a) sum of locked-rotor current of the fire pump motor(s)
(b) locked-rotor current of the pressure maintenance pump motors
(c) full-load current of any associated fire pump equipment
(d) all of these

Article 695 Practice Questions

3. When a fire pump is supplied by an individual source, the pump must be rated to carry, without time limit, the total value of the locked-rotor current of the largest fire pump motor plus the pressure maintenance pump motor, together with the full-load current of every other motor and all accessory equipment tied to the pump.

(a) overcurrent protective device(s)
(b) pump motor conductors
(c) pump motor controllers
(d) source supply conductors

4. Transformers that feed fire pump motors must be sized at no less than _____ percent of the combined full-load ampere rating of the fire pump motor(s), pressure maintenance pump motors, and 100 percent of the associated accessory equipment.

(a) 100
(b) 125
(c) 250
(d) 300

5. The primary overcurrent protective device for a transformer that supplies a fire pump must be able to carry the locked-rotor current of the fire pump motor(s), the pressure maintenance pump motor(s), and the full-load current of connected accessory equipment for _____.

(a) for 15 minutes
(b) for 45 minutes
(c) for 3 hours
(d) indefinitely

6. Fire pump supply conductors on the load side of the final disconnecting means and overcurrent protection can be routed through a building where the conductors are protected from fire for two hours by _____.

(a) encasing the cable or raceway in a minimum 2 in. of concrete
(b) using a cable or receway listed as fire-resistive cable system
(c) using a cable or receway listed as a listed electrical circuit protective system
(d) any of these

7. Feeder conductors supplying fire pump motors and accessory equipment must be sized at no less than _____ percent of the total of the fire pump motor(s) and pressure maintenance motor(s) full-load currents, plus 100 percent of the fire pump accessory equipment ampere rating.

(a) 100
(b) 125
(c) 250
(d) 600

8. All wiring from the controllers to the fire pump motors must be in _____ listed Type MC cable with an impervious covering, or Type MI cable.

(a) rigid or intermediate metal conduit
(b) electrical metallic tubing (EMT)
(c) liquidtight flexible metallic or nonmetallic conduit
(d) any of these

9. Ground-fault protection of equipment shall _____ in any fire pump power circuit.

(a) not be installed
(b) be provided
(c) be permitted
(d) be listed

10. The voltage at the line terminals of a fire pump motor controller must not drop more than _____ percent below the controller's normal rated voltage under motor-starting conditions.

(a) 5
(b) 10
(c) 15
(d) 20

11. When a fire pump motor operates at 115 percent of its full-load current rating, the supply voltage at the load terminals of the fire pump controller must not drop more than _____ percent below the voltage rating of the motor connected to those terminals.

(a) 5
(b) 10
(c) 15
(d) 20

12. All electric motor-driven fire pump control wiring shall be in _____.

(a) rigid metal conduit or intermediate metal conduit
(b) liquidtight flexible metal conduit, electrical metallic tubing, or liquidtight flexible nonmetalic conduit
(c) listed Type MC cable with an impervious covering or Type MI cable
(d) any of these

13. A(an) _____ surge protection device shall be installed in or on the fire pump controller.

(a) listed
(b) labeled
(c) identified
(d) approved

Notes |

CHAPTER 7

SPECIAL CONDITIONS

INTRODUCTION TO CHAPTER 7—SPECIAL CONDITIONS

Chapter 7, which covers special conditions, is the third of the *NEC* chapters that deal with special topics. Chapters 5 and 6 cover special occupancies, and special equipment, respectively. Remember, the first four chapters of the *Code* are sequential and form a foundation for each of the subsequent three. Chapter 8 covers communications systems (twisted pair and coaxial cable) and is not subject to the requirements of Chapters 1 through 7 except where the requirements are specifically referenced there.

What exactly is a "Special Condition"? It is a situation that does not fall under the category of special occupancies or special equipment but creates a need for additional measures to ensure the "safeguarding of people and property" mission of the *NEC* as stated in 90.1(A).

- **Article 700—Emergency Systems.** The requirements of Article 700 apply only to the wiring methods for "Emergency Systems" that are essential for safety to human life and required by federal, state, municipal, or other regulatory codes. When normal power is lost, emergency systems must be capable of supplying emergency power in 10 seconds or less and be able to run loads for at least 2 hours on gasoline and 90 minutes on a battery.
- **Article 701—Legally Required Standby Systems.** Legally required standby systems provide electrical power to aid in firefighting, rescue operations, control of health hazards, and similar operations, and are required by federal, state, municipal, or other regulatory codes. When normal power is lost, legally required standby systems must be capable of automatically supplying standby power in 60 seconds or less and be able to run loads for at least 2 hours on gasoline and 90 minutes on a battery.
- **Article 702—Optional Standby Systems.** Optional standby systems are intended to protect public or private facilities or property where life safety does not depend on the performance of the system. These systems are typically installed to provide an alternate source of electrical power for such facilities as industrial and commercial buildings, farms, and residences, and to serve loads that, when stopped during any power outage, can cause discomfort, serious interruption of a process, or damage to a product or process. Optional standby systems are intended to supply on-site generated power, either automatically or manually, to loads selected by the customer.
- **Article 705—Interconnected Electric Power Production Sources.** It used to be that a premises having more than one electric power source was a unique situation, but as more and more facilities supplement their utility electric supply with alternate sources of energy it's become more commonplace. Alternate power sources such as solar or wind turbine that run in parallel with a primary utility source require particular consideration and requirements. Article 705 provides the guidance necessary to ensure a safe installation.
- **Article 706—Energy Storage Systems.** Energy storage systems can be (and usually are) connected to other energy sources, such as the local utility distribution system. There can be more than one source of power connected to an ESS and the connection to other energy sources is required to comply with the requirements of Article 705 which covers installation of one or more electric power production sources operating in parallel with a utility source of electricity. It might also be a good idea to be mindful of how this article correlates with other articles in the *Code* such as Articles 480, 690, 692, and 694.

- **Article 710—Stand Alone Systems.** A "stand alone system" is an electrical installation that is self-sufficient and entirely disconnected from the utility grid—its only energy source is solar or wind. However, it may still be tied to the utility service as part of an interconnected system; in that case, Article 710 addresses those conditions to ensure safety and clarity.

- **Article 725—Remote-Control, Signaling, and Power-Limited Circuits.** This article sets out the rules for remote-control, signaling, and power-limited circuits that are not a built-in part of a device or appliance.
  - ***Remote-Control Circuit.*** A circuit that operates other equipment through a relay or solid-state device. For example, a circuit that controls the coil of a motor starter or a lighting contactor is a type of remote-control circuit.
  - ***Signaling Circuit.*** A circuit that delivers visual and/or audible signals by using equipment or devices. Examples include doorbells, buzzers, code-calling systems, signal lights, annunciators, burglar alarms, and other indicators or alarm devices that function within signaling circuits.

- **Article 760—Fire Alarm Systems.** This article focuses on installing the wiring and equipment that make up fire alarm systems. These systems include fire detection and alarm notification, voice communications, guard's tour, sprinkler waterflow monitoring, and sprinkler supervisory functions.

- **Article 770—Optical Fiber Cables.** This article covers the installation requirements for optical fiber cables that carry light for control, signaling, and communication. It also includes provisions for raceways that contain optical fiber cables, as well as rules for composite cables (known as "hybrid" cables in the field) that combine optical fibers with current-carrying metal conductors.

ARTICLE 700 EMERGENCY SYSTEMS

Introduction to Article 700—Emergency Systems

Emergency systems are frequently required for a facility as a condition of its operating permit. In accordance with NFPA 101, *Life Safety Code*, emergency power systems are typically installed wherever artificial lighting is needed for safe egress and for panic control in buildings that host large numbers of people, including high-rise buildings, jails, sports arenas, schools, health care facilities, and comparable occupancies.

The authority having jurisdiction decides whether a system is necessary for a particular facility and also what it must accomplish. Many times an emergency system is needed to provide power for exit and egress lighting, to supply power after the normal source is lost, or in the event of a fire. Its purpose is to ensure reliable power for normal business operations—not to provide lighting or control functions that are essential to preserving human life.

The main objective is maintaining dependable emergency operation. The emergency system must be capable of feeding all emergency loads at once. When the emergency source also serves other nonemergency loads, the emergency loads take precedence, while all other loads are subject to automatic pickup and shedding so the emergency loads do not lose adequate capacity and rating.

Article 700 emphasizes that emergency systems support critical lifelines for people. The entire article is built on the principle of keeping those lifelines from being interrupted.

Part I. General

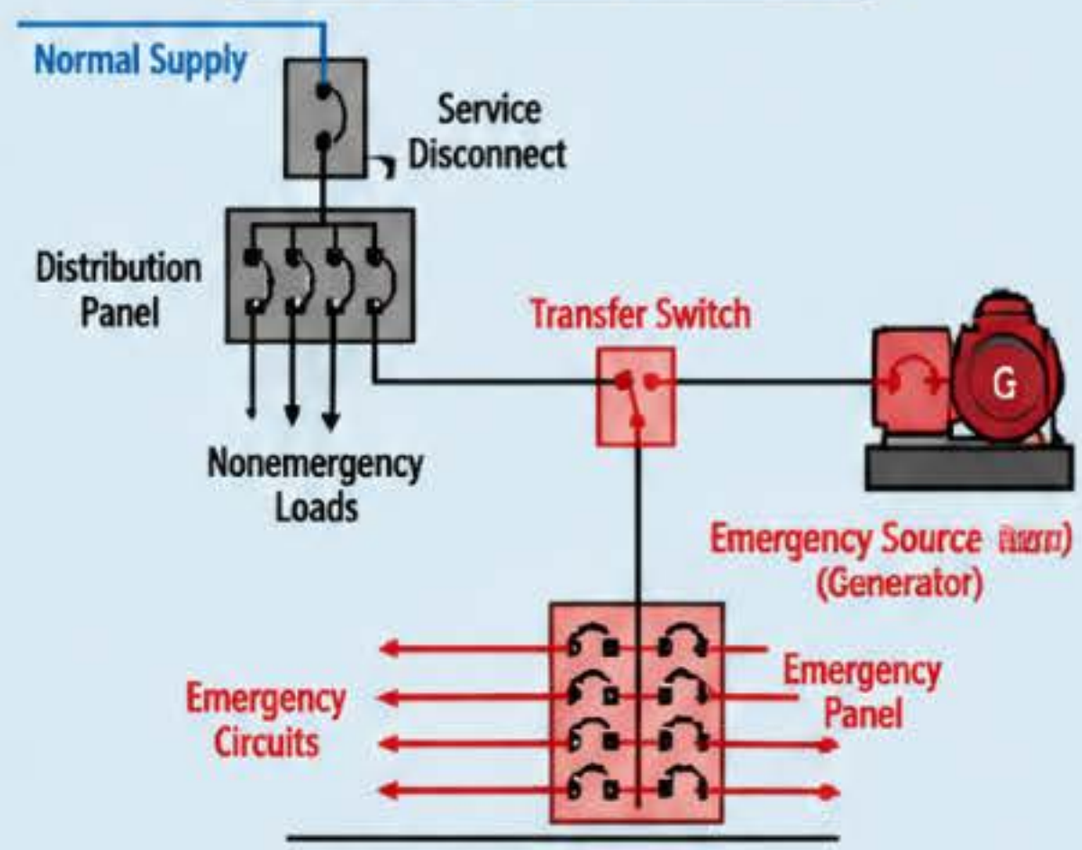
700.1 Scope

Article 700 governs the electrical safety of installation, operation, and maintenance of emergency power systems. These systems consist of equipment and circuits intended to supply illumination, power (or both) for at least 10 seconds [700.12] when the normal electrical supply is interrupted.

Some examples of circuits that require emergency power include those supplying egress lighting, exit signs, fire alarms, fire pumps, and voice evacuation.

Note 3: For details on emergency lighting requirements in specific locations, refer to NFPA 101, *Life Safety Code*.

Emergency Systems 700.1 Scope



Article 700 governs the electrical safety of installation, operation, and maintenance of emergency power systems for illumination, power (or both) for at least 10 seconds [700.12] when the normal electrical supply is interrupted.

▶ Figure 700–1

Author's Commentary:

Emergency power installations are typically used where backup lighting and dependable power ere essential for safe evacuation and for maintaining panic control in facilities with high occupant loads. This includes places such as tall buildings, correctional facilities, sports and entertainment venues, schools, clinics, and other similar occupancies.

— Michael Hamilton

Note 4: For detailed performance expectations of emergency power systems, see NFPA 110, *Standard for Emergency and Standby Power Systems*, 2023 edition.

700.2 Definitions

These definitions apply throughout this article and the *Code*.

Emergency Systems. Emergency power systems refer to systems that are legally required and classified as emergency by an authority having jurisdiction. They are intended to automatically provide illumination and/or electrical power essential to protect human life. See Figure 700–2.

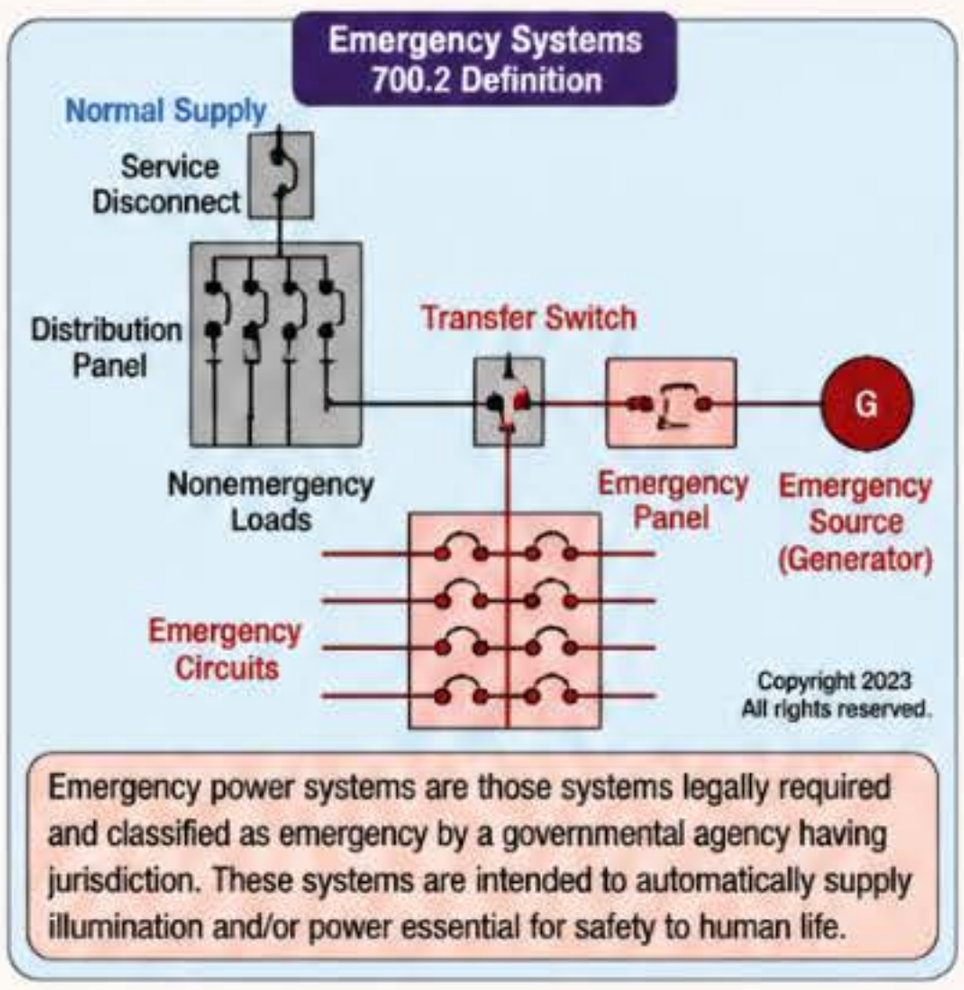


Figure 700–2

Note: Emergency systems can also support life-safety equipment such as fire alarms, smoke control systems, elevators, pumps, public address systems (with hardwired speakers, antennas, and coaxial cables), and industrial processes where power loss could cause serious injury, health hazards, or other dangerous conditions.

700.3 Tests and Maintenance

(A) Conduct or Witness Test. Before placing the emergency system in service, the authority having jurisdiction must either perform or observe and approve an acceptance test confirming successful completion of the system.

(B) Periodic Testing. Emergency systems shall be tested periodically on a schedule approved by the authority having jurisdiction to verify they remain in proper working order and that required maintenance is performed.

Author's Commentary:

Operate the system under its maximum expected load and confirm that power is transferred within 10 seconds. This is commonly accepted as an acceptable approach for operational testing.

— Michael Hamilton

(C) Maintenance. All emergency system equipment must be maintained in accordance with the manufacturer's instructions and industry standards.

(D) Written Record. Keep a written log of acceptance testing, periodic testing, and maintenance activities.

Author's Commentary:

The *Code* does not state a specific retention period for these records.

— Michael Hamilton

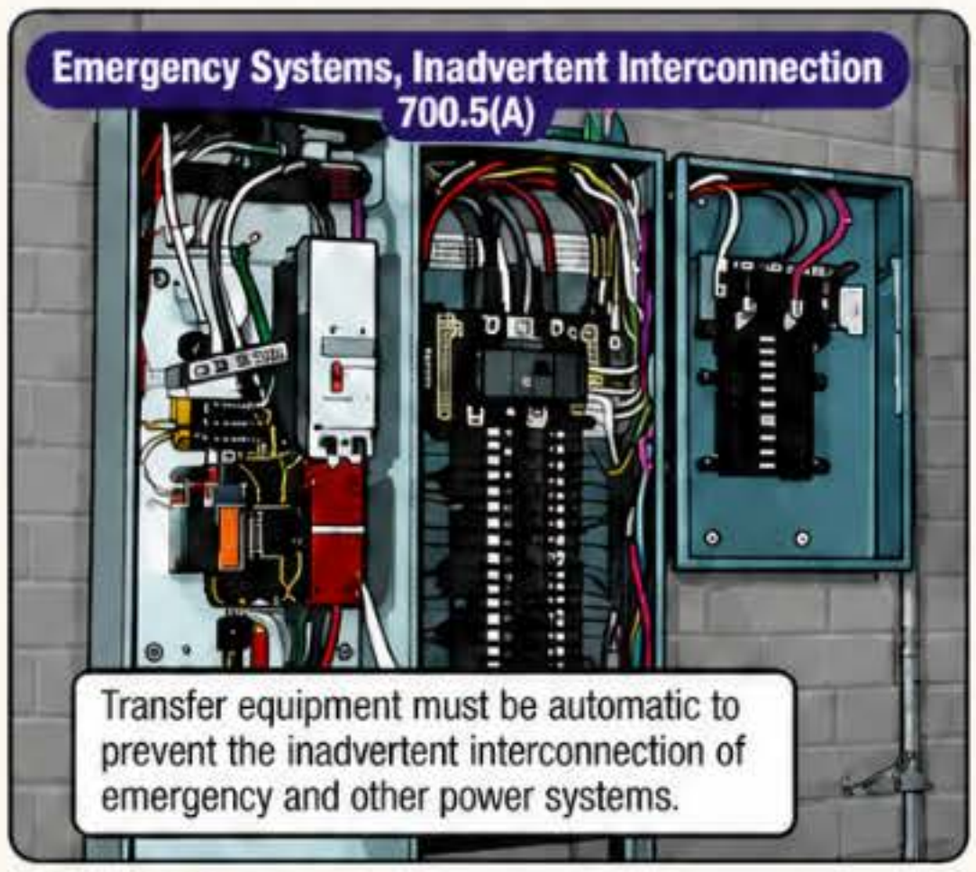
700.4 Capacity and Rating

(A) Rating. Emergency power systems must be appropriate for the fault current available at their terminals.

(B) Capacity. Each emergency power system must have sufficient capacity in accordance with Article 220 or another approved method.

700.5 Transfer Equipment

(A) General. Transfer equipment shall be automatic, listed, identified for emergency use, and approved by the authority having jurisdiction. It must be designed to prevent unintended connection between emergency and normal power sources. See Figure 700–3.

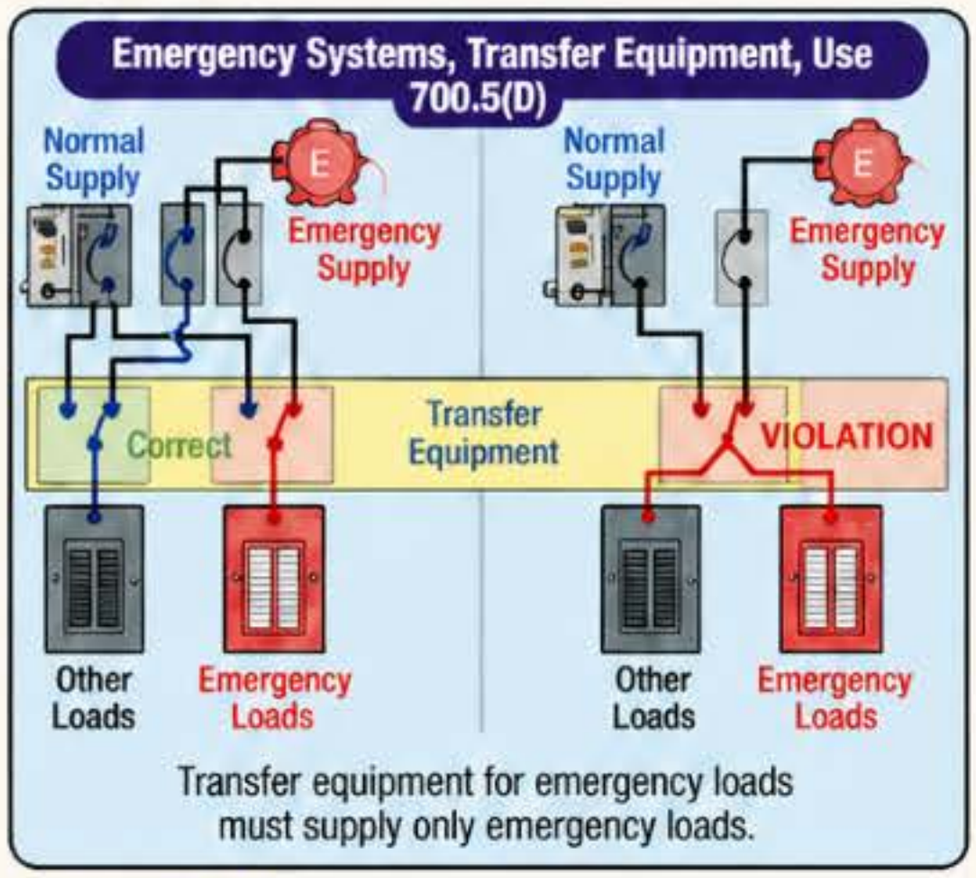


▲ Figure 700–3

Meter-mounted transfer switches are not permitted for emergency system use.

(C) Automatic Transfer Switches. Automatic transfer switches must be capable of being operated both electrically and manually. They are not permitted to be reconditioned.

(D) Use. Transfer equipment must supply only emergency loads. ▼ Figure 700–4



▲ Figure 700–4

Author's Commentary:

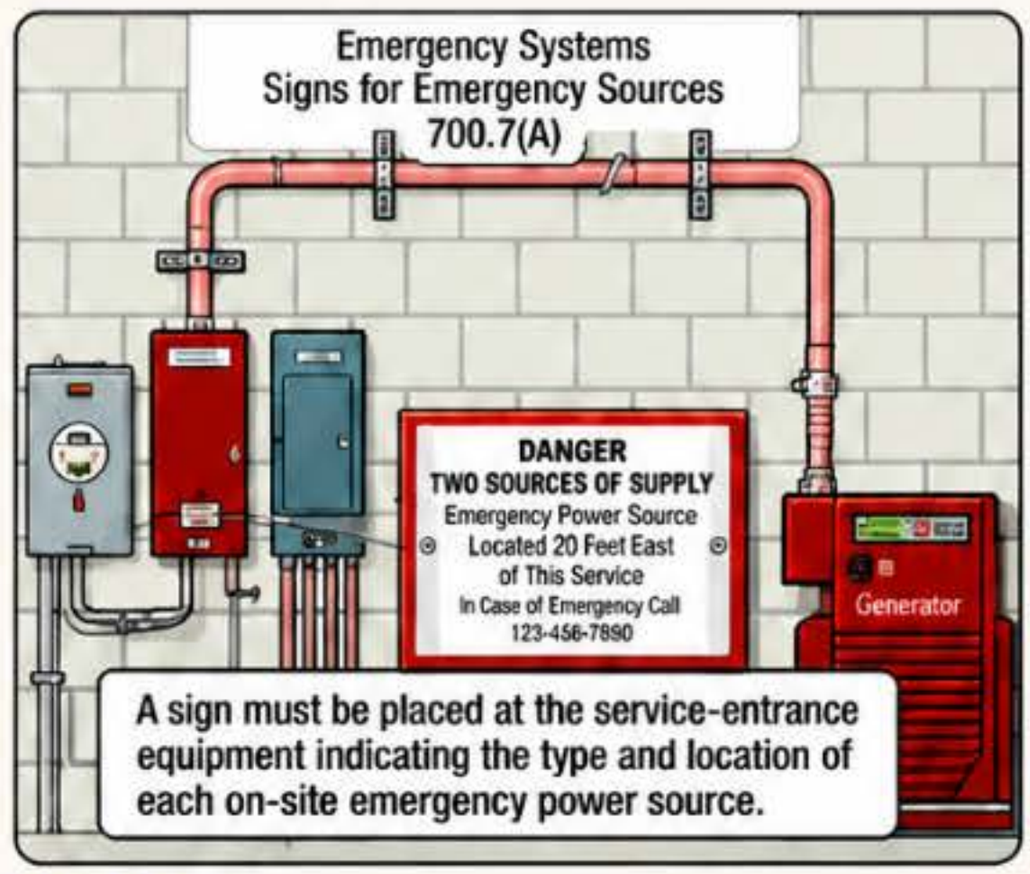
Multiple transfer switches are required when a single generator is used to supply emergency loads, legally required standby loads, and optional loads.

— Michael Hamilton

(E) Documentation. The short-circuit current rating of the transfer equipment must be field marked on the exterior of the transfer – equipment.

700.7 Signs

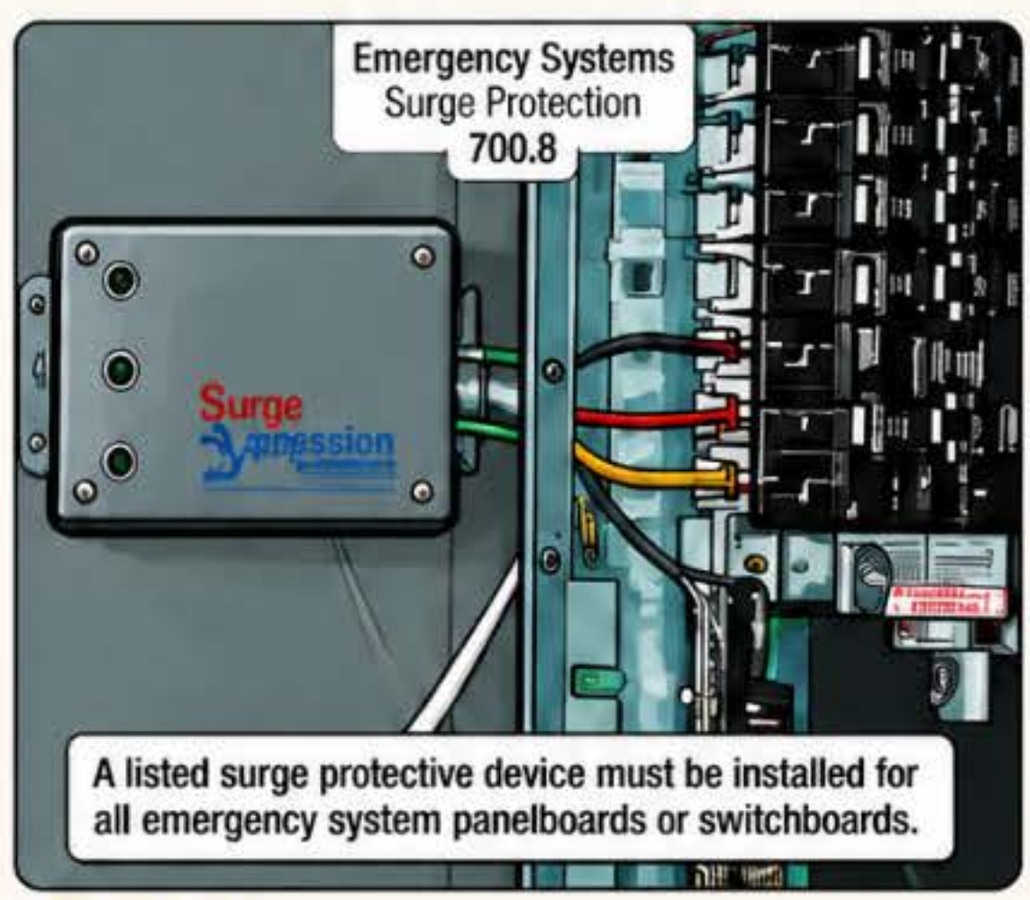
(A) Emergency Sources. A sign must be placed at service-entrance equipment indicating the type and location of each on-site emergency power source. ▼ Figure 700–5



▲ Figure 700–5

700.8 Surge Protection

A listed surge protective device must be installed for aal emergency system panelboards and switchboards. ▼ Figure 700–6



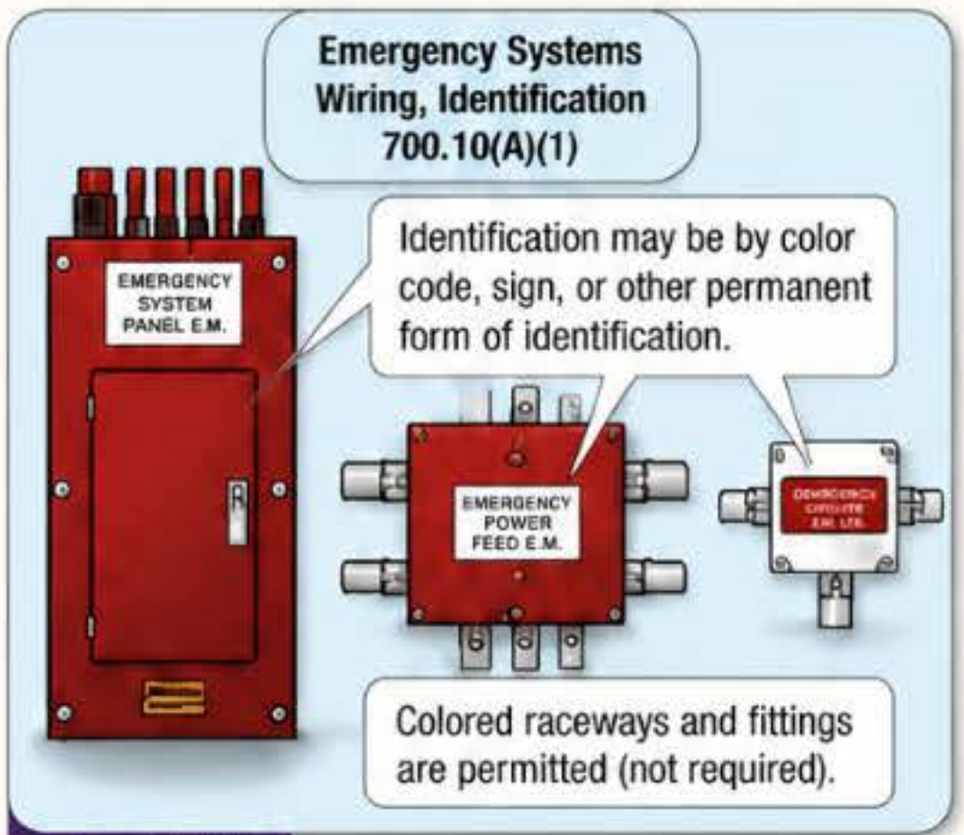
▲ Figure 700–6

Part II. Circuit Wiring

700.10 Wiring

(A) Identification. All parts of the emergency system must carry permanent markings so they can be readily recognized as elements of that system.

(1) Boxes, cabinets, transfer switches, generators, and power panels serving emergency circuits shall be permanently labeled as components of an emergency circuit or system. ▸Figure 700–7



▸Figure 700–7

Author's Commentary:

You can label enclosures, cables, and raceways any approved way that clearly shows the item is part of the emergency system—such as the words "Emergency System," "Emergency Circuits," or a designated color code applied to a raceway or junction box cover. Colored raceways and fittings are allowed, but they are not required.

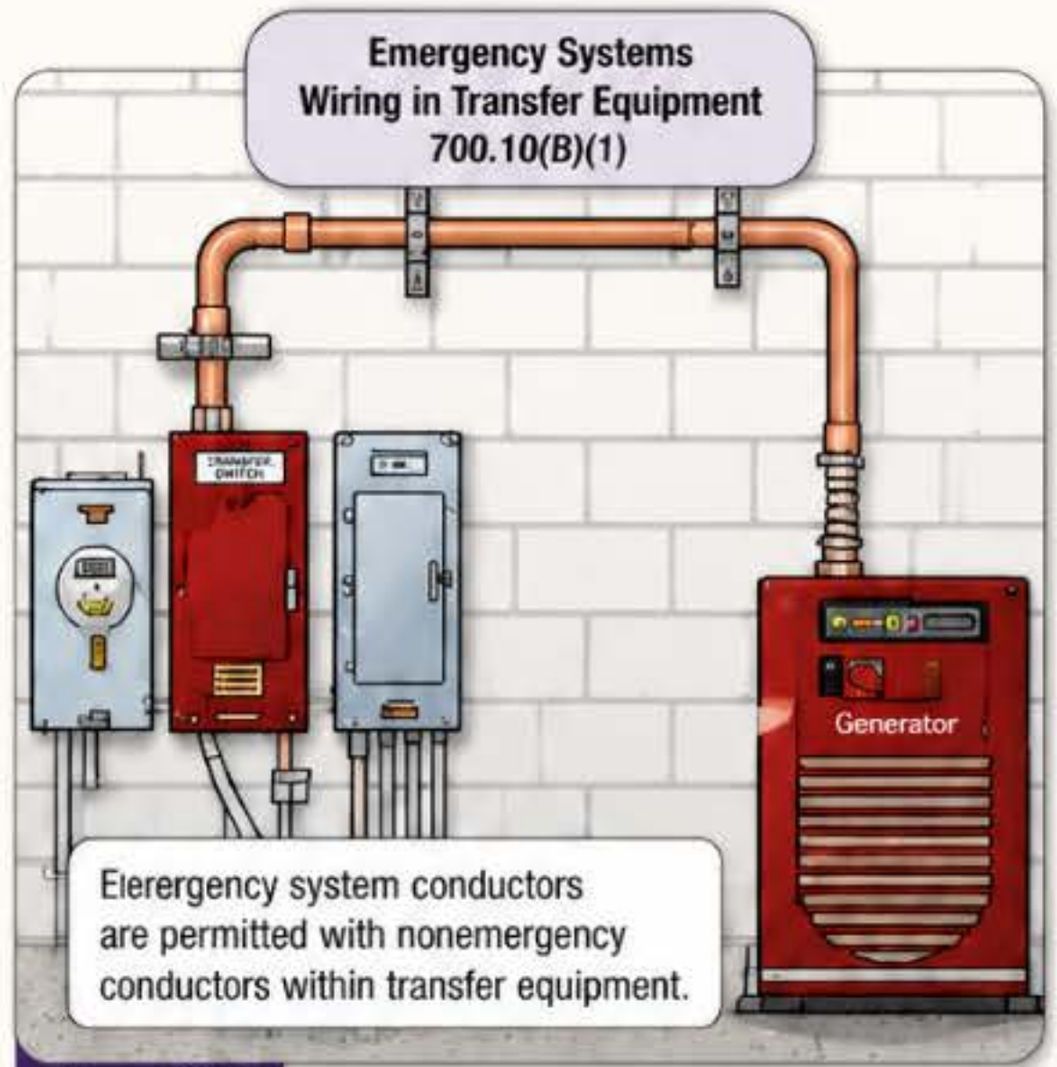
— Michael Hamilton

(2) Cables and raceway system must be permanently marked as part of the emergency system at intervals not greater than 25 ft.

Receptacles that are connected to the emergency power system must be identified by having a unique color or marking on either the receptacle itself or its cover plate.

(B) Wiring. Emergency system conductors are not allowed inside any enclosure, raceway, cable, or luminaire that also contains nonemergency loads, except in the cases listed below:

(1) Wiring in transfer equipment. ▸Figure 700–8



▸Figure 700–8

(2) Luminaires and exit signs supplied from emergency and other sources of power.

(3) Wiring from two power sources in a listed load control relay that supplies exit or emergency luminaires, or in a common junction box connected to exit or emergency luminaires.

(4) Wiring within a common junction box attached to unit equipment that contains only the branch circuit supplying that equipment and the emergency circuit supplied by it.

(5) Wiring from an emergency system can supply emergency and other loads as follows:

a. If emergency and nonemergency loads are separated by individual switchboards or switchgear sections, or by dedicated disconnects mounted in separate enclosures.

b. If the bus is:

(i) Fed by a feeder with no overcurrent protection at the source.

(ii) Fed by a feeder with overcurrent protection that is selectively coordinated with the next downstream protective device in the nonemergency system.

c. Emergency circuits are not permitted to start from the same vertical switchgear section, vertical switchboard section, panelboard enclosure, or individual disconnect enclosure as other circuits.

d. You may use one or more feeders to supply distribution equipment between an emergency source and the point where the emergency loads are separated from all other loads.

EMERGENCY SYSTEMS | 700.12

Note: See *NEC* Note Figure 700.10(B)(5)(b)(1) and **Note** Figure 700.10(B)(5)(b)(2) for additional information.

Author's Commentary:
The separation of conductors supplied by a generator for emergencies, mandatory circuits, and optional standby loads may be accomplished by operating feeders from a single generator to individual overcurrent protective devices, or by using a distribution switchboard that isolates emergency circuits into their own vertical sections.

— Michael Hamilton

(C) Wiring Design and Location. Emergency circuits must be laid out and positioned to reduce risks from conditions that could result in failure, such as flooding, fire exposure, icing, vandalism, and other harmful influences.

Part III. Sources of Power

700.12 General Requirements

If normal power to the building is lost, emergency power must be ready within 10 seconds. Emergency equipment has to be energized from various sources in the event of a normal power failure. The emergency power supply must conform to the following:

(A) Power Source Considerations. When selecting an emergency power source, account for the building's occupancy and the type of service required, whether it's for evacuation of occupants or for extended operations, as well as for supplying emergency power and lighting during a period when no current is available from either inside or outside the building.

(B) Equipment Design and Location. All equipment must be arranged and situated to lower the chance of complete failure because of flooding, fire, icing, or acts of vandalism.

(C) Storage Battery. Storage batteries are allowed as an emergency source if they can supply and maintain the total load for at least 90 minutes with the terminal voltage not dropping below 87% of its normal rating. Automatic-type batteries are not permitted for this application. Automatic battery charging provisions must be included.

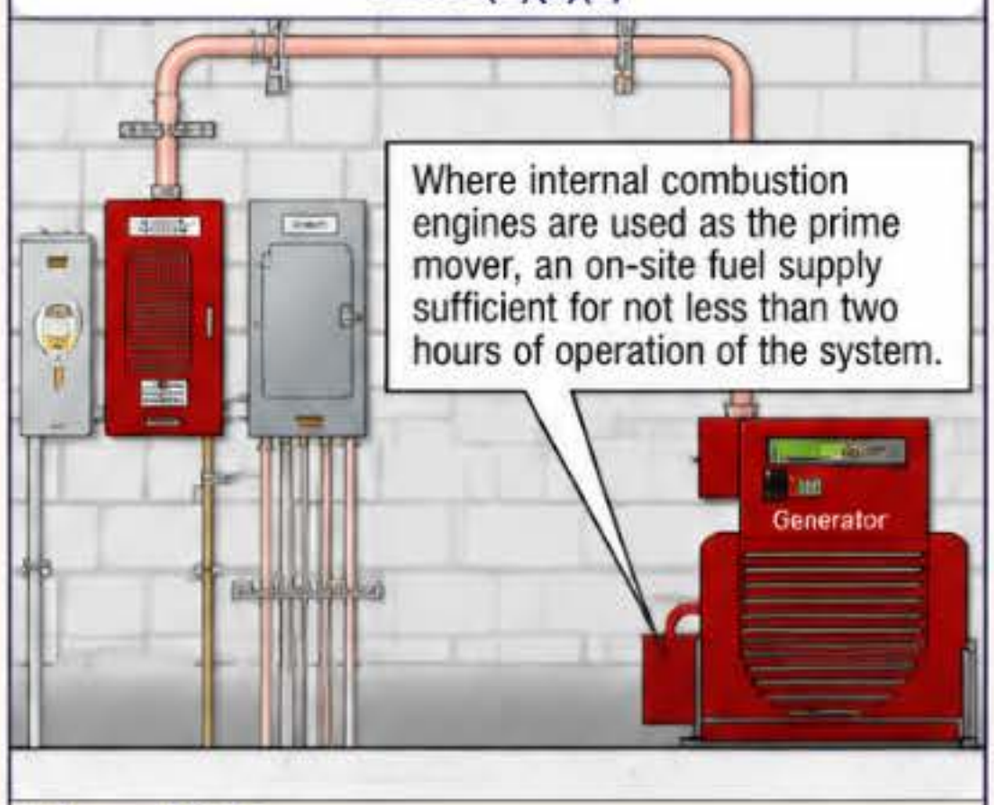
(D) Generator Set.

(1) Prime Mover-Driven. A generator approved by the authority having jurisdiction and sized according to 700.4 may serve as the emergency power source if it can automatically start the prime mover when utility power fails.

(2) Internal Combustion Engines as Prime Movers.

(a) On-Site Fuel Supply. Where engines that burn fuel internally are used as the prime mover, an on-site fuel supply must be provided that is located on the premises and capable of supporting not less than two hours of continuous system operation. ▸ **Figure 700–9**

Emergency Systems, Generator
Internal Combustion Engines, On-Site Fuel Supply
700.12(D)(2)(a)



▸ **Figure 700–9**

(b) Fuel Transfer Pumps. When fuel must be moved to an operating set of transfer pumps to deliver fuel to a generator located at a tank, those pumps need to be tied into the emergency power system.

(c) Public Gas System, Municipal Water Supply. Prime movers cannot rely solely on a public utility gas system for their fuel supply, nor can they depend entirely on a municipal water system for their cooling water.

Ex: Authority approval that permits the use of other than on-site fuels is allowed when the chance of both the off-site fuel delivery system and the utility providing external electricity failing at the same time is minimal.

(d) Automatic Fuel Transfer. When there are two fuel supplies, means must be provided to automatically shift fuel from one source to the other.

(5) Outdoor Generator Sets. If a generator has a readily accessible disconnecting means within view of the building, an additional disconnecting means is not required at the building or other structure. ▸ **Figure 700–10**

(E) Uninterruptible Power Supplies. UPS equipment is permitted to act as an emergency power source if it meets the applicable requirements of 700.12(B) and (C).

(F) Separate Service. An additional service is allowed as the emergency power source where approved by the authority having jurisdiction [230.2(A)] and per the following: ▸ **Figure 700–11**

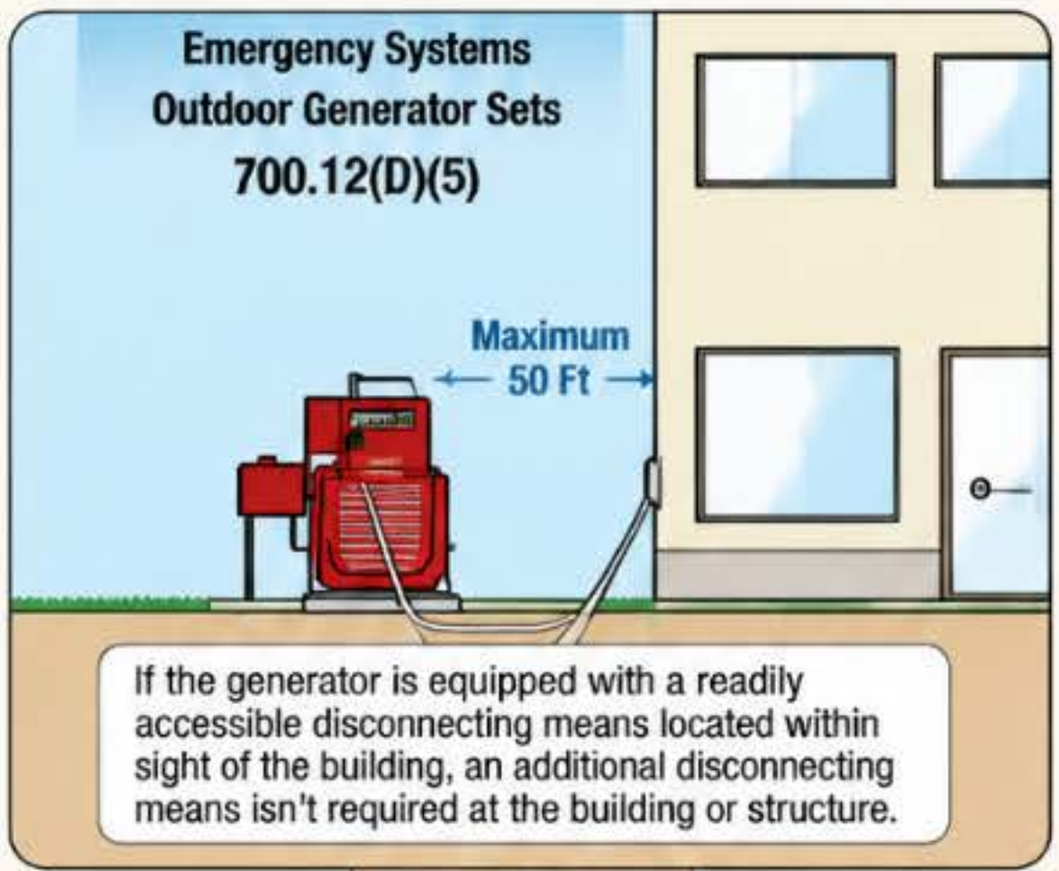


Figure 700–10

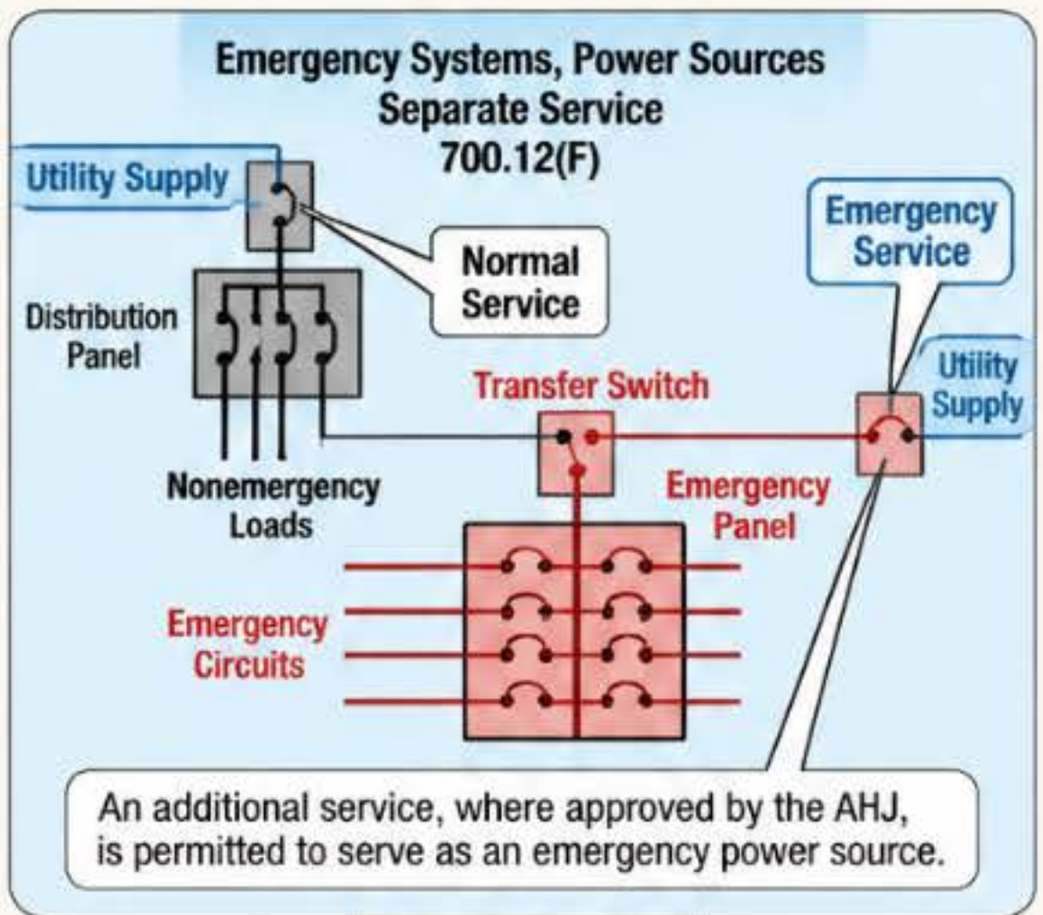


Figure 700–11

(1) Separate service conductors are installed from the utility.

(2) The emergency service conductors are electrically and physically remote from other service conductors to minimize the possibility of simultaneous interruption of supply.

Author's Commentary:

To minimize the chance of both systems being interrupted at the same time, route the emergency system so that it is located remotely from the other power system's service disconnect [230.72(B)].

— Michael Hamilton

(H) Direct-Current Microgrid Systems. Connections for dc microgrid systems are allowed when the system can detach from all nonemergency sources. Direct-current microgrid setups may qualify as an emergency power source if they can supply and sustain the total emergency load for at least 2 hours of full-demand operation. When a dc microgrid system acts as the usual power supply for a building or group of buildings, it must not be the only source of power for the emergency standby system.

(I) **Emergency Battery Pack Unit Equipment.**

(1) **Components of Unit Equipment.** Each emergency battery pack unit is allowed as an emergency power source.

(2) **Installation of Unit Equipment.** Unit equipment must be permanently installed using either the Chapter 3 wiring method or a cord-and-plug connection with a flexible cord not longer than 3 ft in length.

(3) The branch-circuit wiring that supplies emergency battery pack equipment must be one of the following:

a. The same branch circuit that serves the normal lighting in the area, with a connection ahead of any local switches. **Figure 700–12**

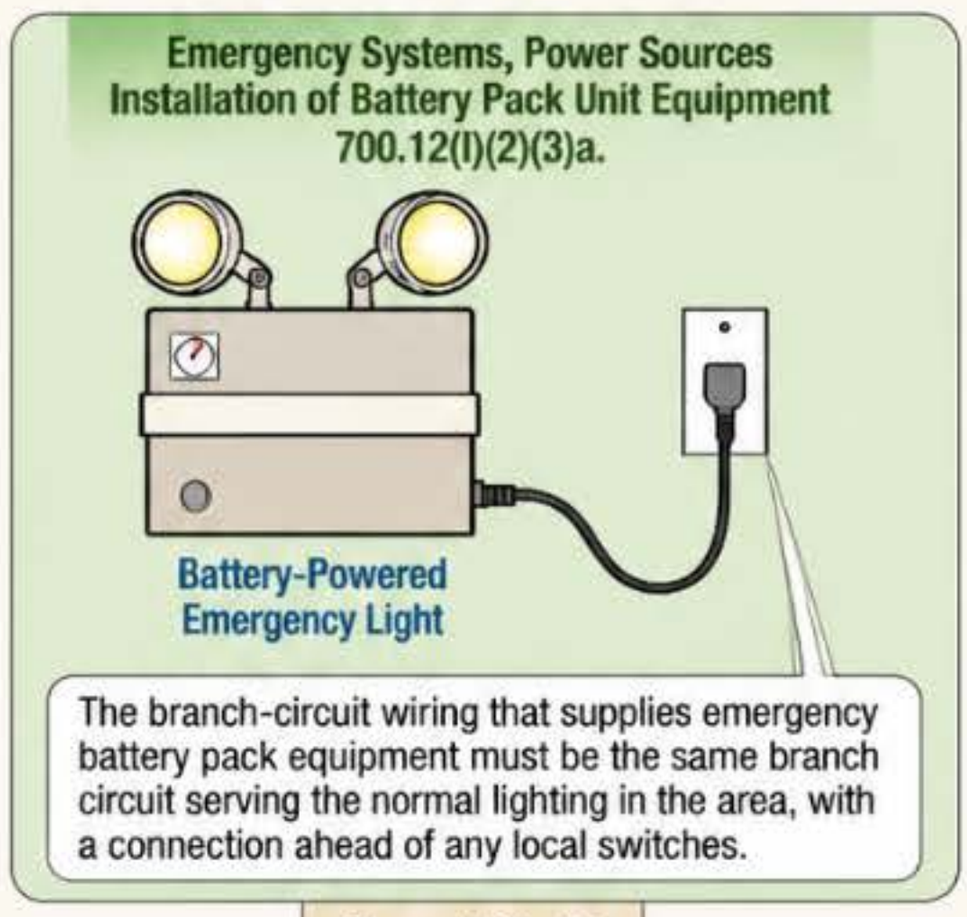


Figure 700–12

Author's Commentary:

There are two main reasons the emergency battery pack unit equipment must be connected ahead of the switch controlling the normal area lighting: (1) if the power goes out to the lighting circuit, the emergency battery lights will remain illuminated.

— Michael Hamilton

EMERGENCY SYSTEMS | 700.16

activate and illuminate exit paths during an emergency, and (2) energize emergency battery packs that will not operate if the normal control circuit for standard lighting is de-energized.

(b) Where the regular lighting supply comes from one or more branch circuits—or from a separate feeder—and includes a locking means on the panelboard that prevents connection to the normal lighting circuit, the disconnection switch for that branch circuit must also be provided with a locking means.

(4) The branch circuit feeding the emergency battery pack unit equipment must be clearly identified at the distribution panel.

> ***Author's Commentary:***
> Labeling and marking must follow the requirements of 110.22(A) and 408.4(A).
>
> ***— Michael Hamilton***

(6) Power for remote emergency heads that illuminate the outside of an exit door can be supplied by the emergency battery pack unit equipment that serves the area immediately inside that exit door.

Part IV. Emergency System Circuits for Lighting and Power

700.15 Loads on Emergency Branch Circuits

Emergency circuits must only supply emergency loads.

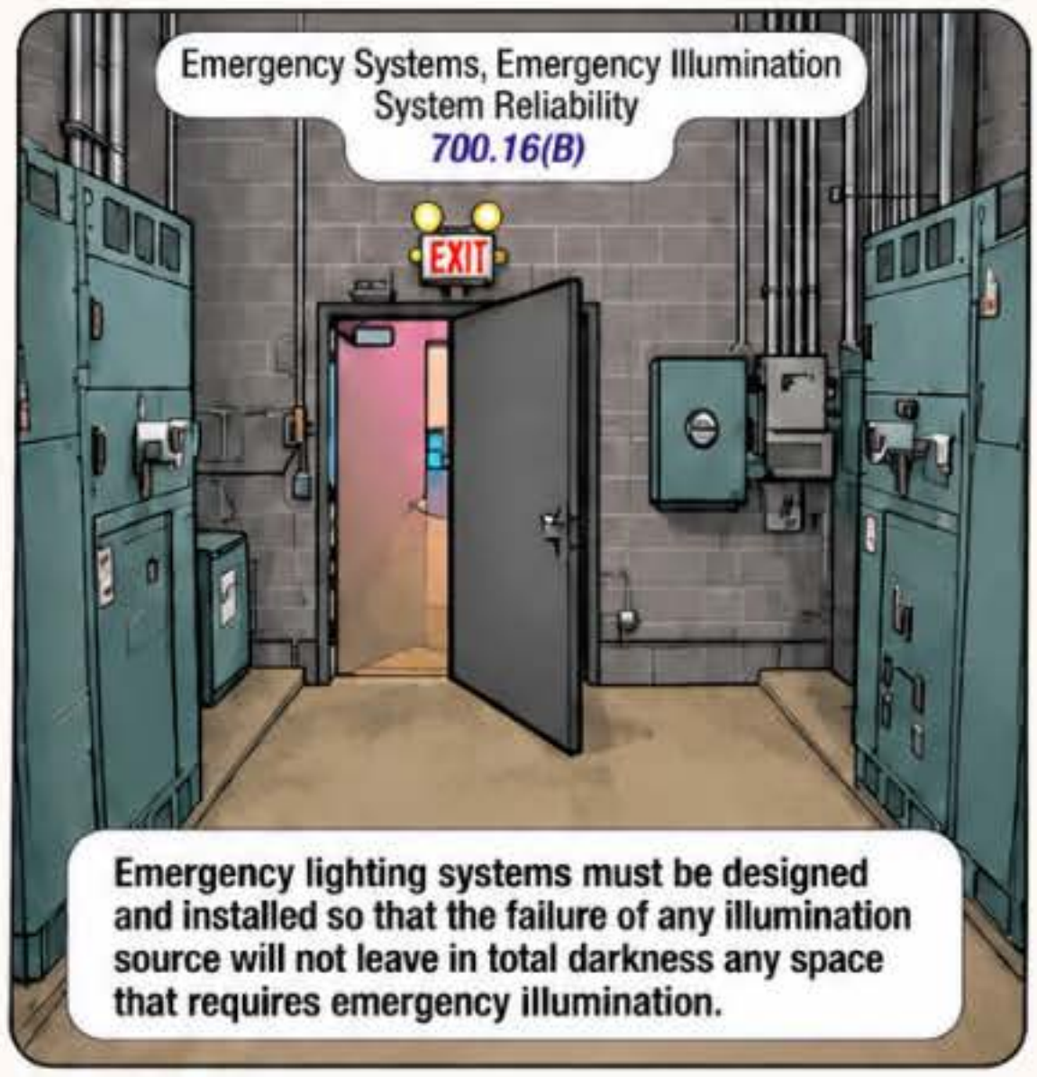
700.16 Emergency Illumination

(A) General. Emergency illumination must include egress lighting, illuminated exit signs, and any other luminaires that are specified as necessary to ensure the required lighting.

(B) System Reliability. Emergency lighting systems must be designed and installed so that the loss of the normal source for illumination does not leave any space that needs emergency illumination in total darkness.

▸ Figure 700–13

> ***Author's Commentary:***
> This means that a single remote head is usually not enough for an area. A minimum of two lighting heads is always required. Individual emergency battery pack units (often called "bug-eyes" in the field) always have two lighting heads.
>
> ***— Michael Hamilton***



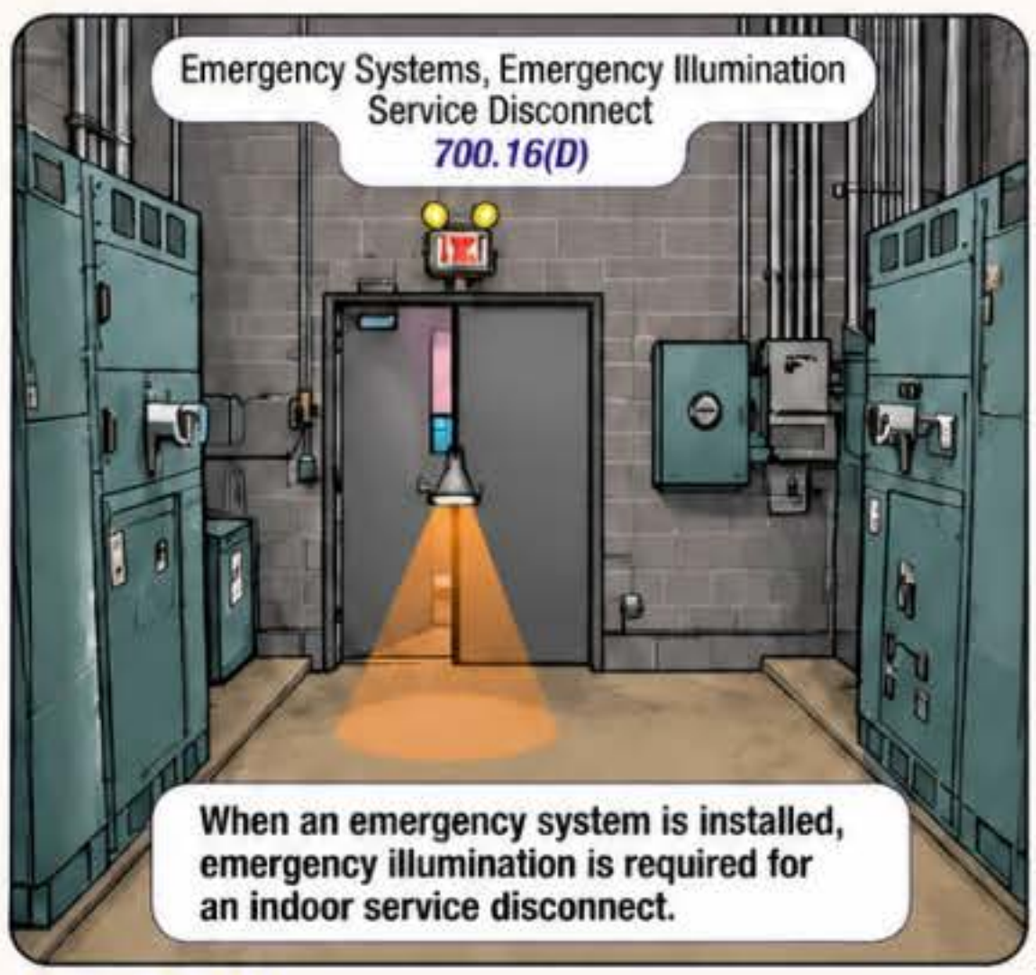
▸ Figure 700–13

Control devices that are part of emergency lighting systems must be listed for use in those systems. See 700.12(F).

Note: 700.23 through 700.26 provide application requirements for emergency system control devices.

(D) Disconnecting Means. When an emergency system is installed, emergency illumination is required for an indoor service disconnect.

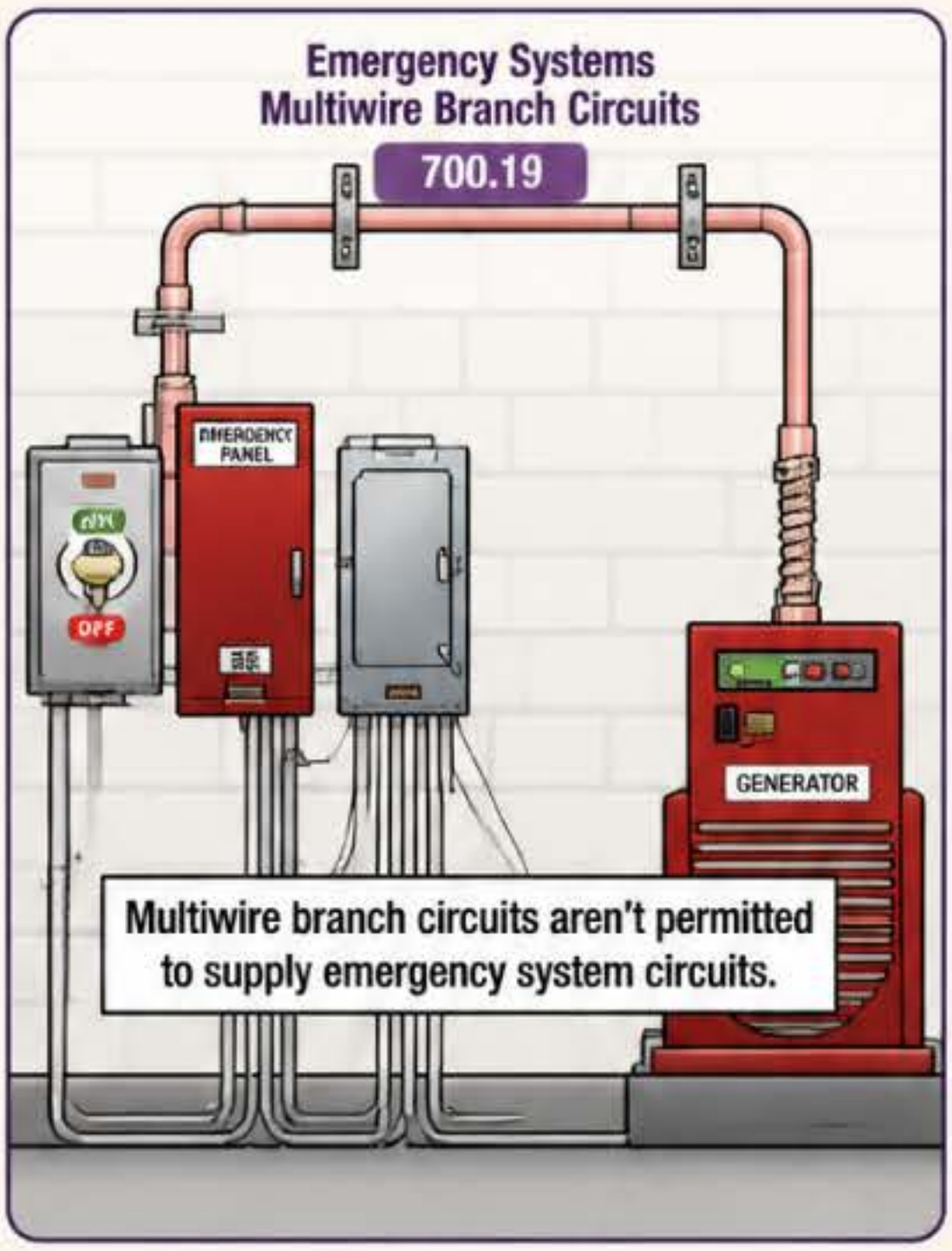
▸ Figure 700–14



▸ Figure 700–14

700.19 Multiwire Branch Circuits

Multiwire branch circuits are not allowed to supply emergency system circuits. ▶ Figure 700–15



▶ Figure 700–15

Part VI. Overcurrent Protection

700.30 Accessibility

Branch-circuit overcurrent devices for emergency systems must be accessible only to authorized personnel.

700.32 Selective Coordination

Overcurrent devices for emergency power systems must be selectively coordinated with all supply-side overcurrent protective devices. The design must be prepared by a qualified engineer or someone with similar qualifications and it must be documented and made available to those authorized to design, install, inspect, maintain, and operate the system.

Author's Commentary:

▶ Article 100 defines "Selective Coordination" as an overcurrent protection arrangement that restricts interruption to only the branch or portion of the system where a fault occurs. For example, if a short circuit or ground fault happens with selective coordination, only the breaker or fuse protecting that branch opens. Without selective coordination, an entire floor or even the whole building could be dark.

— Michael Hamilton

Note: See the *NEC* Note Figure 700.32 for an example of how emergency system overcurrent protective devices (OCPDs) are selectively coordinated with all supply-side OCPDs.

NEC Note Figure 700.32 Emergency System Selective Coordination

- OCPD **D** selectively coordinates with OCPDs **C**, F, E, **B**, and **A**.
- OCPD **C** selectively coordinates with OCPDs F, E, **B**, and **A**.
- OCPD **F** selectively coordinates with OCPD **E**.
- OCPD **B** is not required to selectively coordinate with OCPD A because OCPD B is not an emergency system OCPD.

ARTICLE 701 LEGALLY REQUIRED STANDBY SYSTEMS

Introduction to Article 701—Legally Required Standby Systems

Within the electrical system classification, Article 700 Emergency Systems is given first priority.

Narrowing that down, Legally Required Standby Systems are governed by Article 701. These systems must supply standby power for 60 seconds or less after a power loss. Some typical examples of required standby circuits include those feeding the fire command center, emergency lighting, air handling and ventilation units, and fire detection and alarm systems, as well as elevator circuits.

Article 700 generally covers systems or equipment needed to safeguard individuals during an emergency or while exiting a building, whereas Article 701 focuses on systems and equipment intended to support responders during an emergency.

Part I. General

701.1 Scope

Article 701 governs the installation, operation, and maintenance of legally required standby systems composed of circuits and equipment designed to provide illumination or power whenever the normal electrical supply or system becomes interrupted. ***Figure 701-1***

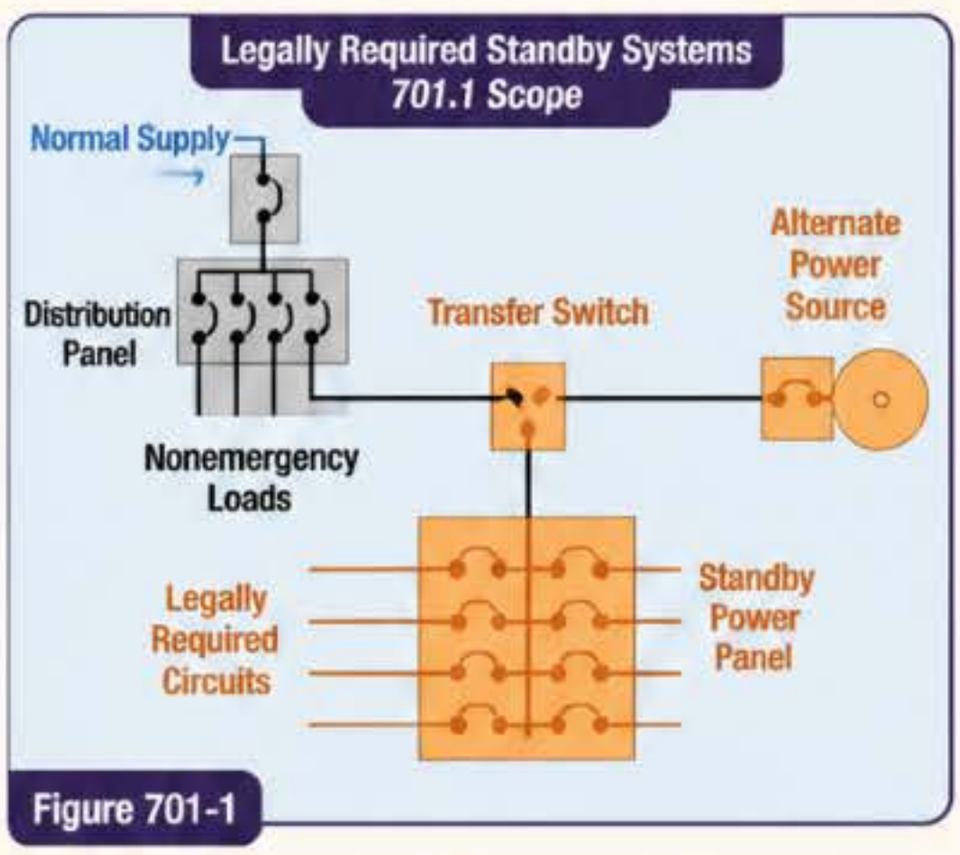


Figure 701-1

Article 701 governs the installation, operation, and maintenance of legally required standby systems composed of circuits and equipment intended to provide illumination or power whenever the normal electrical supply or system becomes interrupted.

Author's Commentary:

Legally required standby systems are designed to deliver electrical power for critical functions such as firefighting, rescue missions, health protection, and other similar operations.

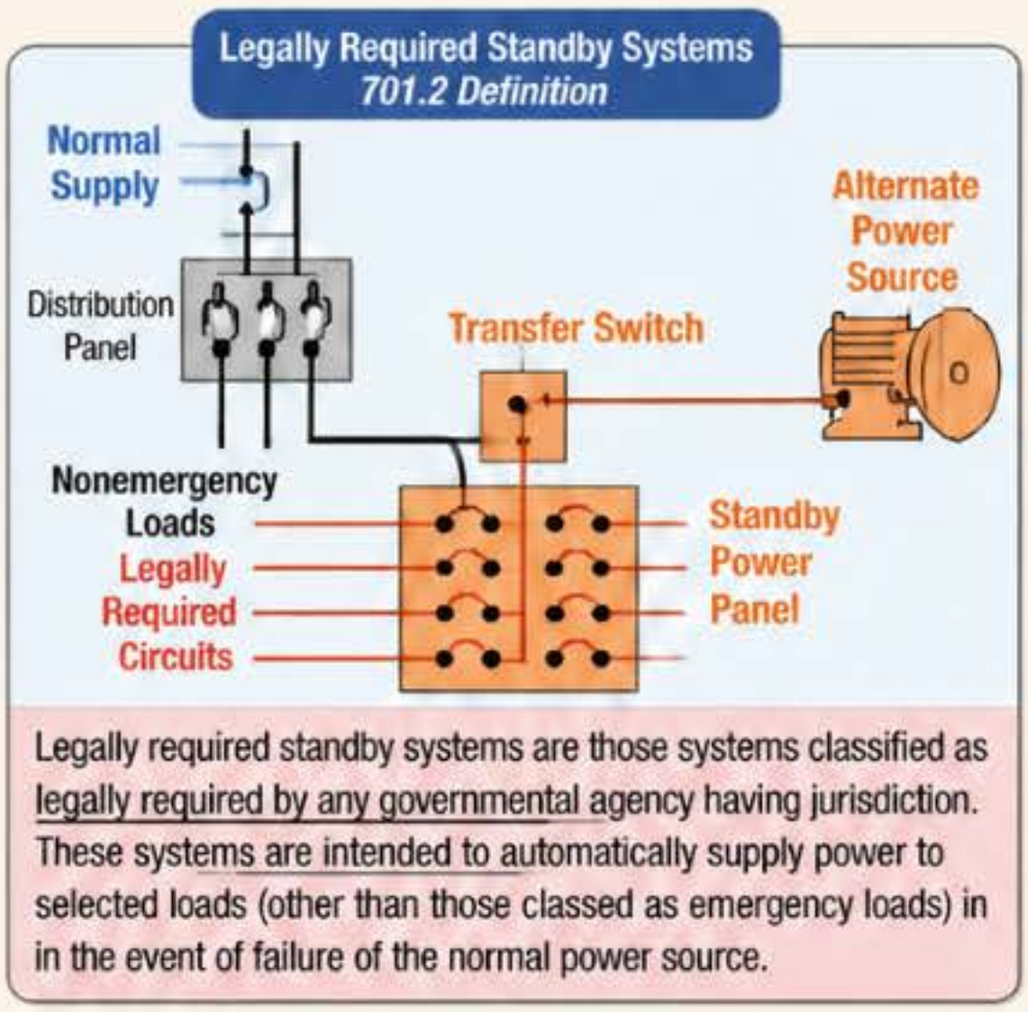
— Michael Hamilton

701.2 Definition

The definition provided in this section is applied throughout the *Code*.

Legally Required Standby Systems. These are standby systems that fall under a legal requirement imposed by a governmental body with authority over the jurisdiction. They are established to automatically provide electrical power to selected loads (excluding those classified as emergency loads) in the event of a failure of the normal power source. ***Figure 701-2***

Note: Legally required standby systems typically serve loads such as heating and refrigeration equipment, communication networks (twisted pair, antennas, and coaxial cable), ventilation and smoke exhaust systems, sewage pumping, emergency lighting, and industrial process equipment that, if shut down, could jeopardize safety or hinder rescue or firefighting operations.



▸ Figure 701–2

701.3 Tests and Maintenance

(A) Conduct or Witness Test. To ensure that the legally required standby system meets or exceeds the original installation specifications, the authority having jurisdiction must conduct or witness an acceptance test of the legally required system upon completion of the installation.

(B) Periodic Testing. Legally required standby systems must be periodically tested in a manner approved by the authority having jurisdiction to ensure adequate maintenance has been performed and the systems are in proper operating condition.

Author's Commentary:

- Running the legally required standby system under the loads of the facility to make sure power transfers within 60 seconds is often considered an acceptable method of operational testing.

— Michael Hamilton

(C) Maintenance. Legally required standby system equipment must be maintained in accordance with the manufacturer's instructions and industry standards.

(D) Written Record. A written record must be kept of all required tests and maintenance.

Author's Commentary:

- The *NEC* does not specify the required record retention period.

— Michael Hamilton

701.4 Capacity and Rating

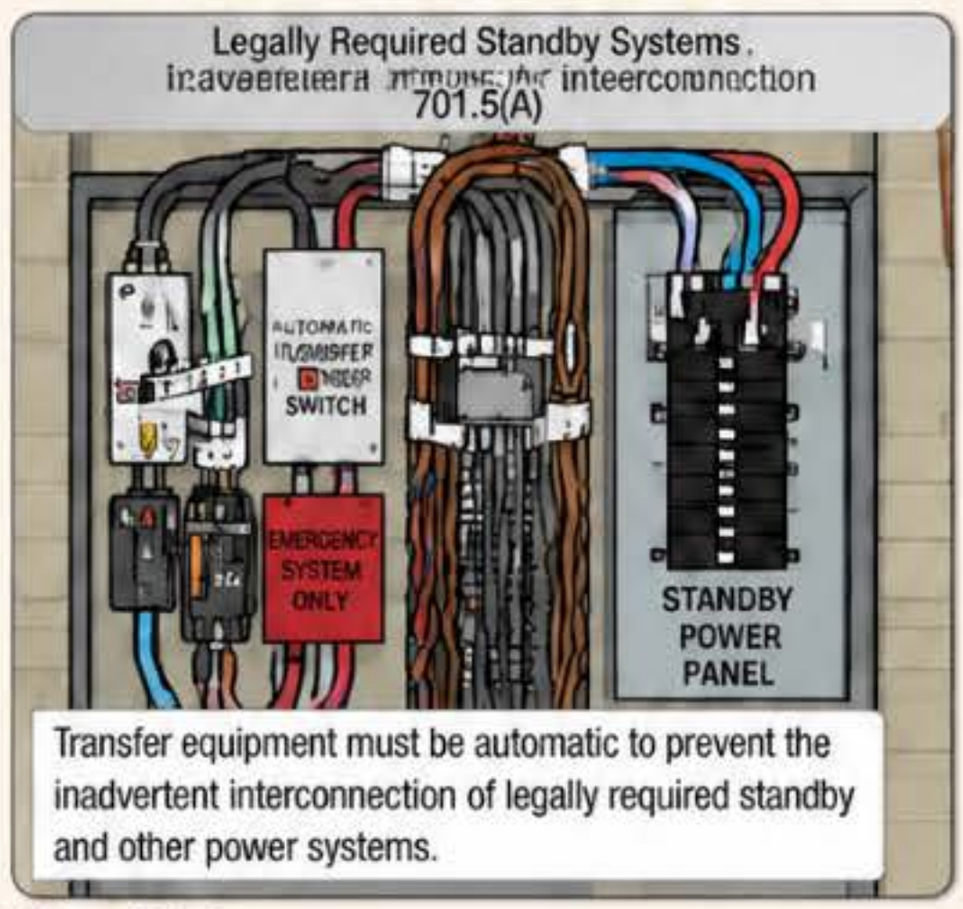
(A) Rating. Equipment for a legally required standby system must be suitable for the available fault current at its terminals.

(B) Capacity. The alternate power supply must have adequate capacity in accordance with Article 220 or by another approved method.

(C) Load Pickup, Load Shedding, and Peak Load Shaving. The legally required standby alternate power supply can supply legally required standby and optional standby system loads if there is adequate capacity or where automatic selective load pickup and load shedding are provided that will ensure adequate power to the legally required standby system circuits.

701.5 Transfer Equipment

(A) General. Transfer equipment must be automatic, listed, and marked for emergency system or legally required standby system use, and approved by the authority having jurisdiction. Transfer equipment must prevent the inadvertent interconnection of legally required standby and other power systems. ▸ Figure 701–3



▸ Figure 701–3

Meter-mounted transfer switches are not permitted for legally required standby system use.

(C) Automatic Transfer Switch. Automatic transfer switches must be able to be electrically operated and mechanically held, and they are not permitted to be reconditioned.

(D) Documentation. The short-circuit current rating of the transfer equipment must be field marked on the exterior of the transfer equipment.

DEFINITIONS | From Michael Hamilton Publications

701.6 Signals

Audible and visual signal devices must be installed where practicable for the purposes of:

(A) Malfunction. To communicate that the standby source of power has failed.

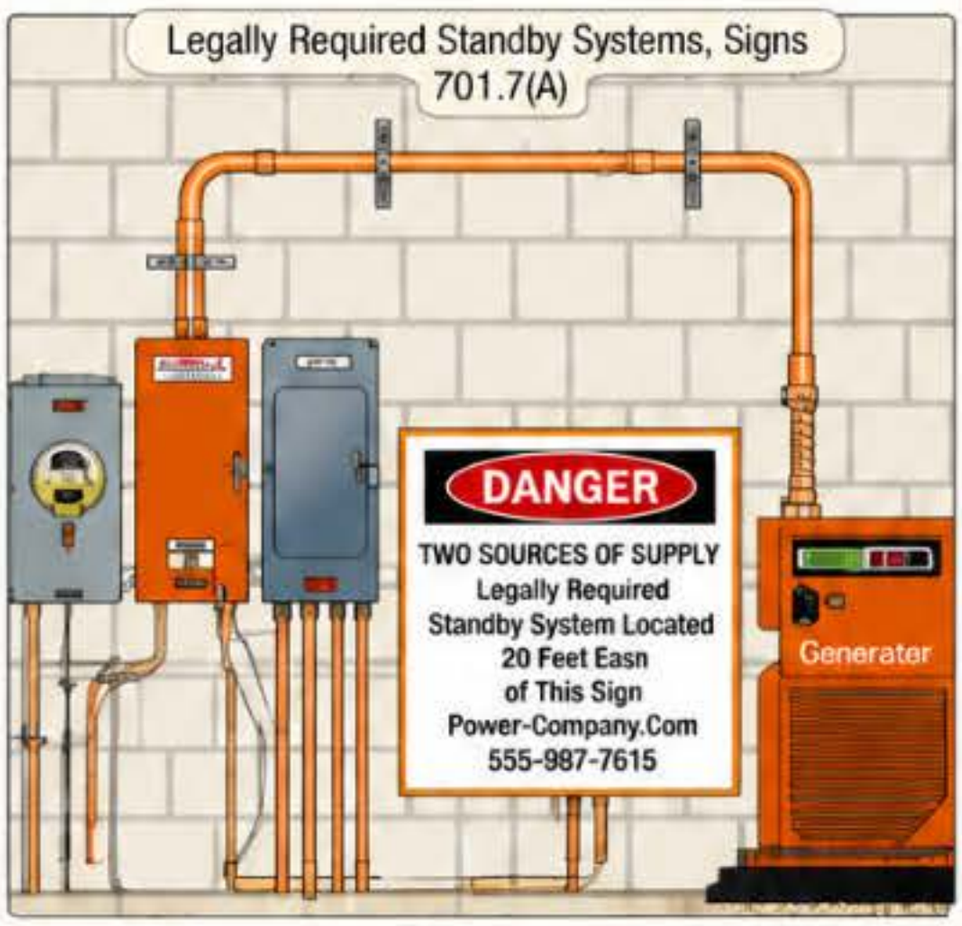
(B) Carrying Load. To show that the standby source is supplying power to the load.

(C) Not Functioning. To signal that the battery charger is not working.

(D) Ground Fault. To alert that a ground fault exists in solidly grounded wye, legally required standby systems of more than 150V to ground and circuit protective devices rated 1,000A or higher.

701.7 Signs

(A) Mandated Standby. A sign must be placed at the service-entrance equipment indicating the type and location of on-site legally required standby power systems. ▸Figure 701–4



▸Figure 701–4

Part II. Circuit Wiring

701.10 Wiring

Legally required standby system wiring is permitted to be in the same raceways, boxes, and cabinets with other general wiring.

Part III. Sources of Power

701.12 General Requirements

If the normal supply fails, legally required standby power must be available within 60 seconds. The supply system for the legally required standby power supply is permitted to be one or more of the following:

(A) Power Source Considerations. In selecting a legally required standby source of power, consideration must be given to the type of service to be rendered, whether of short-time duration or long duration.

(B) Equipment Design and Location. Consideration must be given to the location or design, or both, of all equipment to minimize the hazards that might cause complete failure due to floods, fires, icing, and vandalism.

> ***Author's Commentary:***
>
> *For additional guidance, see ANSI/IEEE 493, Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems.*
>
> ***— Michael Hamilton***

(C) Storage Battery. Storage batteries must be of suitable rating and capacity to supply and maintain the total load for a minimum period of 90 minutes without the voltage dropping below 87% of normal. Automotive-type batteries are not permitted. Automatic battery charging means must be provided.

(D) Generator Set.

(1) Prime Mover-Driven. A generator approved by the authority having jurisdiction and sized in accordance with 701.4 is permitted as the legally required power source if it has the means to automatically start the prime mover on failure of the normal service.

(2) Internal Combustion Engines as Prime Mover. Where internal combustion engines are used as the prime mover, an on-site fuel supply must be provided for not less than two hours of operation of the system. ▸Figure 701–5

(5) Outdoor Generator Sets. if the generator is equipped with a readily accessible disconnecting means located within sight of the building, an additional disconnecting means is not required at the building or structure. ▸Figure 701–6

(E) Uninterruptible Power Supplies. Uninterruptible power supplies are permitted as the legally required power source and must comply with 701.12(B) and (C).

(F) Separate Service. An additional service is permitted as the legally required power source where approved by the authority having jurisdiction [230.2(A)] and separate service conductors are installed from the utility. ▸Figure 701–7

701.30 | Legally Required Standby Systems

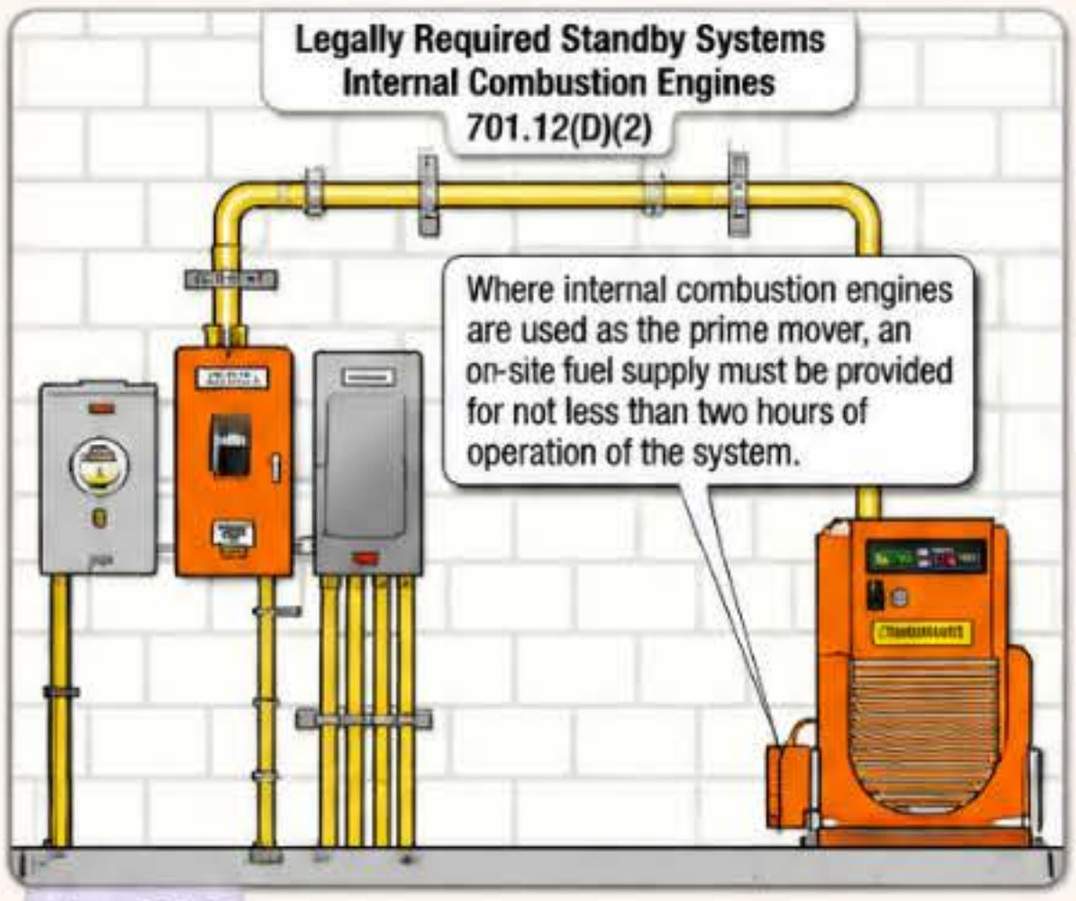


Figure 701–5

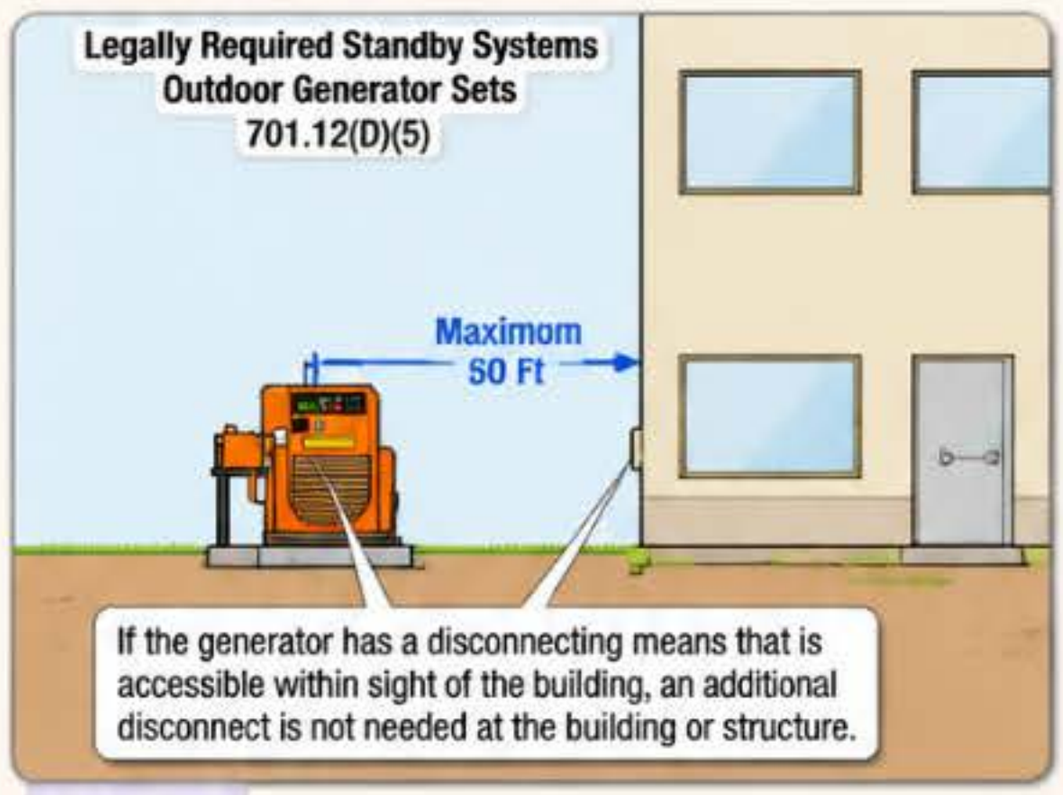


Figure 701–6

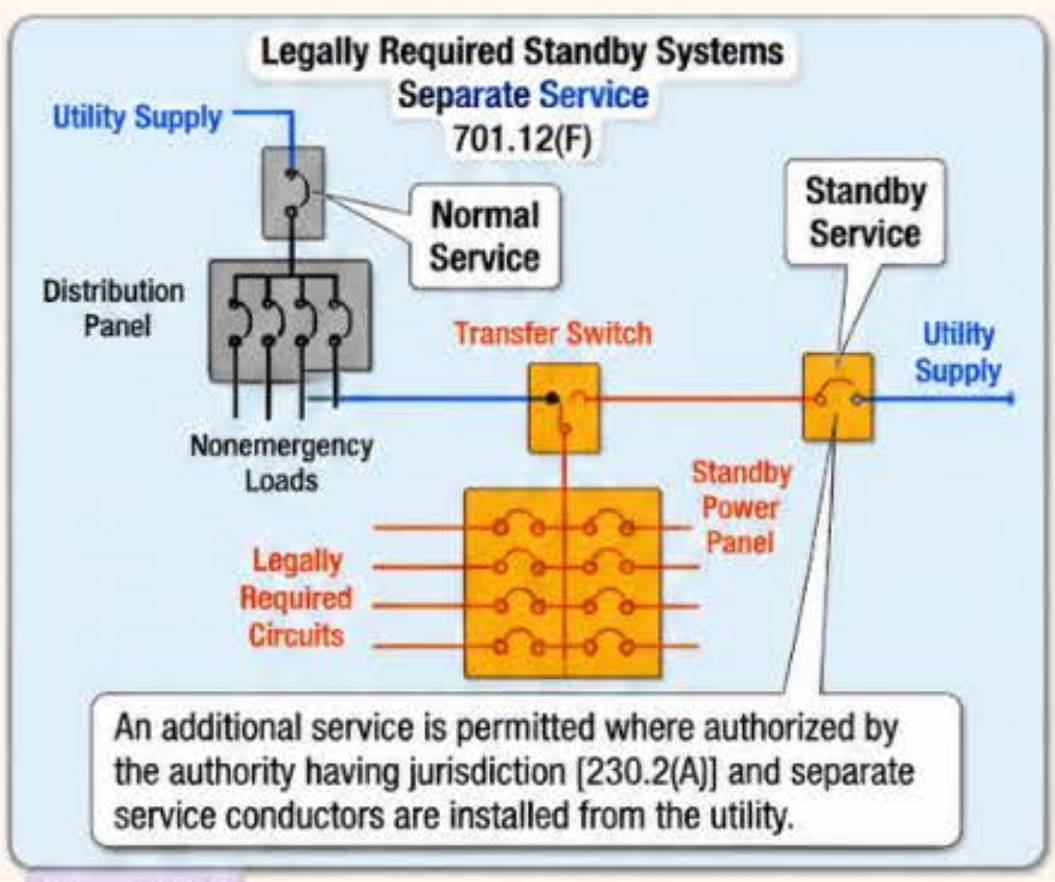


Figure 701–7

Equipment that supplies legally required standby power must be electrically and physically located apart from other service conductors. This separation helps reduce the chance of a shared outage affecting both systems at the same time.

Author's Commentary:

- Design installations so that a fault or disconnection on the normal power system will not also interrupt the legally required standby system. The mandatory service disconnect for legally required power must be positioned remote from the other system's service disconnect [230.72(B)].

— **Michael Hamilton**

(G) Connection Ahead of Service Disconnecting Means. if the authority having jurisdiction approves the method, connection ahead of the service disconnecting means is allowed only when the same cabinet, enclosure, or vertical switchboard or switchgear section functions as the legally required power source.

Refer to 230.82(5) for more details. ▸ **Figure 701–8**

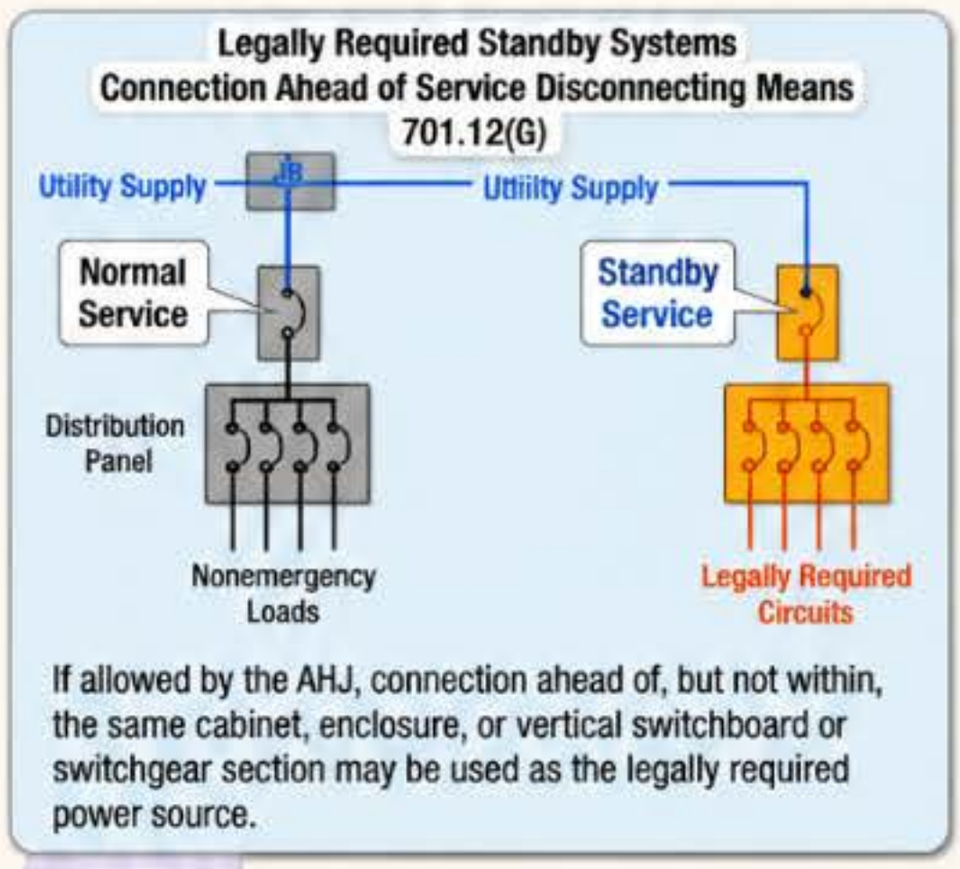


Figure 701–8

To minimize the likelihood of simultaneous interruption, the disconnect for the legally required power system must be located remotely from other power system service disconnects.

Part IV. Overcurrent Protection

701.30 Accessibility

The branch-circuit overcurrent devices protecting legally required standby circuits must be accessible only to authorized personnel.

Legally Required Standby Systems | 701.32

701.32 Selective Coordination

Overcurrent protection devices used in legally required standby systems must be selectively coordinated with every supply-side overcurrent protective device. This coordination must be accomplished by a qualified engineer or by a person with equivalent training. Every step in the design has to be recorded and the details made available to those who install, examine, maintain, and operate the system.

Author's Commentary:

"Selective coordination," according to Article 100, means arranging the overcurrent protection so that, when a short circuit or ground fault happens in a specific area instead of the entire system, only the protective device closest to the problem opens. Without selective coordination, a fault on one branch can trip the main breaker or fuse, shutting down the whole facility."

— Michael Hamilton

Note: See the 2023 NEC, Note Figure 701.32 for an example of how legally required standby system overcurrent protective devices (OCPDs) are selectively coordinated with all supply-side OCPDs.

NEC Note Figure 701.32 Emergency System Selective Coordination

The OCPD for the emergency system is selectively coordinated with these supply-side OCPDs:

- OCPD D is selectively coordinated with OCPDs C, F, E, B, and A.
- OCPD C is selectively coordinated with OCPDs F, E, B, and A.
- OCPD F is selectively coordinated with OCPD E.
- OCPD B is not required to be selectively coordinated with OCPD A because OCPD B is not a legally required standby system OCPD.

Notes

ARTICLE 702 OPTIONAL STANDBY SYSTEMS

Introduction to Article 702—Optional Standby Systems

Standby installations come after systems required for life safety and legal compliance. Their purpose is to shield public and private buildings—or property itself—when the normal electrical source is lost. These arrangements are not intended for life-saving operations.

Think about a glass factory losing power. As the molten glass cools and solidifies in the equipment, the plant could face a long outage and high recovery costs before restarting. An optional standby system can help avoid that scenario.

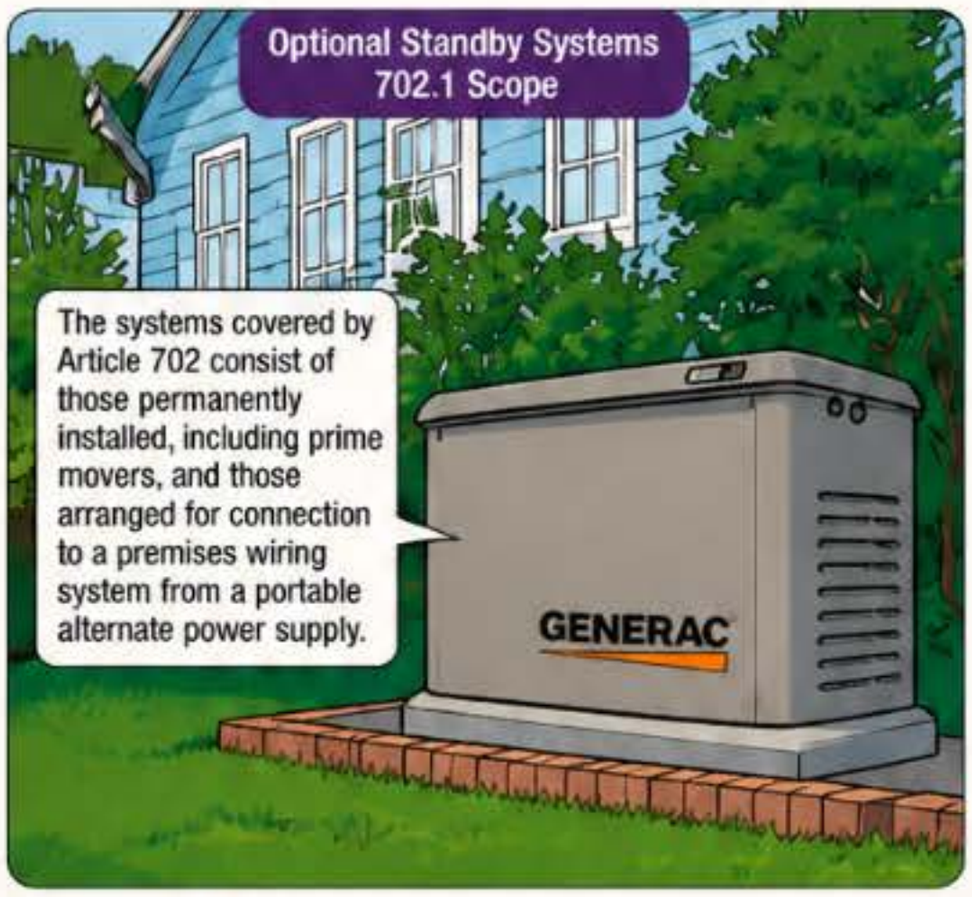
Even brief interruptions can harm finances or business operations. Data centers might lose millions in a single minute. In chemical or pharmaceutical operations, a short outage can ruin an entire batch due to a momentary power sag. In many situations, the lost product cannot be recovered.

Article 702 also addresses standby generator installations in residences, agricultural buildings, small businesses, and other locations where standby power is an option, not a requirement by law.

Part I. General

702.1 Scope

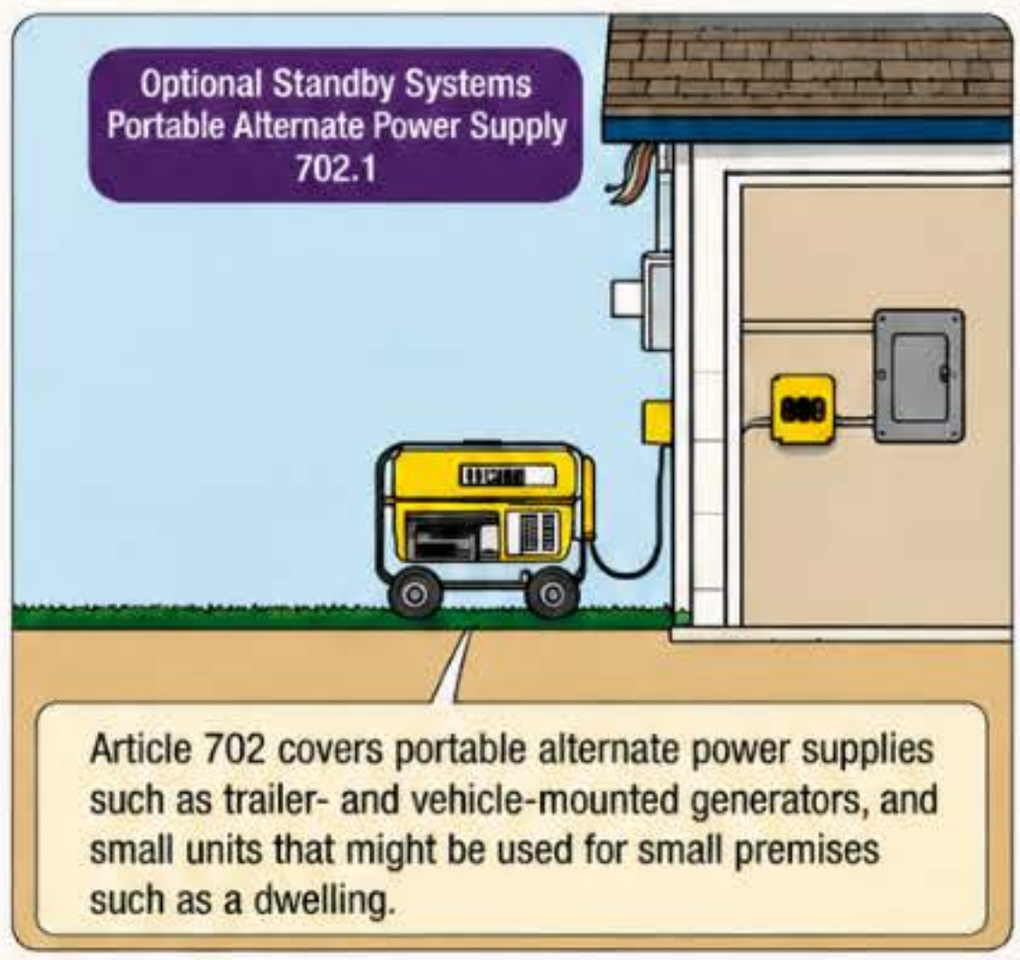
This article covers systems that include permanently installed prime movers and those arranged to connect a premises wiring system to a portable alternate power supply. See **Figure 702-1**.



▶ **Figure 702-1**

Author's Commentary:

Article 702 discusses portable alternate power sources such as trailer- or vehicle-mounted generator sets and small units that can serve small premises like a dwelling. See **Figure 702-2.**



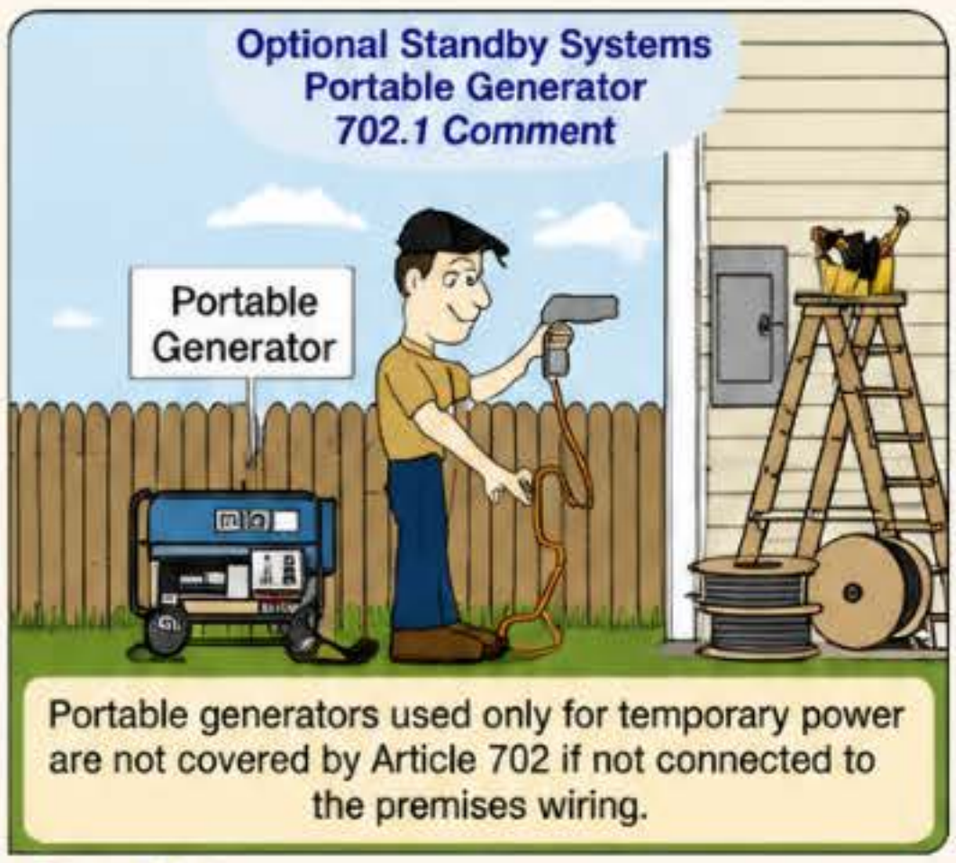
▶ **Figure 702-2**

Author's Commentary:

- Portable generators used only for temporary power
- are not within the scope of Article 702 if they are not connected to the premises wiring.

— Michael Hamilton

▶ Figure 702–3

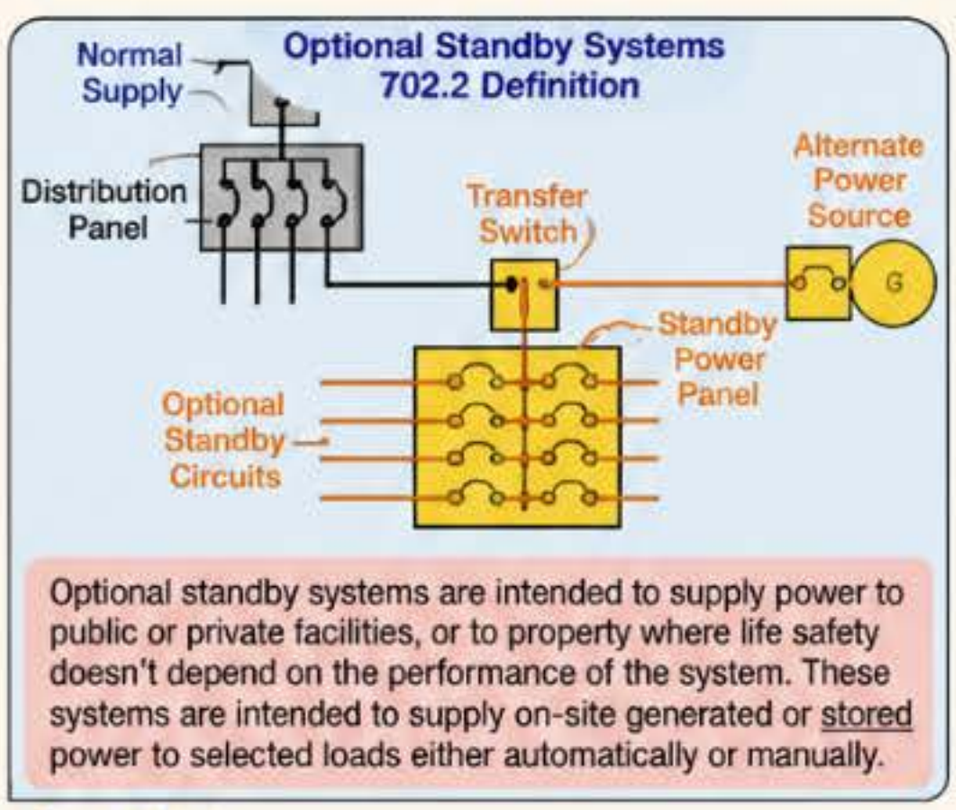


▶ Figure 702–3

702.2 Definition

The definition in this section applies throughout the *Code*.

Optional Standby Systems. Optional standby systems are intended to supply power to public or private facilities, or to property where life safety does not depend on the performance of the system. These systems are intended to supply on-site generated or stored power to selected loads either automatically or manually.



▶ Figure 702–4

Note: Optional standby systems are typically installed to provide an alternate source of electric power for such facilities as industrial and commercial buildings, farms, and residences and to serve loads such as heating and refrigeration systems, data processing and communications systems (twisted pair and coaxial cable), and industrial processes that, when stopped during any power outage, can cause discomfort, economic loss, serious interruption of the process, damage to the product or process, or the like.

702.4 Capacity and Rating

(A) Available Fault Current. Optional standby system equipment must be suitable for the available fault current at its terminals.

(B) System Capacity.

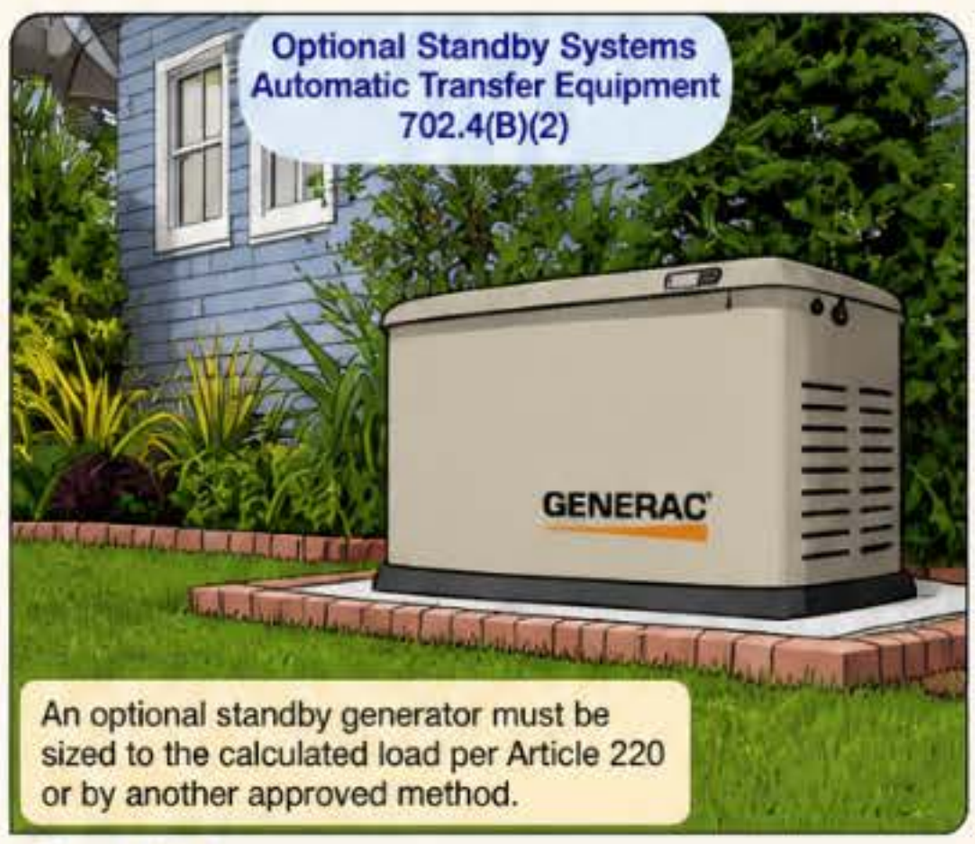
(1) Manual Transfer Equipment. Where manual transfer equipment is used, an optional standby system must be capable of supplying all of the equipment intended to be operated at one time. The user of the optional standby system is permitted to select the load connected to the system.

Author's Commentary:

- When a manual transfer switch is used, the user of the
- optional standby system chooses the loads to be connected to the system, which determines the system's kVA/kW rating.

— Michael Hamilton

(2) Automatic Transfer Equipment. An optional standby generator must be sized to the calculated load in accordance with Article 220 or by another approved method. ▶ Figure 702–5



▶ Figure 702–5

Optional Standby Systems | 702.5

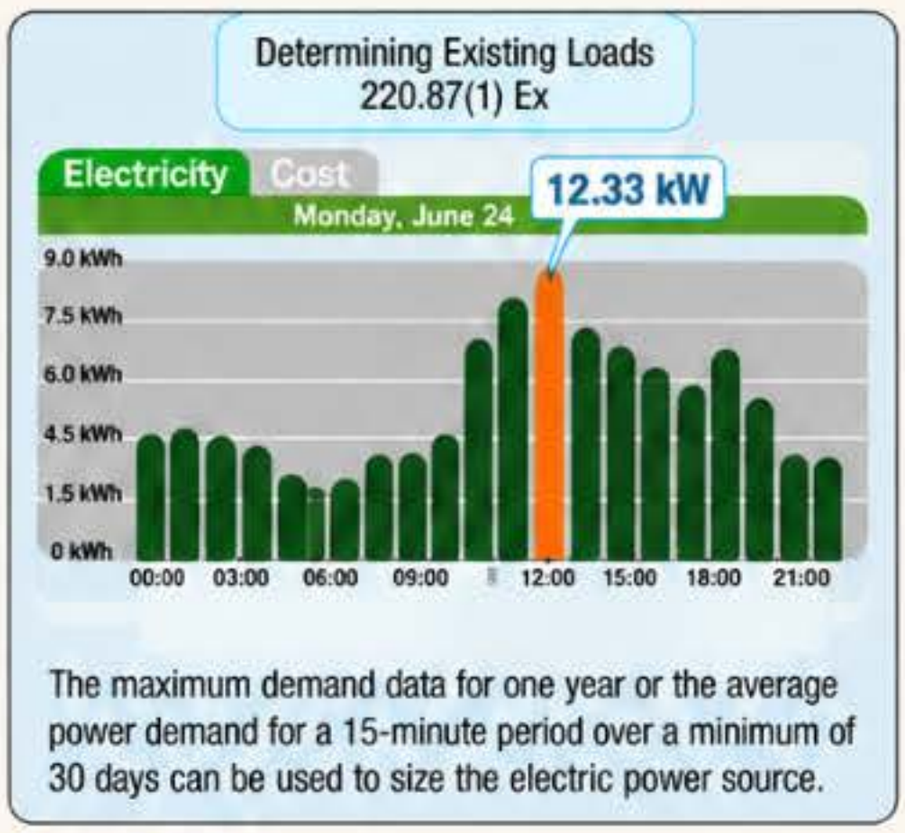
(a) Full Load. The standby source must be able to supply the entire connected load during an automatic transfer.

(b) Load Management. When an automatic load management system is used, the standby system must be capable of supplying the full load that will be connected.

Author's Commentary:

- For existing facilities, the greatest demand for one year or the average power demand over a 15-minute interval across a minimum of 30 days can be used to size the electric power source [220.87].

— Michael Hamilton



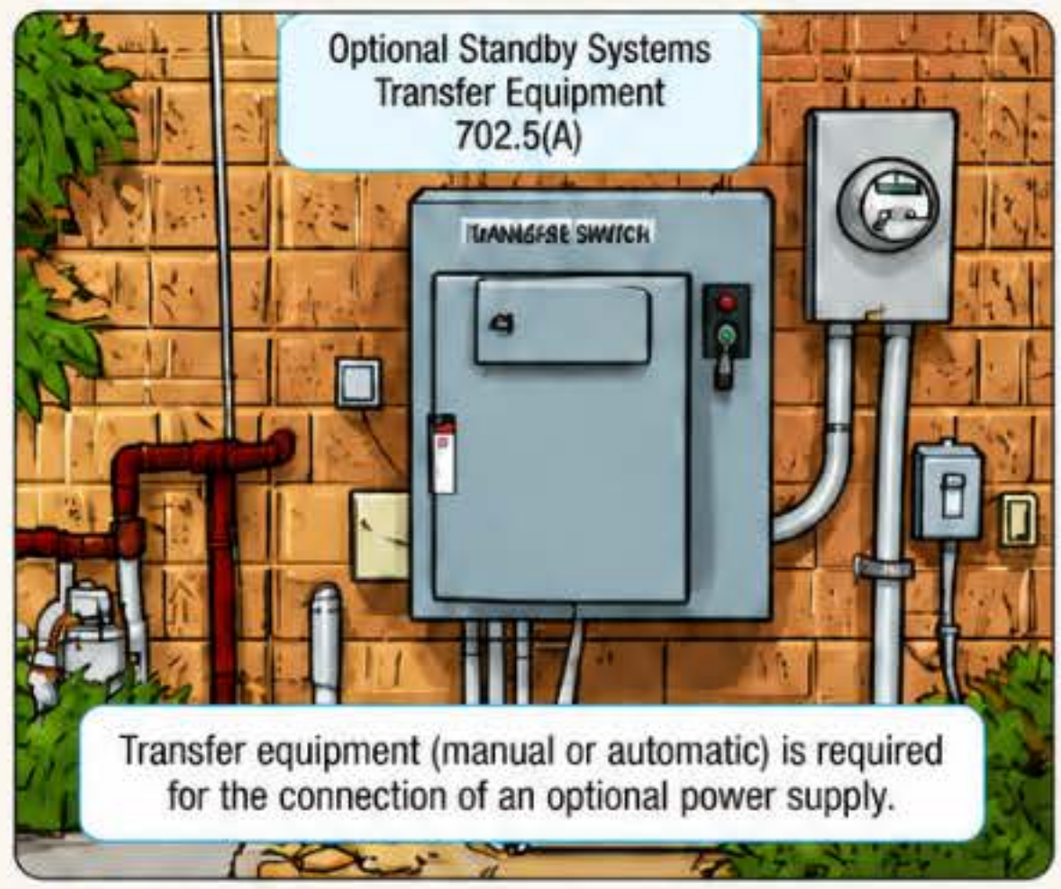
▶ **Figure 702–6**

702.5 Transfer Equipment

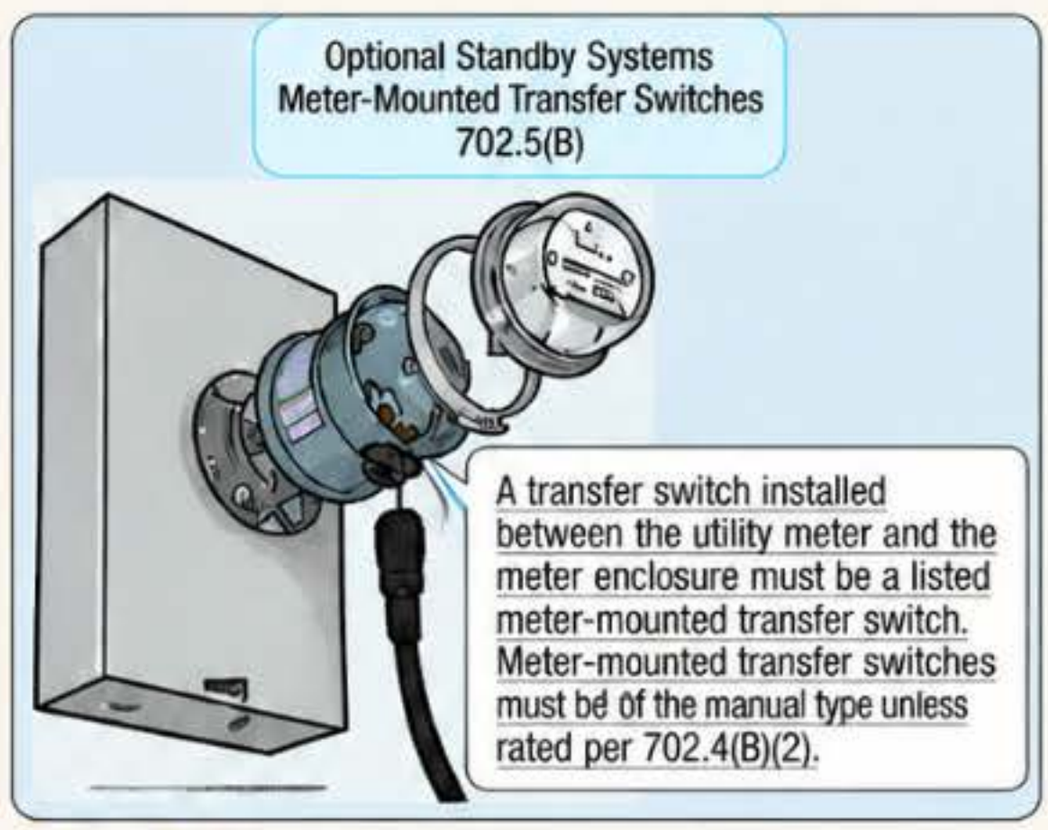
(A) General. Transfer equipment (manual or automatic) is required for attaching an optional power supply. ▶ **Figure 702–7**

Example: Temporary connection of a portable generator without transfer equipment is allowed only while maintenance and supervision ensure that only qualified persons install the connection, the normal supply is physically isolated by a lockable disconnect or by opening the normally supplied conductors.

(B) Meter-Mounted Transfer Switches. A transfer switch installed between the utility meter and the meter enclosure must be a listed meter-mounted transfer switch. Meter-mounted transfer switches must be of the manual type unless rated in accordance with 702.4(B)(2). ▶ **Figure 702–8**



▶ **Figure 702–7**

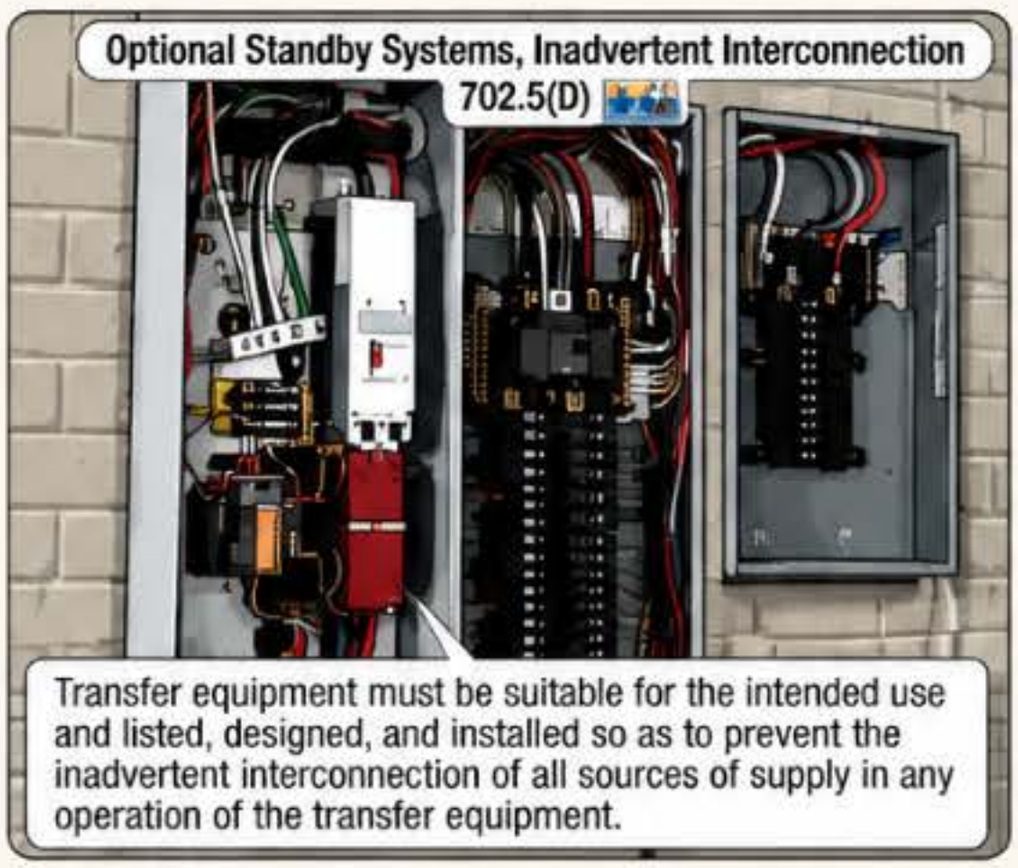


▶ **Figure 702–8**

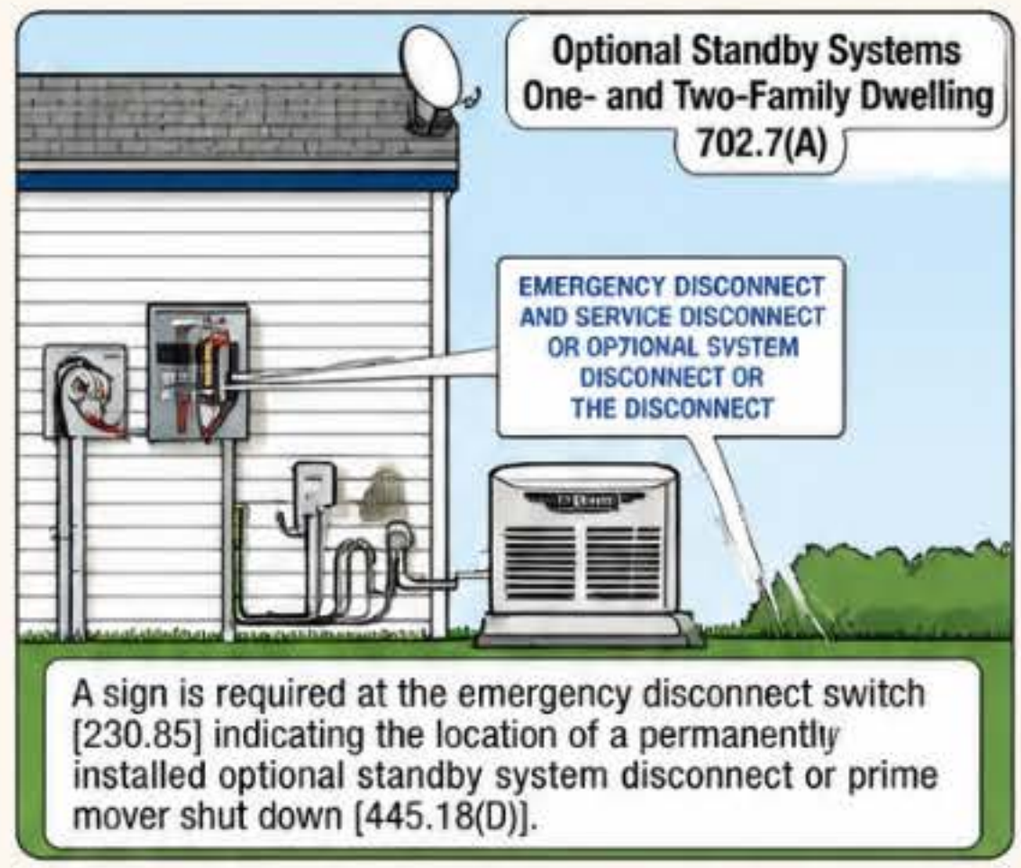
(C) Documentation. In all other locations than dwelling units, the short-circuit current rating of the transfer equipment must be field marked on the outside of the equipment.

(D) Inadvertent Interconnection. Transfer equipment must be suitable for the intended service and must be listed, designed, and installed so as to prevent unintended interconnection of any supply in operation with the transfer equipment. ▶ **Figure 702–9**

(E) Parallel Installation. Transfer equipment and electric power production systems installed to permit parallel operation with the normal source must also comply with Article 705.



▸Figure 702-9



▸Figure 702-10

702.6 Signals

Audible and visual signal devices must be installed where practicable for the purposes of:

(A) Malfunction. To indicate a malfunction of the optional standby source of power.

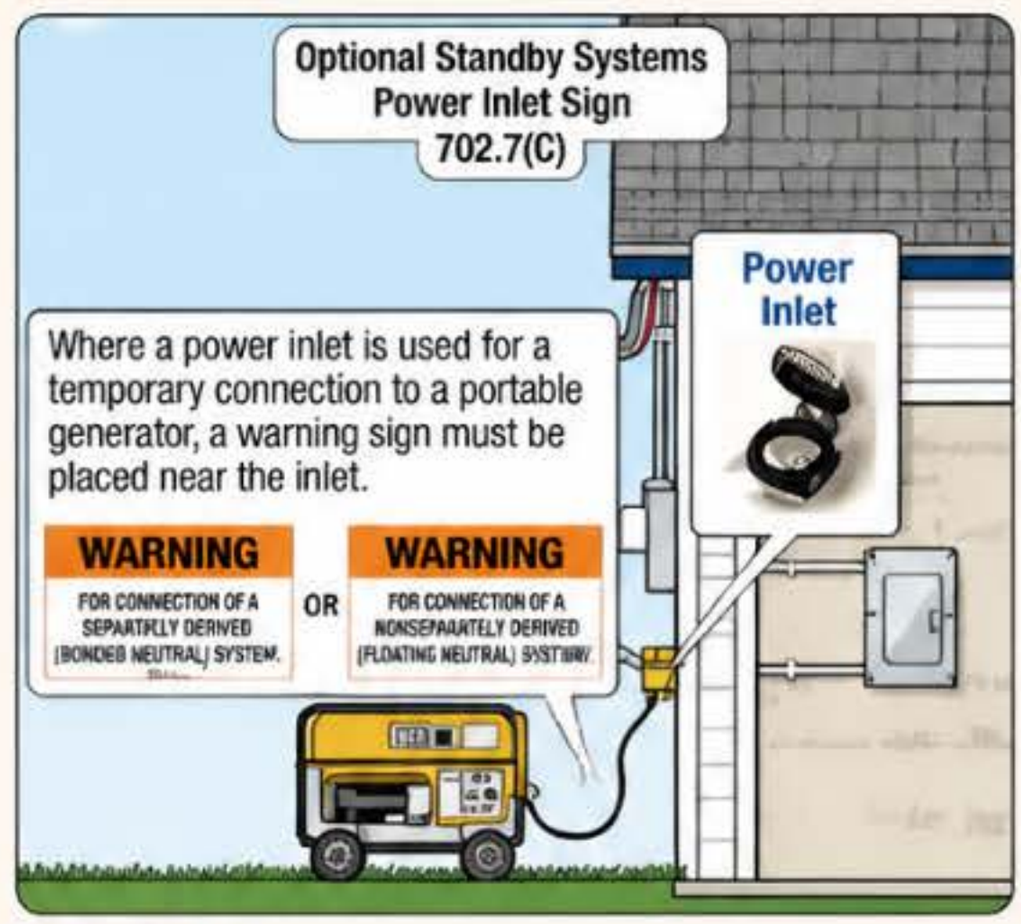
(B) Carrying Load. To indicate that the optional standby source is carrying load.

702.7 Signs

(A) Optional Power Sources. A sign is required at service equipment for commercial and industrial installations that indicates the type and location of each on-site optional standby power source.

For one- and two-family dwelling units, a sign is required at the emergency disconnect switch mandated in 230.85 that indicates the location of each permanently installed on-site optional standby power source disconnect or means to shut down the prime mover as required in 445.18(D). ▸Figure 702-10

(C) Power Inlet. Where a power inlet is used for a temporary connection to a portable generator, a warning sign must be placed near the inlet to indicate the type of transformer permitted to be connected to the inlet stating: ▸Figure 702-11



▸Figure 702-11

WARNING—FOR CONNECTION OF A SEPARATELY DERIVED (BONDED NEUTRAL) SYSTEM ONLY
OR
WARNING—FOR CONNECTION OF A NONSEPARATELY DERIVED (FLOATING NEUTRAL) SYSTEM ONLY

Author's Commentary:
Clear signaling and signage prevent confusion during emergencies and help ensure that optional standby systems are operated safely and effectively.
— Michael Hamilton

Part II. Circuit Wiring

702.10 Wiring

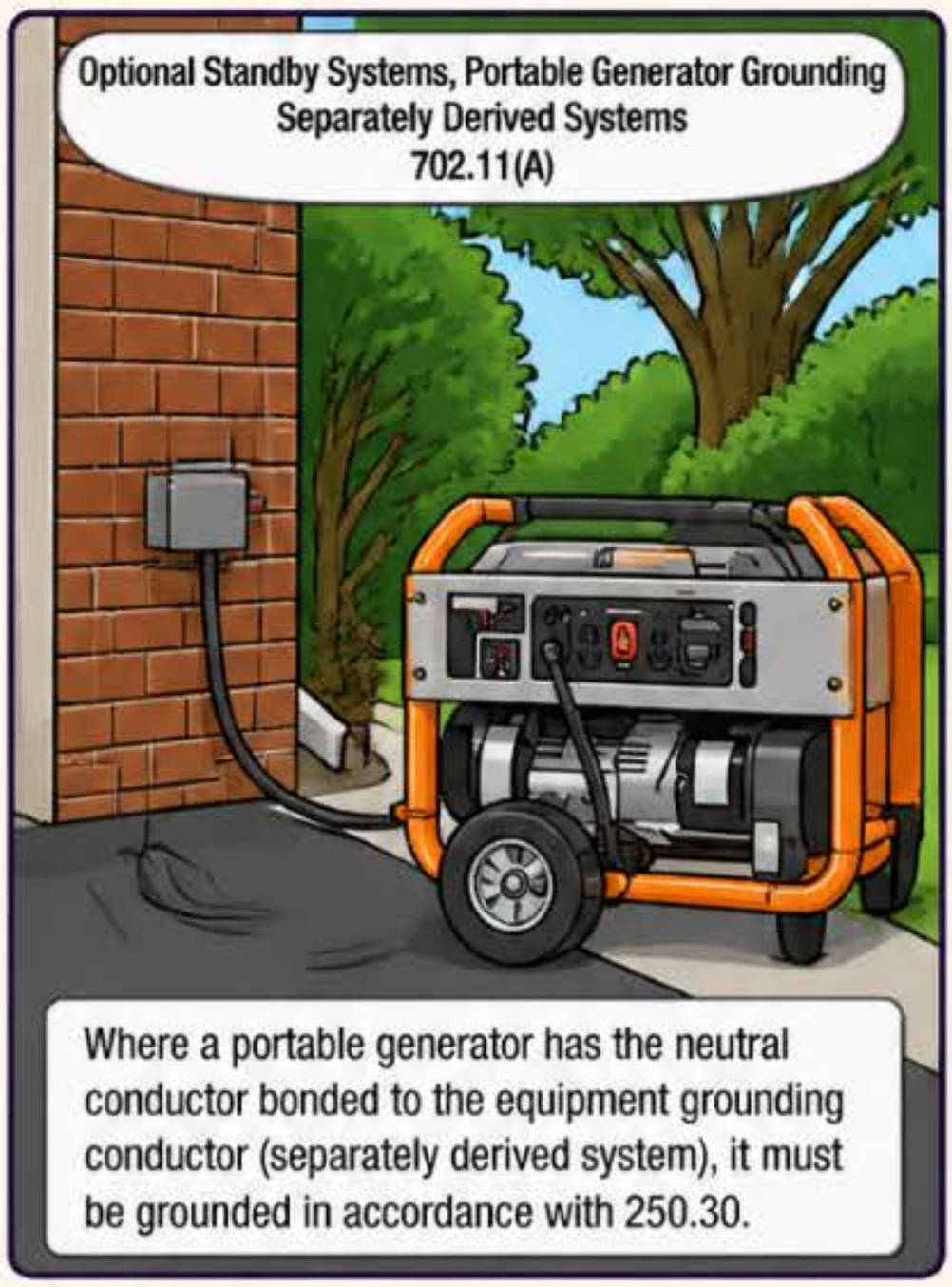
Optional standby system wiring can occupy the same raceways, cables, boxes, and cabinets with other wiring.

DEFINITIONS | From Michael Hamilton Publications

702.11 Portable Generator Grounding

(A) Separately Derived System. When a portable generator has its neutral conductor bonded to the equipment grounding conductor (separately derived system), it must be grounded in accordance with 250.30.

▸ **Figure 702–12**



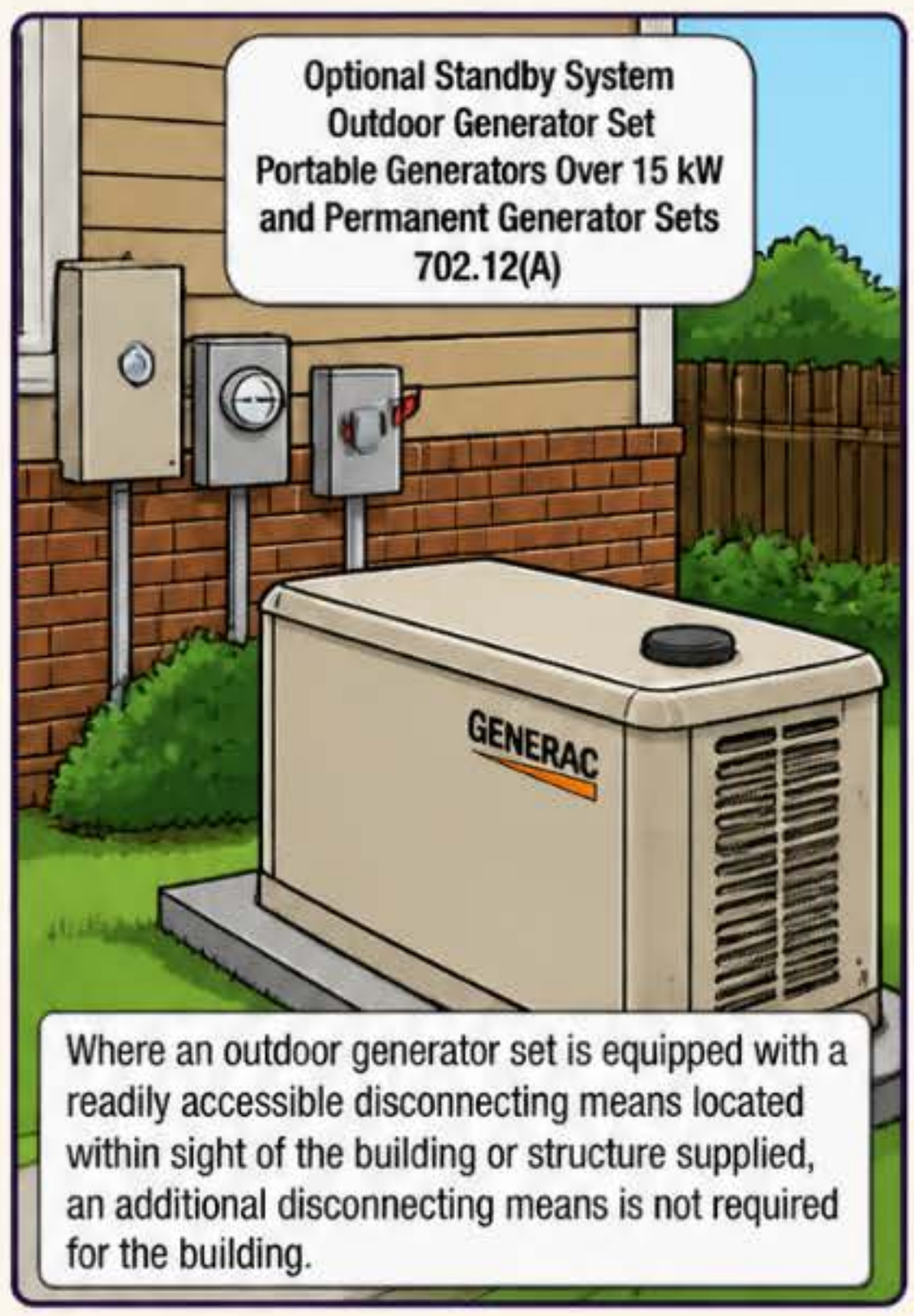
▸ **Figure 702–12**

(B) Nonseparately Derived System. When a portable generator does not have the neutral conductor bonded to the equipment grounding conductor, the generator must be grounded in accordance with 250.34(A).

702.12 Outdoor Generator Sets

(A) Portable Generators Greater Than 15 kW and Permanently Installed Generators. When an outdoor generator set is equipped with a readily accessible disconnecting means located within sight of the building or structure supplied, an additional disconnecting means is not required for the building.

▸ **Figure 702–13**



▸ **Figure 702–13**

(B) Portable Generators 15 kW or Less. When a portable generator rated 15 kW or less is installed using a flanged inlet, a disconnecting means is not required.

Notes

ARTICLE 705 INTERCONNECTED ELECTRIC POWER PRODUCTION SOURCES

Introduction to Article 705—Interconnected Electric Power Production Sources

Whenever a building has more than one source of electrical power, safety concerns come into play. Situations where a generator is used strictly for backup, Articles 700, 701, or 702 require transfer switches and other safety arrangements to be installed. In systems that interconnect different generation sources—such as wind turbines, solar photovoltaic (PV) arrays, or fuel cells—operating in parallel with the utility, there is usually no transfer switch. In these cases, multiple electrical supplies are connected at the same time.

Article 705 explains the rules for connecting such power sources that operate in parallel with a main source. The primary source is normally the electric utility, but it can also be a local (on-site) source.

Part I. General

705.1 Scope

This article establishes the requirements for the installation of electric power production sources used in parallel with the primary source of electricity.

Figure 705–1

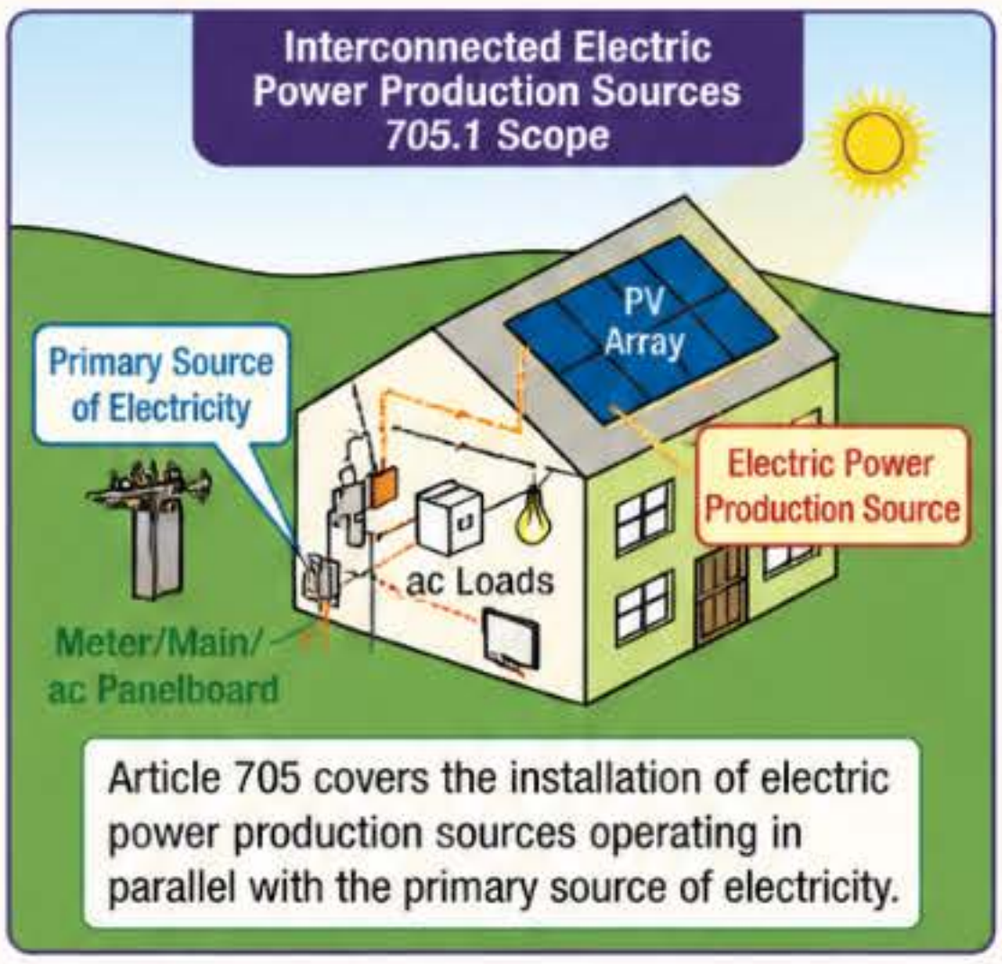


Figure 705–1

Note: The primary source of electricity usually includes the utility power service or it may be a local (on-site) source.

Author's Commentary:

Additional on-site power sources typically include the following:

- Energy storage systems (see Article 706).
- Fuel cells (see Article 692).
- Generators (see Article 445).
- Solar photovoltaic (PV) systems (see Article 690).
- Large-scale PV electric power production facilities (see Article 691).
- Storage batteries (see Article 480).
- Wind electric systems (see Article 694).

— Michael Hamilton

705.2 Definitions

Terms used in this article are defined in the *Code*.

Microgrid Interconnect Device. Equipment that allows a microgrid system to separate from and reconnect to a primary power source while operating in parallel.

Figure 705–2

Note: Microgrid controllers are generally used to monitor and measure electrical parameters and provide the logic needed for signal initiation and complete transition sequences.

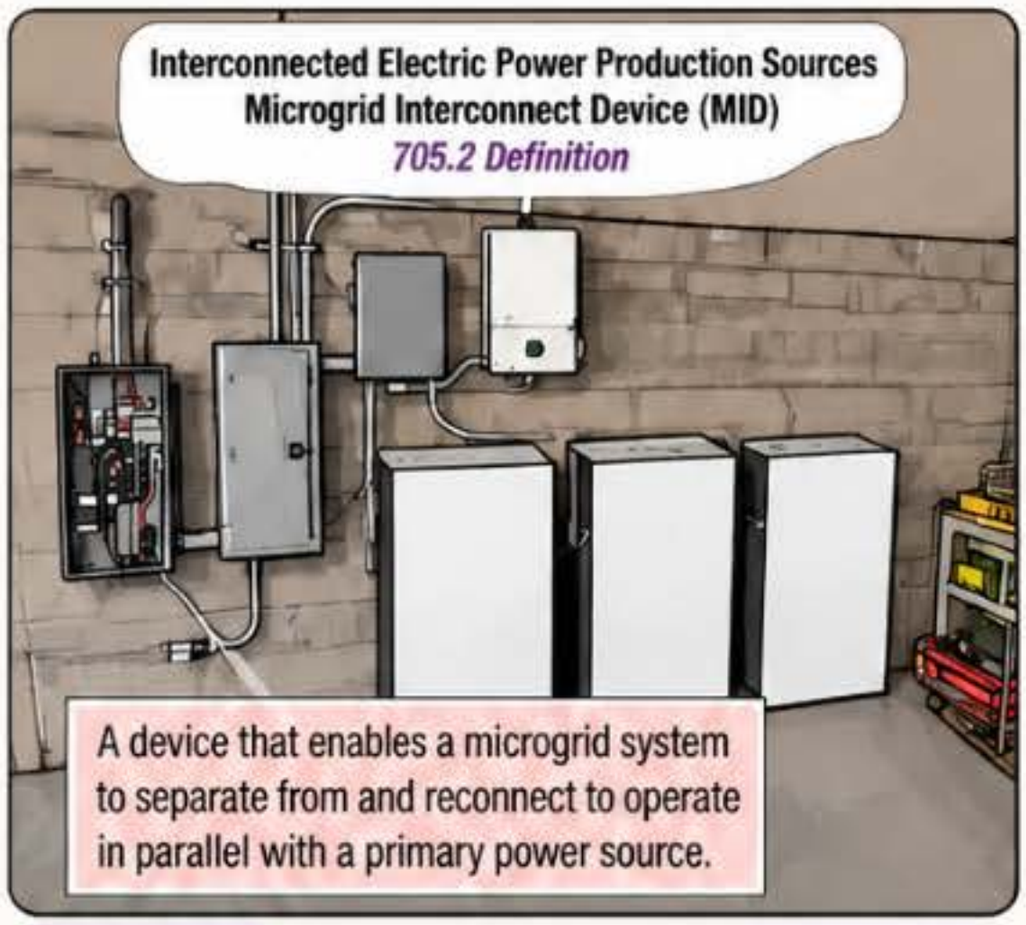


Figure 705–2

Microgrid System. A premises wiring system that has generation, energy storage, and load(s), or any combination of them, that includes the ability to disconnect from and operate in parallel with the primary source. ▸Figure 705–3

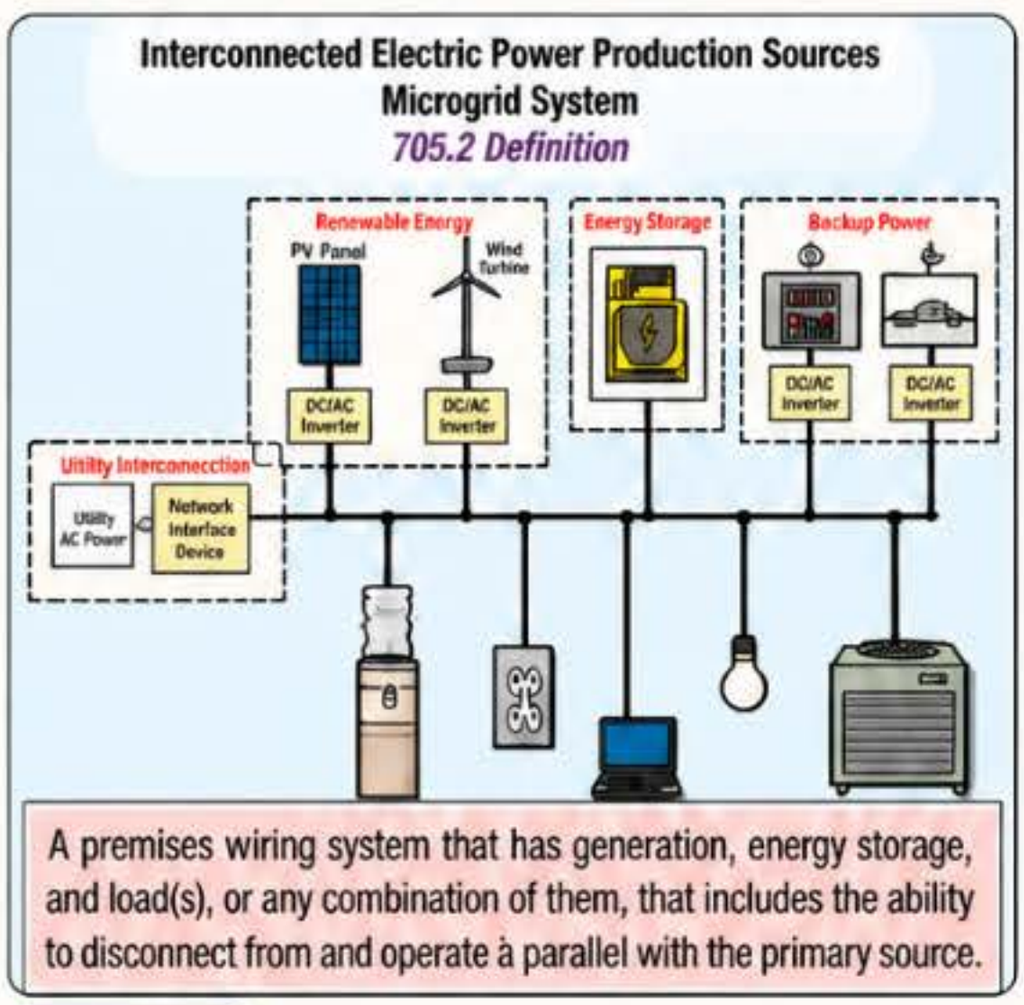


Figure 705–3

Power Source Output Circuit. The conductors from the power production equipment to distribution equipment or service equipment. ▸Figure 705–4

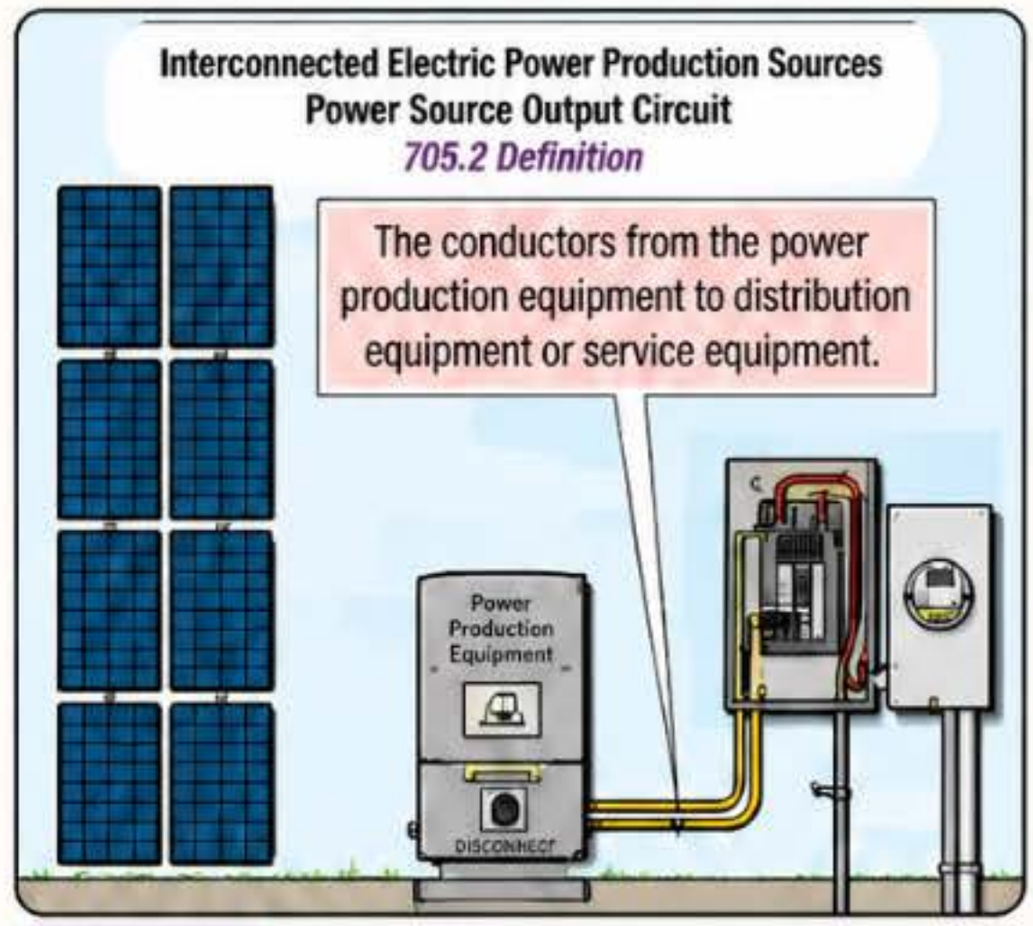


Figure 705–4

705.6 Equipment Approval

Interactive equipment intended to operate in parallel with electric power production sources including (but not limited to) interactive inverters, engine generators, energy storage equipment, and wind turbines must be approved for interactive function and be listed or be evaluated for interactive function and have a field label applied, or both.

705.8 System Installation

The installation of electrical power production sources operating in parallel with a primary source of electricity (electric utility) must be performed by a qualified person.

Note: A qualified person is one who has the knowledge related to the construction and operation of the interconnection of electrical power production sources and installations; along with safety training to recognize and avoid hazards to persons and property relating to those systems [Article 100]. ▸Figure 705–5

705.10 Identification of Power Sources

A permanent plaque or directory must be installed at each utility service disconnecting means location, or at an approved readily visible location. The plaque or directory must indicate the location of all building power source disconnecting means and be grouped with other plaques or directories for other on-site sources of power. ▸Figure 705–6

INTERCONNECTED ELECTRIC POWER PRODUCTION SOURCES

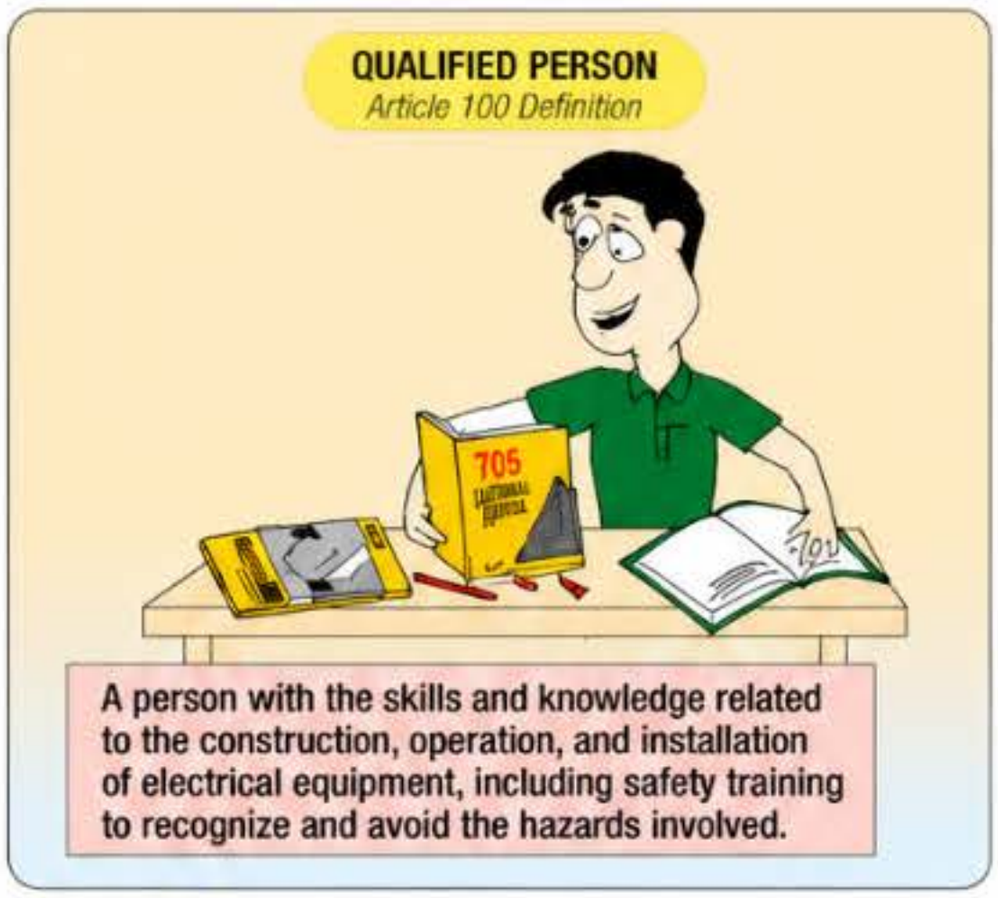


Figure 705–5

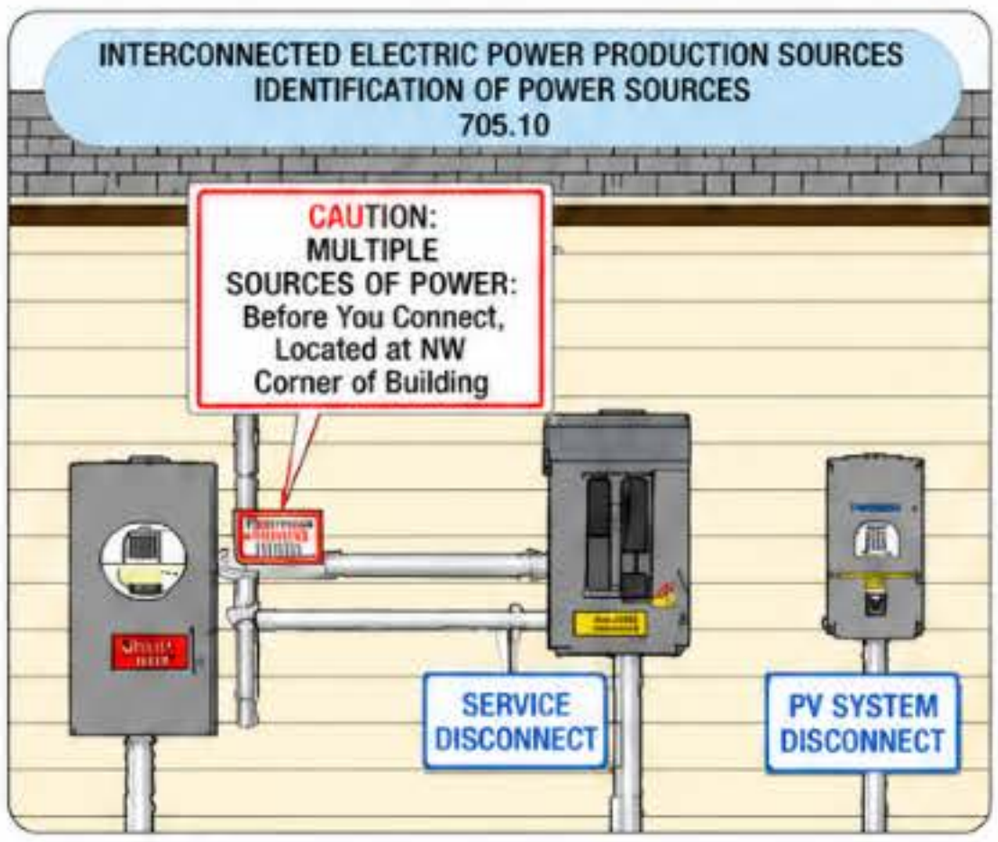


Figure 705–6

A durable plaque or directory has to be mounted by every utility's service disconnecting means location, or at an authorized reality visible location. The plaque or directory must indicate the location of each power source that is interconnected in the building.

The plaque or directory must include the warning wording "CAUTION: MULTIPLE SOURCES OF POWER." Any posted diagrams must be aligned with the site's actual location.

The marking must be permanently affixed and robust enough to withstand the environment it will be exposed to [110.21(B)].

Example: *Plaques or directories for installations that have multiple co-located power production sources are permitted to identify them as a group(s).*
A plaque or directory is not required for each individual source.

Author's Commentary:

The exception to 705.10 indicates that, because there is typically only one utility supply location available at a site, merely providing a plaque or directory is sufficient at that utility source location to point out the other remote power sources.

— ***Michael Hamilton***

705.11 SUPPLY-SIDE SOURCE CONNECTIONS

An electric power production source that is connected on the supply side of the electric utility service disconnecting means is allowed, provided it complies with 230.82(6) and 705.11(A) through (E). ***Figure 705–7***

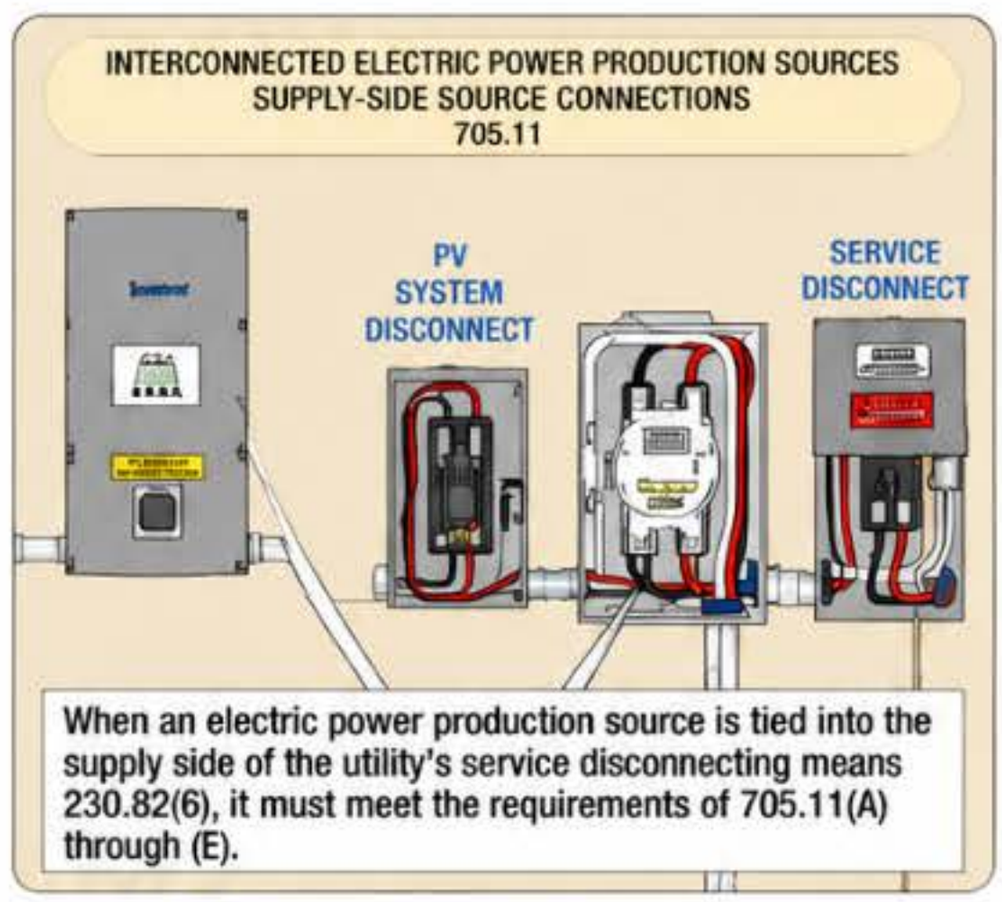


Figure 705–7

(A) Output Rating. The total output current of the supply-side source, excluding outputs governed by a power control system per 705.13, cannot be greater than the ampacity permitted by the service conductors. ***Figure 705–8***

Author's Commentary:

- Service conductors are the conductors on the load side of the utility's service point at the service disconnect [Article 100]. ***Figure 705–9***
- Service conductors (on the load side of the service point) include overhead service conductors, overhead service entrance conductors, and underground service conductors. These conductors aren't under the utility's control. They are owned by the customer and must meet the requirements of Article 230.

— ***Michael Hamilton***

Note: See Article 100 for the definition of "Service Conductors."

705.11 | Interconnected Electric Power Production Sources

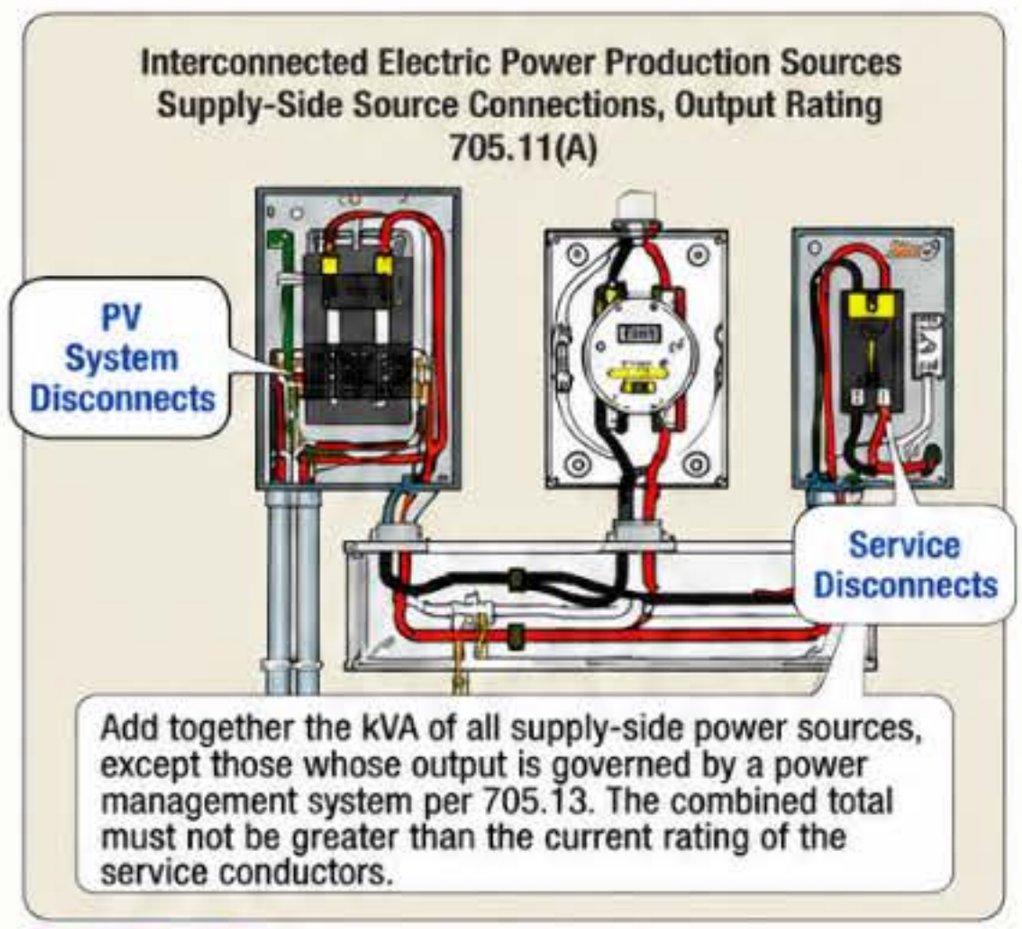


Figure 705–8

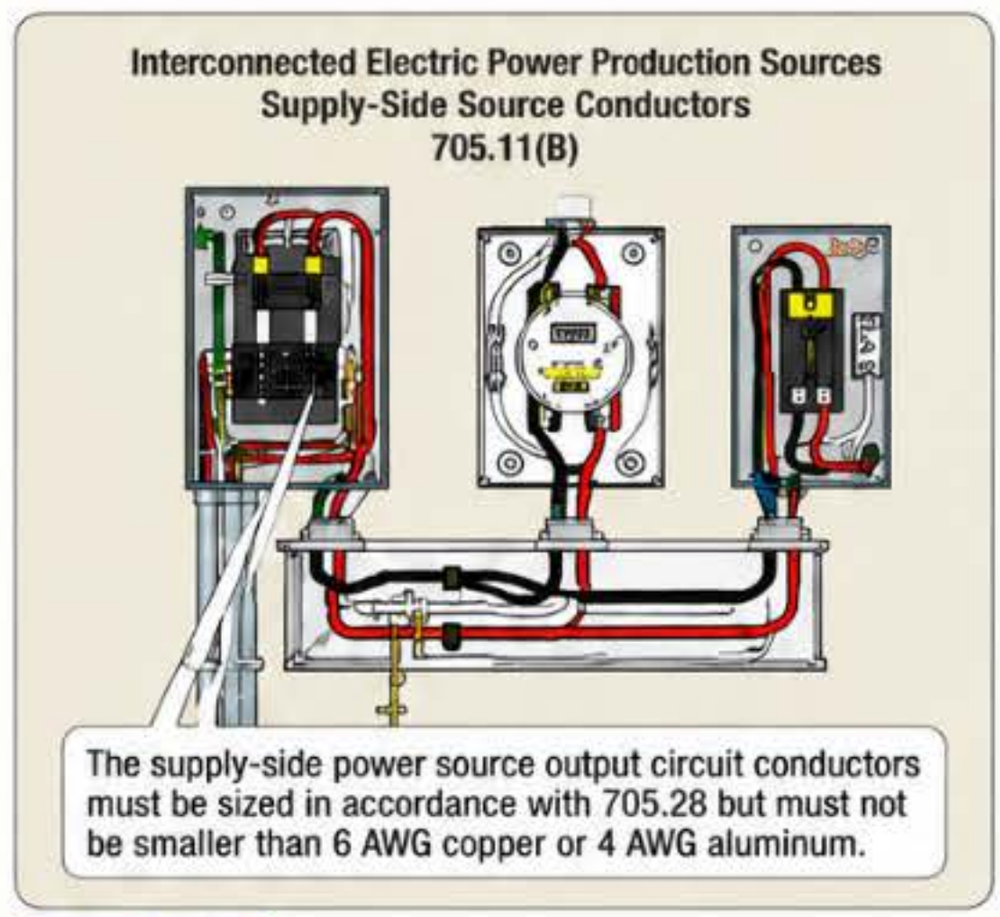


Figure 705–10

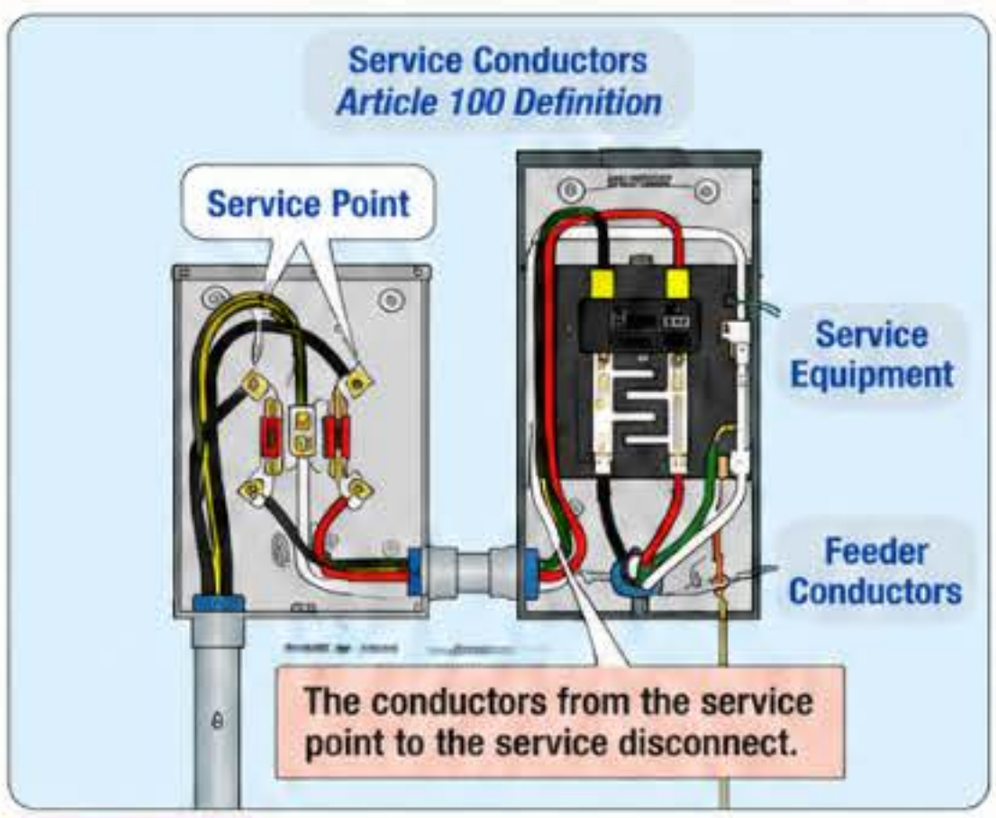


Figure 705–9

(B) Conductors. The supply-side power source output circuit conductors must be sized per 705.28 but are not permitted to be less than 6 AWG copper or 4 AWG aluminum. **Figure 705–10**

Supply-side power source output circuit conductors must be installed using wiring methods in accordance with 230.30 for underground installations and 230.43 for aboveground installations.

(C) Overcurrent Protection. Supply-side source output circuit conductors must have overcurrent protection in accordance with 705.30.

Outside. Where the supply-side power source output circuit conductors supply service conductors outside a building, the overcurrent protective device for the supply-side source output circuit conductors must be located at a readily accessible point outside the building or at the first readily accessible location where the conductors enter the building.

Inside. When the supply-side power source output circuit conductors supply service conductors within a building, the length of those conductors must comply with one of these requirements:

(1) For dwelling units, the supply-side source output circuit conductors must not extend beyond 10 ft from the supply-side connection to the overcurrent protection [705.30]. **Figure 705–11**

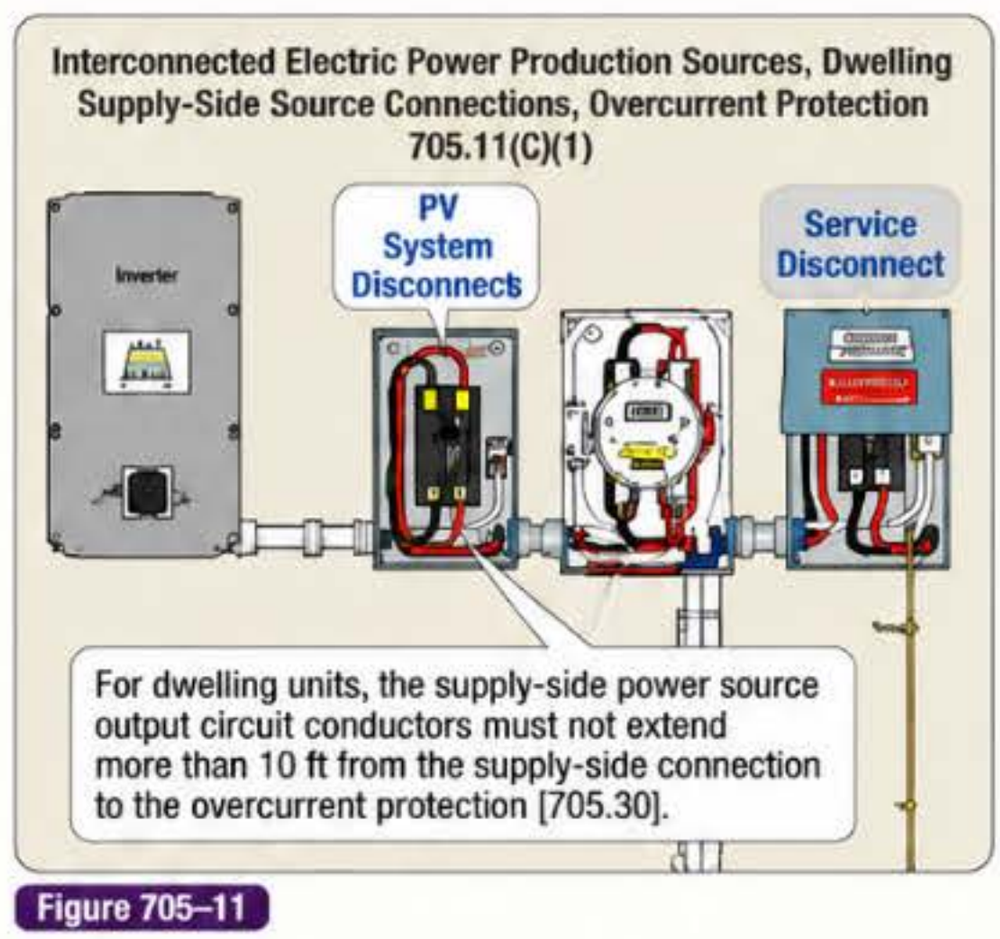


Figure 705–11

For other thandwelling units, the length of the supply-side power source output circuit conductors must not be longer than 16.50 ft from the point of the supply-side connection to the overcurrent protection [705.30].

705.12 Interconnected Electric Power Production Sources

(2) In other than dwelling units, when cable limiters are installed within 16.50 ft of the service-side connection, overcurrent protection for the supply-side conductors must be provided within 7 ft from the point where the supply-side connection is made [705.30].

(D) Connections. Supply-side connections must be constructed using the listed connectors that meet the requirements of 110.14.

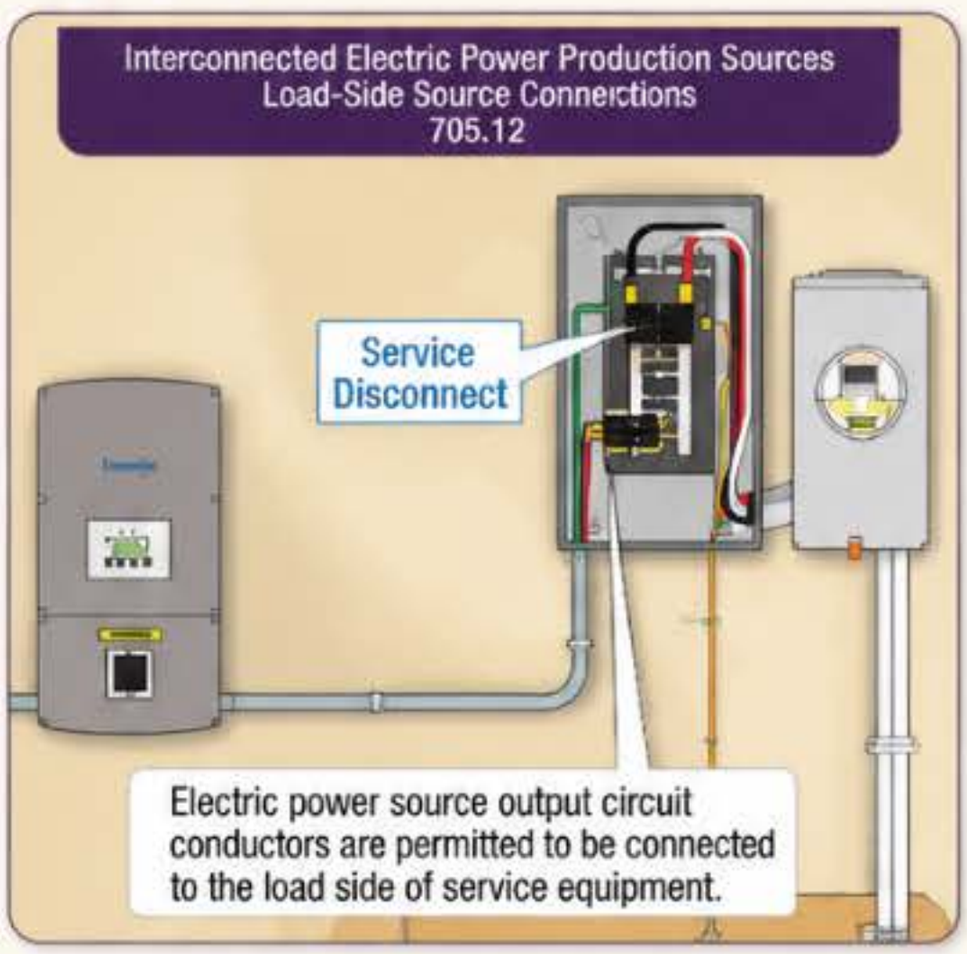
Changes to equipment for accommodating the supply-side connection must follow the manufacturer's installation guidelines. Every modification must be evaluated for the specific application and carry a field label.

Inside meter socket enclosures under the exclusive control of the utility, supply-side connections are allowed only when the electric utility grants approval.

(E) Ground-Fault Protection. Equipment that meets the requirements of 230.95 must be supplied with ground-fault protection. This protection is provided by the source output circuit, which is a solidly grounded wye system, where the voltage from phase to ground is 150V or the phase-to-phase voltage does not exceed 1,000V.

705.12 Load-Side Source Connections

Electric power source output circuit conductors are permitted to be connected to the load side of service equipment. ▶ Figure 705-12



▶ Figure 705-12

Where distribution equipment or feeders can supply branch circuits and/or feeders, or are fed by a primary source of electricity and other production sources, the interconnection of power production source equipment to the primary source must comply with one of the following methods:

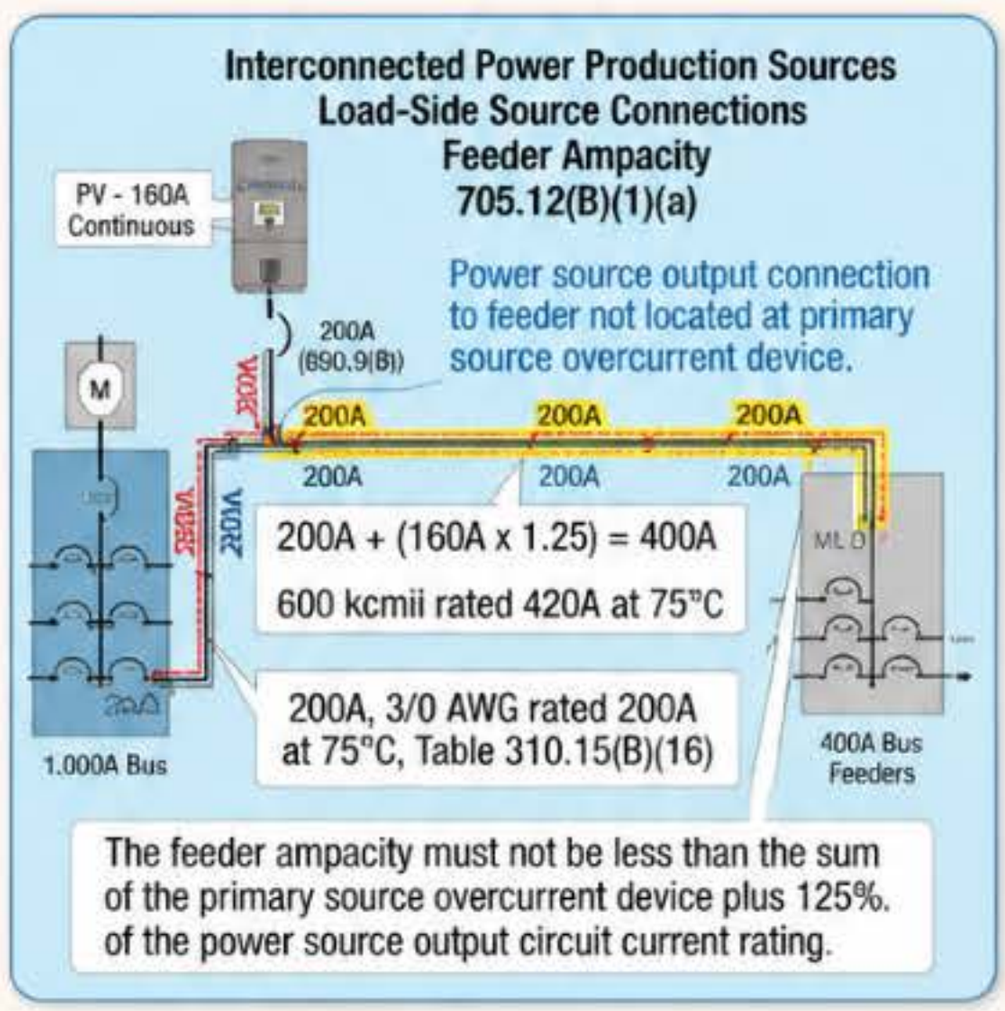
(A) Dedicated Overcurrent and Disconnect. The production source must terminate at a dedicated circuit breaker or fused disconnect.

(B) Bus or Conductor Ampere Rating. Each power source must be interconnected to a bus or conductor in accordance with one of these methods:

(1) Feeder Ampacity. If the power source connects to the feeder primary source overcurrent device, the feeder conductor must have an ampacity of not less than 125 percent of the source output circuit current.

A power source output connection made to a feeder at a location other than the opposite end of the feeder primary protection device requires the feeder ampacity on the load side of the source output to be as follows:

(a) The feeder ampacity on the load side of the source connection must not be less than the higher of: the primary source overcurrent device plus 125 percent of the source output circuit current. ▶ Figure 705-13



▶ Figure 705-13

(b) If an overcurrent protective device is installed on the load side of the source connection to the feeder conductor, the feeder ampacity must not be less than the rating of that overcurrent protective device. ▶ Figure 705-14

705.12 INTERCONNECTED ELECTRIC POWER PRODUCTION SOURCES

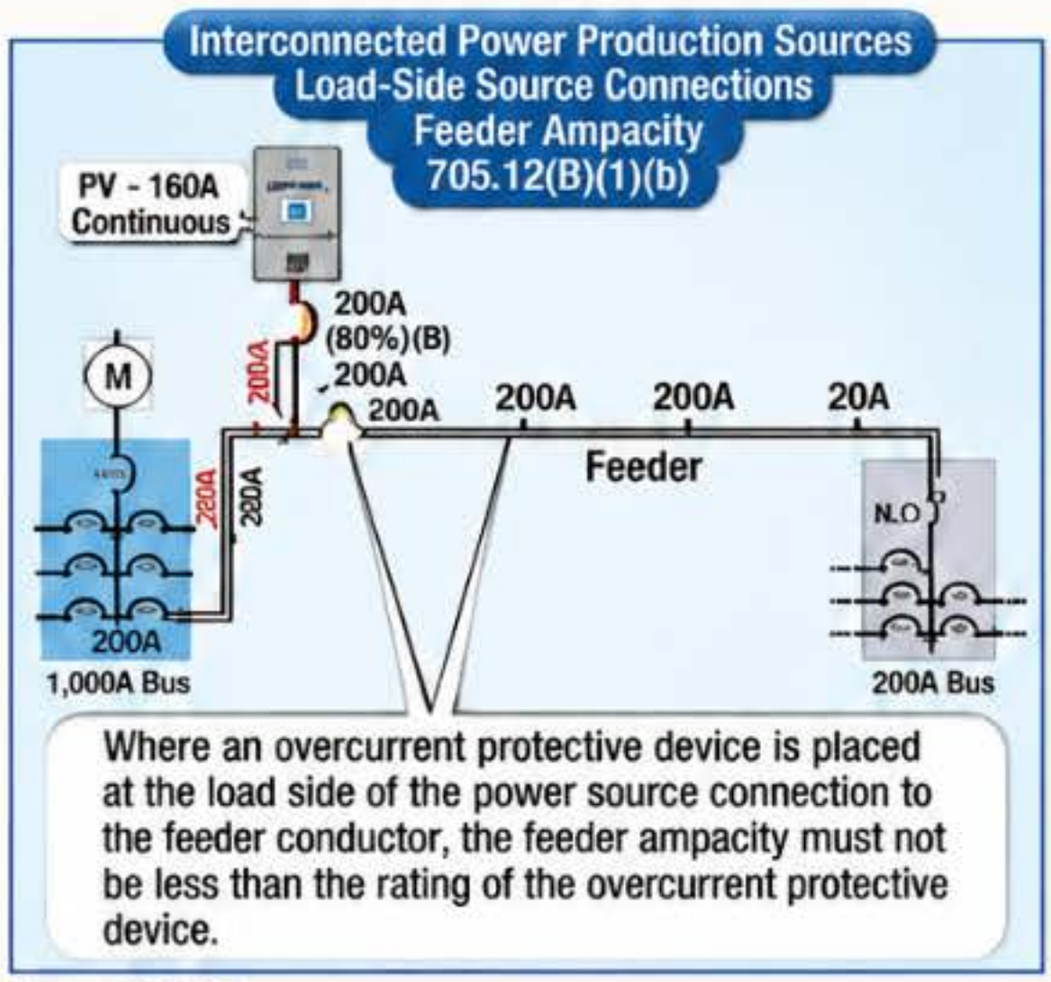


Figure 705–14

(2) Taps. Where a tap connection is made to a feeder that is supplied with both a primary source of power and an additional power source, the tap conductors in accordance with 240.21(B) must be sized based on the sum of the feeder protective device plus 125 percent of the PV system rated output circuit current.

AUTHOR'S COMMENTARY:

- A 10-foot tap is no longer required to have an ampacity of at least 10 percent of the combined rating of the feeder protective device plus 125 percent of the PV system's output circuit current. It can now have a smaller ampacity than the disconnecting device at the end of the tap.

— Michael Hamilton

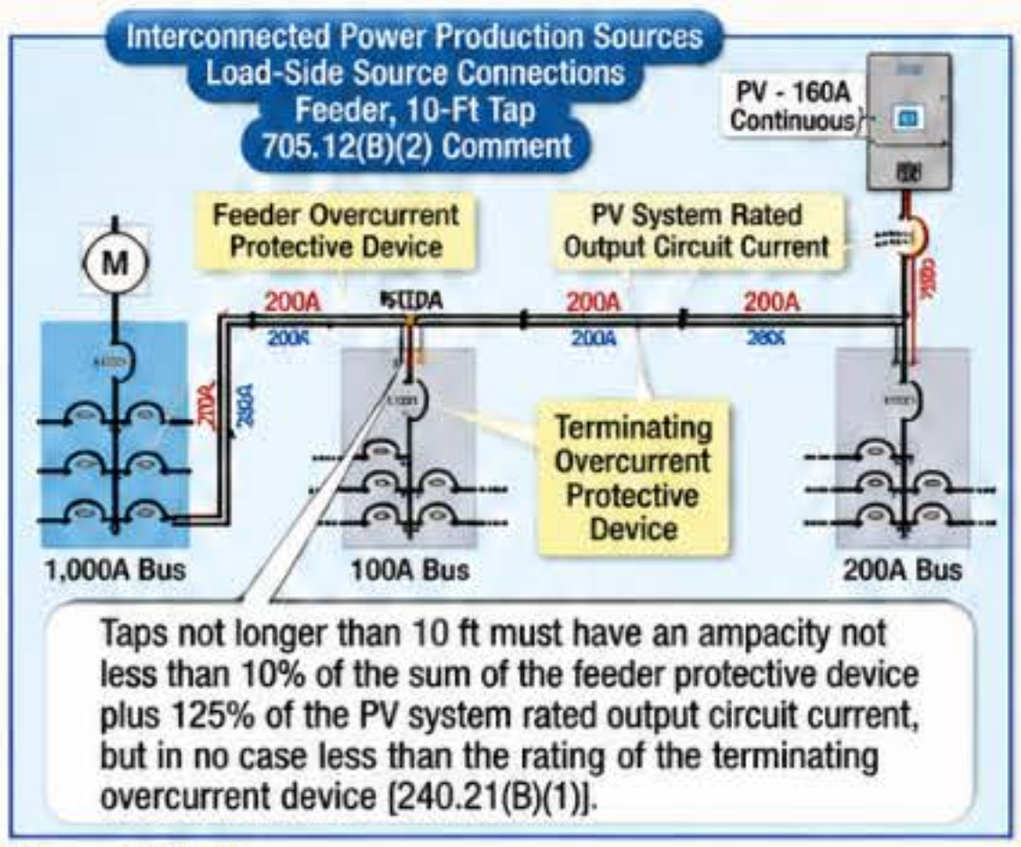


Figure 705–15

AUTHOR'S COMMENTARY:

- The requirement for feeder tap sizing has changed. A PV system tap is no longer required to carry at least 25 ft and have an ampacity of not less than 33 percent of the combined rating of the feeder protective device plus 125 percent of the PV system output circuit current. It can now be smaller than the disconnecting device, even if the protective device at the end of the tap has a lower rating.

— Michael Hamilton

▶ Feeder Tap—10-Foot Example

Question: *What size tap conductor (not over 10 ft long) made from a 200A-protected feeder supplied with an inverter having an ac output current rating of 160A is required to be a 100A overcurrent protective device?*

(a) 3 AWG (b) 2 AWG (c) 1 AWG (d) 3/0 AWG

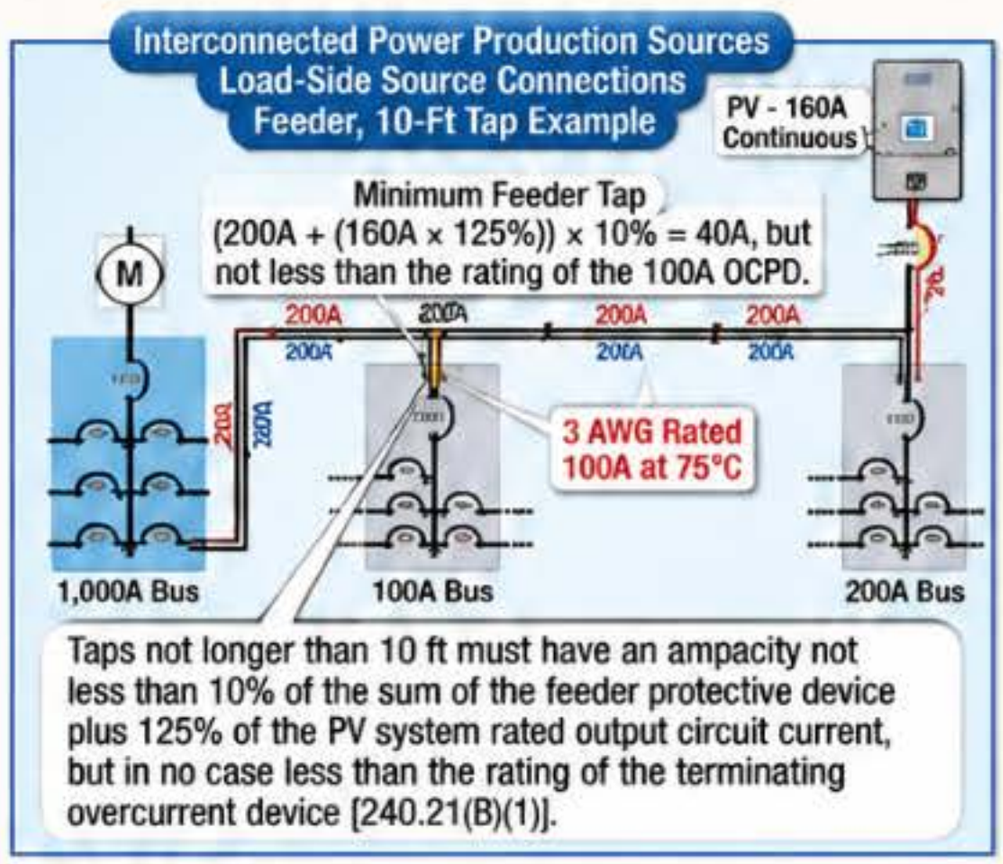


Figure 705–16

Solution:

PV system taps not longer than 10 ft must have an ampacity of not less than 10 percent of the sum of the feeder protective device (200A) plus 125 percent of the PV system rated output circuit current (160A); but in no case can the tap be less than the rating of the terminating overcurrent protective device (100A) [240.21(B)(1)].

Feeder Tap Conductor Ampacity => [200A + (160A × 125%)] × 10%, but not less than 100A

Feeder Tap Conductor Ampacity => (200A + 200A) × 10%, but not less than 100A

Feeder Tap Conductor Ampacity => 400A × 10%, but not less than 100A

Feeder Tap Conductor Ampacity => 40A, but not less than 100A

Feeder Tap Conductor Size = 3 AWG rated 100A at 75°C (Table 310.16)

Answer: *(a) 3 AWG*

INTERCONNECTED ELECTRIC POWER PRODUCTION SOURCES | 705.12

▶ Feeder Tap—25-Foot Example

Question: *If a tap conductor is shorter than 10 ft yet not longer than 25 ft and is connected to a 200A-protected feeder that has an inverter with an output rating of 160A, what ampacity is required for a 100A overcurrent protective device? See* **Figure 705–17.**

(a) 3 AWG (b) 2 AWG (c) 1 AWG (d) 1/0 AWG

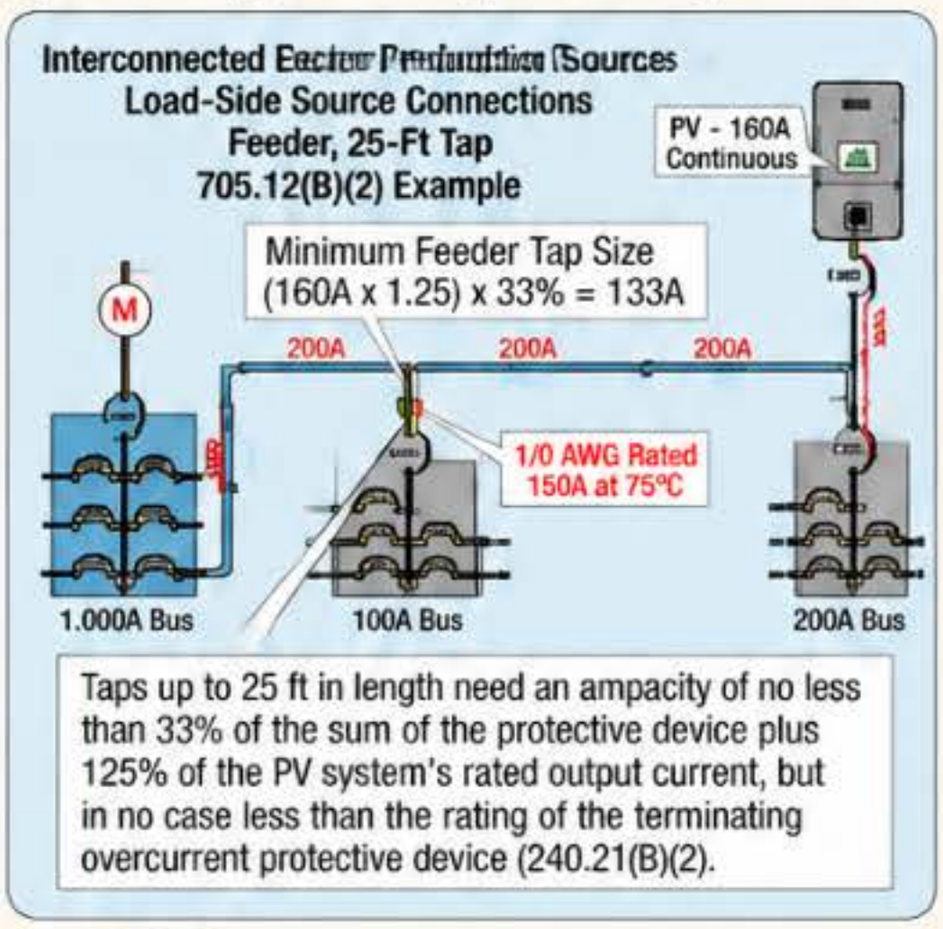


Figure 705–17

Solution:

Because the tap is not longer than 25 ft, it must have an ampacity of at least 33 percent of the total of the feeder protective device (200A) plus 125 percent of the PV system's rated output (160A); however, it can't be less than the rating of the terminating OCPD (100A) [240.21(B)(2)].

Feeder Tap Conductor Ampacity => [200A + (160A x 125%)] x 33%, but not less than 100A

Feeder Tap Conductor Ampacity => (200A + 200A) x 33%, but not less than 100A

Feeder Tap Conductor Ampacity => 400A x 33%, but not less than 100A

Feeder Tap Conductor Ampacity => 133A, but no less than 100A

Feeder Condactor Size = 1/0 AWG rated 150A at 75°C [Table 310.16]

Answer: *(d) 1/0 AWG*

(3) Busbars. Power source connections to panelboard busbars must be made using one of the methods below:

(1) Busbars at 100%. If conductors supplying a power source termination or an OCPD located anywhere on a panelboard busbar have an ampacity that is not less than the sum of the ratings of the overcurrent protective device for protecting the panelboard busbar plus 125 percent of the output circuit current from the power source(s). See **Figure 705–18.**

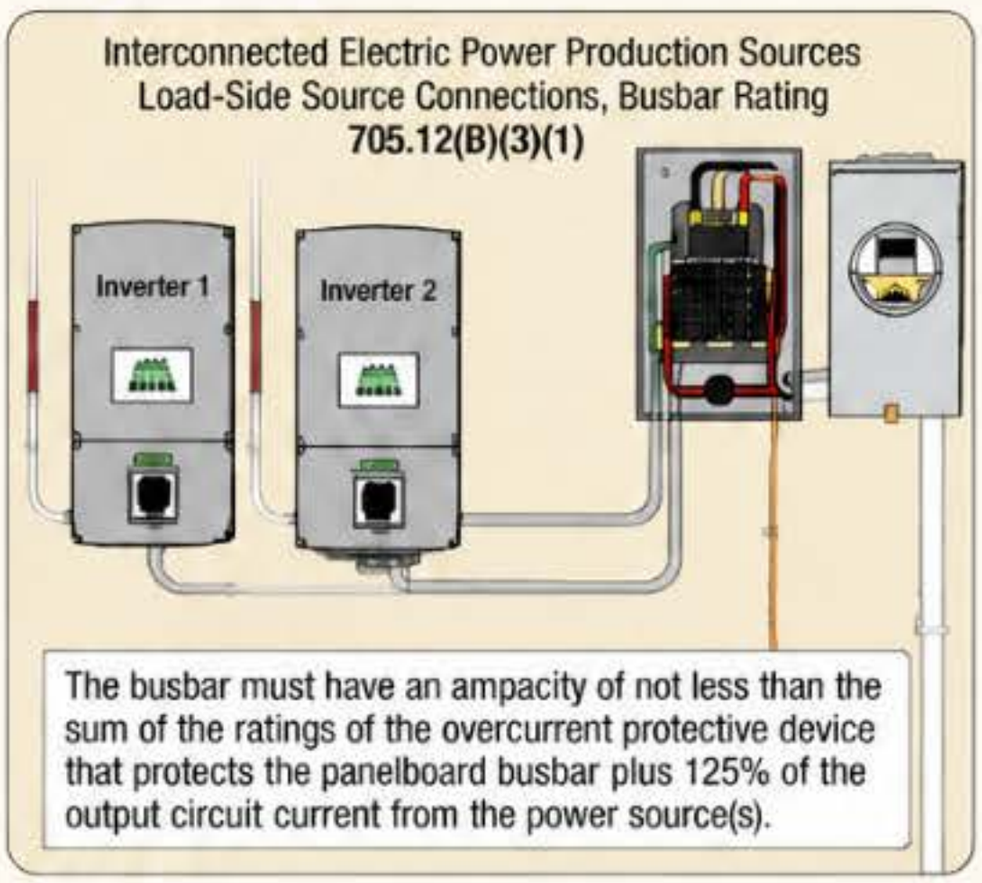


Figure 705–18

▶ Panelboard Busbar Ampere Rating—Example

Question: *What is the minimum busbar ampere rating for a panelboard protected by a 150A overcurrent protective device if it is supplied by two interactive inverters with an output current rating of 20A? See* **Figure 705–19.**

(a) 200A (b) 250A (c) 260A (d) 300A

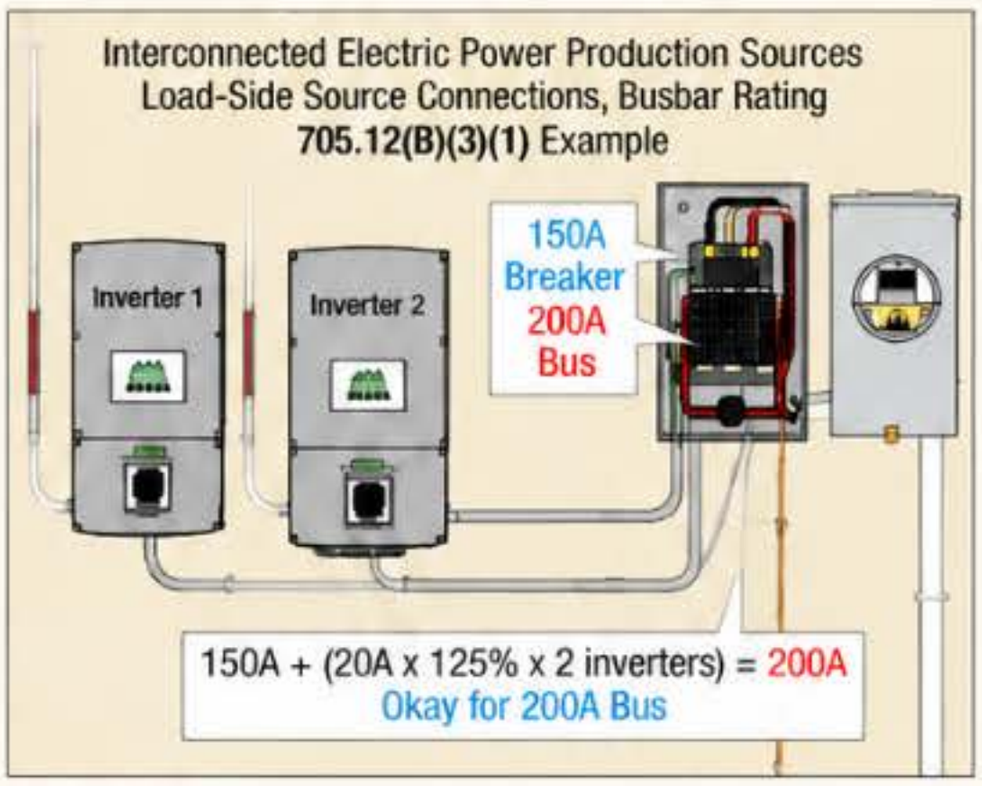


Figure 705–19

•••

705.12 | Interconnected Electric Power Production Sources

Solution:

Minimum Busbar Ampere Rating => 150A + (24A x 125% x 2 interactive inverters)

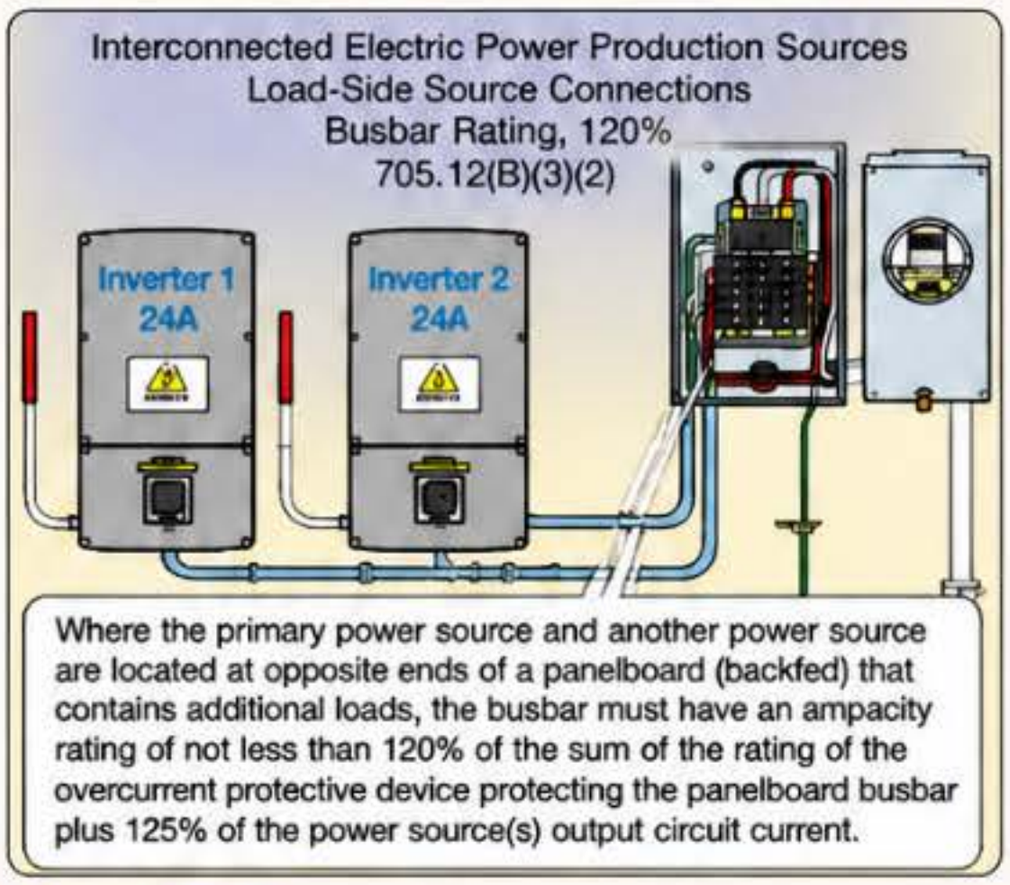
Minimum Busbar Ampere Rating => 150A + 60A

Minimum Busbar Ampere Rating => 210A

Answer: *(a) 210A*

(2) One Hundred Twenty Percent. When the main power source and an additional power source are installed on opposite ends of a panelboard (backfed) that supplies extra loads, the busbar must have a rating of at least 120 percent of the total of the rating of the overcurrent protective device protecting the panelboard busbar plus 125 percent of the output circuit current from the additional source.

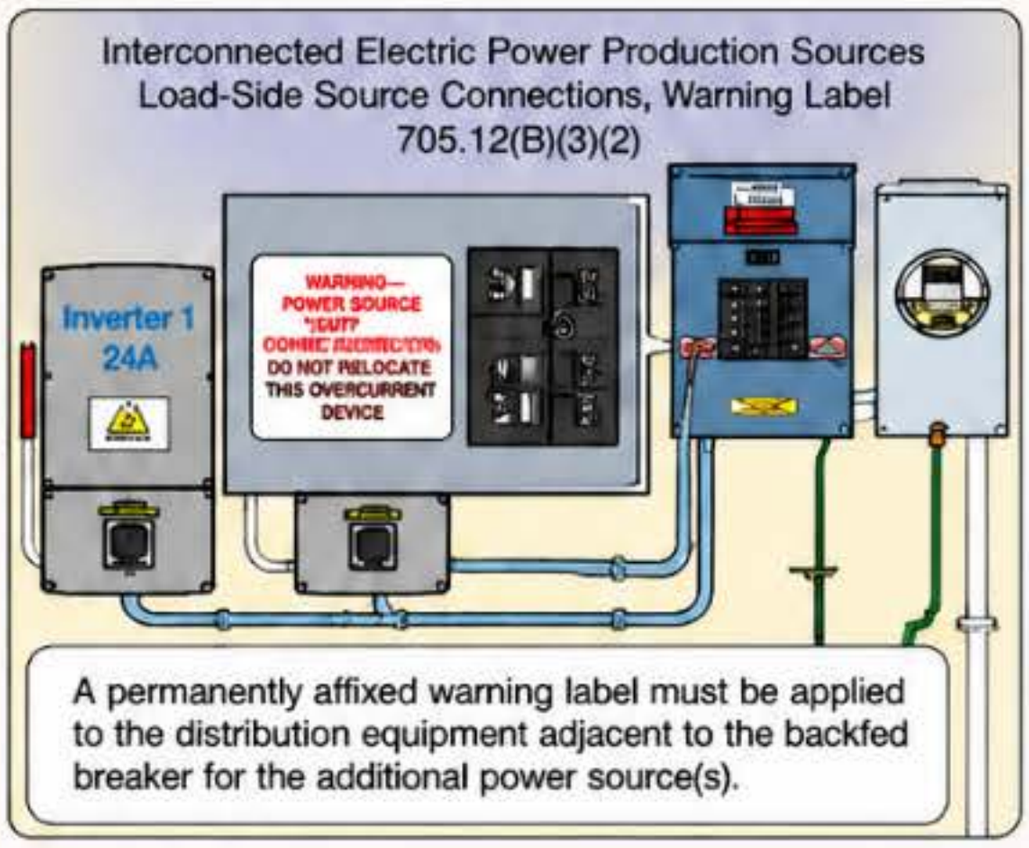
▶ **Figure 705–20**



▶ **Figure 705–20**

A permanently affixed warning label that has sufficient durability to withstand the environment involved [110.21(B)] must be applied to the distribution equipment adjacent to the backfed breaker for the additional power source(s) and must read: ▶ **Figure 705–21**

WARNING—POWER SOURCE OUTPUT CONNECTION
DO NOT RELOCATE THIS OVERCURRENT DEVICE

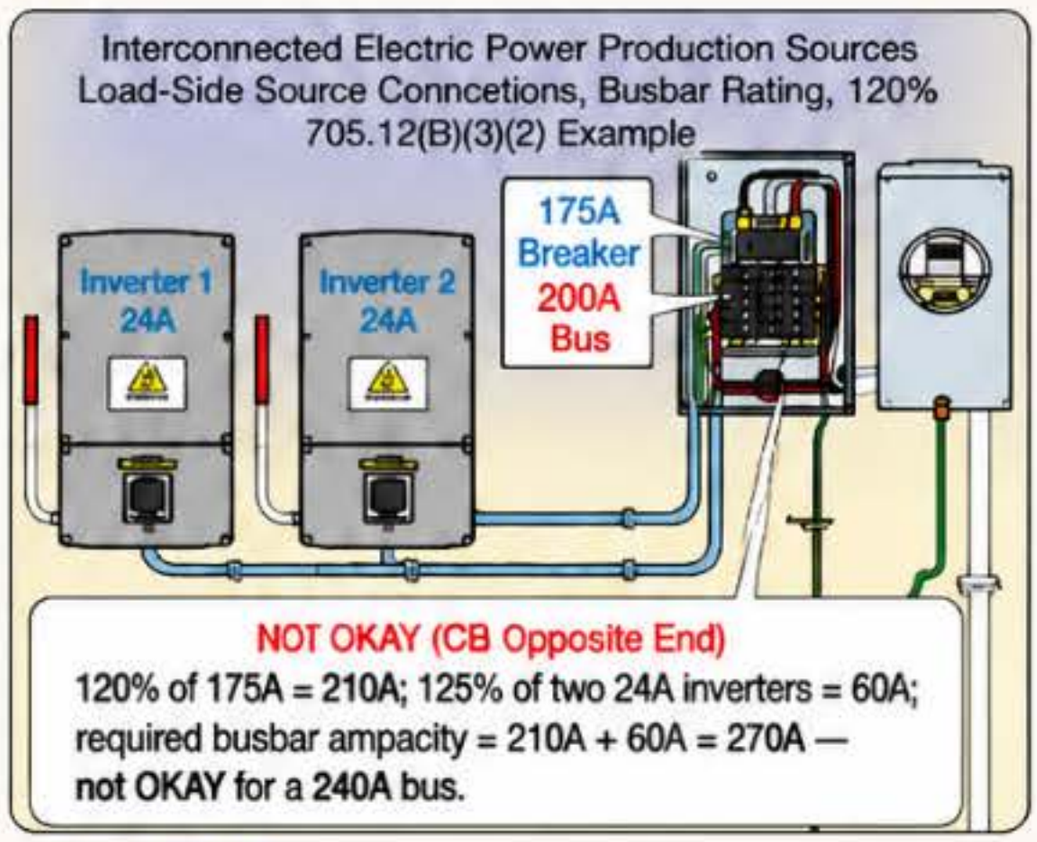


▶ **Figure 705–21**

▶ Panelboard Busbar Ampere Rating—Opposite Feeder Termination Example

Question: *Can a 200A rated panelboard protected by a 175A overcurrent device be supplied by two interactive inverters where each has an output ac current rating of 24A and are located opposite the feeder termination?*

(a) Yes *(b) No*



▶ **Figure 705–22**

Solution:

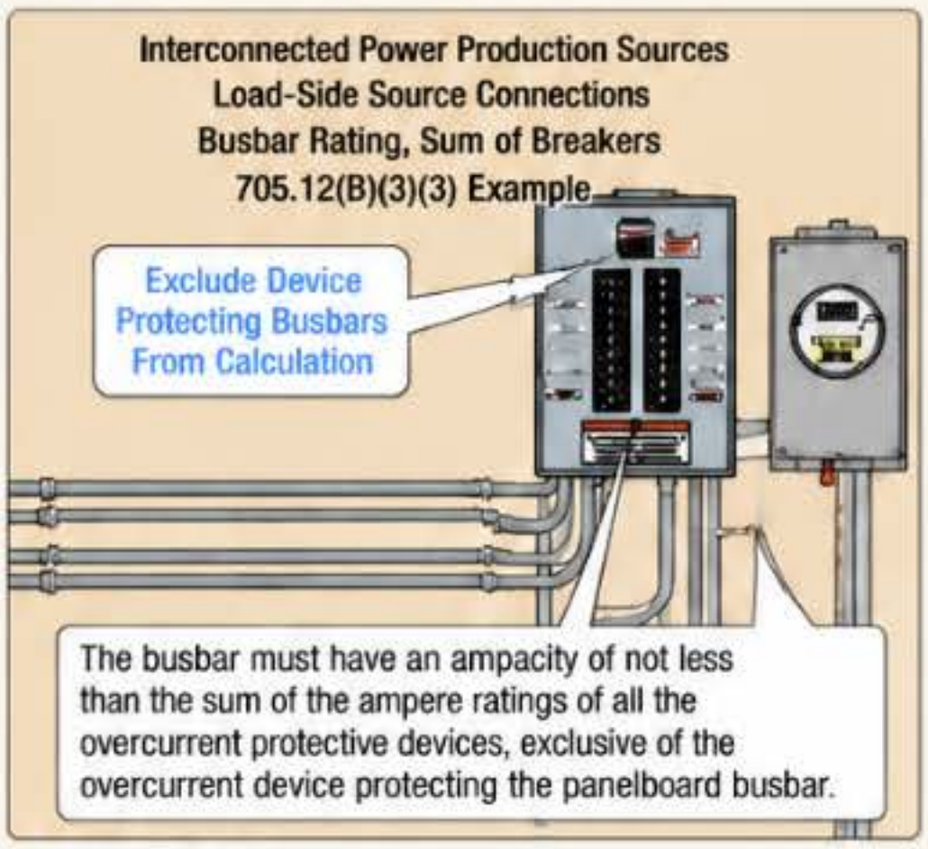
The panelboard busbar ampacity must have an ampacity of not less than 120 percent of the sum of the rating of the overcurrent protective device protecting the panelboard busbar plus 125 percent of the power source(s) output circuit current.

Interconnected Electric Power Production Sources 705.12

Panelboard Ampacity x 120% => 175A + (24A x 125% x 2 interactive inverters)
200A x 120% => 175A + 60A
240A =>235A

Answer: *(a) Yes*

(3) Sum of Breakers. When the main supply and one additional power source are connected at different ends of a panelboard, the busbar must have an ampacity that is at least equal to the total of the ampere ratings of every overcurrent protective device, except the device that safeguards the panelboard busbar. ▶ **Figure 705–23**



▶ **Figure 705–23**

▶ Panelboard Busbar Ampere Rating—Sum of Breakers Not to Exceed Busbar Ampere Rating Example 1

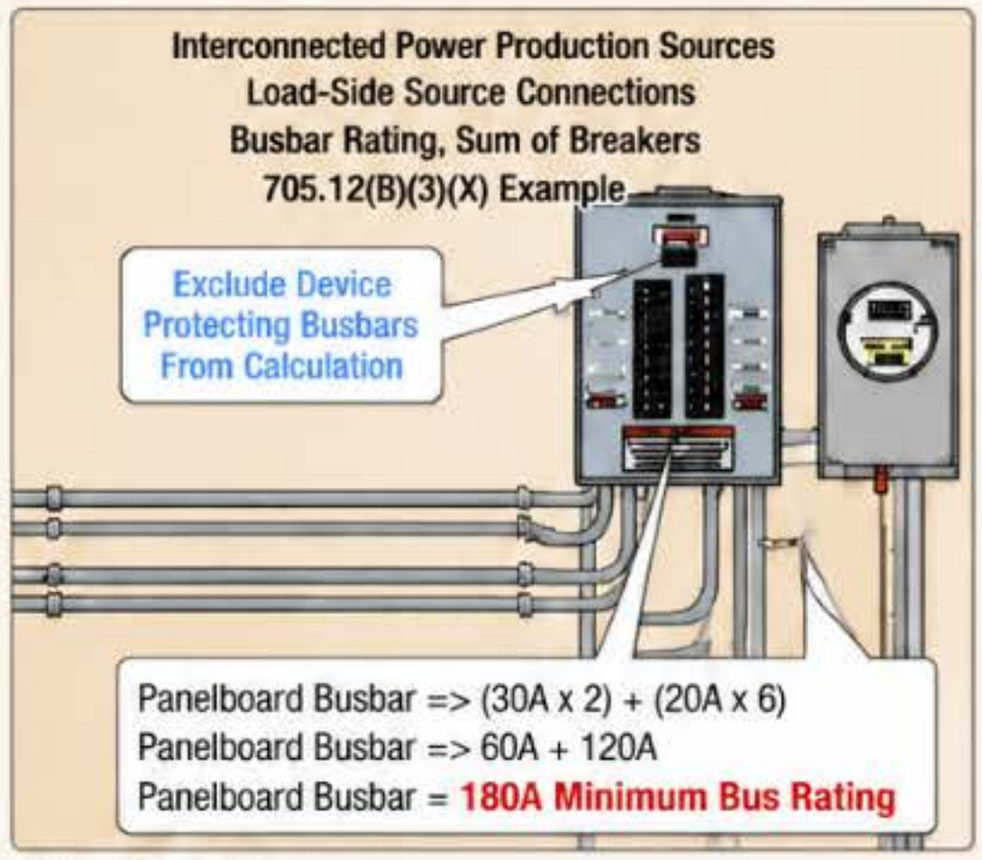
Question: *What is the minimum busbar ampere rating for a panelboard containing two 30A, two-pole circuit breakers and six 20A, two-pole circuit breakers?* ▶ **Figure 705–24**

(a) 125A (b) 140A (c) 175A (d) 200A

Solution:

The panelboard busbar must have an ampacity that is no less than the total ampere ratings of all the overcurrent protective devices, exclusive of the device that protects the panelboard busbar.

Panelboard Busbar => (30A x 2) + (20A x 6)
Panelboard Busbar => 60A + 120A
*Panelboard Busbar = **180A***



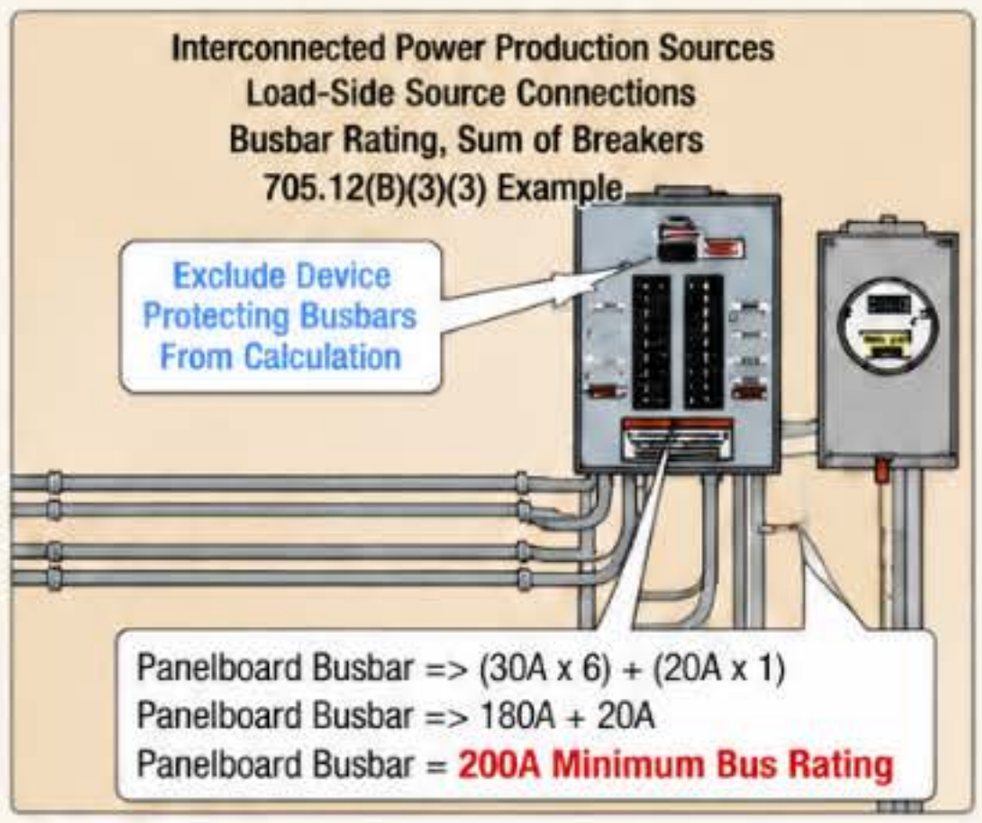
▶ **Figure 705–24**

Answer: *(c) 180A*

▶ Panelboard Busbar Ampere Rating—Sum of Breakers Not to Exceed Busbar Ampere Rating Example 2

Question:
What is the minimum busbar ampere rating for a panellboard containing six 30A, two-pole circuit breakers and one 20A, one-pole circuit breaker? ▶ **Figure 705–25**

(a) 125A (b) 150A (c) 175A (d) 200A



▶ **Figure 705–25**

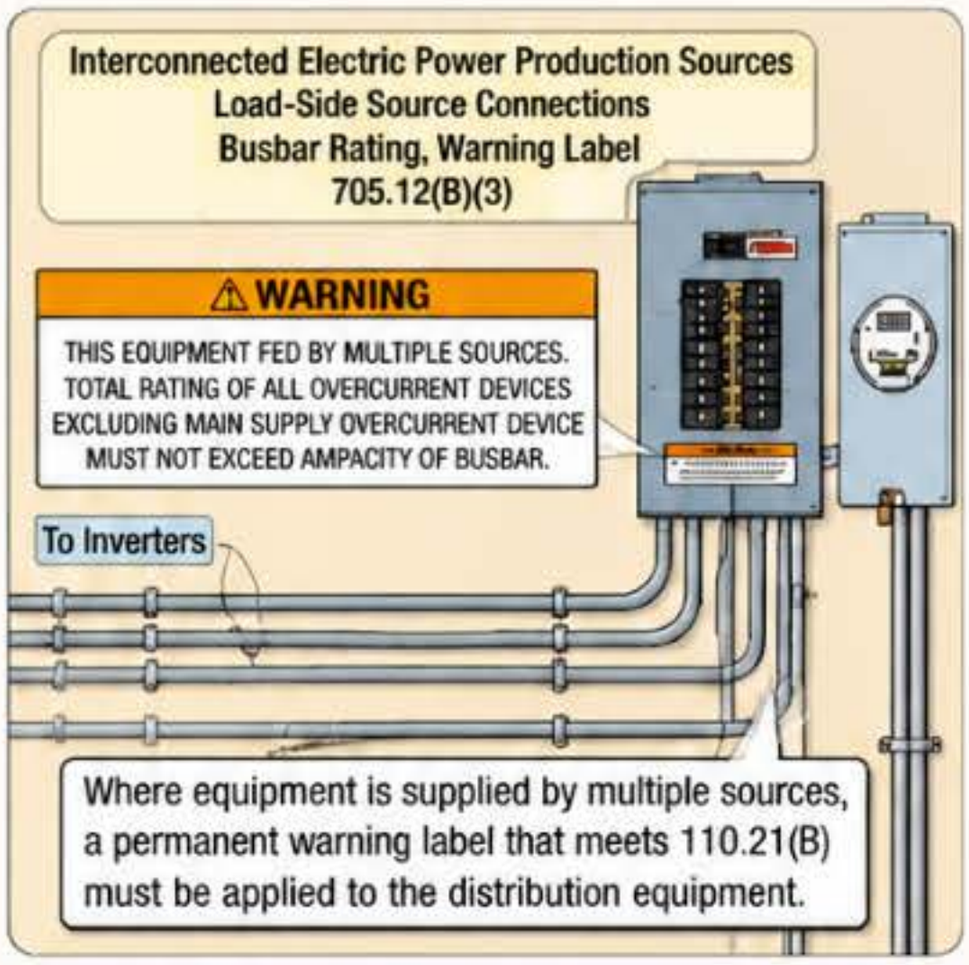
Solution:

The panelboard busbar ampacity must be equal to or greater than the sum of the ampere ratings of all the overcurrent protective devices on the panelboard busbar.

Panelboard Busbar => (30A x 6) + (20A x 1)
Panelboard Busbar => 180A + 20A
Panelboard Busbar = 200A

Answer: *(d) 200A*

A permanently affixed warning label that has adequate durability to resist the environment (110.21(B)) must be mounted in a visible location on the distribution equipment or rated panelboard. ▸ Figure 705–26

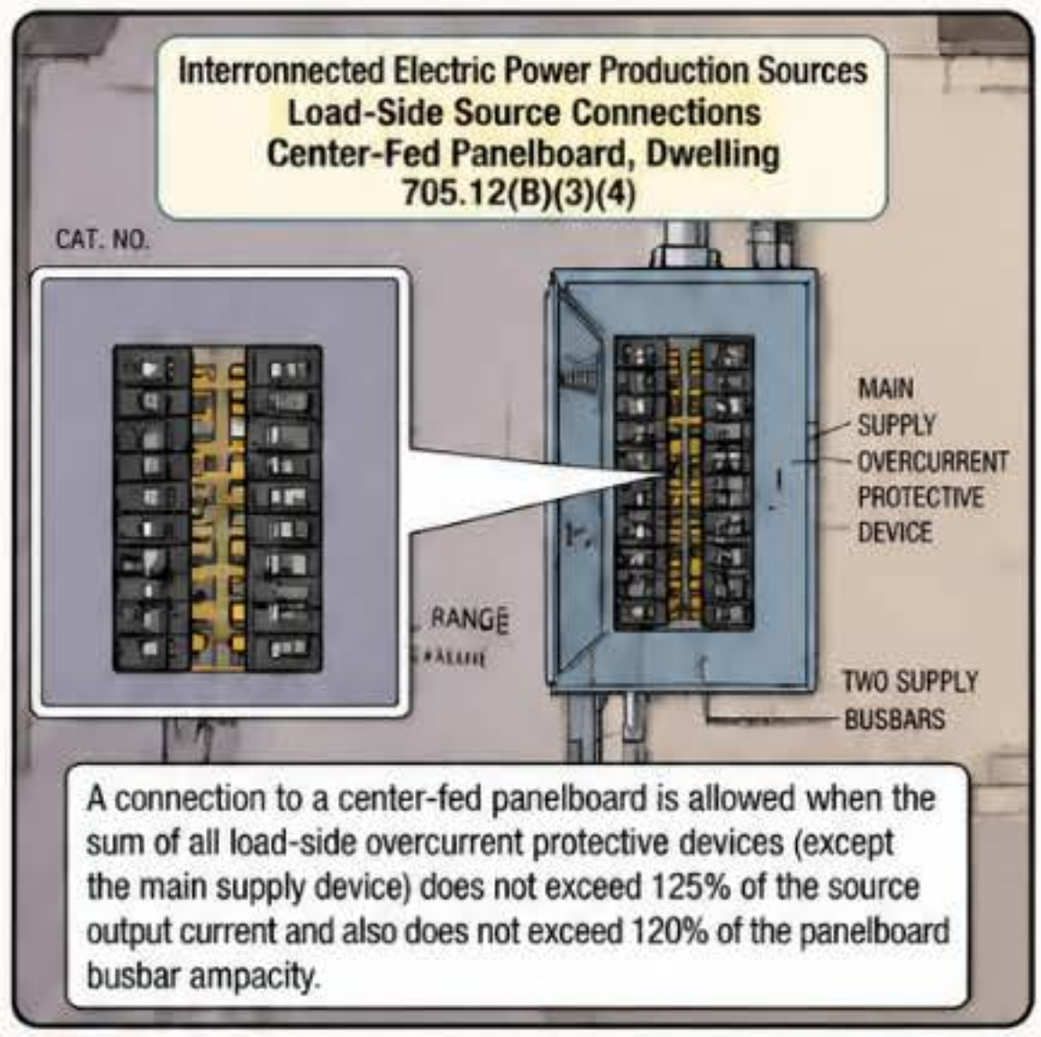


▸ Figure 705–26

WARNING—THIS EQUIPMENT FED BY MULTIPLE SOURCES. TOTAL RATING OF ALL OVERCURRENT DEVICES EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE MUST NOT EXCEED AMPACITY OF BUSBAR.

(4) Center-Fed Panelboard. A source connection is permitted at either end of a dwelling unit center-fed panelboard where the total rating of the overcurrent protective device covering the panelboard busbar, plus 125 percent of the power source output circuit current, does not exceed 120 percent of the panelboard busbar ampacity. ▸ Figure 705–27

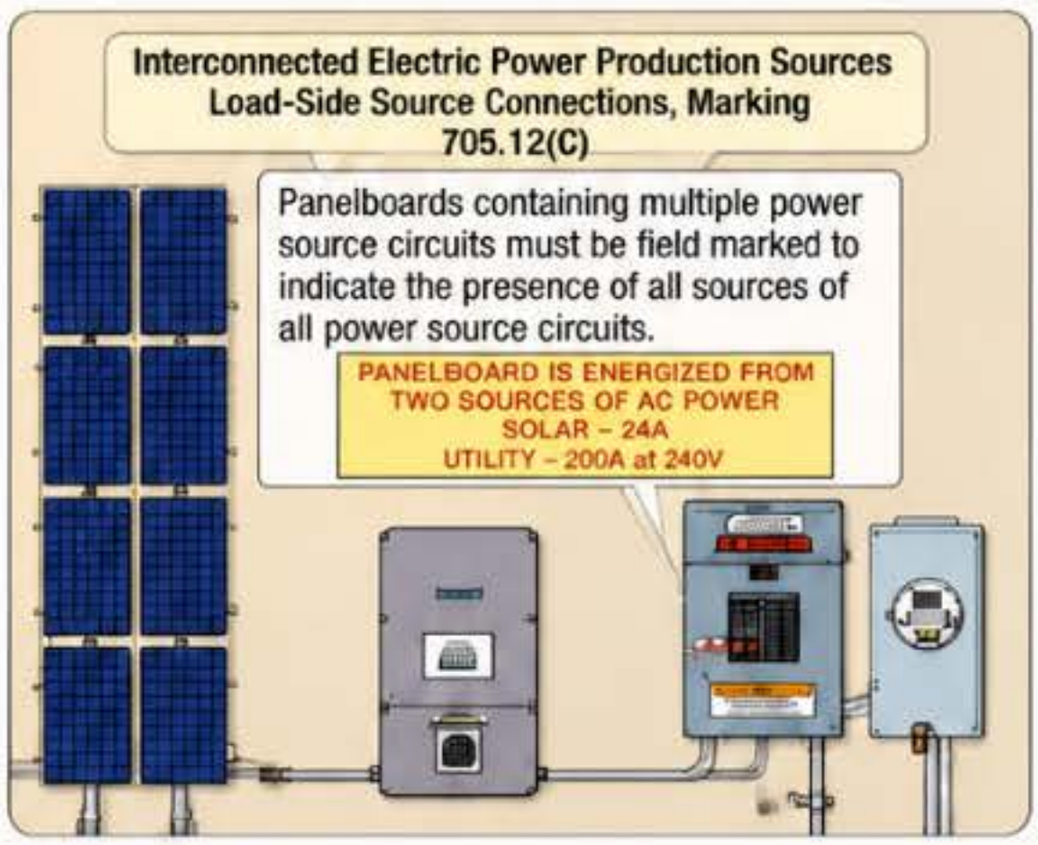
(5) Engineering Supervisions. Switchgear, switchboards, and panelboards designed under engineering supervision must include available fault current and busbar load calculations for each power source connection.



▸ Figure 705–27

(6) Feed-Through Connections. Power source connections on panelboard busbars that are connected to feed-through conductors must be sized following 705.12(B)(1). If an overcurrent protective device is installed at the supply end of the feed-through conductors, the busbar in the supplying panelboard may be sized in accordance with 705.12(B)(3).

(C) Marking. Panelboards containing more than one power source circuit must be clearly marked to identify the presence of each power source circuit. ▸ Figure 705–28



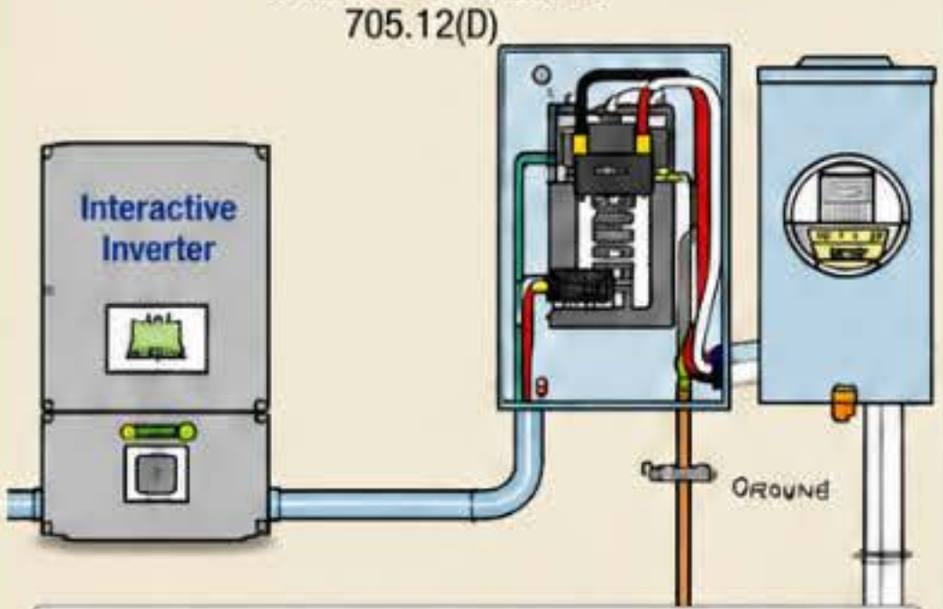
▸ Figure 705–28

(D) Suitable for Backfeed. Fused disconnects and circuit breakers not marked "line" and "load" are acceptable for backfeed. Devices marked "line" and "load" may be used for backfeed or reverse current if specifically rated for that application. ▸ Figure 705–29

705.13 Interconnected Electric Power Production Sources

Interconnected Electric Power Production Sources

Load-Side Source Connections
Suitable for Backfeed
705.12(D)



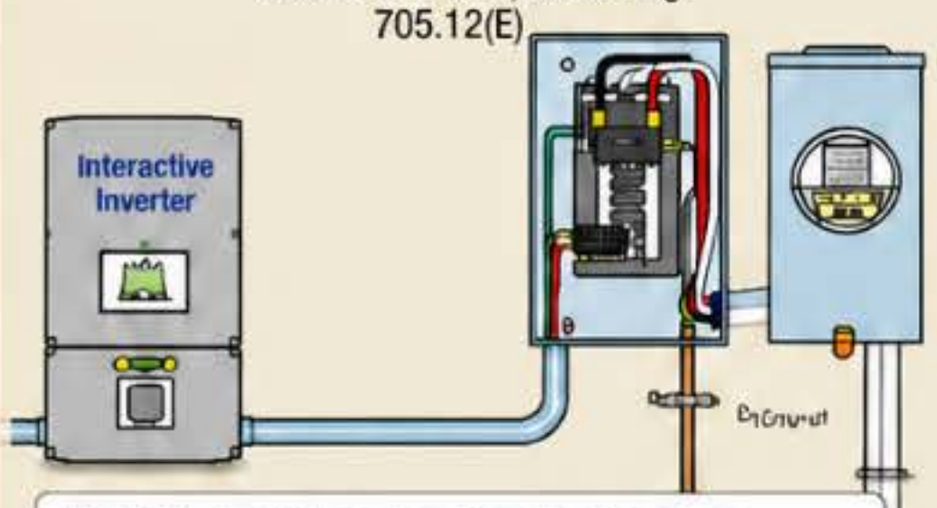
Fused disconnects and circuit breakers not identified as "line" and "load" are acceptable for backfeed applications. Breakers marked "line" and "load" may be used for backfeed only when rated or listed for it.

Figure 705–29

(E) Fastening. Backfed circuit breakers for electric power sources that are identified as interactive are not required to be fastened in place by an additional fastener as required by 408.36(D). ◆ Figure 705–30

Interconnected Power Production Sources

Load-Side Source Connections, Backfed
Circuit Breakers, Fastening
705.12(E)



Backfed circuit breakers for electric power sources that are listed and identified as interactive are not required to be secured in place.

Figure 705–30

Author's Commentary:

- PV ac inverter circuit breakers are not required to be fastened in place because the PV interactive inverter automatically ceases to export ac current when the breaker is removed.

— Michael Hamilton

705.13 Power Control Systems

Power control systems that control the output of power production sources, energy storage systems, and other equipment must be tested. The power control system must limit the current to the ampacity of the conductors or the ratings of the busbars to which it is connected in accordance with 705.13(A) through (E).

(A) Monitoring. The power control system controller must monitor all current within the power control system.

A busbar or conductor on the load side of the service disconnect that is not monitored by the power control system must be sized in accordance with 705.12.

Where the power control system is connected to the supply side of service equipment as permitted by 705.11, the power control system must monitor the current on the service conductors and prevent overload of those conductors.

(B) Settings. The sum of the power control system currents plus all monitored currents from other sources of supply must not exceed the ampacity of any busbar or conductor ampplied by the power production sources.

Where the power control system is connected to an overcurrent device protecting busbars or conductors not monitored by the power control system, the setting of the power control system must be set to the ratings of that overcurrent device.

(C) Overcurrent Protection. The power control system must provide overcurrent protection either by overcurrent devices or the functionality as an overcurrent device in the product listing.

Note: Some power control systems are listed to provide overcurrent protection.

(D) Single Power Source Rating. The rating of the overcurrent device for any single power source controlled by the power control system is not permitted to exceed the rating of the busbar or the ampacity of the conductors to which it is connected.

(E) Access to Settings. The access to settings of the power control system must be restricted to qualified personnel in accordance with the requirements of 240.6(C).

705.16 | INTERCONNECTED ELECTRIC POWER PRODUCTION SOURCES

Author's Commentary:

To achieve restricted access in accordance with 240.6(C), one or more of these methods must be used:

- Being positioned behind removable, lockable covers installed over the adjusting means.
- Being located behind doors on bolted enclosures.
- Being located behind locked doors that only permit entry to authorized personnel.
- Employing password protection, where the password is accessible only to qualified individuals.

— Michael Hamilton

705.16 INTERRUPTING AND SHORT-CIRCUIT CURRENT RATING

Fault current from any interconnected source must be factored into the interrupting and short-circuit current ratings of equipment within interactive systems.

705.20 DISCONNECT

A means must be provided to disconnect the output-side conductors from all other system conductors. The supply-side power source disconnect must comply with the following:

(1) The disconnect must be one of these types:

(a) A manually operated switch or circuit breaker.

(b) A load-break-rated pull-out switch.

(c) A remote-control switch or circuit breaker able to be operated manually and open automatically when the power is interrupted.

(d) A device listed or approved for the intended use.

(2) The disconnect must open all ungrounded conductors together.

(3) The disconnect must be readily accessible from a readily accessible location.

(4) The disconnect must be operable externally without exposing live parts.

(5) Enclosures with doors or hinged covers that have exposed live parts, when open, must require a tool to open or must be lockable where readily accessible to unqualified persons.

(6) The disconnect must clearly show whether it is in the open (off) or closed (on) position.

(7) The disconnecting device must be rated to handle the highest possible short-circuit current available at the terminals and the terminal voltage.

(8) The disconnect must be labeled in accordance with 690.13(B), where the line and load terminals are suitable for being energized in the open position.

Note: In setups with interconnected power sources, certain switches and fuses may be energized from either direction. See 240.40.

705.25 WIRING METHODS

(A) General. All raceway and cable wiring methods described in Chapter 3, along with other wiring systems and fittings specifically listed, intended, and identified for use with power production equipment, are permitted. **Figure 705–31**

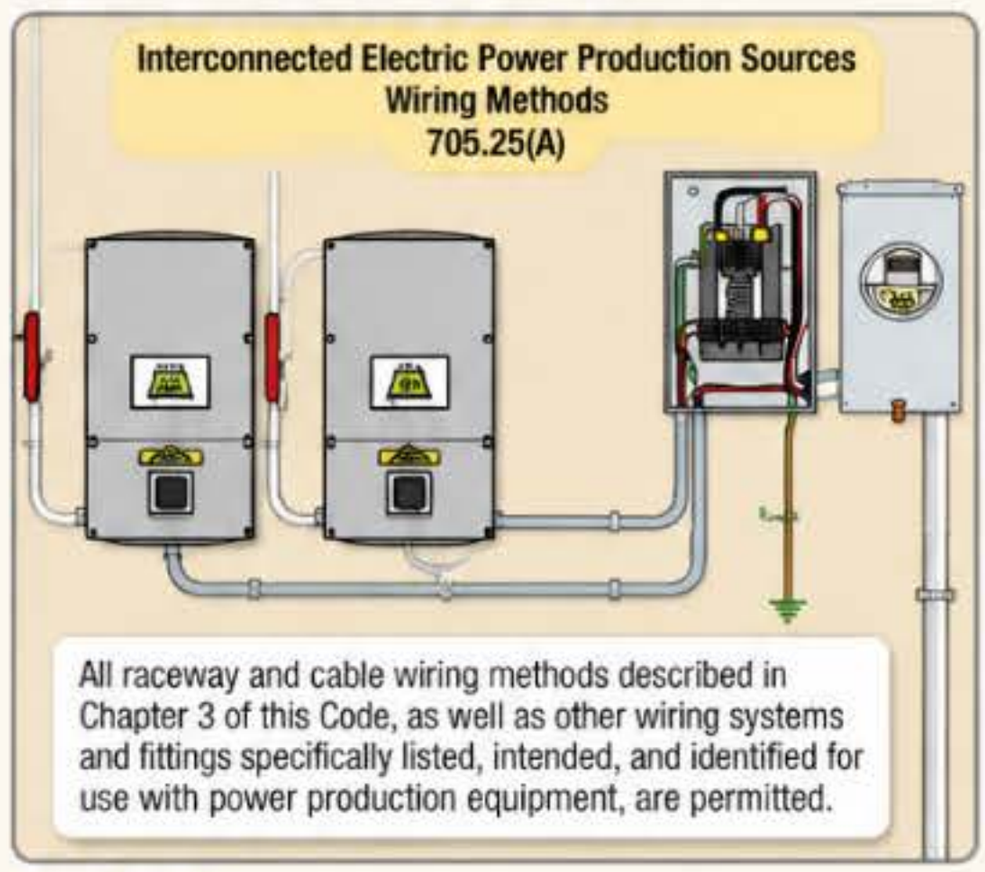


Figure 705–31

(B) Flexible Cords and Cables. Flexible cords and cables used to connect movable parts of a power production system, or those used for removal during maintenance and repair, must meet the requirements in Article 400. Flexible cords or cables must be identified as Type DG cable, service cord, or portable power cable, suitable for extra-hard usage. They must also be listed for outdoor use and water resistant. Cables exposed to sunlight must be sunlight resistant. Flexible, fine-stranded cables must terminate on terminals, lugs, devices, or connectors identified for use with finely stranded conductors, in accordance with 110.14(A).

705.30 Interconnected Electric Power Production Sources

(C) Multiconductor Cable Assemblies. Multiconductor cable assemblies used in accordance with their listings are allowed.

> *Author's Commentary: An example of this is a module harness, which qualifies as a multiconductor cable assembly.*
>
> *— Michael Hamilton*

705.28 Circuit Sizing and Current

(A) Calculation of Maximum Circuit Current. The greatest power source output circuit current must be the same as the continuous output current rating of the generating equipment. ▶ Figure 705–32

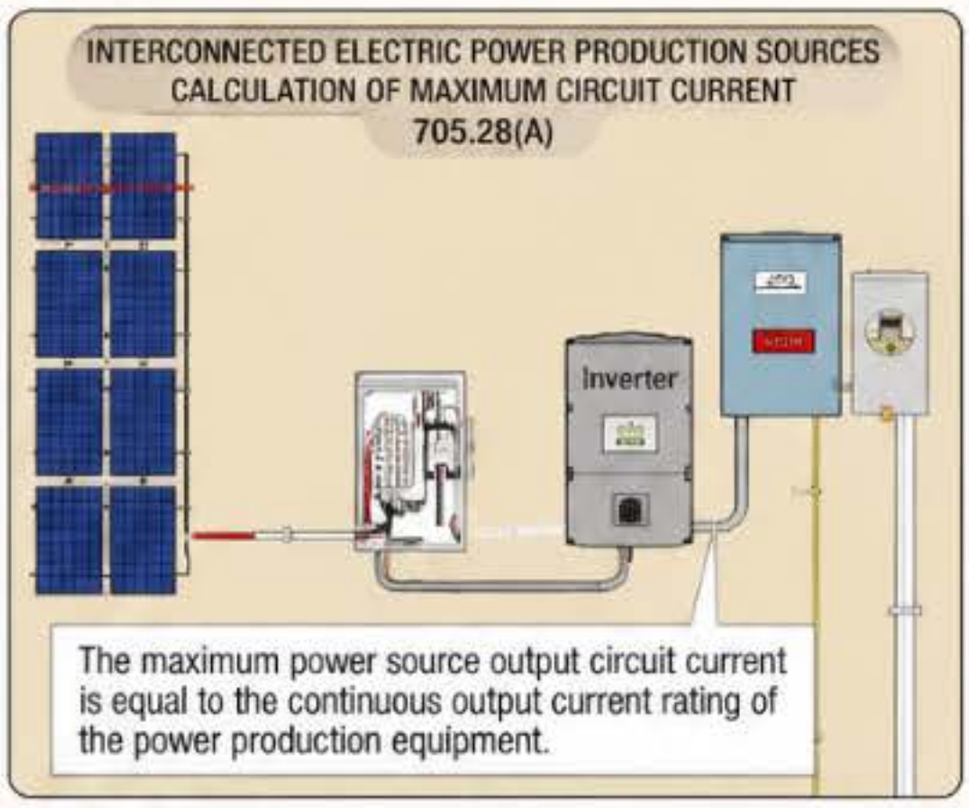


Figure 705–32

(B) Conductor Ampacity. Circuit conductors must be sized to the largest of the following:

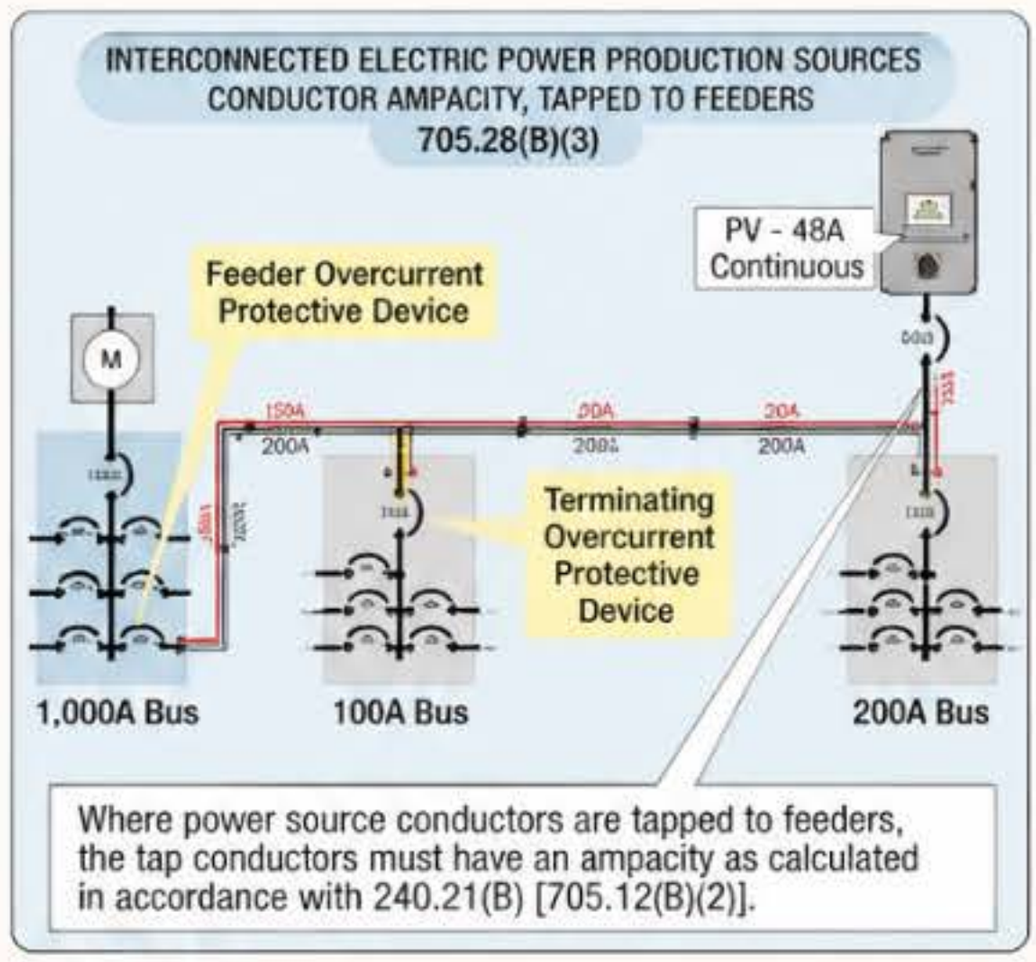
① One hundred twenty-five percent of the maximum continuous output current rating of the power production equipment [705.28(A)] without conductor ampacity correction and/or adjustment.

② One hundred percent of the maximum continuous output current rating of the power production equipment [705.28(A)] after conductor ampacity correction and/or adjustment.

③ Where circuit conductors are tapped to feeders, the tap conductors must have an ampacity as calculated in accordance with 240.21(B) [705.12(B)(2)]. ▶ Figure 705–33

(C) Neutral Conductors. Neutral conductors may be sized in accordance with either of the following:

(1) **Single-Phase Line-to-Neutral Power Sources.** The ampacity of a neutral conductor to which a single-phase line-to-neutral power source is connected is not permitted to be less than the ampacity calculation in accordance with 705.28(B).



▶ Figure 705–33

(2) **Neutral Conductor for Instrumentation, Voltage Detection, or Phase Detection.** A neutral conductor to power production equipment that is used solely for instrumentation, voltage detection, or phase detection is permitted to be sized in accordance with Table 250.102(C)(1).

705.30 Overcurrent Protection

(A) Circuits and Equipment. Power source output circuit conductors must be provided with overcurrent protection. Circuits connected to more than one electrical power source must have overcurrent protection located so as to provide overcurrent protection from all sources of power. ▶ Figure 705–34

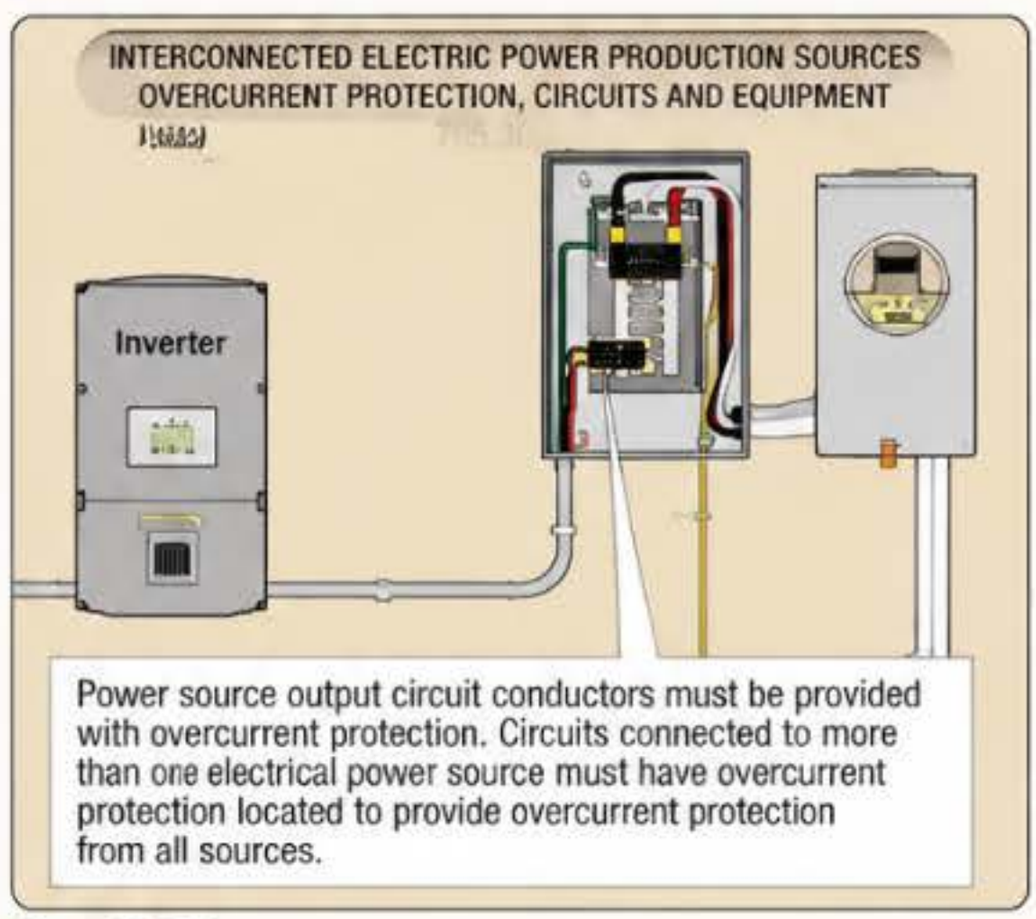


Figure 705–34

705.32 | Interconnected Electric Power Production Sources

(B) Overcurrent Device Ratings. Every overcurrent protective device must have an ampere rating that is at least 125 percent of the highest current the device can carry, based on 705.28(A).

Example: When the assembly, together with its largest overcurrent device(s), is intended for continuous operation at 100 percent of the device's rating, the calculated overcurrent device must be sized to 100 percent of the maximum current from 705.28(A).

(C) Power Transformers. Each transformer that draws power from its own side (inverter and utility) must be equipped with overcurrent protection that follows 450.3(B), taking into account the utility-provided side of the transformer as the primary.

705.32 Ground-Fault Protection

When a ground-fault protection device (GFPE) is installed per 230.95, the output of an interactive system must be tied to the supply side of the GFPE.

Example: The output taken from an interactive system can be connected on the load side of the ground-fault protection, if ground-fault protection is provided for all ground-fault current coming from any source.

705.40 Loss of Utility Power

Equipment that produces power must automatically disconnect from all phase conductors of the interconnected systems when any one phase from the primary (utility) source is lost. If the power-producing equipment cannot be reconnected to the primary source until every part of the interconnected system to which it is attached has been restored.

This rule does not apply to electrical equipment that supplies power to emergency or legally required standby systems.

Example: A listed interactive inverter is allowed to automatically stop sending power to the interconnected system when one or more phases of the primary source are lost, and it may either automatically or manually resume exporting power to the grid once all phases of the source are back in service.

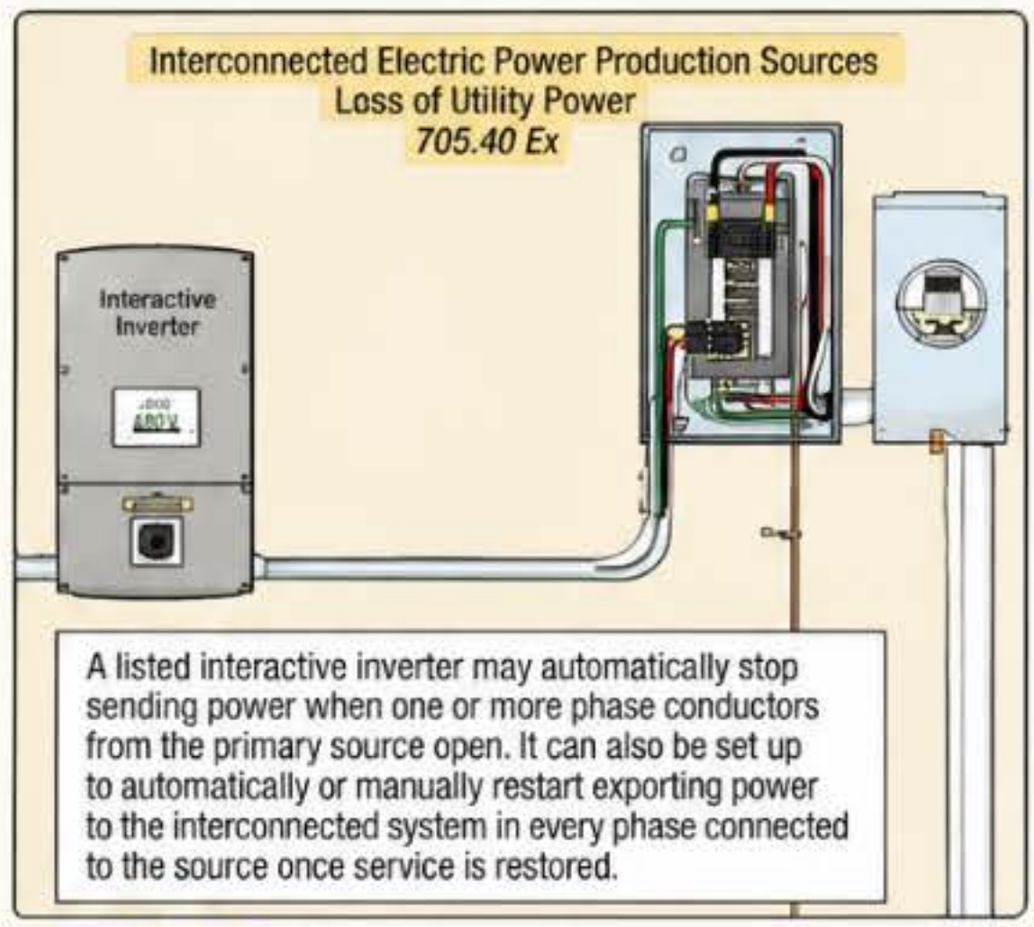
▸ Figure 705–35

Author's Commentary:

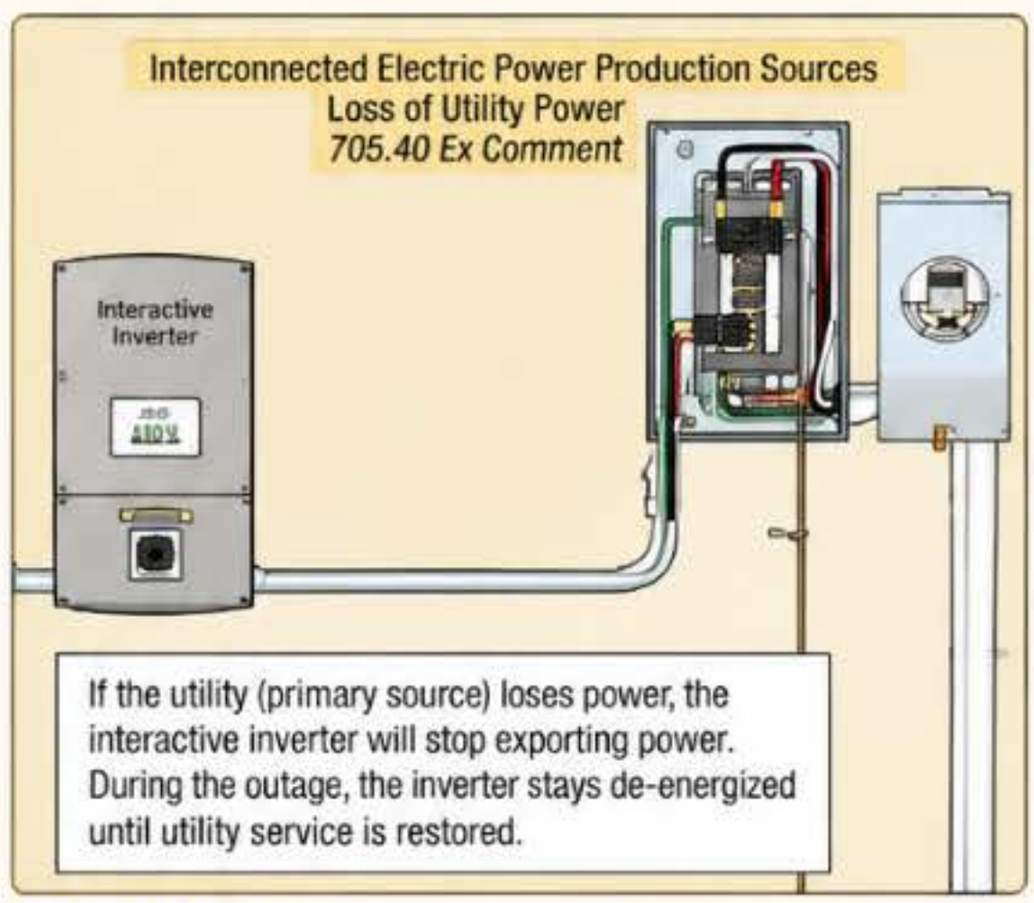
- If the utility (primary source) experiences a loss of power, an interactive inverter must cease exporting power. During that time, the inverter will stay de-energized until the utility power is fully restored.

— *Michael Hamilton*

▸ Figure 705–36



▸ Figure 705–35



▸ Figure 705–36

Note 1: Risks to people and equipment tied to the primary source may occur if an interactive power production source is used on an intentional island. Special detection methods are required to determine that the primary source is de-energized, and whether or not automatic disconnection is needed. Once the primary source is restored, such detection is generally used to limit exposure to power when sources that are not part of the phase reconnection are reconnected.

Interactive power production equipment is permitted to run on islands made to deliver loads that have been disconnected from the electric power production and distribution network.

705.45 Unbalanced Interconnections

(A) Single-Phase. Single-phase inverters must be installed on a system so that the unbalanced system voltage at the utility service disconnect does not exceed **three percent.**

Note: For interactive power sources, unbalanced voltages can be minimized by using the same methods applied to ringed single-phase loads on a three-phase power system. See ANSI/CSA C84.1, *Electric Power Systems and Equipment—Voltage Ratings (60 Hertz).*

Author's Commentary:

- ANSI/CSA C84.1, *Electric Power Systems and Equipment—Voltage Ratings (60 Hertz)* advises that electric supply systems be designed to restrict maximum voltage unbalance to three percent when measured at the electric-utility revenue meter under no-load conditions between the phases.
- The calculation for the highest allowable unbalanced voltage is:
  Maximum Unbalanced Voltage = Maximum Deviation from Average Voltage/Average Voltage × 100%.

— **Michael Hamilton**

▶ Existing Installation Example

Question: If two single-phase PV systems are connected to lines B–C and this causes the B–C voltage to increase from 200V to 202V because of a decrease in loading, the maximum unbalanced system voltage for the following line voltages: A–B 206V, B–C 202V, and A–C 204V will be _____ percent.

(a) 1 (b) 1.50 (c) 2.04 (d) 3

Solution:

Maximum Unbalanced Voltage = Maximum Deviation Volts from Average Voltage/Average Voltage × 100%

Average Voltage = (206V + 202V + 204V)/3 lines

Average Voltage = 612V/3 lines

Average Voltage = 204V

Maximum Deviation from Average = 206V–204V

Maximum Deviation from Average = 2V

Maximum Deviation from Average = 2V/204V x 100%

Maximum Unbalanced Voltage = 0.098 × 100%

Maximum Unbalanced Voltage = 1%

Answer: (a) 1

▶ Unbalanced System Voltage—Two Inverters Example 1

Question: If two single-phase PV systems are connected to lines B–C and this results in the B–C voltage increasing from 200V to 201V because of a decrease in loading, the maximum unbalanced system voltage for the following line voltages: A–B 206V, B–C 201V, and A–C 204V will be _____ percent.

(a) 1 (b) 1.15 (c) 1.50 (d) 2.06

Solution:

Maximum Unbalanced Voltage = Maximum Deviation from Average Voltage/Average Voltage × 100%.

Average Voltage = (206V + 201V + 204V)/3 lines

Average Voltage = 611V/3 lines

Average Voltage = 203.67V

Maximum Deviation from Average = 206V–203.67V

Maximum Deviation from Average = 2.33V

Maximum Unbalanced Voltage = 2.33V/203.66V × 100%

Maximum Unbalanced Voltage = 0.114 × 100%

Maximum Unbalanced Voltage = 1.15%

Answer: (b) 1.15

▶ Unbalanced System Voltage—Two Inverters Example 2

Question: If two single-phase PV systems are connected to lines A–B and this causes the A–B voltage to increase from 206V to 208V because of a decrease in loading, the maximum unbalanced system voltage for the following line voltages: A–B 2008, B–C 200V, and A–C 204V will be _____ percent.

(a) 1 (b) 1.15 (c) 1.50 (d) 1.96

Solution:

Maximum Unbalanced Voltage = Maximum Deviation from Average Voltage/Average Voltage × 100% (for Percent).

Average Voltage = (208V + 200V + 204V)/3 lines

Average Voltage = 612V/3 lines

Average Voltage = 204V

Maximum Deviation from Average = 208V–204V

Maximum Deviation from Average = 4V

Maximum Unbalanced Voltage = 4V/204V × 100%

Maximum Unbalanced Voltage = 0.196 × 100%

Maximum Unbalanced Voltage = **1.96%**

Answer: (d) 1.96

(B) Three-Phase. Three-phase inverters are required to have every phase automatically de-energized when loss of power occurs, or when unbalanced conditions create a voltage on one or more phases, unless the inverter is intentionally designed so that substantial unbalanced voltages will not be produced.

Part II. Microgrid Systems

705.50 System Operation

Microgrid systems are allowed to disconnect from the main power source or from other linked electric power production sources and function as a self-contained microgrid system operating in island mode.

705.60 Primary Power Source Connection

Connections to primary power sources that are external to a microgrid system must follow the provisions of 705.11, 705.12, or 705.13.

Conductors that connect power sources to a microgrid system, including those that supply distribution equipment, are regarded as power source output conductors.

Author's Commentary:

Microgrid systems are designed to isolate from the utllity grid when needed so they can keep supplying power on their own. The system becomes an islanded electrical network.

— Michael Hamilton

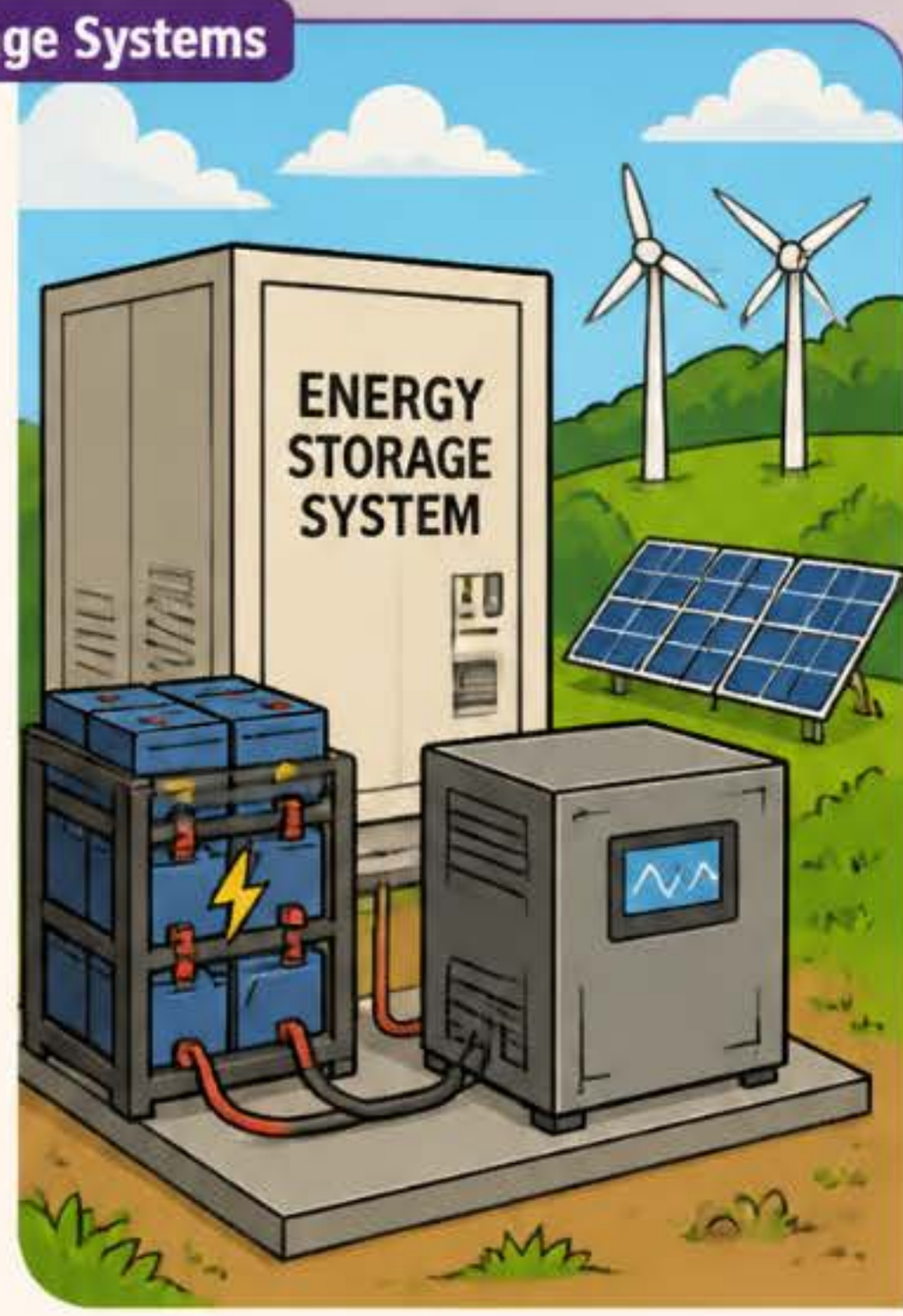
ARTICLE 706 ENERGY STORAGE SYSTEMS

Introduction to Article 706—Energy Storage Systems

The 2023 edition of the NEC recognizes the major role that energy storage plays in handling large amounts of electricity from renewable sources like wind and solar. Because storage is essential for this purpose, the NEC Correlating Committee created a 79-member task group (with input from many other sources) to develop these requirements.

Understanding what Article 706 does and does not apply to is important. It covers permanently installed energy storage systems (ESSs) whose rated capacity exceeds 1 kWh. These systems may operate on their own or work interactively with electric power production sources. Although the language is adapted from related sections in Article 690 (Solar Photovoltaic Systems), an ESS can store energy from any source—there are no source limitations.

An ESS is made up of one or more components that, together, can store electrical energy for later use. Typical components include (but are not limited to) batteries, capacitors, and kinetic energy devices such as flywheels and compressed air systems. Some ESSs can deliver either AC or DC output. They may also include inverters and converters that change stored energy from one electrical form to another. An ESS might connect directly to the utility grid in a standard configuration, or it might provide additional energy management functions like buffering power produced intermittently by wind or PV systems.



ESSs can connect to other energy sources, such as a local utility distribution system. More than one source of power may feed these systems, and their connection to other sources must follow the rules in Article 705. Those rules give requirements for installing one or more elecrtic power production sources that operate in parallel with a primary source like a utility.

It is important to note that Article 480 (Storage Batteries) has not been removed. While this may create some confusion when deciding between an ESS and a battery system, the easiest method is to focus on the system intent. Updates to the 2023 *NEC* now require that any ESS be listed as a system and will most often be based on the requirements of UL 9540, *Standard for Energy Storage Systems and Equipment*. There is no system listing requirement for battery systems in Article 480, and all lead-acid batteries are exempt from any listing. Unlike battery systems, an ESS often also includes other equipment such as inverters or other electronic power converters.

Part I. General

706.1 Scope

This article applies to all energy storage systems having a capacity greater than 1 kWh that may be stand-alone or interactive with the electric utlity supply. Energy storage systems are primarily intended to store and provide energy during normal operating conditions.

Figure 706–1

Note 1: For batteries rated in ampere hours, kWh is equal to the battery nominal rated voltage times the battery ampere-hour rating, divided by 1,000.

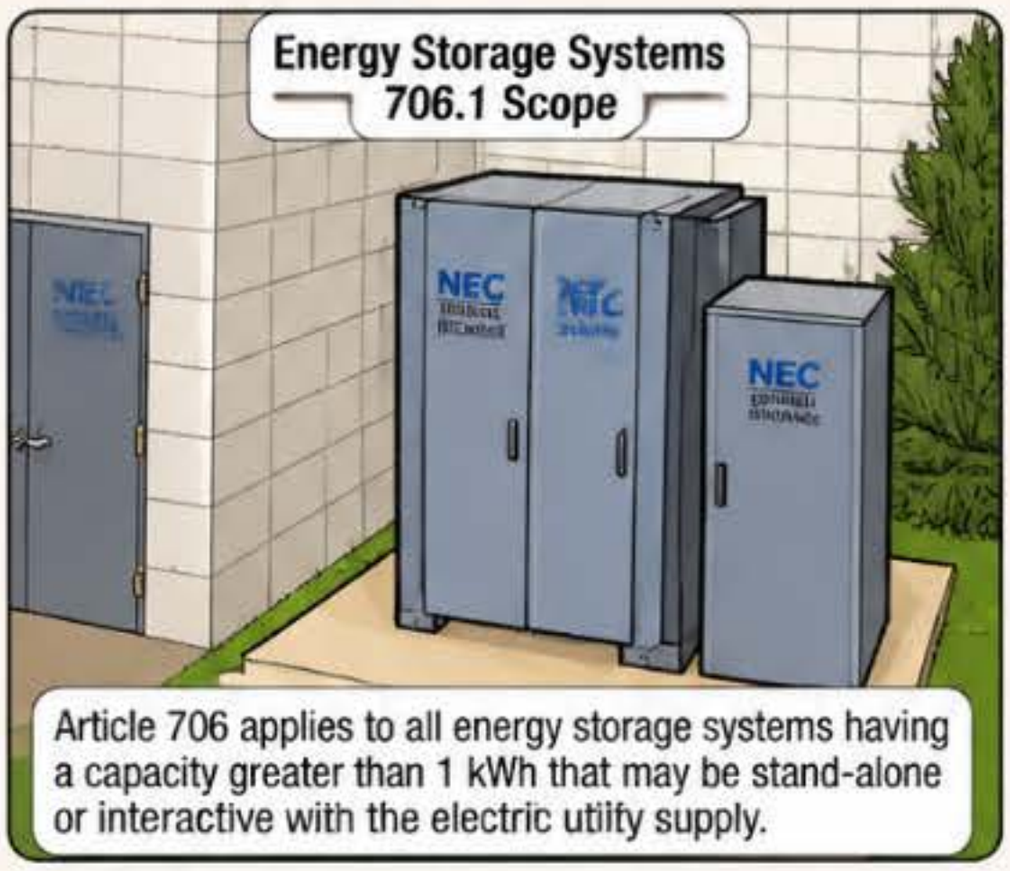


Figure 706-1

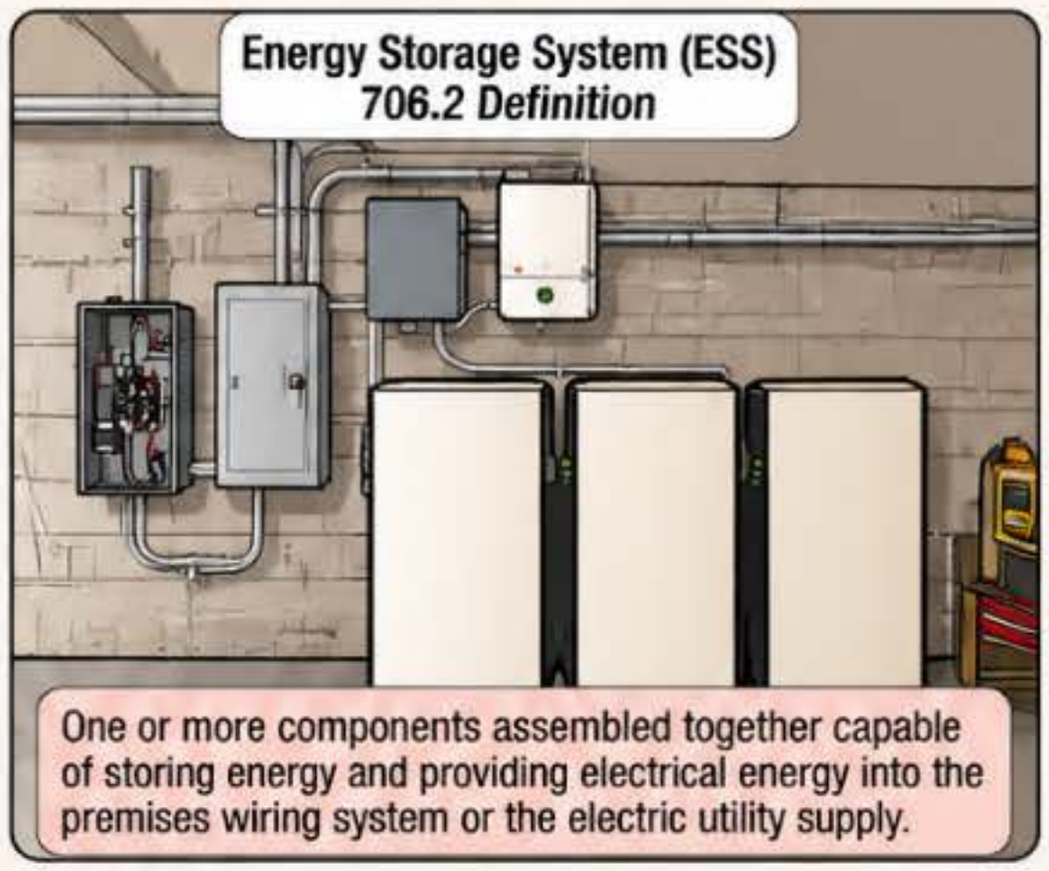


Figure 706-2

Author's Commentary:

- To better appreciate ampere-hours relative to kilowatt-hours, consider your cellphone. Many phones come with a 3,000 mAh (milliamp-hour) battery, which when divided by 1,000, equals 3 ampere-hours. Lithium-ion cells typically have a voltage of 3.70 V, so when you multuply 3 ampere-hours by 3.70 V you get about 11.10 watt-hours. As you probably now realize, figuring out the energy in a battery is just Ohm's Law on a bigger scale.

— Michael Hamilton

706.2 Definitions

The definitions in this section only apply to this article.

Energy Storage System (ESS). One or more components assembled together capable of storing energy and providing electrical energy into the premises wiring system or the electric utility supply. ***Figure 706-2***

Note 1: Energy storage systems can include (but are not limited to) batteries, capacitors, and kinetic energy devices such as flywheels and compressed air. Energy storage systems can include inverters or converters to change voltage levels or to make a change between an alternating-current or a direct-current system.

Note 2: Energy storage systems differ from other storage systems such as a UPS system, which is a power supply that provides alternating-current power for loads for some period of time in the event of a power failure.

Flow Battery. An energy storage component similar to a fuel cell that stores its active materials in the form of two electrolytes external to the reactor interface.

Note: Two commercially available flow battery technologies are zinc bromine and vanadium redox, sometimes referred to as a pumped electrolytic energy storage system.

706.3 Qualified Personnel

The installation and maintenance of energy storage system equipment and all associated wiring and interconnections must be performed only by qualified persons.

Note: See Article 100 for the definition of "Qualified Person."

706.4 System Requirements

Each energy storage system must have a nameplate plainly visible after installation and marked with the following:

1. Manufacturer's name, trademark, or other descriptive marking by which the organization responsible for supplying the energy storage system can be identified.
2. Rated frequency.
3. Number of phases if alternating current.
4. Rating (kW or kVA).
5. Available fault current derived by the energy storage system (ESS) at the output terminals.

Energy Storage Systems | 706.15

(6) Maximum output and input current of the energy storage system (ESS) at the output terminals.

(7) Maximum output and input voltage of the energy storage system (ESS) at the output terminals.

(8) Utility-interactive capability if applicable.

706.5 Listing

Energy storage systems must be listed.

Author's Commentary:

The *Code* does not prescribe a precise standard list to use for ESS. Instead, authored building and fire codes may require particular standards like UL 9540, *Standard for Energy Storage Systems and Equipment*, for these systems. Annex A of the NEC provides references to product safety standards that the *Code*-Making Panels generally consider relevant to each article.

— Michael Hamilton

706.6 Multiple Systems

Multiple energy storage systems are permitted in or on a single building.

Author's Commentary:

With PV systems, energy storage systems may be made up of multiple pieces of equipment that are assembled into one system, or each individual piece of equipment may be treated as its own ESS on its own. The best way to determine an ESS is to look for a nameplate and review the instructions, both of which are part of the equipment's listing.

— Michael Hamilton

706.8 Storage Batteries

Storage batteries not associated with an energy storage system (ESS) must comply with Article 480.

Author's Commentary:

The distinction between a storage battery as covered in Article 480 and an ESS covered in Article 706 is not always clear in the NEC. We expect this distinction will improve in future *Code* revisions. From a practical prespective, storage batteries in Article 480 will be more limited to commercial or industrial uses such as starting generators or backing up exit lighting. The popularity of packaged and listed ESS systems using new battery chemistries such as lithium-ion will continue to rise so Article 706 will be increasingly used for future battery storage applications. Also note that unlike Article 480, Article 706 is not just limited to battery-based energy storage.

— Michael Hamilton

706.9 Maximum Voltage

The maximum voltage of an energy storage system must be the rated energy storage system input and output voltage(s) indicated on the energy storage system nameplate(s) or system listing.

Part II. Disconnect

706.15 Disconnect

(A) ESS Disconnecting Means. A disconnecting means must be provided for all phase conductors derived from an energy storage system (ESS) and is permitted to be integral to listed ESS equipment. The disconnecting means must be readily accessible and located within sight of the ESS. The disconnecting means must comply with all of the following:

(1) The disconnecting means must be readily accessible.

(2) The disconnecting means must be located within sight of the ESS. Where it is impracticable to install the disconnecting means within sight of the ESS, the disconnect is permitted to be installed as close as practicable, and the location of the disconnecting means must be field marked on (or immediately adjacent to) the ESS. The marking must be of sufficient durability to withstand the environment involved and must not be handwritten.

(3) The disconnecting means must be lockable in the open position in accordance with 110.25. For dwelling unit(s), the disconnect must be located at a readily accessible location outside the building.

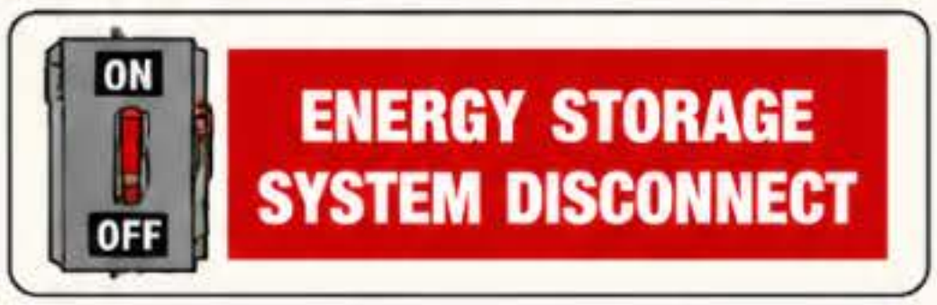
Author's Commentary:

- Note that the disconnecting requirements in 706.15(A) apply to disconnects that are built into the listed energy storage system (ESS) equipment. Because an ESS deployment may include multiple ESS units, each unit might need its own disconnect. However, it may be acceptable for a single disconnect to serve adjacent units. Manufacturers may design their ESS products so the disconnects are inside the units. The evaluation of those disconnects occurs as part of listing the system.

— Michael Hamilton

(B) Remote Actuation. If system controls initiate opening the disconnect of an energy storage system, the disconnect must be positioned where it can be clearly seen from that location.

(C) Notification and Marking. Every energy storage system disconnect must be durably labeled to show whether its contacts are in the open (off) or closed (on) position.



The disconnect must be legibly labeled in the field with wording such as the following:

1. Rated energy storage system AC voltage and the maximum and minimum permitted DC voltages.
2. The available fault current contributed by the storage system.
3. Arc-flash hazard information in accordance with accepted industry methods.
4. The date when the available fault current calculation was completed.

Examples (2), (3), and (4) do not apply to one- and two-family dwellings.

Note 1: Equipment labeling shall follow the guidelines in NFPA 70E, *Standard for Electrical Safety in the Workplace*. The standard defines how to create arc-flash warning labels, including criteria like nominal system voltage, incident energy levels, arc-flash boundaries, and the minimum personal protective equipment (PPE) required.

Note 2: Battery suppliers can provide the available fault current for a given battery model.

Where the line and load terminals within an energy storage system disconnect may become energized while the disconnect is open, the disconnect must be marked with words or symbols similar to the following:

The notification(s) and marking(s) must be permanent and durable for the environment where they are installed [110.21(B)].

(D) Partitions Between Components. If wiring from input or output terminals of energy storage components runs through walls, floors, or ceilings, a readily accessible disconnect must be installed on the same part of the energy storage component. Fused disconnect switches or circuit breakers are allowed to be used as the required disconnect.

Author's Commentary:

- 706.15(D) does not cover every possible ESS installation where circuit conductors pass through structural elements such as walls, floors, or ceilings. This requirement applies when (typically large) batteries are in one room and other equipment, which is part of the ESS, is in another. In those cases, a nearby disconnect must be installed in the room contaning the battery. This requirement does not apply to situations where the entire ESS is located in one room and the output circuitry exits the ESS to feed other systems in different rooms. In those situations, the disconnect location rules in 706.15(A) are the only ones that apply.

— Michael Hamilton

Part III. Installation Requirements

706.20 General

(A) Ventilation. Suitable ventilation must be provided for energy storage technology to ensure sufficient airflow for any gases released from the storage device (if present) to prevent the buildup of an explosive mixture. Whether pre-engineered or custom-built, energy storage systems must be ventilated according to the manufacturer's instructions and the system listing.

Note 1: See NFPA 1, *Fire Code*, Chapter 52, for ventilation considerations related to specific battery chemistries.

Note 2: Some storage technologies do not require ventilation.

Note 3: Design sources for ventilation of battery systems include IEEE 1635-2012/ASHRAE Guideline 21, *Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications*, and the UBC.

Note 4: Fire protection considerations are addressed in NFPA 1, *Fire Code*.

706.30 CIRCUIT SIZING AND CURRENT

Author's Commentary:

To accommodate the wide range of situations involving ventilation for energy storage systems (ESS), the manufacturer's setup instructions provided with the product's listing must be followed. Requiring installers to analyze every ventilation detail will not guarantee safer systems. Installers only need to follow the installation directions, just as they do with other electrical equipment.

— Michael Hamilton

(B) Dwelling Units. Energy storage systems in one- and two-family dwellings are not allowed to use a direct-current voltage above 100 V between conductors or to ground.

Example: *In places where access is not available during normal maintenance, a maximum system voltage of 600 V dc for the energy storage system is acceptable.*

Author's Commentary:

Since an ESS might provide both alternating-current and direct-current output, there will be many situations where the voltage limits in 706.20(B) won't even apply to installers or inspectors. DC voltages will be handled according to the equipment listing.

— Michael Hamilton

(C) Spaces About Energy Storage System Components.

(1) General. Work areas around energy storage systems must comply with 110.26.

(2) Space Between Components. Clearances between parts of energy storage systems must follow the manufacturer's instructions and the listing.

Note: *Extra space may be necessary for tasks like hoisting equipment, removing trays, or cleaning up spills from the energy storage system.*

706.21 DIRECTORY (IDENTIFICATION OF POWER SOURCES)

Energy storage systems must be clearly labeled or marked so they can be found and recognized, and so they remain usable for their expected service life in the environment involved (110.21(B)).

(A) Facilities with Utility Services and Energy Storage Systems.

Directories or signage must be installed per 705.10.

Part IV. Circuit Requirements

706.30 CIRCUIT SIZING AND CURRENT

(A) Maximum Rated Current for a Specific Circuit. The maximum current for a specific circuit must be calculated according to the following:

(1) **Nameplate-Rated Circuit Current.** The circuit current must not exceed the rated current shown on the energy storage system's nameplate or system listing. If the system has separate input (charge) and output (discharge) circuits or ratings, each must be considered individually. Where the same terminals are used for both charging and discharging, the rated current must be the greater of the two.

(2) **Inverter Output Circuit Current.** Do not exceed the inverter's continuous output current rating.

(3) **Inverter Input Circuit Current.** Do not exceed the inverter's continuous input current rating at the lowest input voltage that produces its rated power.

(4) **Inverter Utilization Output Circuit Current.** Do not exceed the continuous alternating-current output current rating of the inverter when it delivers its rated power.

(5) **DC-to-DC Converter Output Current.** Do not exceed the continuous output current rating of the DC-to-DC converter.

(6) **Conductor Ampacity.** The ampacity of each feeder or branch-circuit conductor from the storage system to the service wiring that supplies the loads must be at least the larger of: (1) the nameplate(s)-rated circuit current per 706.30(A)(1), or (2) the storage system's overcurrent protective device rating.

(C) Ampacity of Grounded or Neutral Conductor. For a single-phase, 2-wire system, the neutral conductor is either the grounded conductor or a single-phase conductor in a 3-wire system. For a three-phase, 4-wire or 5-wire system, the maximum unbalanced neutral current must not be greater than the ampacity of the grounded or neutral conductor.

706.31 Overcurrent Protection

(A) Circuits and Equipment. Branch circuits and all associated equipment in an energy storage system must be protected as required by Article 240. Overcurrent protective devices for these circuits shall comply with the specifications in 706.31(B) through (F), and they must be located on the source side of any potential overcurrent condition.

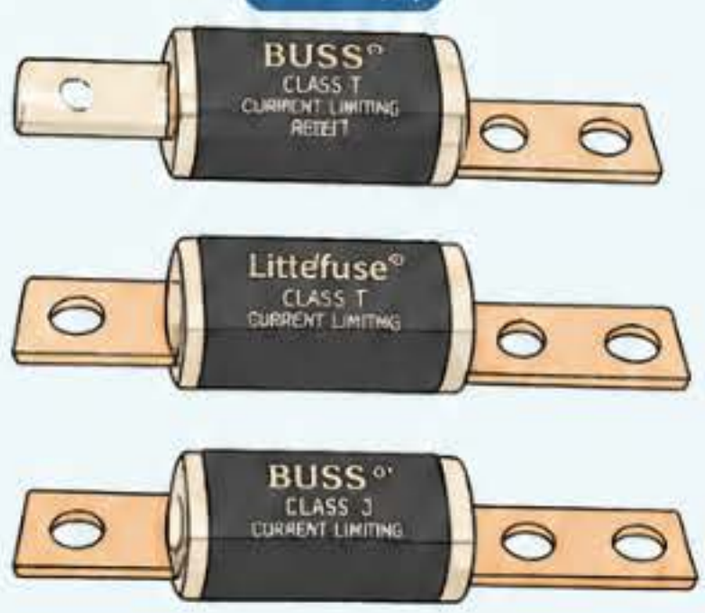
(B) Overcurrent Device Ampere Ratings. Devices used for overcurrent protection must be selected in accordance with Article 240 and their ampere rating must be based on the energy storage system rating. In no case shall this rating be less than 125% of the maximum current computed by 706.30(A).

Ex: When an assembly (including the protective overcurrent device) is rated to operate at 100% of its rating, the ampere rating of the overcurrent device is not required to exceed the maximum current calculated in 706.30(B).

(C) Direct-Current Rating. Overcurrent protective equipment, whether fuses or circuit breakers, intended for direct-current service in energy storage systems must be chosen for the expected dc voltage, current, and interrupting capability of the application.

(D) Current Limiting. Labeled current-limiting overcurrent devices must be installed on the dc output side of the energy storage system. ▶ **Figure 706–3**

Energy Storage Systems, Overcurrent Protection
Current Limiting
706.31(D)



A labeled and marked current-limiting overcurrent device shall be installed next to each dc output circuit of the energy storage system.

Figure 706–3

Ex: Where current-limiting overcurrent protection is provided for the dc output circuits of a listed energy storage system, additional current-limiting devices are not required.

(E) Fuses. Fuses must be provided so they can disconnect any fuses connected to energy storage system components when the fuse is energized from either direction, and the fuse must be within reach of other qualified persons. Switches, pullouts, or similar disconnecting means rated for the intended use may be used as a way to disconnect fuses on all supply sources.

(F) Location. A barrier, floor, or ceiling must seperate the input and output terminals of energy storage system components. If a physical separation is not present, overcurrent protection must be supplied at the component's connection point.

Author's Commentary:

Sections including 706.15(D) do not apply to every energy storage system situation where circuits run through walls, floors, or ceilings. These rules are intended for those applications (usually large battery rooms) where the battery is in a separate room from other ESS equipment.

— Michael Hamilton

706.33 Charge Control

(A) General. Controls must be provided to manage the charging process of the energy storage system. All adjustable controls shall be accessible only to qualified individuals.

(B) Diversion Charge Controller.

(1) Sole Means of Regulating Charging. An energy storage system that uses a diversion charge controller as its only method of regulating charge must include independent means to prevent overcharging.

(2) Circuits with Diversion Charge Controller and Diversion Load. Circuits that include both a diversion charge controller and a diversion load must meet the following.

(1) The current rating of the diversion load must be less than or equal to the current rating of the diversion charge controller. The voltage rating of the diversion load must exceed the maximum voltage rating of the energy storage system. The diversion load power rating must be at least 150% of the source's power rating.

(2) The overcurrent device's interrupting capability and current rating for this circuit must be at least 150% of the diversion charge controller's maximum current rating.

Energy Storage Systems 706.33

(3) Energy Storage System Using Interactive Inverters. Systems that employ interactive inverters to manage the state of charge in an energy storage system by redirecting excess electricity from an alternate source (such as a generator or distribution panel), including standalone utility systems, must adhere to 706.33(B)(3)(a) and (b).

(a) These systems are exempt from the requirements in 706.33(B)(2).

(b) They must incorporate an independent secondary method for controlling the charging sequence of the energy storage system whenever the alternate source is not present or the primary charging controller is malfunctioning or turned off.

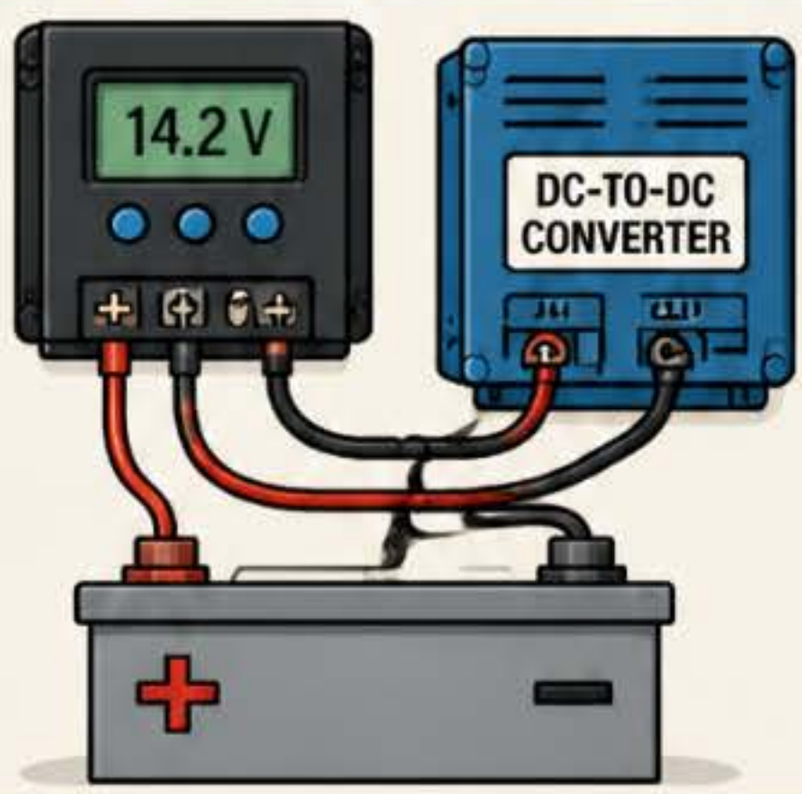
Author's Commentary:

Interactive inverters add flexibility, but redundancy in control is essential to ensure dependable operation.

— Michael Hamiiton

(C) Charge Controllers and DC-to-DC Converters. Where charge controllers or other dc-to-dc power converters that adjust either the output current or output voltage with respect to the input current or input voltage are installed, all of the following must apply:

Charge Controller and DC-to-DC Converter



(1) The current-carrying capacity of the conductors within the output circuits must be determined by the maximum continuous output current rating of the charge controller or converter across the chosen output voltage range.

(2) The voltage rating of the output circuits must be determined by the highest output voltage rating of the charge controller or converter for the selected output voltage range.

Author's Commentary:

Correct conductor ampacity and voltage ratings are critical to prevent overheating and ensure safe performance.

— Michael Hamilton

Part V. Flow Battery Energy Storage Systems

Part V applies to energy storage systems that are either composed of or incorporate flow batteries.

Note:

BeBecause flow batteries differ in construction and operating behavior from storage batteries such as lead acid or lithium ion, the specifications for flow batteries are addressed elsewhere in the Code—see Article 480.

Notes |

ARTICLE 710 STAND-ALONE SYSTEMS

Introduction to Article 710—Stand-Alone Systems

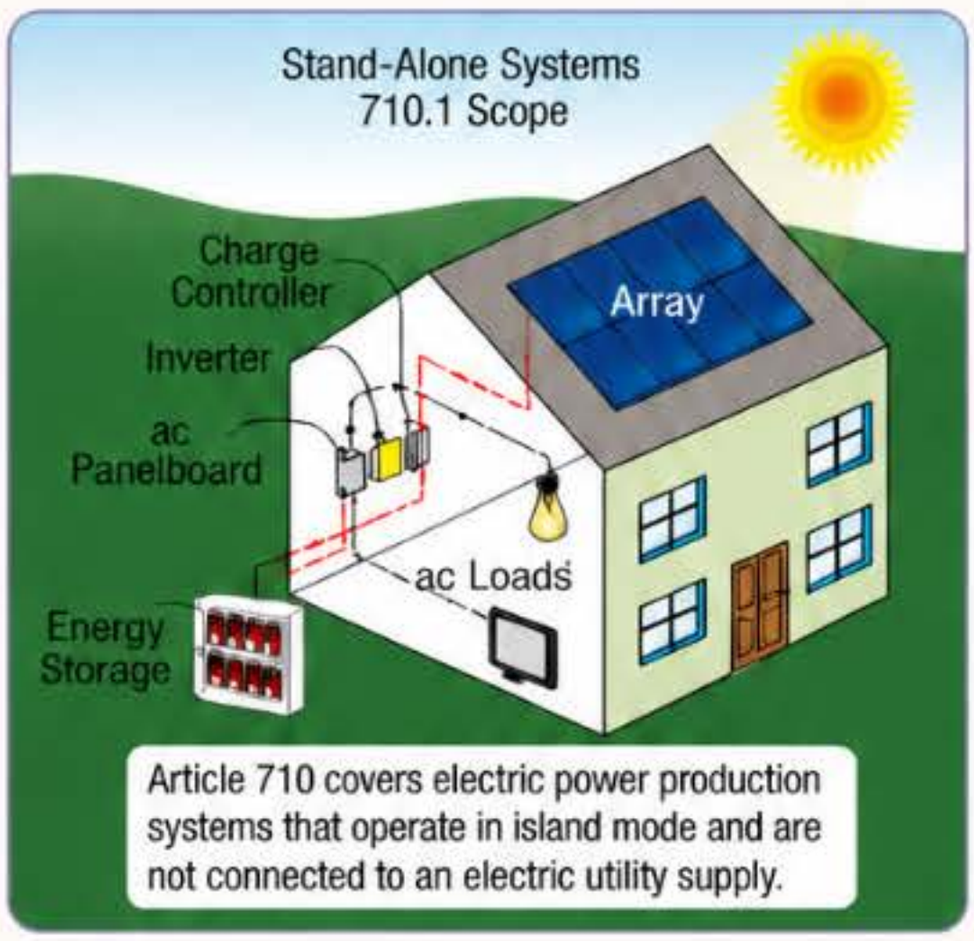
Stand-alone power production sources are what the name implies; they are not connected to the utility power grid or any other power production/distribution network.

The wiring for stand-alone systems must comply with Chapters 1 through 4 of the *NEC*. Depending on the purpose and design of a particular stand-alone source, the wiring might need to comply with Chapter 6 and other articles in Chapter 7.

Occupying about half a page, this article is one of the shortest in the Code, but its brevity does not imply insignificance. In fact, it will take on increasing signficace as the growth in stand-alone system installations continues. Many of these are systems that use solar or other "alternative energy" sources, but fossil fuel sources are also in the mix.

710.1 Scope

This article covers electric power production systems that operate in island mode and are not connected to an electric utility supply. Figure 710–1



▸Figure 710-1

Note: Stand-alone systems are capable of operating in island mode, independent from the electric utility, and include isolated microgrid systems or they can be interactive with other power sources. Stand-alone systems often include a single or a compatible interconnection of sources such as engine generators, solar PV, wind, an energy storage system, or batteries.

of sources such as engine generators, solar PV, wind, an energy storage system, or batteries.

Author's Commentary:

According to Article 100, "Island Mode" is the operational mode for stand-alone power production equipment, an isolated microgrid, multimode inverter, or an interconnected microgrid that is disconnected from the electric utility supply.

— Michael Hamilton

710.6 Equipment Approval

Stand-alone equipment must be approved for the intended use in accordance with one of the following: Figure 710–2

① Be listed for the application.

② Be evaluated for the application and have a field label applied.

Note: Inverters identified as "multimode" and "stand-alone" are specifically identified and certified to operate in this application. Stand-alone inverters operate only in island mode. Multimode inverters operate in either island mode or interactive mode setting. A multimode inverter operates in island mode when it is not connected to an electric utility supply. Stand-alone inverters are not evaluated and are not intended for connection to export power in parallel with an electric utility.

710.10 | Stand-Alone Systems

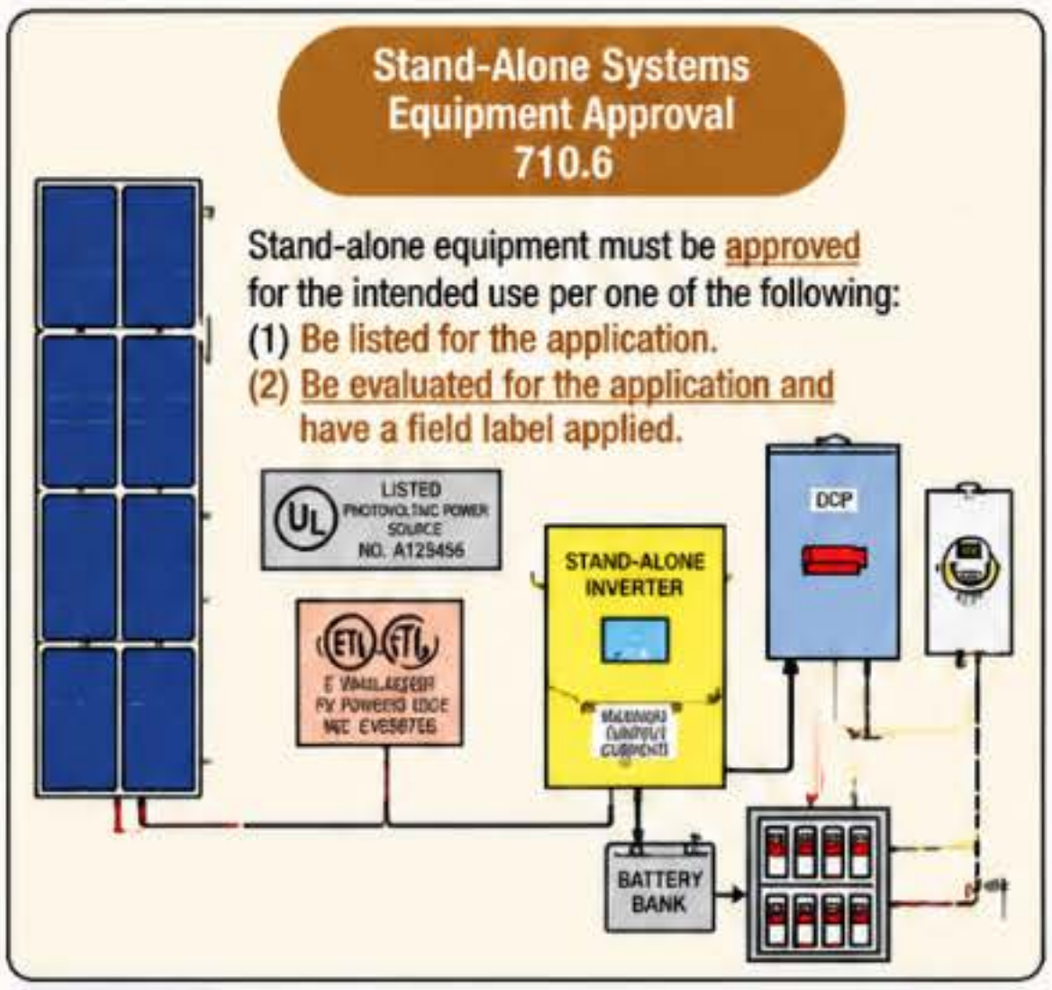


Figure 710-2

Author's Commentary:

- *According to Article 100, a "Multimode Inverter" is equipment having the capabilities of both interactive and stand-alone inverters.*

— Michael Hamilton

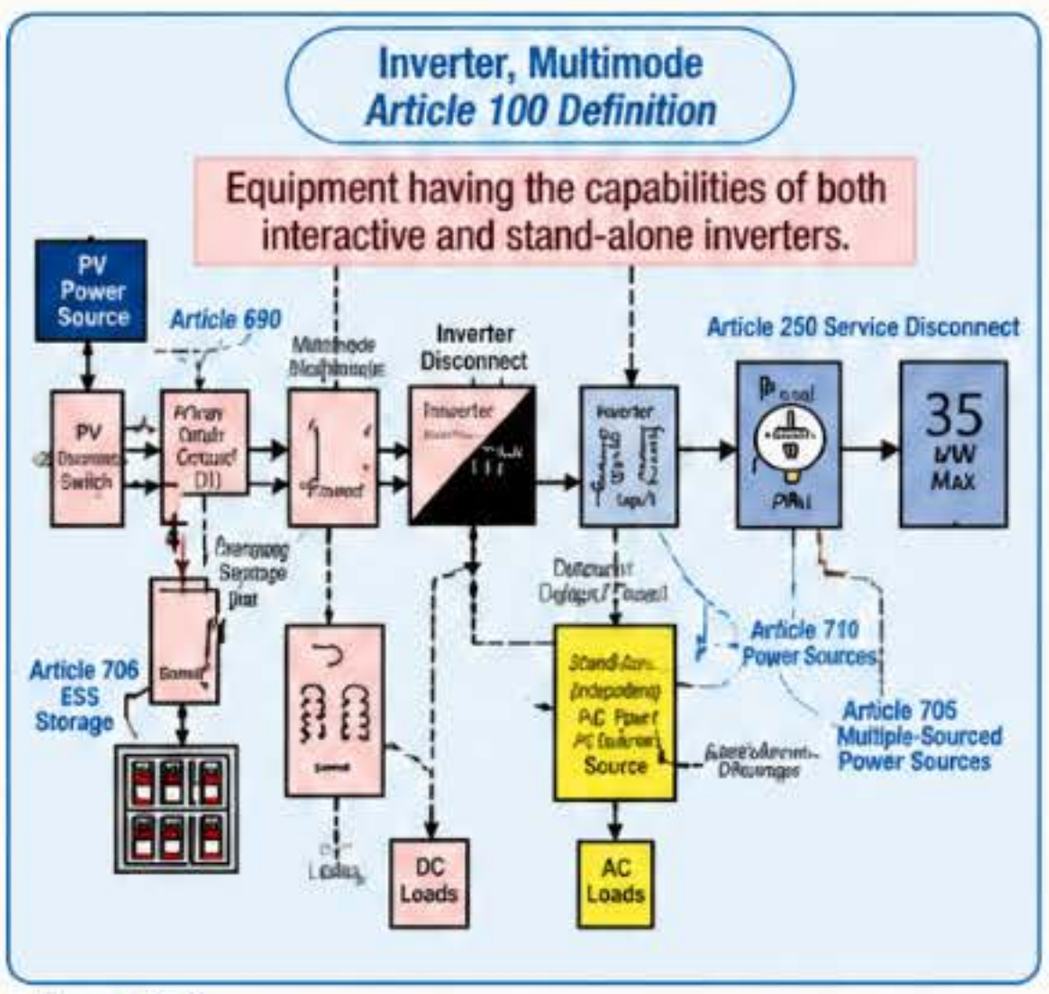


Figure 710-3

710.10 Identification of Power Sources

A permanent plaque or directory must be installed at the service equipment location or an approved readily visible location for a building supplied by a stand-alone system. The plaque or directory must identify the location of each power source disconnect or be grouped with other plaques or directories for other on-site sources.

Where multiple sources supply the building, the plaque or directory must be marked with the wording "CAUTION: MULTIPLE SOURCES OF POWER." The marking must be permanently affixed with sufficient durability to withstand the environment involved [110.21(B).

Ex: Installations with multiple co-located power production sources can be identified as a group(s). The plaque or directory is not required to identify each power source individually.

710.12 Stand-Alone Inverter Input Circuit Current

The maximum inverter input current is the continuous inverter input current rating when the inverter is producing its rated power at the lowest input voltage.

710.15 General

The wiring on the supply side of the building disconnect must comply with the following:

(A) Supply Output. The power supply to premises wiring systems fed by stand-alone or isolated microgrid power sources can have a capacity that is less than the calculated load, but it must not be less than the largest single utilization equipment connected to the stand-alone system.

Note: For general-use loads, the stand-alone system capacity is based on the sum of the capacity of all firm sources such as generators and energy storage system inverters. For specialty loads intended to be powered directly from a variable source, the stand-alone capacity is calculated using the sum of the variable sources, such as PV or wind inverters, or the combined capacity of both firm and variable sources.

(B) Sizing and Protection. The circuitconductors between a stand-alone source and a building disconnect must be sized based on the sum of the output ratings of the stand-alone source(s).

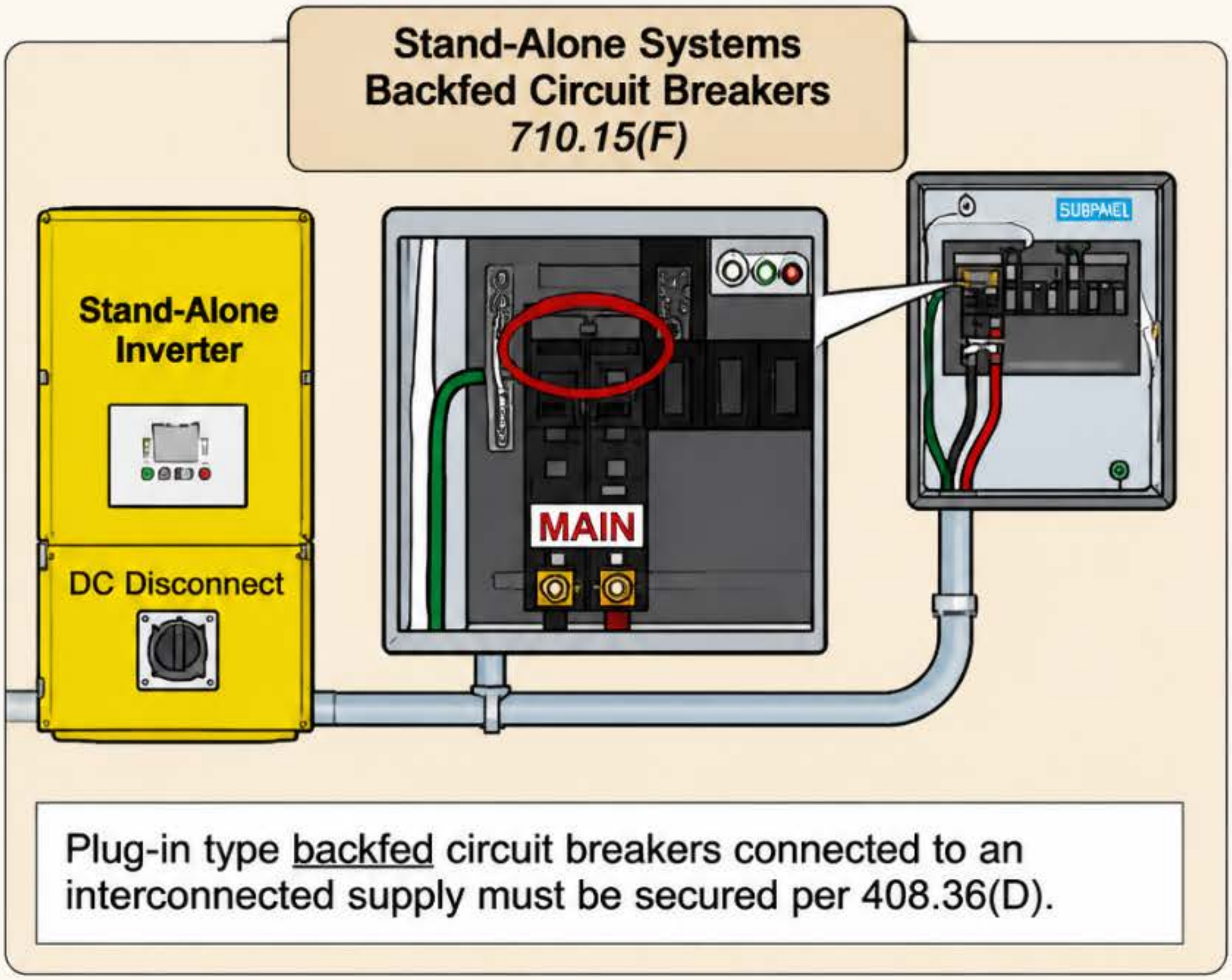
(C) Single 120V Supply. Stand-alone and isolated microgrid systems can supply 2-wire, single-phase, 120V or 3-wire, 120/240V service equipment or distribution panels where there are no 240V outlets and no multiwire circuits. Service equipment or distribution panels must be marked with the following words or equivalent:

WARNING: SINGLE 120-VOLT SUPPLY. DO NOT CONNECT MULTIWIRE BRANCH CIRCUITS!

(E) Energy Storage or Backup Power System Requirements. Stand-alone systems are not required to include energy storage or backup power.

(F) Backfed Circuit Breakers. Plug-in type backfed circuit breakers must be secured in accordance with 408.36(D).

Figure 710-4



▶ **Figure 710-4**

Notes |

ARTICLE 725 REMOTE-CONTROL, SIGNALING, AND POWER-LIMITED CIRCUITS

Introduction to Article 725—Remote-Control, Signaling, and Power-Limited Circuits

The rules in Article 725 address remote-control, signaling, and power-limited circuits that are not integral parts of a device or appliance. This article covers examples such as burglar alarms, access control systems, audible notification devices, nurse call systems, intercoms, certain computer networks, lighting dimmer controls, and some low-voltage industrial control systems.

Below are the three main types of circuits discussed in Article 725:

- **Remote-control circuits** activate other circuits through a relay or solid-state device, such as a motion-detected security floodlight.
- **Signaling circuits** produce an output that acts as a signal or indicator—for example, a buzzer, a flashing lamp, or an annunciator.
- **Power-limited circuits** are supplied by a transformer or other source that restricts the available energy to a level that helps reduce the risk of electric shock and/or fire.

Article 725 exists to allow these circuits to be treated differently from standard power circuits. As stated in 725.1 Note, they are distinguished by their limited use and restricted energy levels. This article sets out alternate requirements for conductor sizing, overcurrent protection, insulation, wiring methods, and materials.

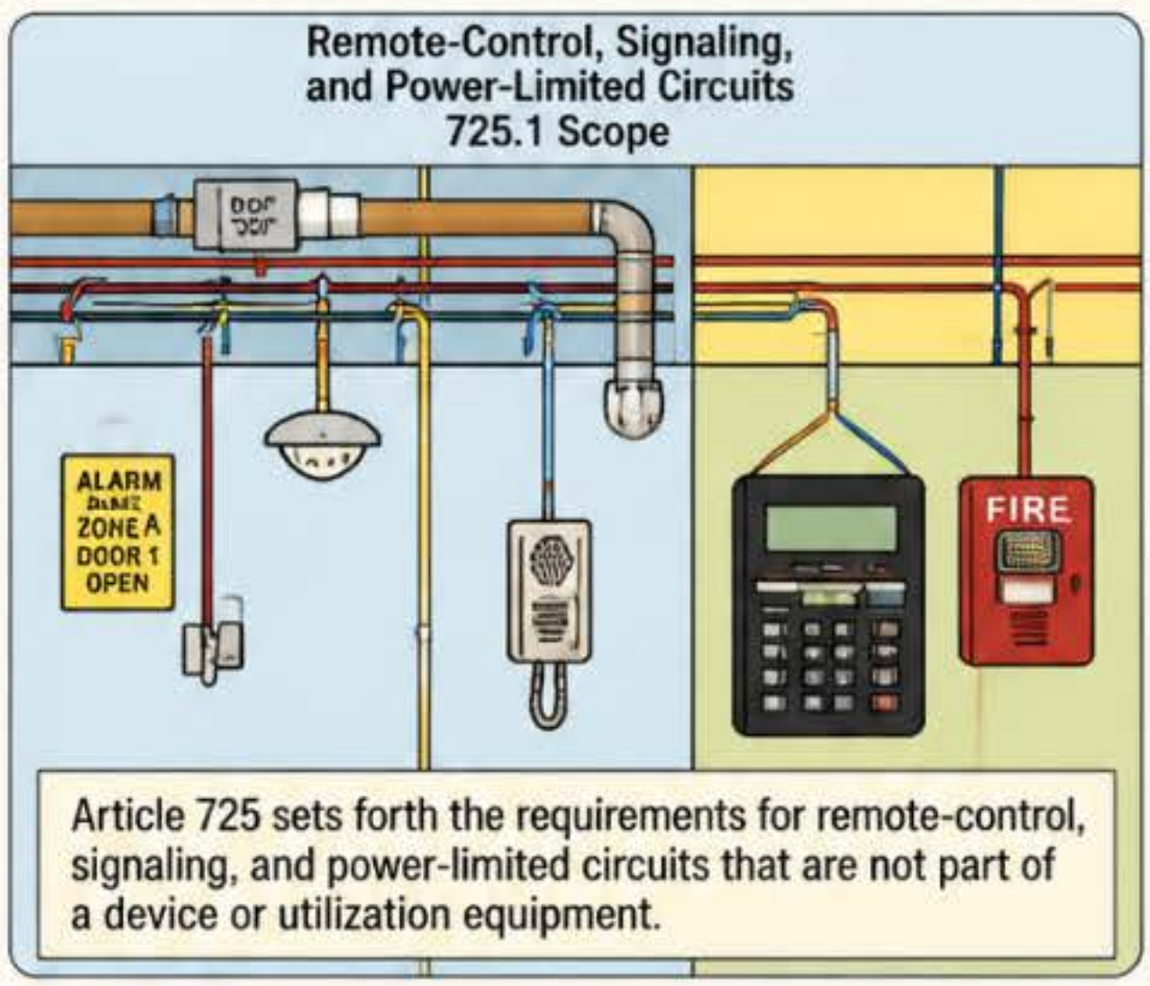
Article 725 is divided into four parts. Part I provides general information, Part II covers Class 1 circuits, Part III addresses Class 2 circuits, and Part IV is focused on listing requirements. A firm grasp of the voltage and energy levels involved, the permitted wiring methods, and the purpose behind the rules is the key to applying each part correctly.

Part I. General

725.1 Scope

Article 725 sets forth the requirements for remote-control, signaling, and power-limited circuits that are not part of a device or utilization equipment.

Note: These circuits operate at electrical power and voltage levels that set them apart from typical power circuits. Different rules apply for minimum conductor sizes, overcurrent protection, insulation requirements, wiring methods, and materials.



▶ Figure 725–1

725.2 | Remote-Control, Signaling, and Power-Limited Circuits

Author's Commentary:

Understanding Article 725 begins with knowing how its terms are defined. These definitions provide the foundation for correctly applying the rules that follow.

— Michael Hamilton

- **Remote-Control Circuit.** A circuit that operates another circuit through a relay or a similar device is considered a remote-control circuit. Examples include a 120V branch circuit that starts a motor starter or lighting contactor, or a 24V circuit that opens a garage door operator.

- **Signaling Circuit.** A circuit used to transmit information is a signaling circuit. Typical signaling equipment includes doorbells, buzzers, signal beacons, annunciators, burglar alarms, and other indication or alarm devices.

- **Class 1 Circuit.** This term describes the wiring system between the load side of a Class 1 overcurrent protective device and the equipment it feeds. See 725.41 for the voltage and power restrictions that apply to Class 1 circuits.

- **Class 2 Circuit.** This refers to the wiring system from the load side of a Class 2 power supply to the devices it powers. Because of the limited output of Class 2 power supplies, Class 2 circuits are inherently safe from an initiation standpoint and give acceptable protection against electric shock.

725.2 Definitions

The definitions in this section are used only within this article.

Abandoned Cable. A cable that is not connected to any equipment and is not identified for future use with a tag. ▸ **Figure 725–2**

Cable Bundle. A group of cables that are tied together or in contact with one another in a closely packed arrangement for a minimum of 40 in. ▸ **Figure 725–3**

Note: Separating individual cables can reduce heat buildup. Combining cables can reduce heat dissipation and may increase signal interference between cables.

Author's Commentary:

Section 725.25 requires that the accessible portions of abandoned cables be removed.

— Michael Hamilton

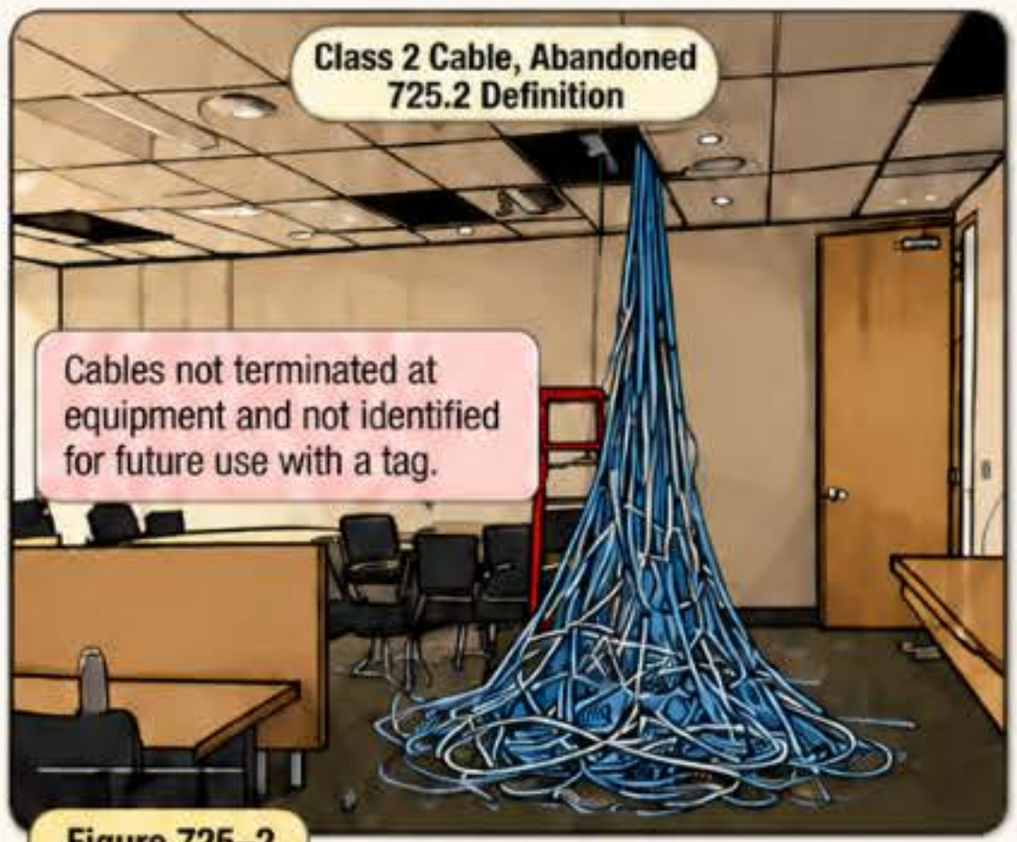


Figure 725–2

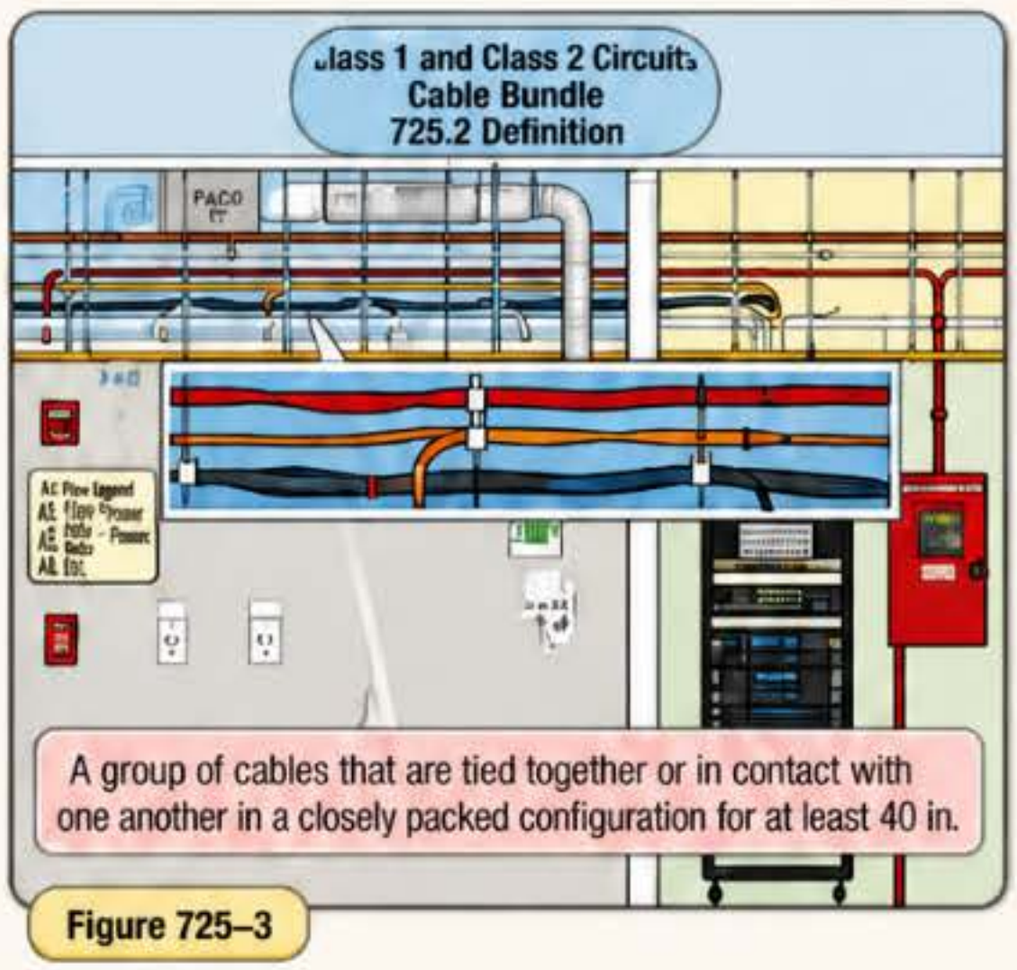


Figure 725–3

725.3 Other Articles

Beyond the requirements of this article, circuits and equipment must comply with the articles or sections listed in 725.3(A) through (P). Only the portions referenced below apply to Class 1, Class 2, and Class 3 circuits.

Author's Commentary:

Enclosures and boxes are not required for Class 2 splices or terminations because Article 725 does not reference 300.15, which includes that requirement. ▸ **Figure 725–4**

— Michael Hamilton

Remote-Control, Signaling, and Power-Limited Circuits 725.3

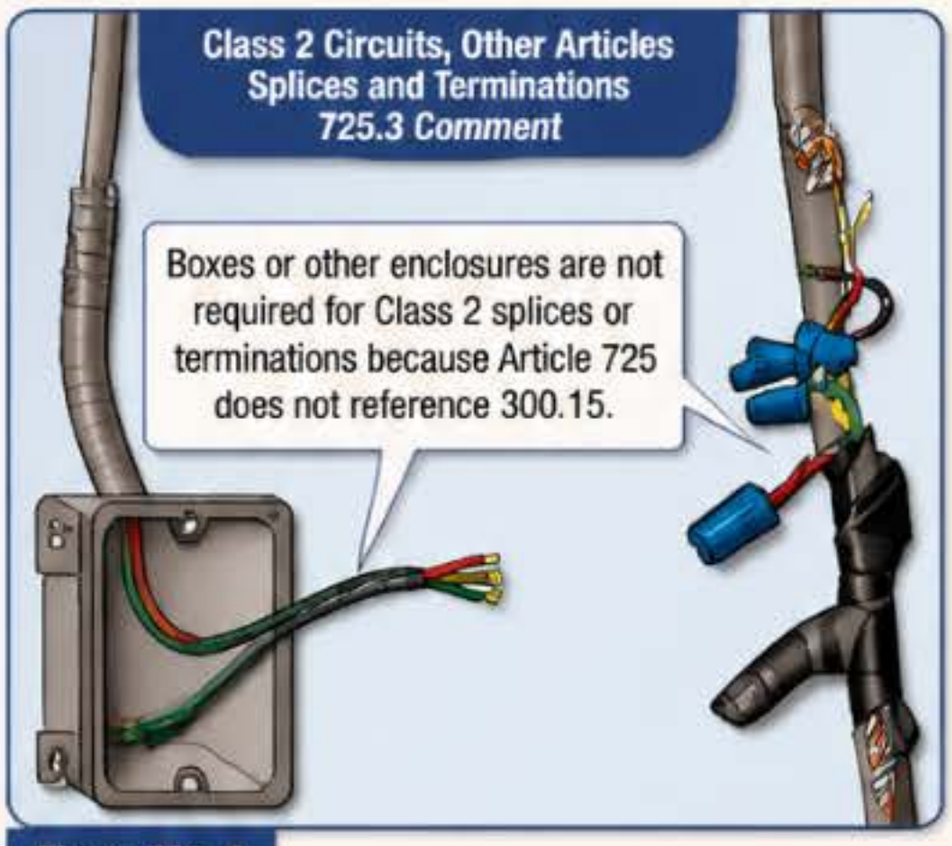


Figure 725–4

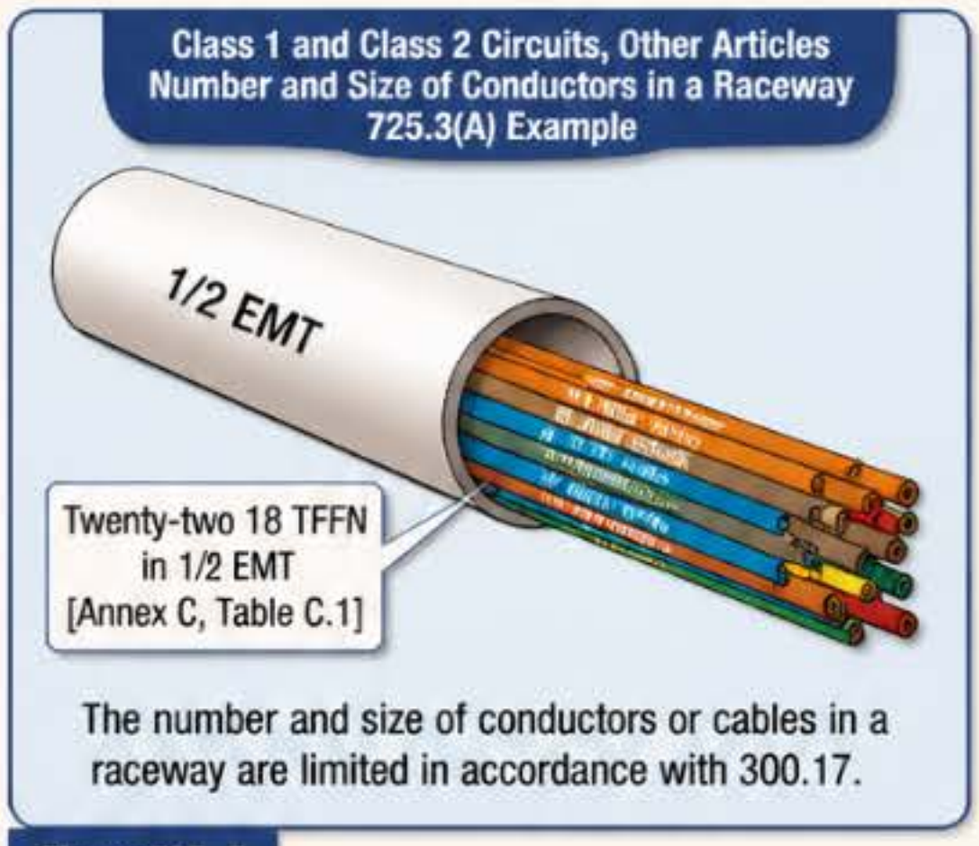


Figure 725–5

(A) Number and Size of Conductors in a Raceway. The number and size of conductors or cables within a raceway are limited in accordance with 300.17.

Author's Commentary:

- Raceways must be sufficiently large so that conductors can be installed and removed without damaging the insulation [300.17].
- When all conductors in a raceway have the same size and insulation type, the permitted count is found in Annex C of the raceway type [Chapter 9, Notes to Tables, Note 1].
- For conductors not listed in Chapter 9 (such as multiconductor cable), use the actual dimensions. If one multiconductor cable is used, only the single-conductor percentage fill applies [Chapter 9, Notes to Table, Notes 5 and 9].

— Michael Hamilton

▶ Example

Question: *How many 18 TFFN fixture wires can be installed in trade size 1/2 electrical metallic tubing?*

▶ **Figure 725–5**

(a) 16 (b) 18 (c) 22 (d) 38

Answer: *(c) 22 [Annex C, Table C.1]*

(B) Spread of Fire or Products of Combustion. Installation of Class 1 and Class 2 circuits must comply with 300.21.

Author's Commentary:

- Electrical wiring and equipment must be arranged so that the spread of fire or combustion byproducts is not materially increased. This can be achieved through fire-resistive walls, floors, and ceilings for electrical equipment or by using firestopped openings where permitted by the authority having jurisdiction to maintain the required fire-resistance rating of the fire-resistive assembly [300.21].

— Michael Hamilton

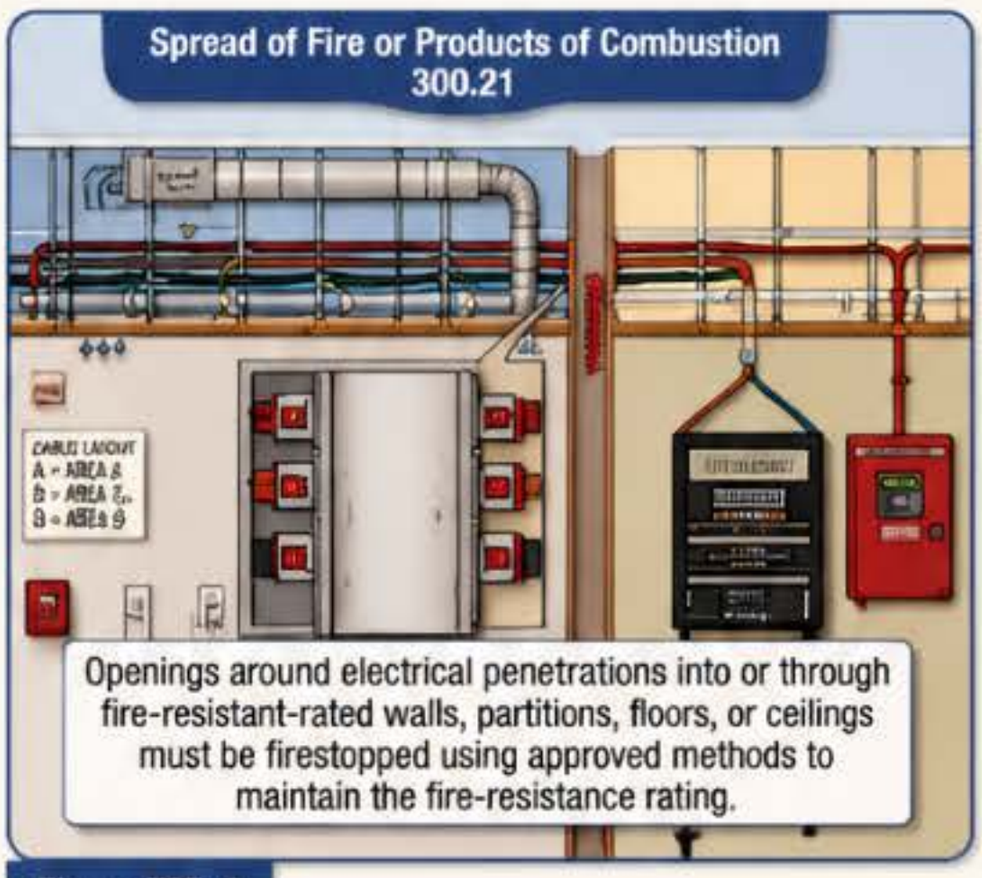


Figure 725–6

725.3 Remote-Control, Signaling, and Power-Limited Circuits

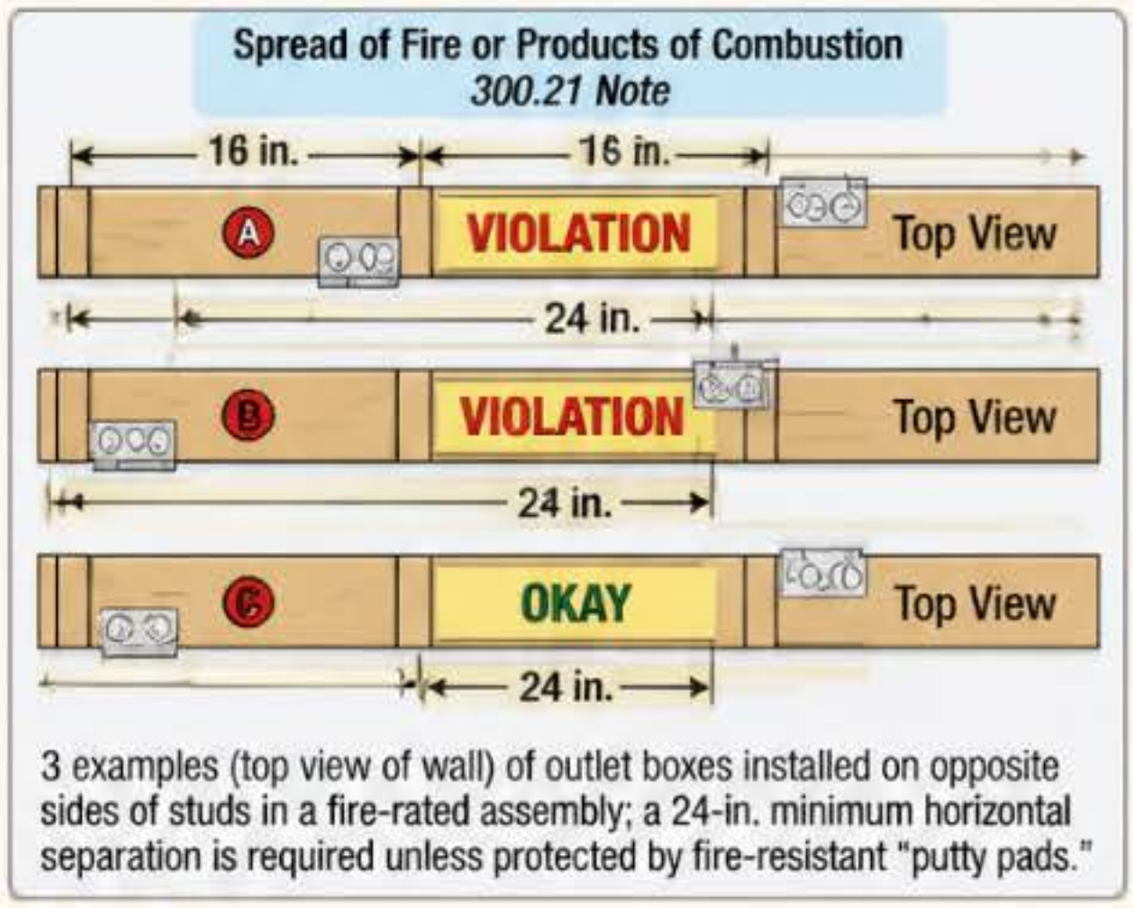
Author's Commentary:

- Firestopping materials are specified for various wiring methods and for the way assemblies are built where they pass through.

  ▸ Figure 725–7

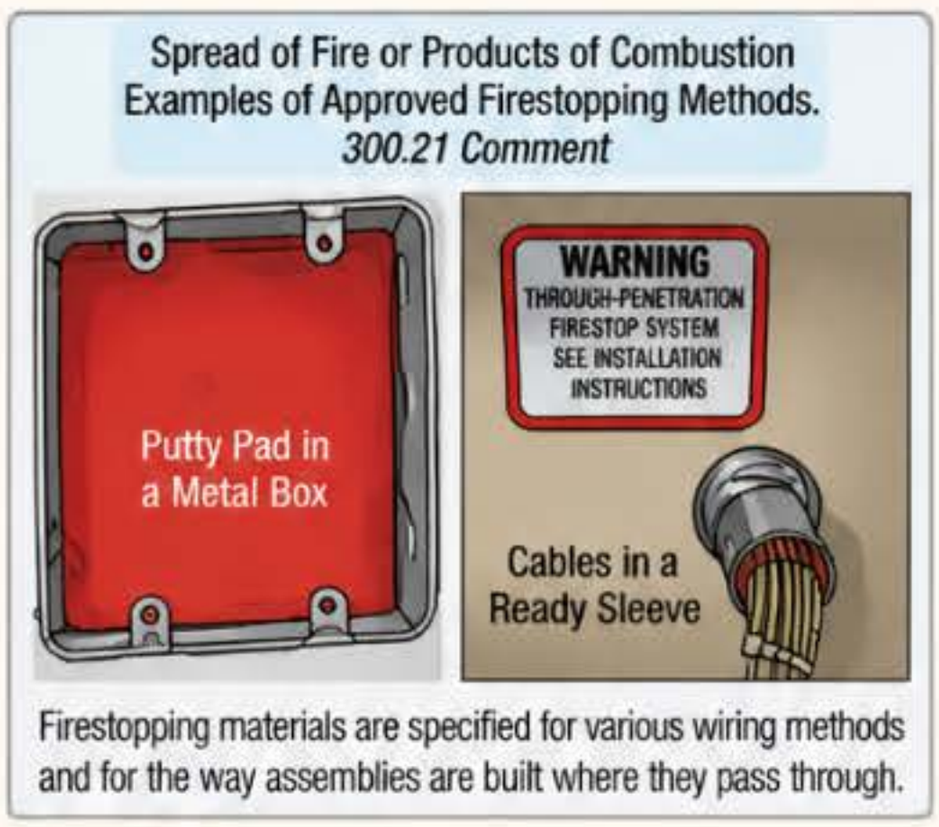
- Check the International Firestop Council's website (www.firestop.org) for more resources on firestop system education that conforms with ASTM E2174, *Standard Practice for On-Site Inspection of Installed Firestops*, and ASTM E2393, *Standard Practice for On-Site Inspection of Installed Fire Resistive Joint Systems and Penetration Fire Barriers.*

— *Michael Hamilton*



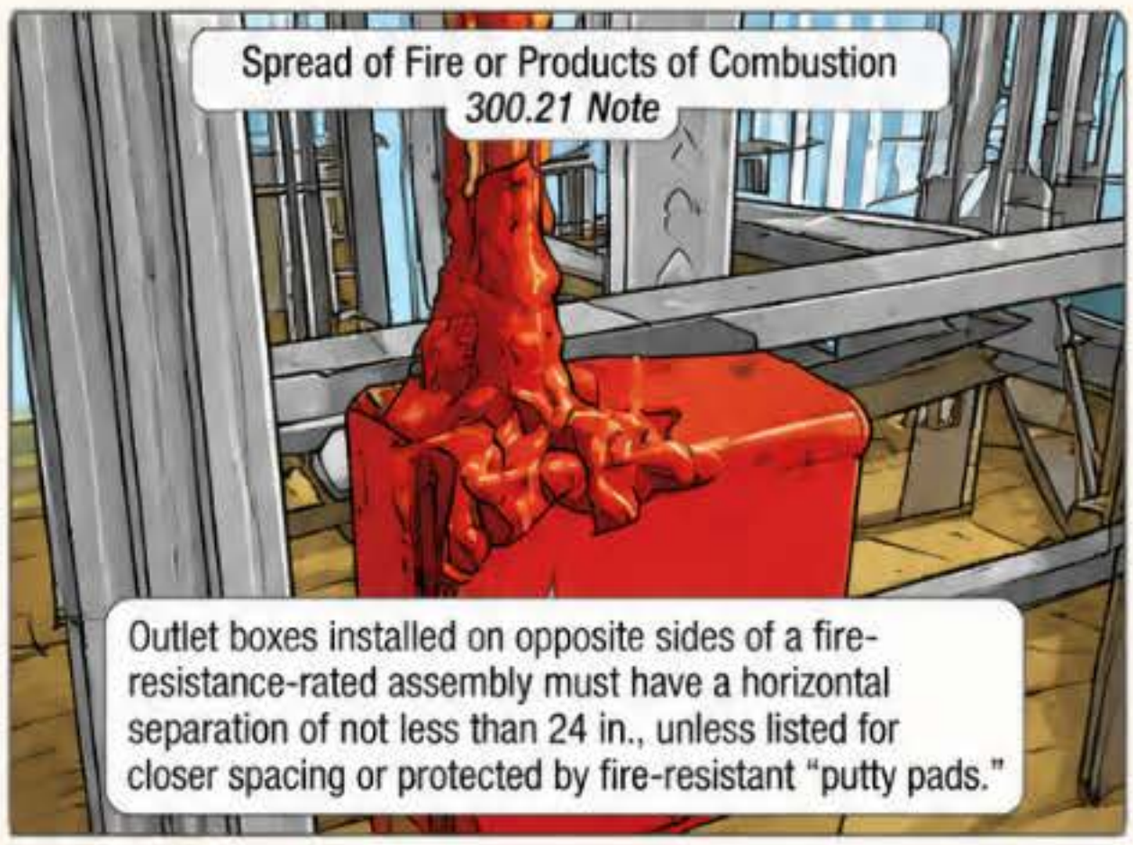
3 examples (top view of wall) of outlet boxes installed on opposite sides of studs in a fire-rated assembly; a 24-in. minimum horizontal separation is required unless protected by fire-resistant "putty pads."

▸ Figure 725–8



Firestopping materials are specified for various wiring methods and for the way assemblies are built where they pass through.

▸ Figure 725–7



Outlet boxes installed on opposite sides of a fire-resistance-rated assembly must have a horizontal separation of not less than 24 in., unless listed for closer spacing or protected by fire-resistant "putty pads."

▸ Figure 725–9

Author's Commentary:

- Directories of electrical construction materials published by qualified testing labs contain installation listings and limitations needed to keep the fire-resistance rating of assemblies intact. Building codes can also impose limits on penetrations on opposite sides of a fire-resistive wall.
- Outlet boxes must be separated horizontally by at least 24 in. when installed on opposite sides within a fire-ressitive assembly, unless the outlet box is approved for closer spacing or shielded with fire-resistant "putty pads" in accordance with the manufacturer's instructions.

— *Michael Hamilton*

▸ Figure 725–8 and Figure 725–9

Author's Commentary:

- Boxes in fire-resistive assemblies must be installed for their intended purpose. If steel boxes are used, secure them to the framing member so cut-in boxes are not permitted (see UL White Book, *Guide Information for Electrical Equipment*).
- "Putty pads" are typically installed on the exterior of the box, but many manufacturers offer inserts for inside the box.

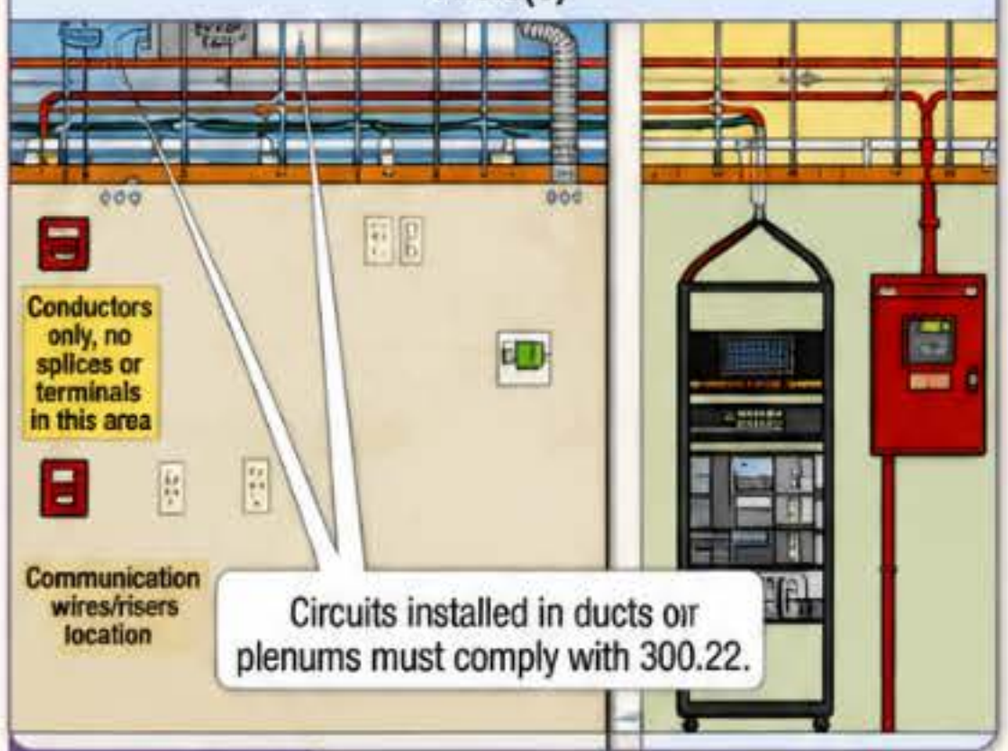
— *Michael Hamilton*

(C) Ducts and Plenum Spaces. Class 1 and Class 2 circuits installed in ducts or plenums must comply with 300.22.

▸ Figure 725–10

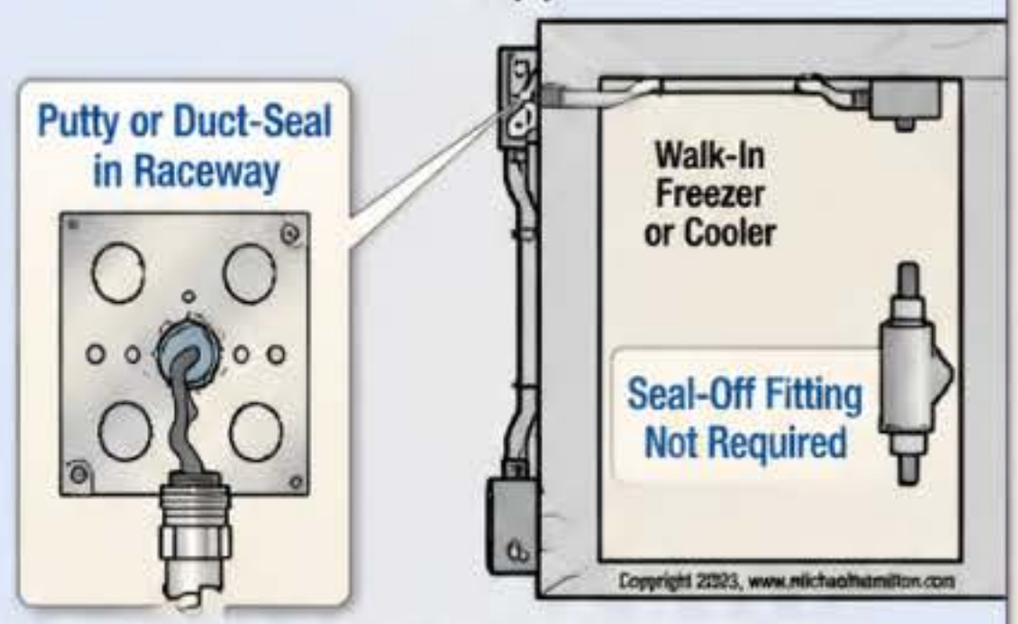
REMOTE-CONTROL, SIGNALING, AND POWER-LIMITED CIRCUITS | 725.3

Class 1 and Class 2 Circuits, Other Articles
Ducts and Plenums Spaces
725.3(C)



▸ Figure 725–10

Class 1 and Class 2 Circuits, Other Articles
Raceways Exposed to Different Temperatures
725.3(H)



Raceways must be filled to prevent the circulation of warm air to a colder section of the raceway [300.7(A)].

▸ Figure 725–11

Ex 1: Class 2 cables selected in accordance with Table 725.154 and installed in accordance with 725.135(B) and 300.22(B) Ex, are permitted to be installed in ducts specifically fabricated for environmental air.

Ex 2: Class 2 cables selected in accordance with Table 725.154 and installed in accordance with 725.135(C) are permitted to be installed in plenum spaces.

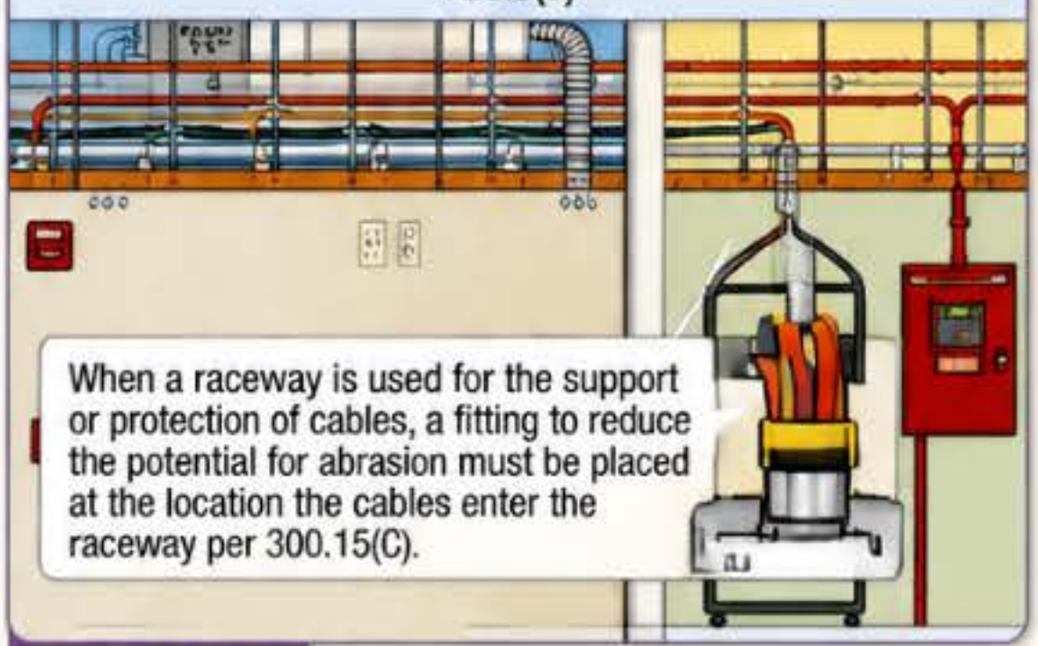
(D) Hazardous Locations. Class 1 and Class 2 circuits installed in hazardous (classified) locations must comply with 501.10(B)(1), 501.150, 502.10(B)(1), 502.150, 503.10(A)(1), 503.150, 506.15(A), 506.15(C), 511.7(B)(1), 515.7(A), and Article 517, Part IV.

(E) Cable Trays. Class 1, 2 and 3 circuits in cable trays must be installed in accordance with Parts I and II of Article 392.

(H) Raceways Exposed to Different Temperatures. If a raceway is subjected to different temperatures, and where condensation is known to be a problem, the raceway must be filled with a material approved by the authority having jurisdiction that will prevent the circulation of warm air to a colder section of the raceway [300.7(A)].

(J) Bushing. When a raceway is used for the support or protection of cables, a fitting is required to reduce the potential for abrasion and must be placed at the location the cables enter the raceway in accordance with 300.15(C). ▸ Figure 725–12

Class 1 and Class 2 Circuits
Other Articles, Bushing
725.3(J)



▸ Figure 725–12

Author's Commentary:

This raceway seal is one that is approved by the authority having juirisdiction to prevent the circulation of warm air to a cooler section of the raceway and is not the same thing as an explosionproof seal.

— Michael Hamilton

(L) Corrosive, Damp, or Wet Locations. Where installed in corrosive, damp, or wet locations, Class 2 cables must be identified for the location in accordance with 110.11 and 310.10(F). Conductors and cables installed in underground raceways [300.5(B)], or in raceways aboveground in wet locations [300.9], must also be identified for wet locations. Where corrosion may occur, the requirements of 300.6 must be used.

(M) Cable Routing Assemblies. Two Class 2 cables may be installed in a cable routing assembly chosen from those listed in Table 800.154(c), provided the assembly complies with 800.182, and is installed following 800.110(c) and 800.113. ▸**Figure 725–13**

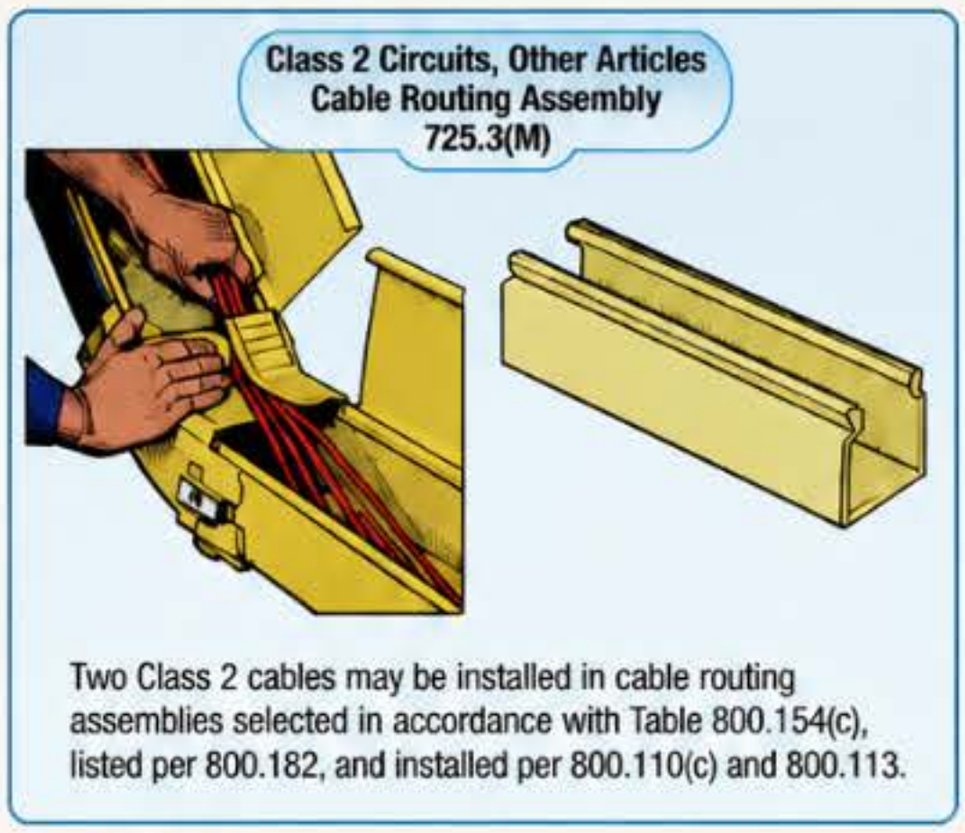


Figure 725–13

(N) Communications Raceways. Two Class 2 cables may be installed in communications raceways selected from those listed in Table 800.154(b), in accordance with 800.182, and installed per 800.110 and 360.214 through 362.56, where the requirements applicable to electrical nonmetallic tubing apply.

Figure 725–14

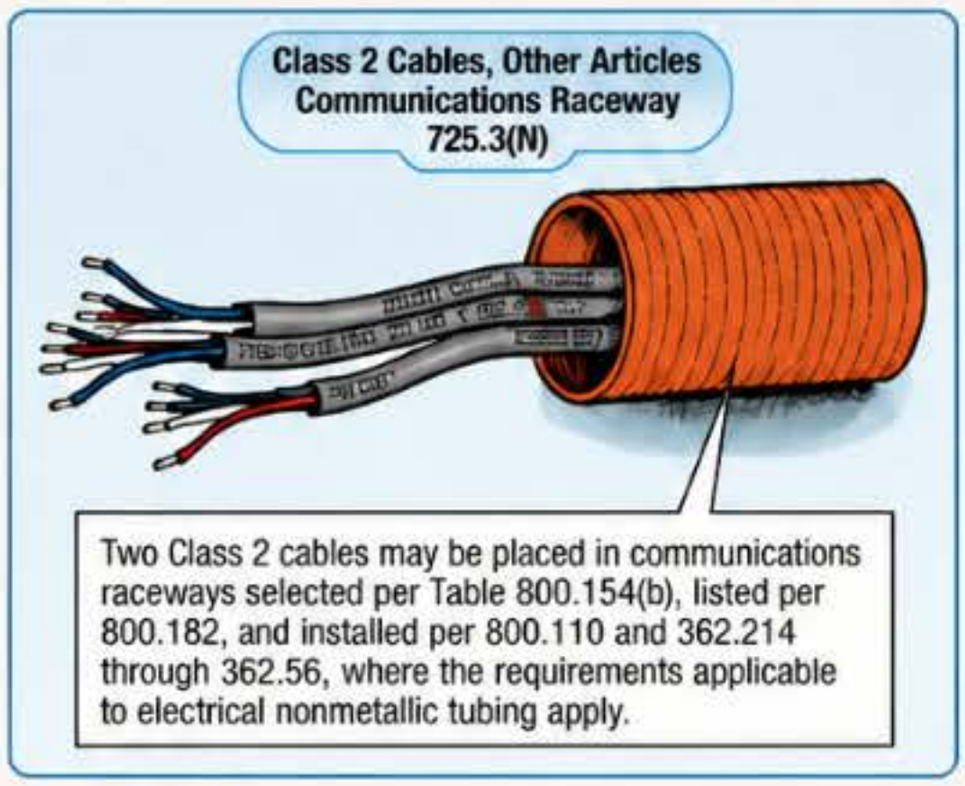


Figure 725–14

(O) Temperature Limitation of Class 2 Cables. The provisions of 310.14(A)(3) addressing conductor temperature limits apply to Class 2 cables.

(P) Identification of Equipment Grounding Conductors. Equipment grounding conductors must be identified in accordance with 250.119.

Example: Conductors with green insulation are allowed for use as ungrounded signal conductors for Types CL3P, CL2P, CL3R, CL2R, CL3, CL2, CL3X, CL2X, and substitute cables installed in accordance with 725.154(A).

725.21 Electrical Equipment Behind Access Panels

Access to equipment is not allowed to be blocked by any accumulation of cables that would prevent the removal of suspended-ceiling panels.

▸**Figure 725–15**

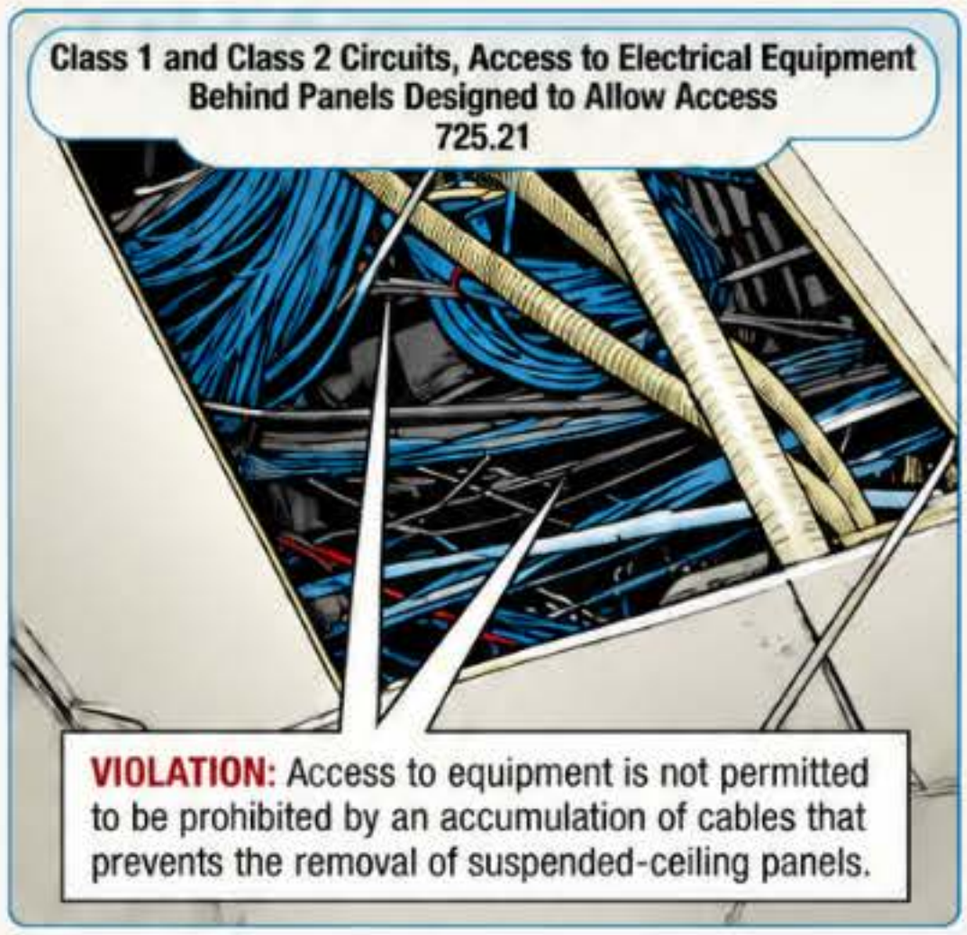


Figure 725–15

725.24 Mechanical Execution of Work

Equipment and cabling must be installed in a neat and workmanlike manner. ▸**Figure 725–16**

Exposed cables must be supported by the structural components of the building so the cable will not be damaged by normal building use. Support is provided by straps, staples, hangers, cable ties, or similar fittings designed and installed in a manner that will not damage the cable. ▸**Figure 725–17**

Note: Paint, plaster, cleaners, abrasives, corrosive residues, or other contaminants can result in an undetermined alteration of Class 2 cable properties.

Remote-Control, Signaling, and Power-Limited Circuits | 725.25

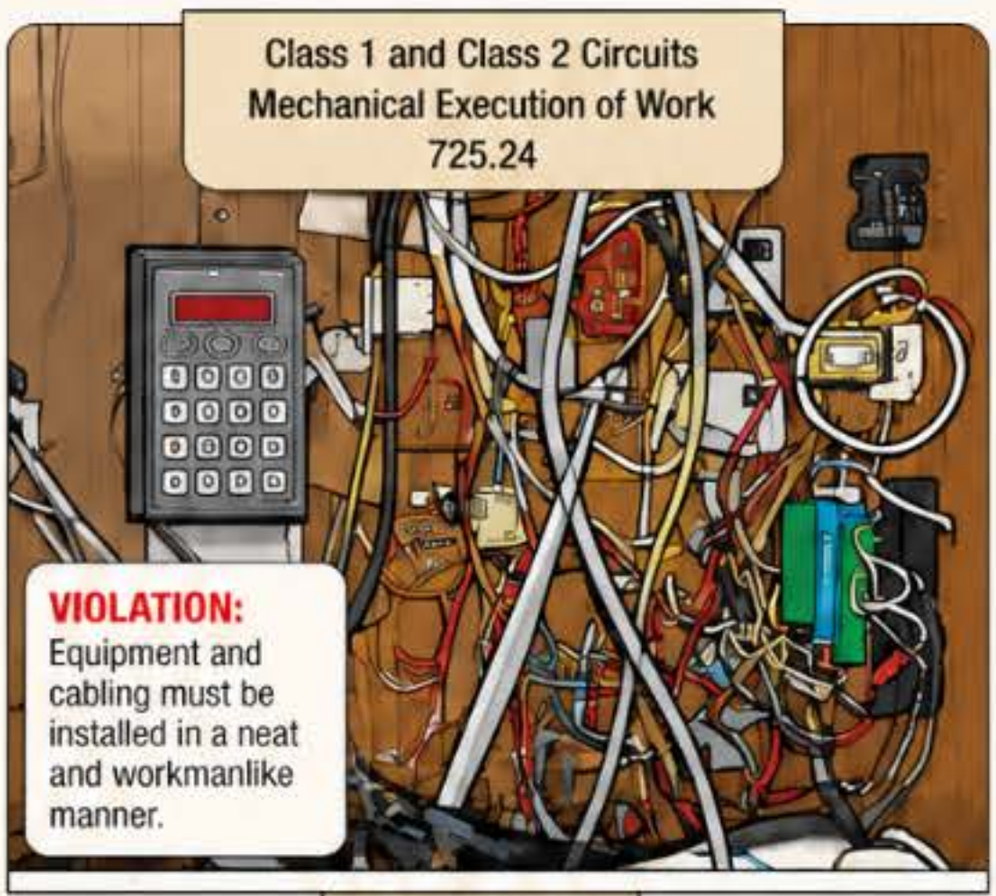


Figure 725–16

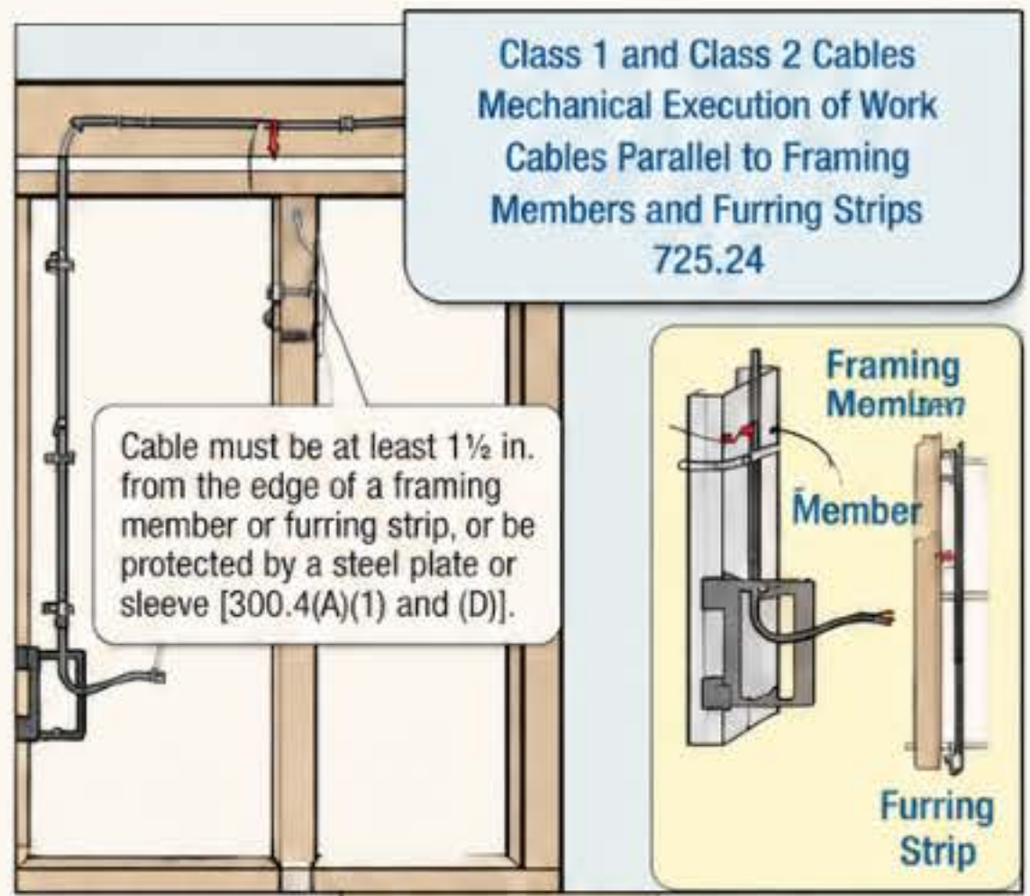


Figure 725–18

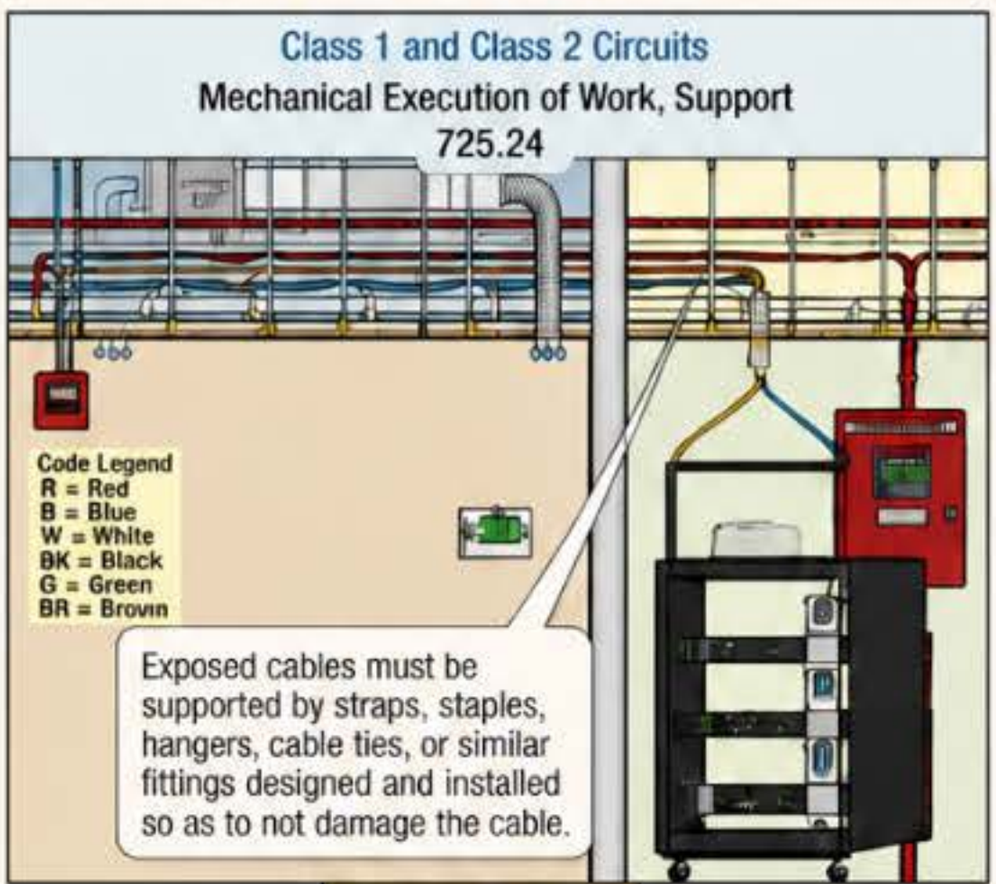


Figure 725–17

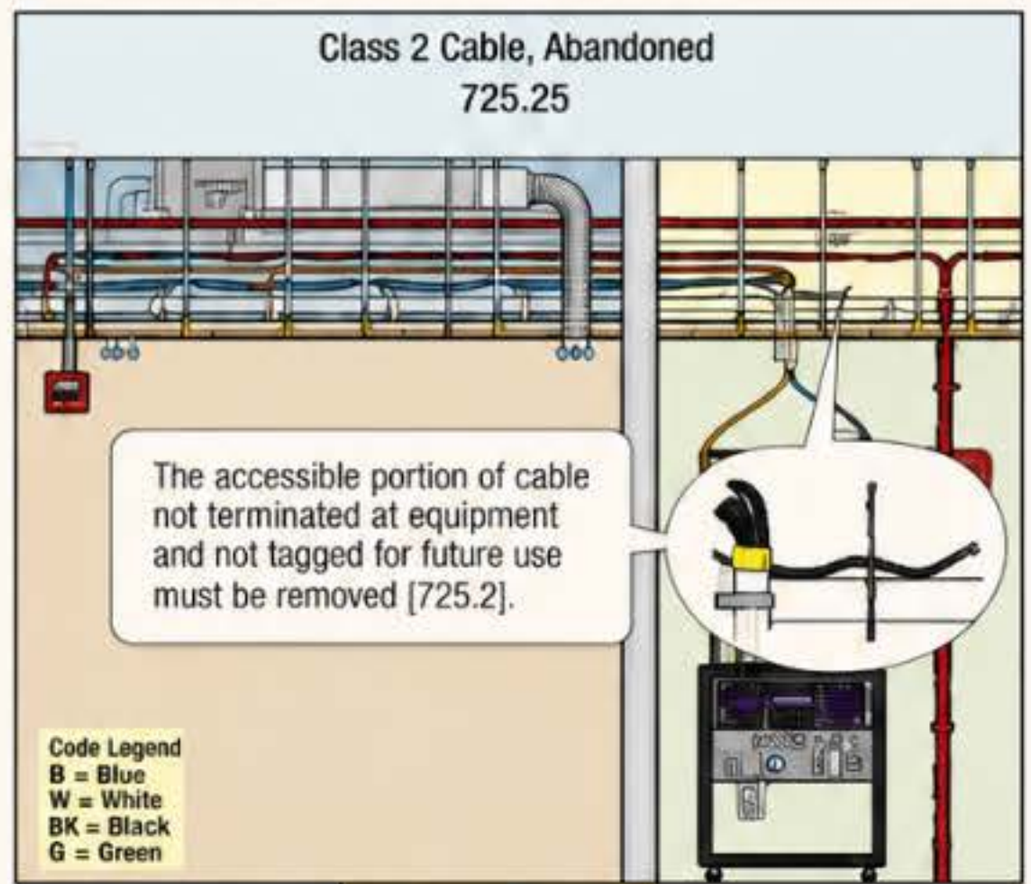


Figure 725–19

Cables installed through or parallel to framing members or furring strips must be protected where they are likely to be penetrated by nails or screws by installing the wiring method so it is not less than 1½ in. from the nearest edge of the framing member or furring strips, or by protecting it with a ⅛ in. thick steel plate or equivalent [300.4(A) and (D)]. • **Figure 725–18**

725.25 Abandoned Cable

To limit the spread of fire or products of combustion within a building, the accessible portion of Class 2 cables not terminated at equipment or tagged for future use must be removed [725.2]. • **Figure 725–19**

Tags identifying cables for future use must be able to withstand the environment involved.

Author's Commentary:

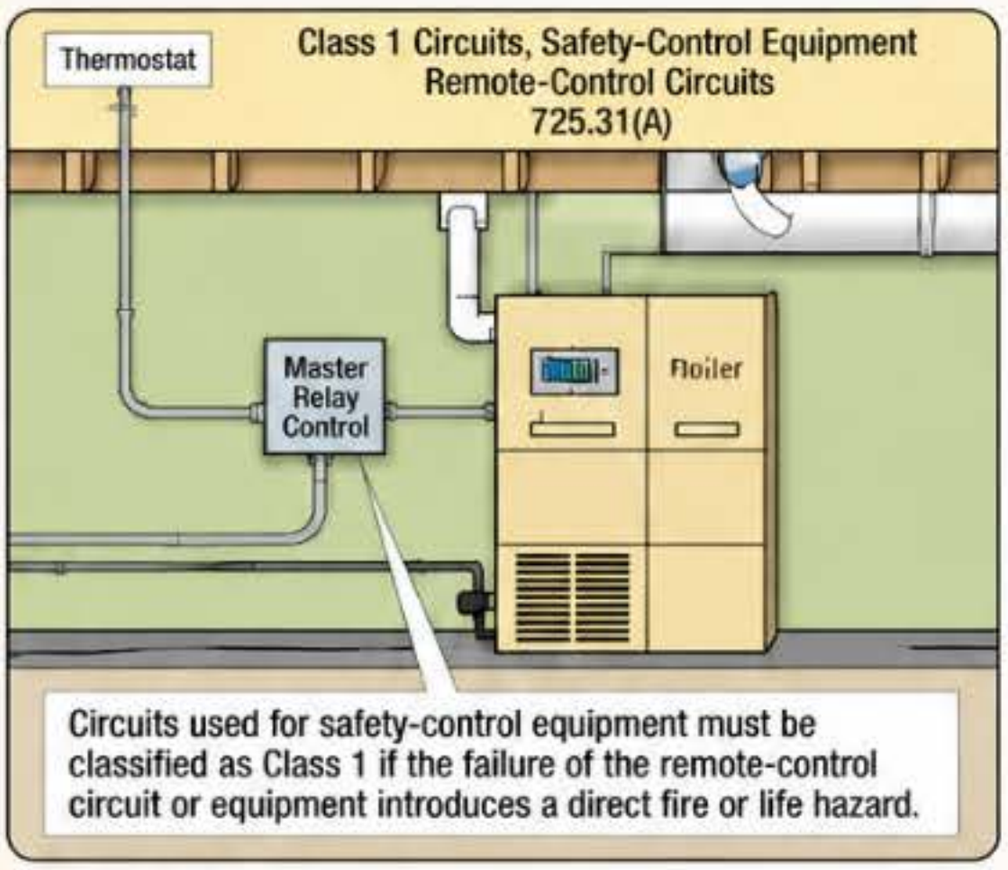
Cables installed in concealed raceways are not considered accessible; therefore, they are not required to be removed. See the definition of "Abandoned Cable" in 725.2.

— Michael Hamilton

725.31 | Remote-Control, Signaling, and Power-Limited Circuits

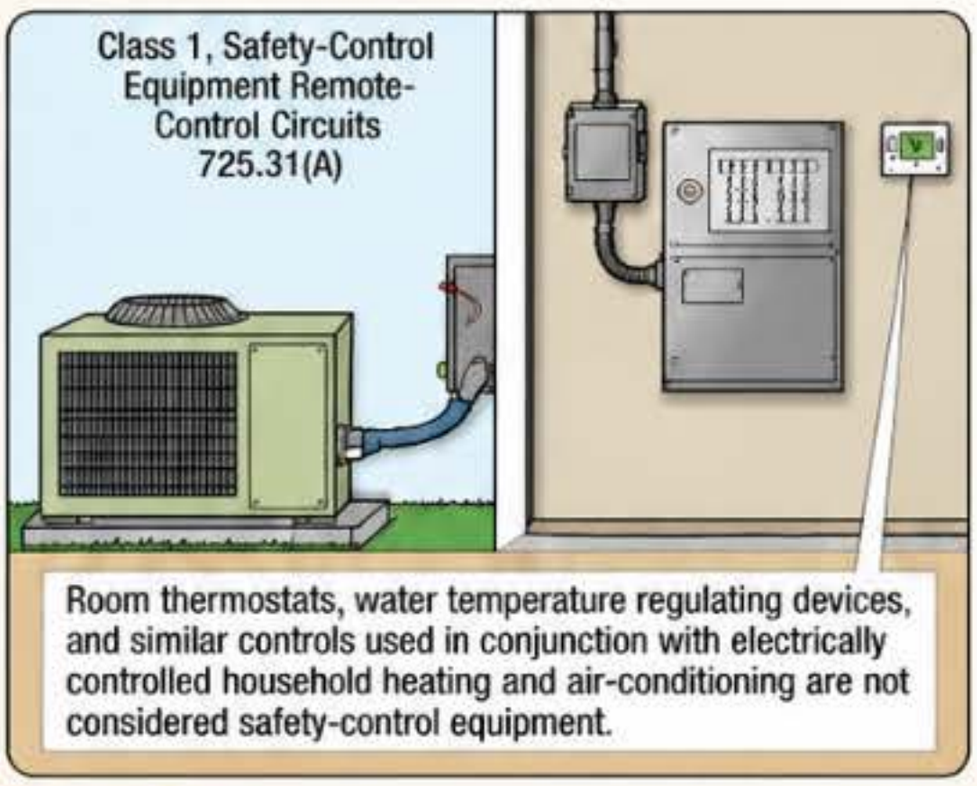
725.31 Safety-Control Equipment

(A) Remote-Control Circuits. Electrical circuits that operate safety-related equipment must be treated as Class 1 when failure of the remote-control circuit or its associated equipment could result in a direct fire or life hazard.
▶ Figure 725–20



▶ Figure 725–20

Room thermostats, temperature-regulating devices, and similar controls used with electrically powered household heating and air-conditioning systems are not considered safety-control equipment.
▶ Figure 725–21



▶ Figure 725–21

(B) Physical Protection. If damage to remote-control circuits of safety-control equipment would introduce a hazard [725.31(A)], conductors must be installed in rigid metal conduit, intermediate metal conduit, PVC conduit, electrical metallic tubing, Type MI cable, Type MC cable, or be otherwise suitably protected from physical damage.

725.35 Circuit Requirements

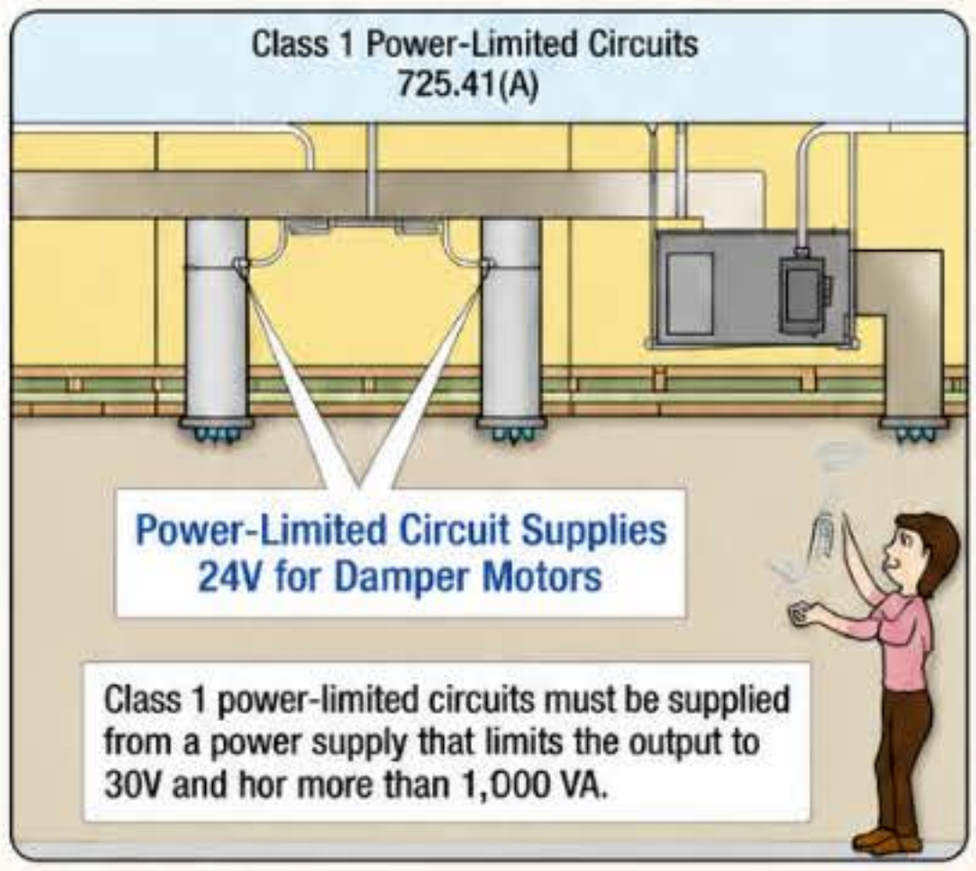
(1) Class 1 circuits must comply with Parts I and II of Article 725.

(2) Class 2 circuits must comply with Parts I and III of Article 725.

Part II. Class 1 Circuit Requirements

725.41 Class 1 Circuit Classifications and Requirements

(A) Class 1 Power-Limited Circuits. Class 1 power-limited circuits must be supplied from a power supply that limits the output to 30V and no more than 1,000 VA.▶ Figure 725–22



▶ Figure 725–22

Author's Commentary:

- Class 1 power-limited circuits are not commonly used. They are applied when the system voltage is 30V or less (safe from electric shock in dry environments) and when the load demands exceed the 100 VA energy restriction of Class 2 circuits, such as for motorized blinds like those controlled by remote devices [Chapter 9, Table 11(A)].

— *Michael Hamilton*

REMOTE-CONTROL, SIGNALING, AND POWER-LIMITED CIRCUITS 725.48

(B) Class 1 Remote-Control and Signaling Circuits. A Class 1 remote-control and signaling circuit must not exceed 600V. The power delivered by the source is not required to be limited. See Figure 725-23.

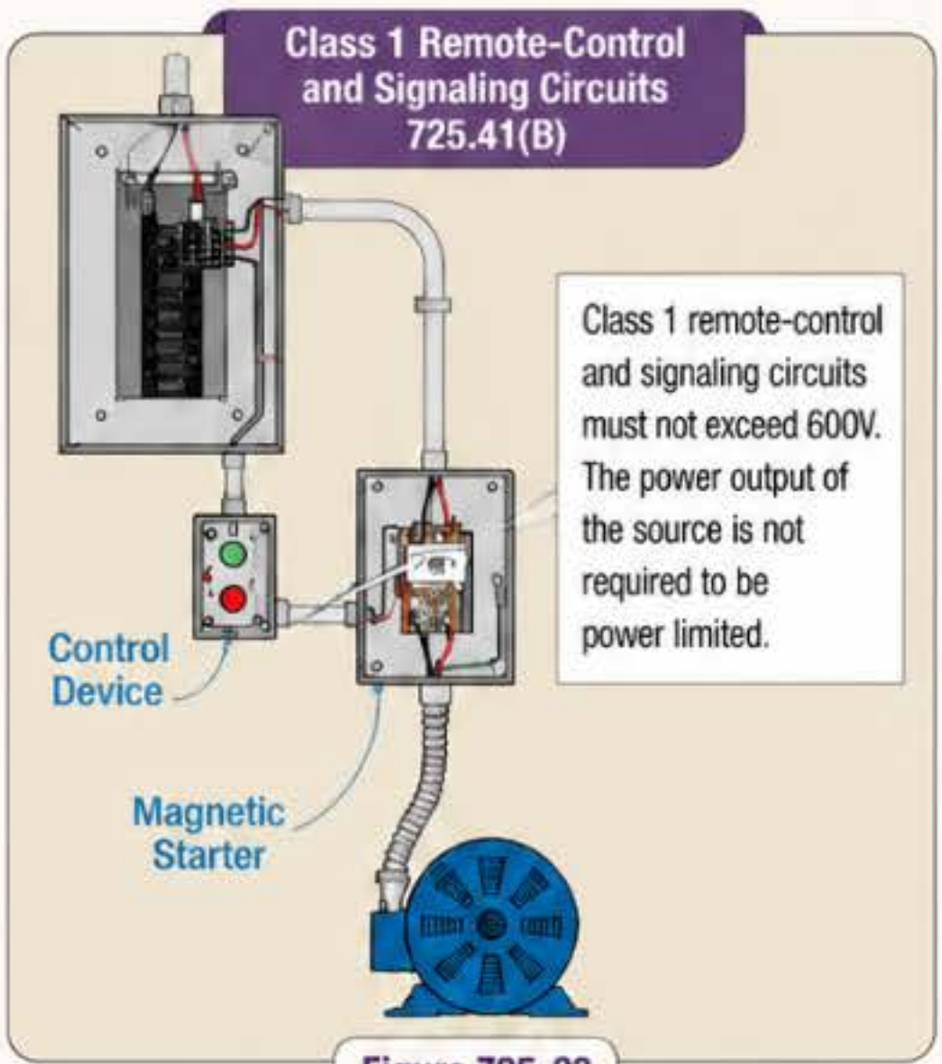


Figure 725-23

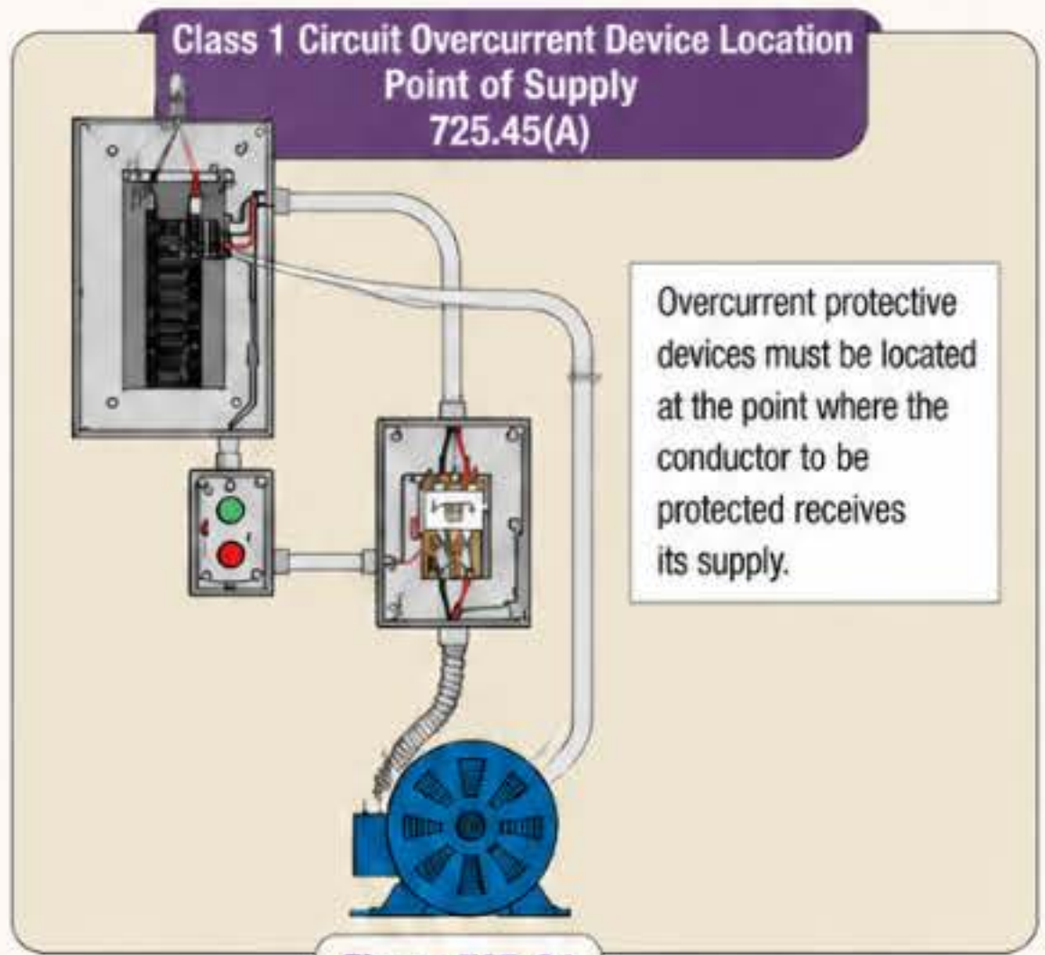


Figure 725-24

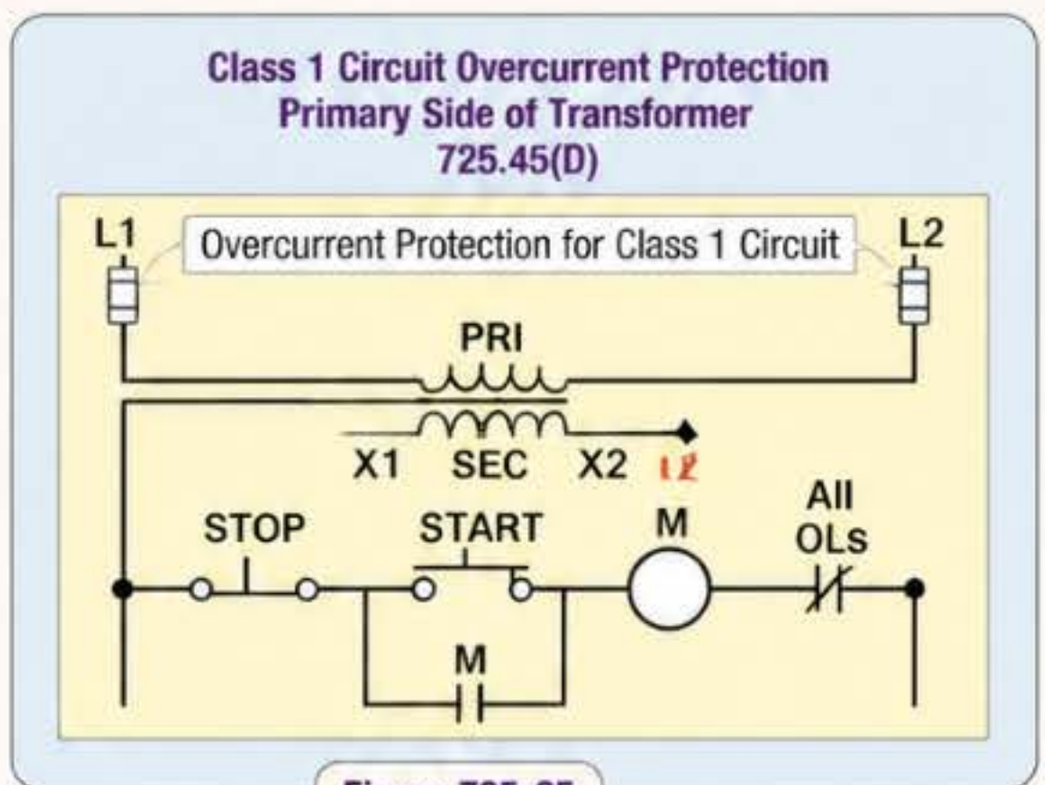


Figure 725-25

725.43 Class 1 Circuit Overcurrent Protection

When the conductors are size 14 AWG or larger, overcurrent protection must comply with the ampacity rules in 110.14(C)(1) and Table 310.16. Protection for 18 AWG is not required to exceed 7A, and 16 AWG conductors and smaller are not required to be protected above 10A.

725.45 Class 1 Circuit Overcurrent Protective Device Location

(A) Point of Supply. Overcurrent protective devices are to be installed at the exact location where the conductor that needs protection is fed from the source. See Figure 725-24.

(D) Primary Side of Transformer. For Class 1 circuits that use a transformer with only a two-wire secondary, overcurrent protection on the primary must follow 450.3(B). The computed value of the primary overcurrent protective device can be greater than the result obtained by multiplying the secondary conductor ampacity by the secondary-to-primary transformer voltage ratio. See Figure 725-25.

725.46 Class 1 Circuit Wiring Methods

Class 1 circuits must be installed in accordance with Part I of Article 300, and Class 1 wiring must be installed using a proper method found in Chapter 3.

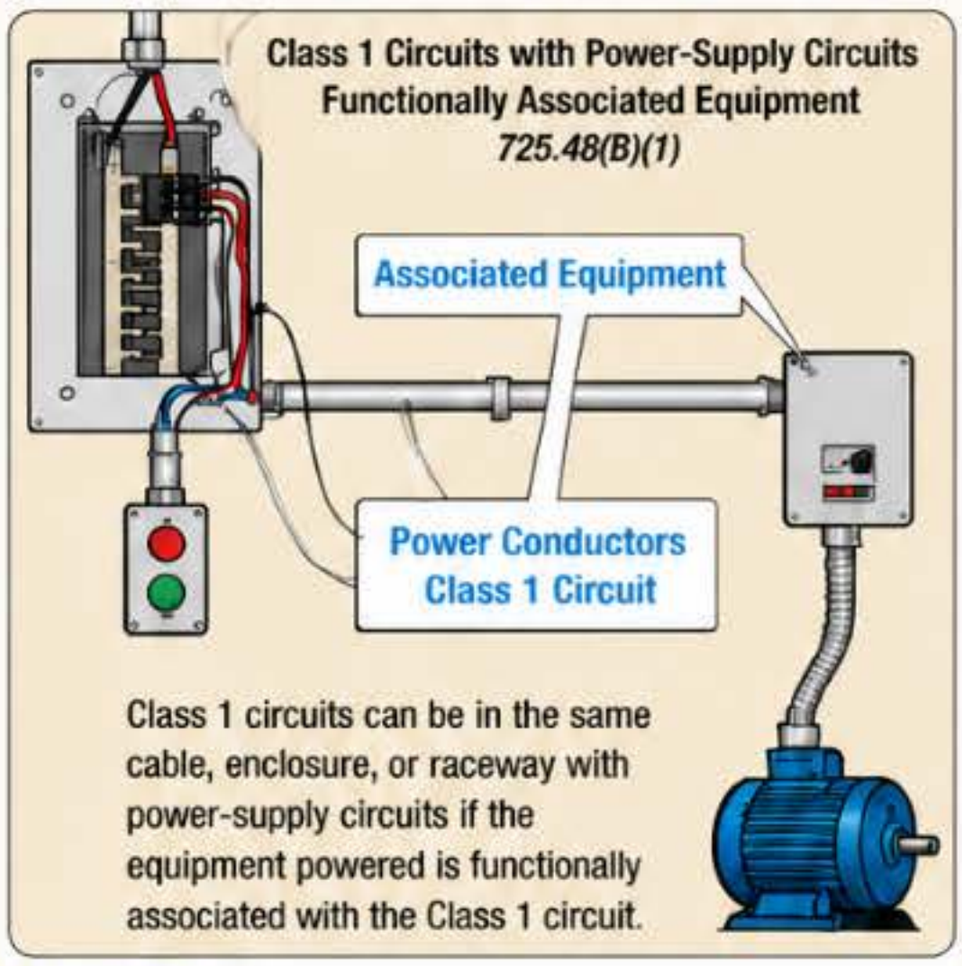
725.48 Conductors of Different Circuits in Same Cable, Cable Tray, Enclosure, or Raceway

(A) Class 1 Circuits with Other Class 1 Circuits. If two or more Class 1 circuits are placed in the same cable, enclosure, or raceway, all conductors must be insulated for the highest voltage present on any conductor.

725.49 | Remote-Control, Signaling, and Power-Limited Circuits

(B) Class 1 Circuits with Power Circuits. Class 1 circuits are allowed to be installed with electrical power conductors when the following conditions are satisfied:

(1) In a Cable, Enclosure, or Raceway. Class 1 circuits may share the same cable, enclosure, or raceway as power-supply circuits if the equipment powered by the Class 1 circuit is operationally linked to those power circuits. ▸Figure 725–26



▸Figure 725–26

Class 1 circuits are permitted to be installed together with the conductors of electric light, power, nonpower-limited fire alarm, and medium power network-powered broadband communications circuits where separated by a barrier.

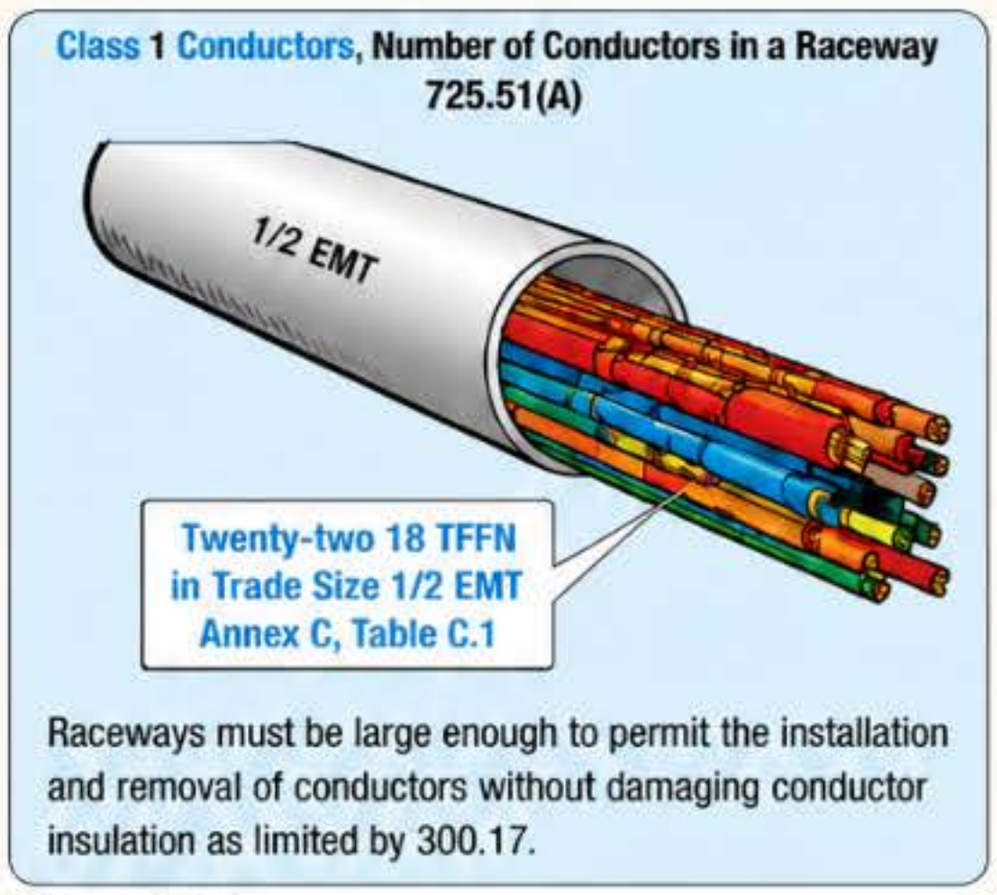
725.49 Class 1 Circuit Conductors

(A) Size and Use. Conductors sized 18 AWG and 16 AWG, installed within a raceway, enclosure, or listed cable, are permitted if they do not transport a load that exceeds the ampacities shown in Table 402.5. Conductors 14 AWG and larger must comply with the ampacities listed in Table 310.16.

(B) Insulation. Class 1 circuit conductors are required to have a minimum 600V insulation rating.

725.51 Number of Conductors in a Raceway

(A) Class 1 Circuit Conductors. Raceways must be large enough to allow the addition and removal of conductors without damaging their insulation as limited by 300.17. ▸Figure 725–27



▸Figure 725–27

Author's Commentary:

- When all conductors within a raceway are the same size and insulation, the number of conductors permitted can be found in Annex C for the raceway type (Chapter 9, Notes to Tables, Note 1).
- For conductors not listed in Chapter 9 (such as multiconductor cable), the actual dimensions must be used. If one multiconductor cable is used inside a raceway, the single conductor percentage fill area must be used (Chapter 9, Notes to Tables, Note 5 and 9).
- These conductors are subject to the ampacity adjustment factors in 310.15(C)(1) only if they carry continuous loads in excess of 10 percent of the conductor's ampacity.

— Michael Hamilton

Part III. Class 2 Circuit Requirements

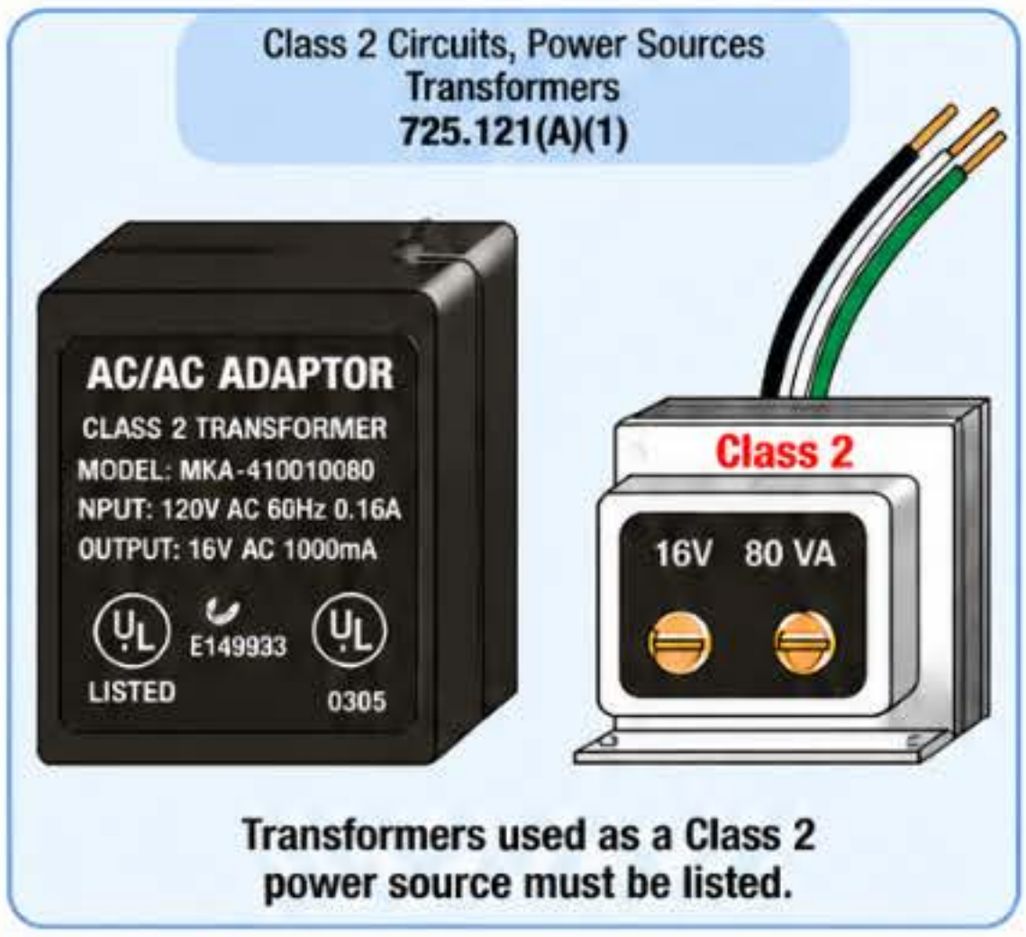
725.121 Power Sources for Class 2 Circuits

(A) Power Source. The power supply for a Class 2 circuit must be as follows:

(1) A listed Class 2 transformer. ▸Figure 725–28

(2) A listed Class 2 power supply.

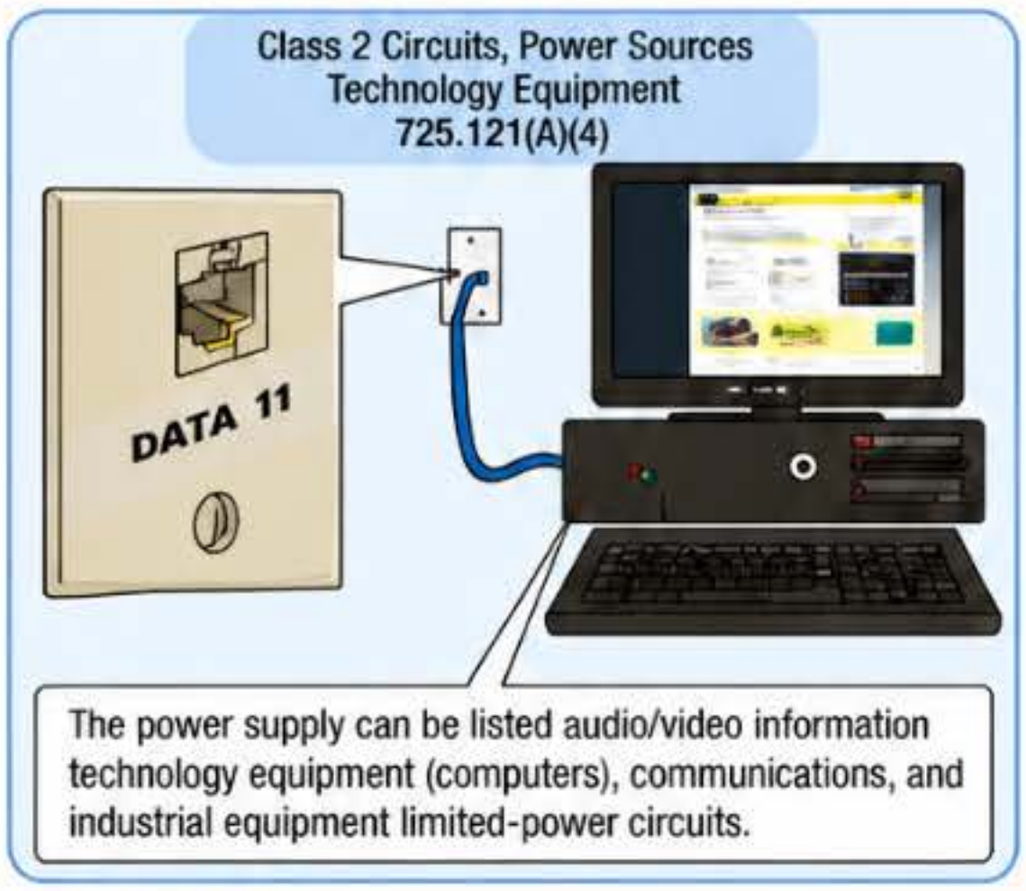
(3) Equipment listed as a Class 2 power source.



▶ Figure 725–28

Ex. 2: *If a circuit's energy level falls within the limits set out in Chapter 9, Table 11(A) and 11(B), the equipment is not required to be classified as Class 2 power transformer, power supply, or power source.*

(4) Listed audio/video information technology equipment (computers), communications, and industrial equipment limited-power circuits. ▶ Figure 725–29



▶ Figure 725–29

(5) A battery source or battery source system that is listed and identified as Class 2.

(C) Marking. Power sources for power-limited circuits in 725.121(A)(3) and power-limited circuits for listed audio/video equipment, listed information technology equipment, listed communications equipment, and listed industrial equipment in 725.121(A)(4) must have a label indicating the maximum voltage and rated current output per conductor for each connection point on the power source. Where multiple connection points have the same rating, a single label is permitted to be used.

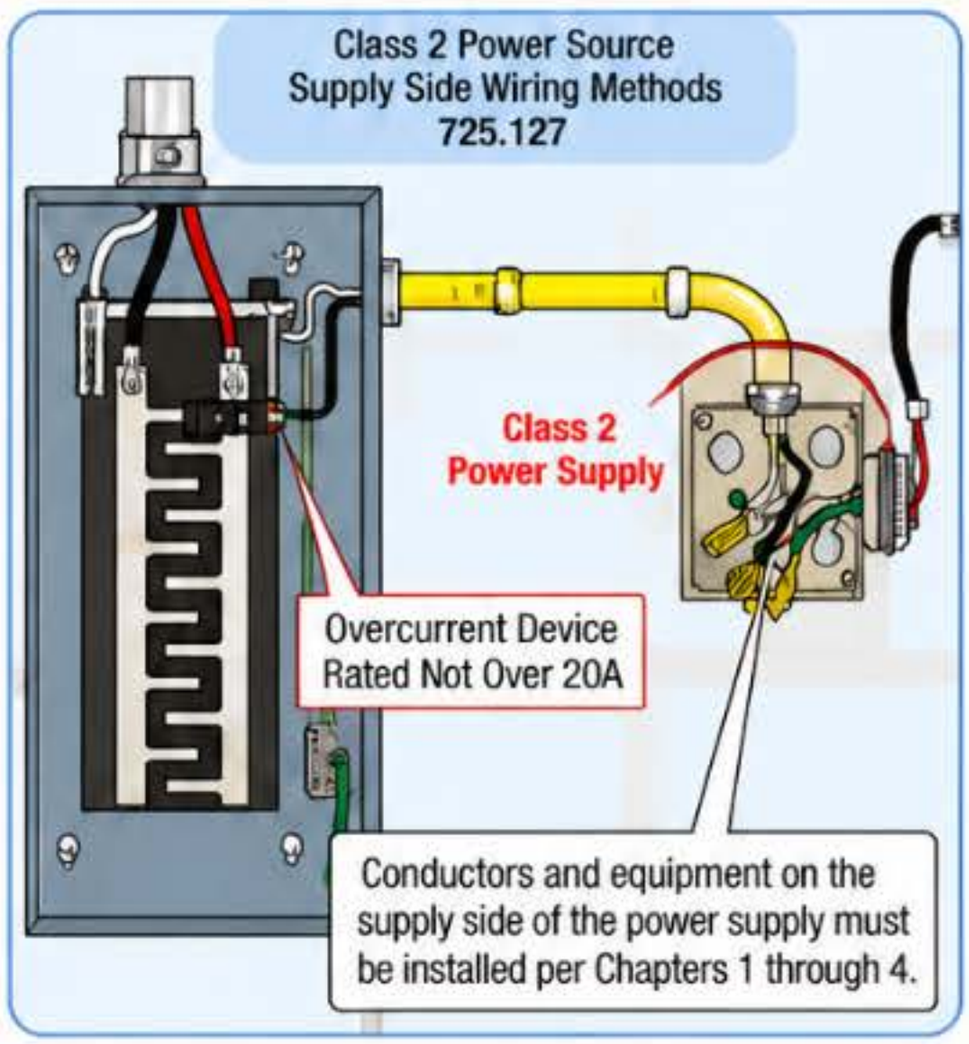
Note 1: The rated current for power sources referenced in 725.144 represents the output current per conductor the power source is designed to deliver to an operational load at normal operating conditions, as declared by the manufacturer.

725.124 Circuit Marking

Equipment supplying Class 2 circuits must be clearly marked to indicate each circuit that is a Class 2 circuit.

725.127 Wiring Methods on Supply Side of the Class 2 Power Source

Conductors and equipment on the supply side of the Class 2 power supply must be installed in accordance with Chapters 1 through 4. The overcurrent protection for Class 2 transformers or power supplies must not exceed 20A. ▶ Figure 725–30



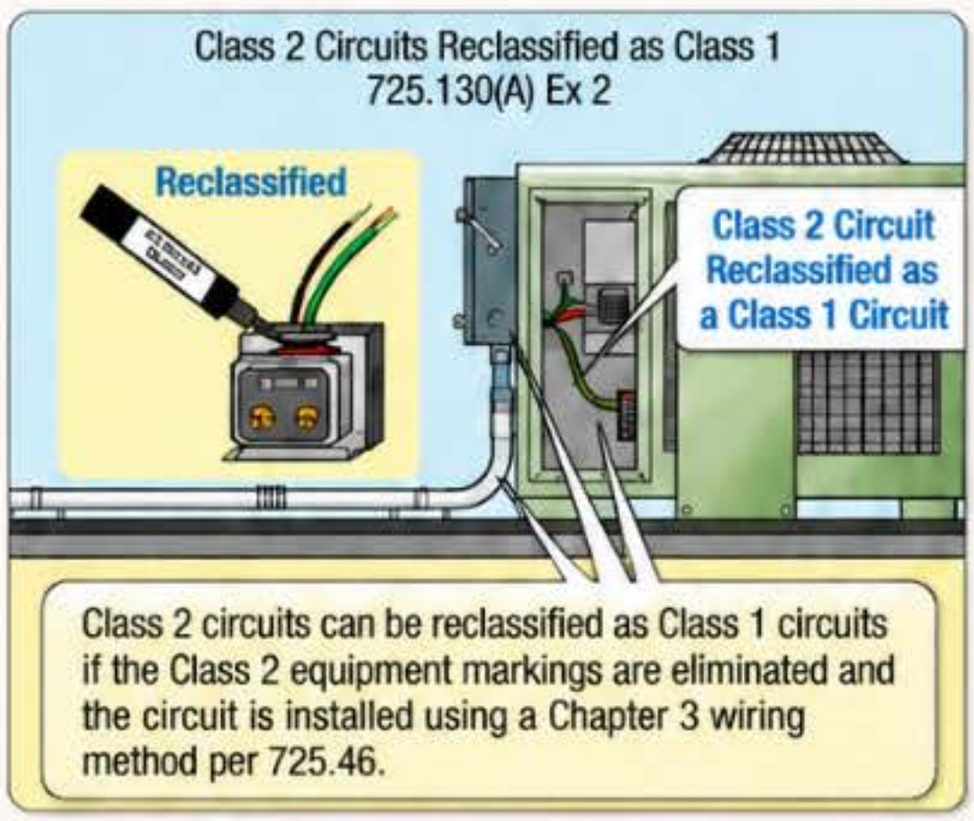
▶ Figure 725–30

725.130 | Remote-Control, Signaling, and Power-Limited Circuits

725.130 WIRING METHODS ON LOAD SIDE OF THE CLASS 2 POWER SOURCE

(A) Class 1 Wiring Methods. Class 2 circuits are permitted to use a Class 1 wiring method in accordance with 725.46.

Ex 2: Class 2 circuits can be reclassified as a Class 1 circuit if the Class 2 equipment markings are eliminated and the circuit is installed using a Chapter 3 wiring method in accordance with 725.46. ▶ **Figure 725–31**



▶ **Figure 725–31**

Author's Commentary:

- Where a Class 2 circuit is reclassified as a Class 1 circuit, it can be run in the same raceway, cable, or enclosure with power conductors of functionally associated equipment [725.48(B)]. ▶ **Figure 725–32**

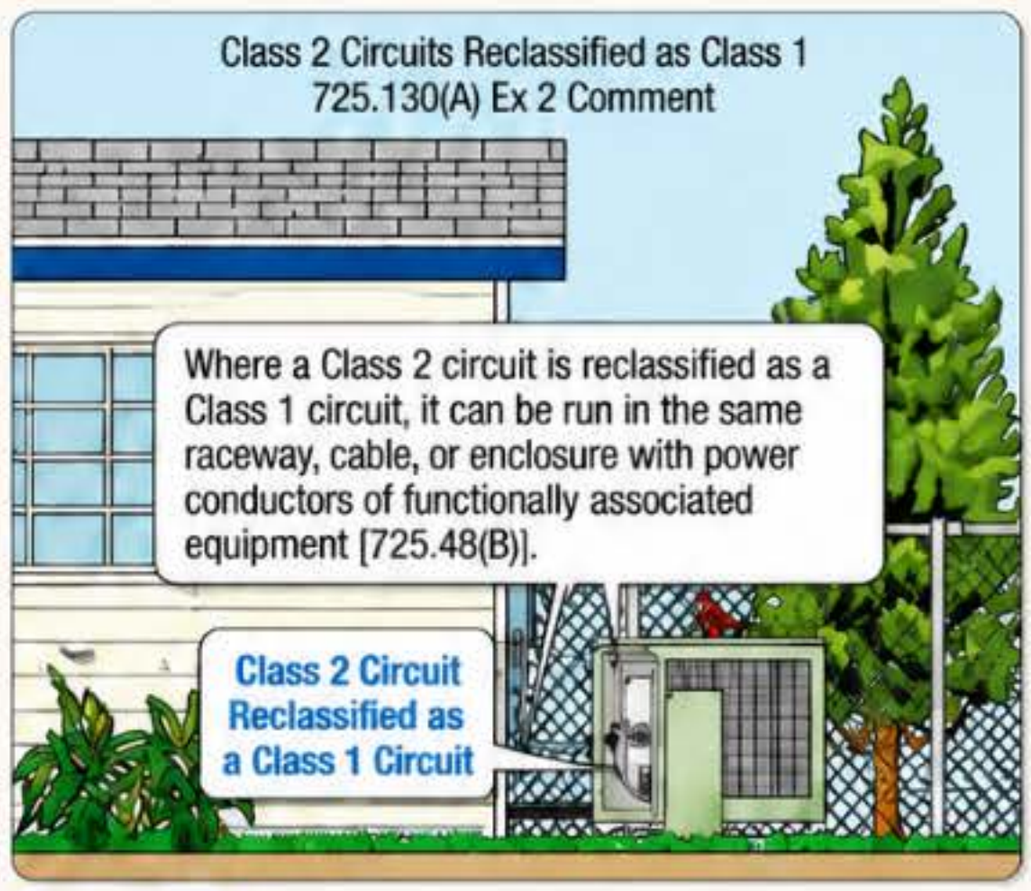
Note: Class 2 circuits reclassified and installed as Class 1 circuits are no longer Class 2 circuits, regardless of their continued connection to a Class 2 power source.

(B) Class 2 Wiring Methods. Class 2 circuits are permitted to use Class 2 wiring of the type in 725.179 if installed in accordance with 725.133 and 725.154.

725.135 INSTALLATION OF CLASS 2 CABLES

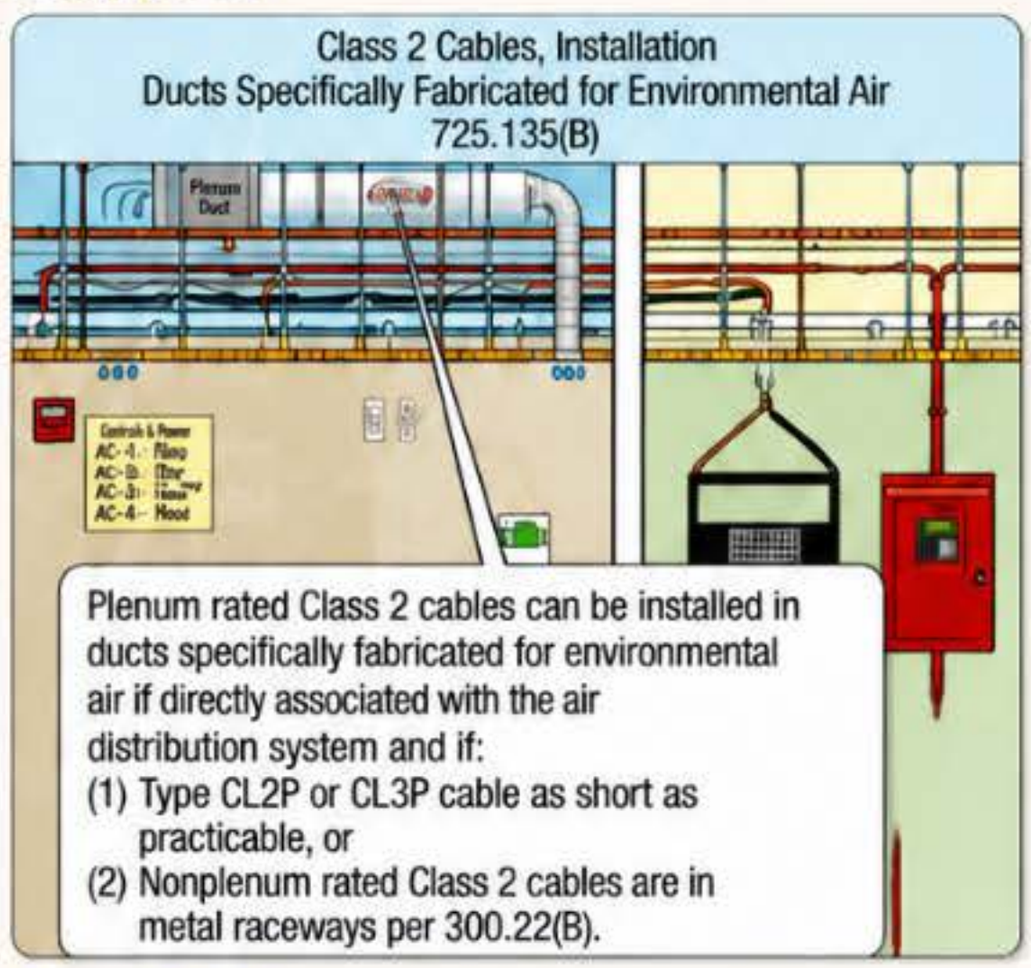
Installation of Class 2 cables must comply with 725.135(A) through (M).

(A) Listing. Class 2 cables installed in buildings must be listed.



▶ **Figure 725–32**

(B) Ducts Specifically Fabricated for Environmental Air Spaces. Plenum rated Class 2 cables are permitted to be installed within ducts specifically fabricated for environmental air spaces in accordance with 725.135(C) Ex 1 if the cable is directly associated with the air distribution system and complies with (1) or (2): ▶ **Figure 725–33**



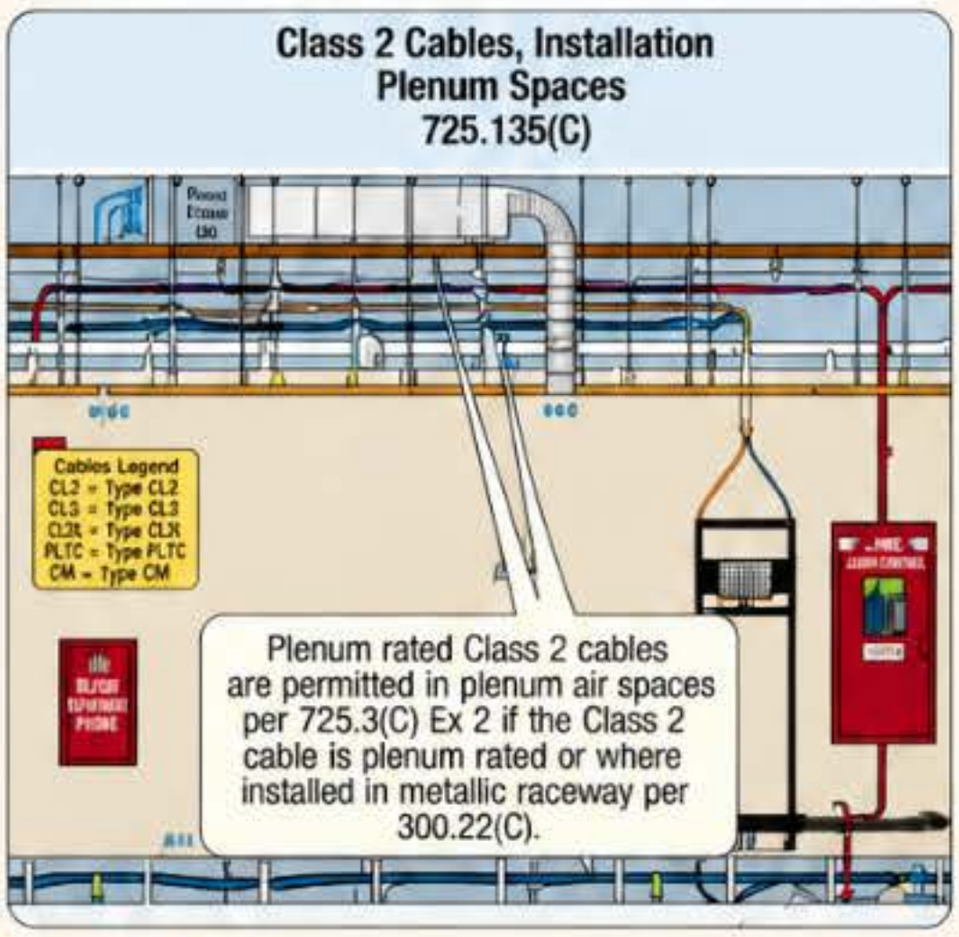
▶ **Figure 725–33**

(1) Types CL2P or CL3P cable (without a raceway) are permitted where the length is as short as practicable to perform the required function.

(2) Nonplenum rated Class 2 cables installed in metal raceways in accordance with 300.22(B).

Remote-Control, Signaling, and Power-Limited Circuits 725.136

(C) Plenum Spaces. Install Class 2 cable that has a plenum rating inside plenum air spaces in accordance with 725.3(C) Exception 2 and the Class 2 rules for plenum spaces, except use metallic raceway instead of the raceway specified in 300.22(C). Figure 725–34



▶ Figure 725–34

(H) Cable Trays. Cables installed in cable trays outdoors must be Type PLTC. The following cables are permitted in cable trays in buildings:

(1) Types CM, CL2P, CL3P, CL2R, CL3R, CL2, CL3, and PLTC cables.

(2) Types CL2P, CL3P, CL2R, CL3R, CL2, CL3, and PLTC cables installed in:

a. Plenum communications raceways.

b. Riser communications raceways.

c. General-purpose communications raceways.

(K) Other Building Locations. The following cables are permitted in building locations other than the locations covered in 725.135(B) through (J):

(1) Types CL2P, CL3P, CL2R, CL3R, CL2, CL3, and PLTC cables.

(2) A maximum of 10 ft of exposed Type CL2X in nonconcealed spaces.

(3) A maximum of 10 ft of exposed Type CL3X in nonconcealed spaces.

(4) Types CL2P, CL3P, CL2R, CL3R, CL2, CL3, and PLTC cables installed in:

a. Plenum communications raceways.

b. Plenum cable routing assemblies.

c. Riser communications raceways.

d. Riser cable routing assemblies.

e. General-purpose communications raceways.

f. General-purpose cable routing assemblies.

(5) Types CL2P, CL3P, CL2R, CL3R, CL2, CL3, CL2X, CL3X, and PLTC cables installed in raceways recognized in Chapter 3.

(M) One- and Two-Family Dwelling Units. The following cables are permitted in dwelling units:

(1) Types CL2P, CL3P, CL2R, CL3R, CL2, CL3, and PLTC cables.

(2) Type CL2X less than ¼ in. in diameter.

(3) Type CL3X less than ¼ in. in diameter.

(4) Types CL2P, CL3P, CL2R, CL3R, CL2, CL3, and PLTC cables installed in:

a. Plenum communications raceways.

b. Plenum cable routing assemblies.

c. Riser communications raceways.

d. Riser cable routing assemblies.

e. General-purpose communications raceways.

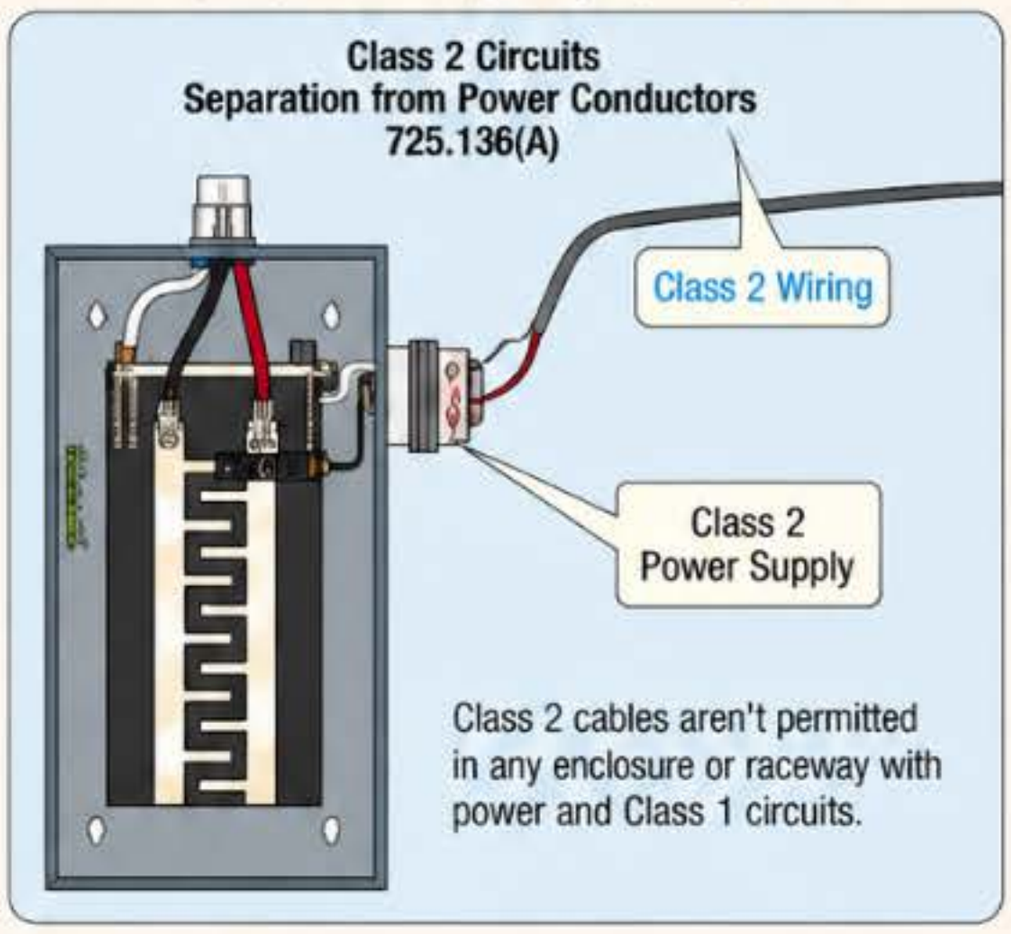
f. General-purpose cable routing assemblies.

(5) Types CL2P, CL3P, CL2R, CL3R, CL2, CL3, CL2X, CL3X, and PLTC cables installed in raceways recognized in Chapter 3.

(6) Type CMUC under-carpet communications cables.

725.136 Separation from Power Conductors

(A) Enclosures, Raceways, or Cables. Class 2 cables are not permitted in any enclosure or raceway with power and Class 1 circuits, except as permitted in (B) through (I). Figure 725–35



▶ Figure 725–35

725.136 | Remote-Control, Signaling, and Power-Limited Circuits

Author's Commentary:

- Class 2 wiring must be separated from power, lighting, and Class 1 circuits so the higher-voltage conductors do not inadvertently energize the Class 2 conductors.

— *Michael Hamilton*

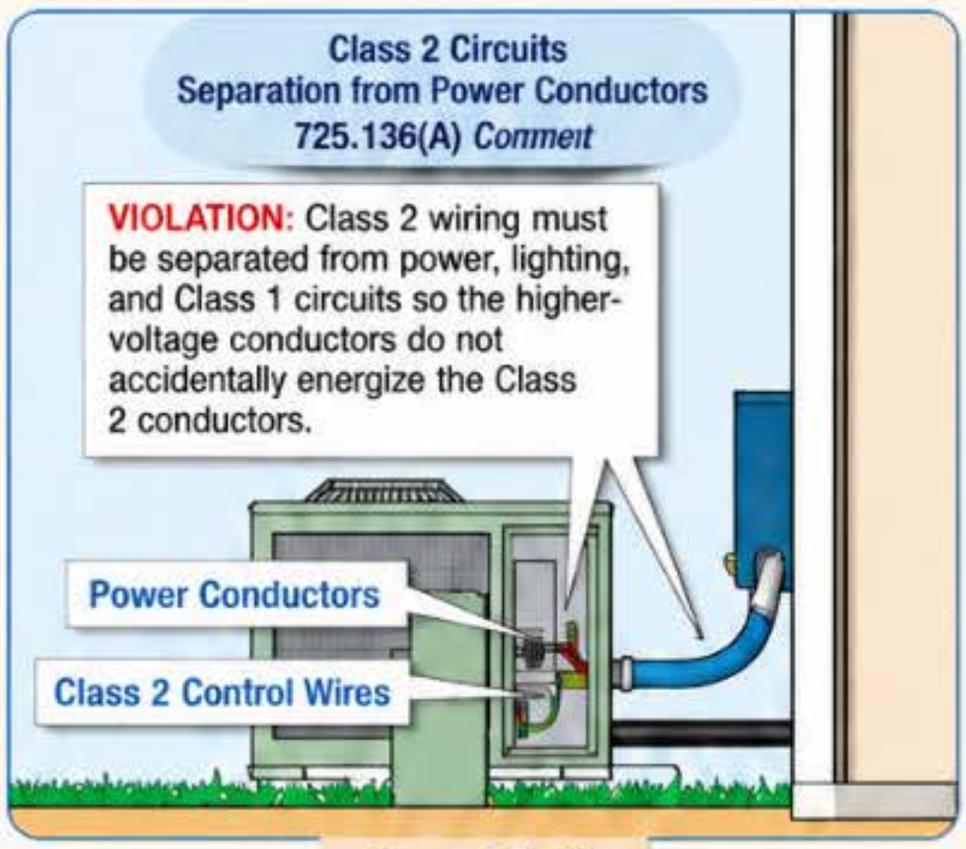


Figure 725–36

(B) Separated by Barriers. Class 2 circuit conductors can be installed with power conductors and Class 1 conductors if separated by a barrier. ▸Figure 725–37 and ▸Figure 725–38

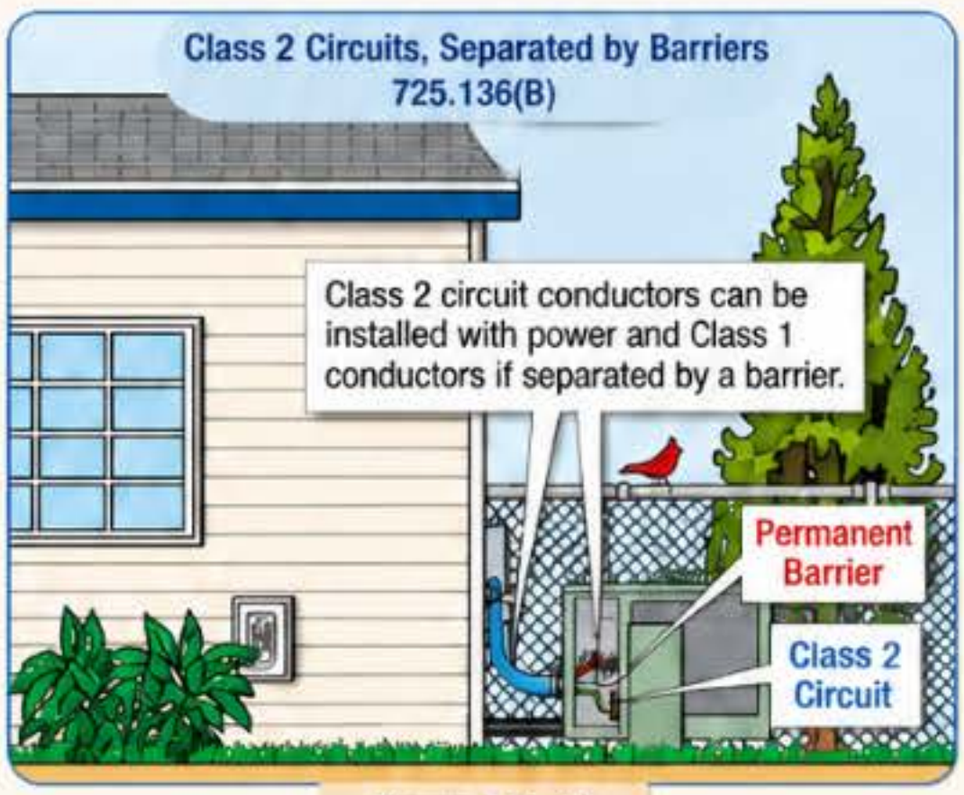


Figure 725–37

Author's Commentary:

- Separation is required to prevent a fire or shock hazard that can occur from a short between the Class 2 circuits and the higher-voltage circuits.

— *Michael Hamilton*

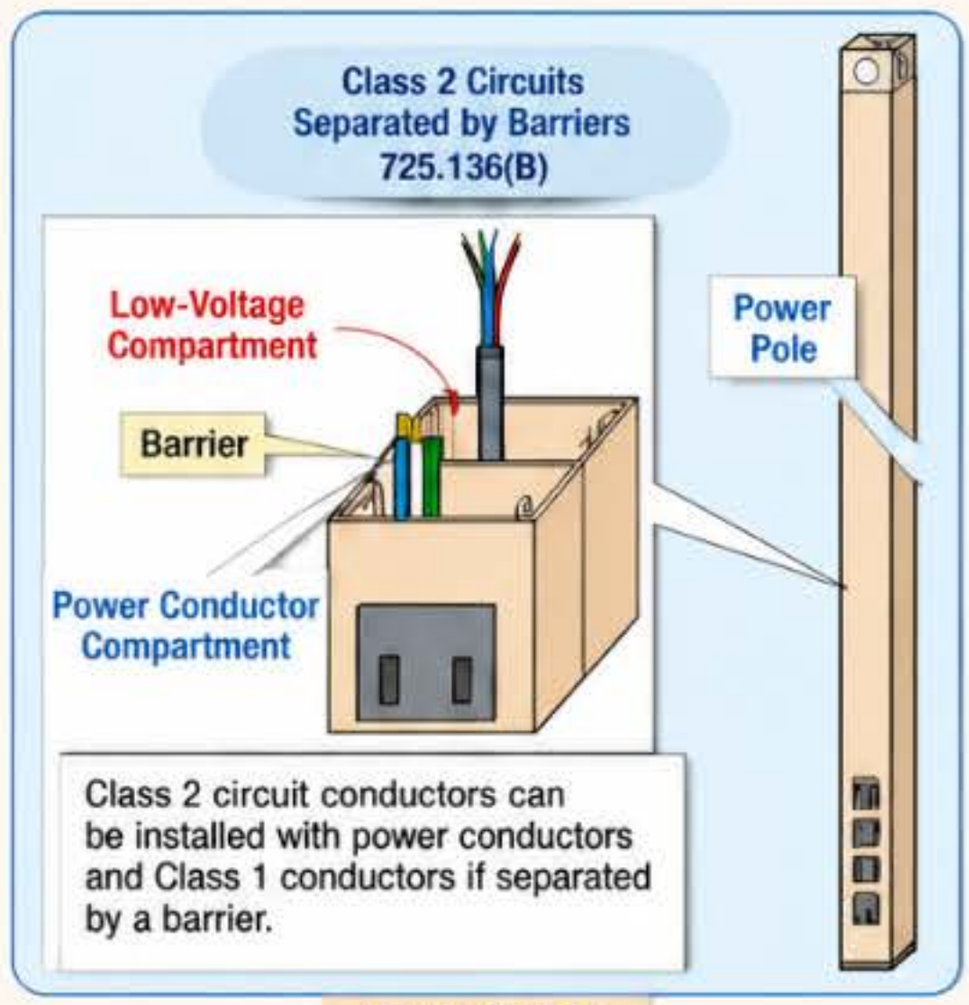


Figure 725–38

(D) Associated Systems Within Enclosures. Class 2 circuit conductors are permitted to be installed in compartments, enclosures, and outlet boxes with electric light and power circuits where (1) or (2) applies:

(1) Class 2 circuit conductors are permitted to be installed with power, Class 1, and nonpower-limited fire alarm circuit conductors where routed to maintain a minimum of ¼ in. separation. ▸Figure 725–39

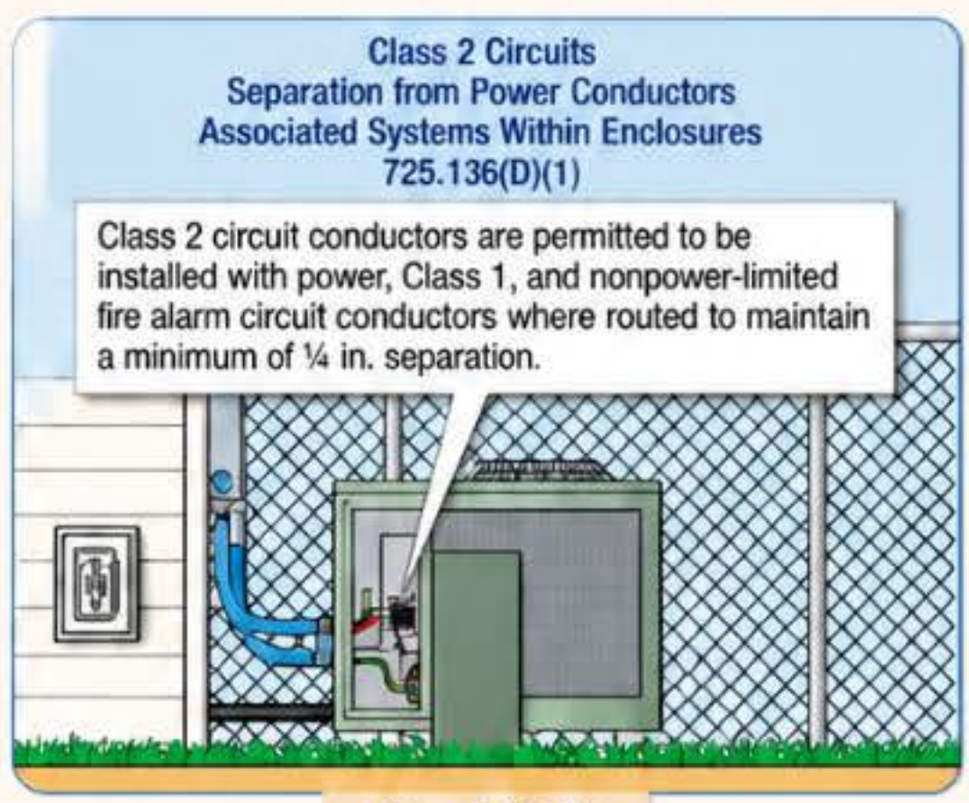
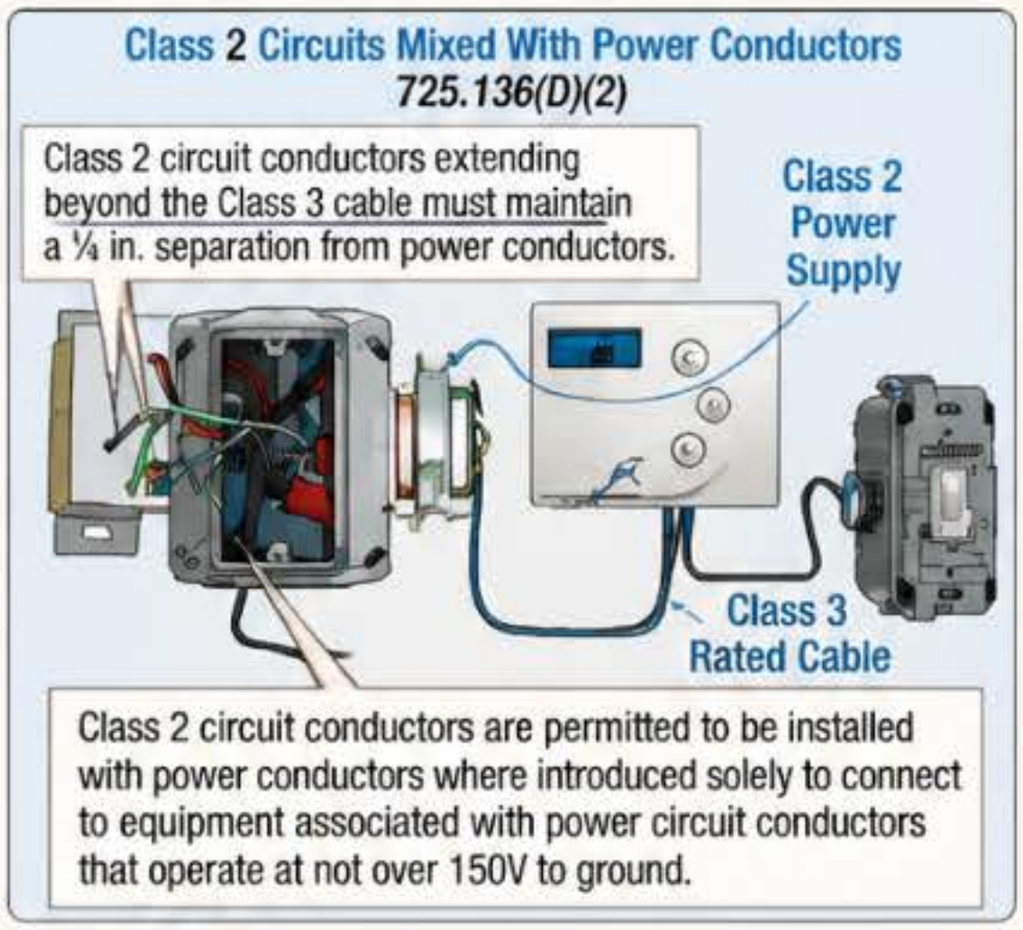


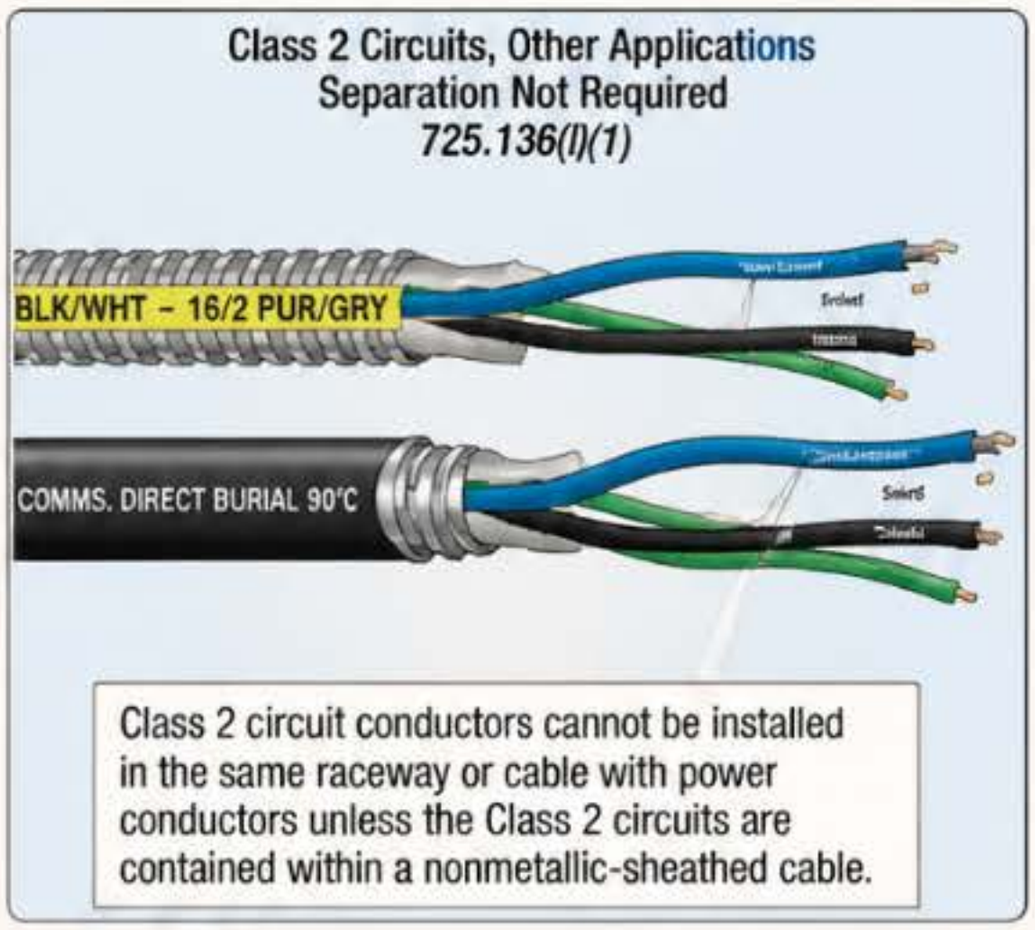
Figure 725–39

(2) Class 2 circuit conductors are permitted to be installed with power conductors where introduced solely to connect to equipment associated with power circuit conductors that operate at not over 150V to ground if the Class 2 circuits are contained in a Class 3 cable, and the Class 2 circuit conductors extending beyond the Class 3 cable maintain a minimum of ¼ in. separation from the power conductors. ▸Figure 725–40

Remote-Control, Signaling, and Power-Limited Circuits 725.139

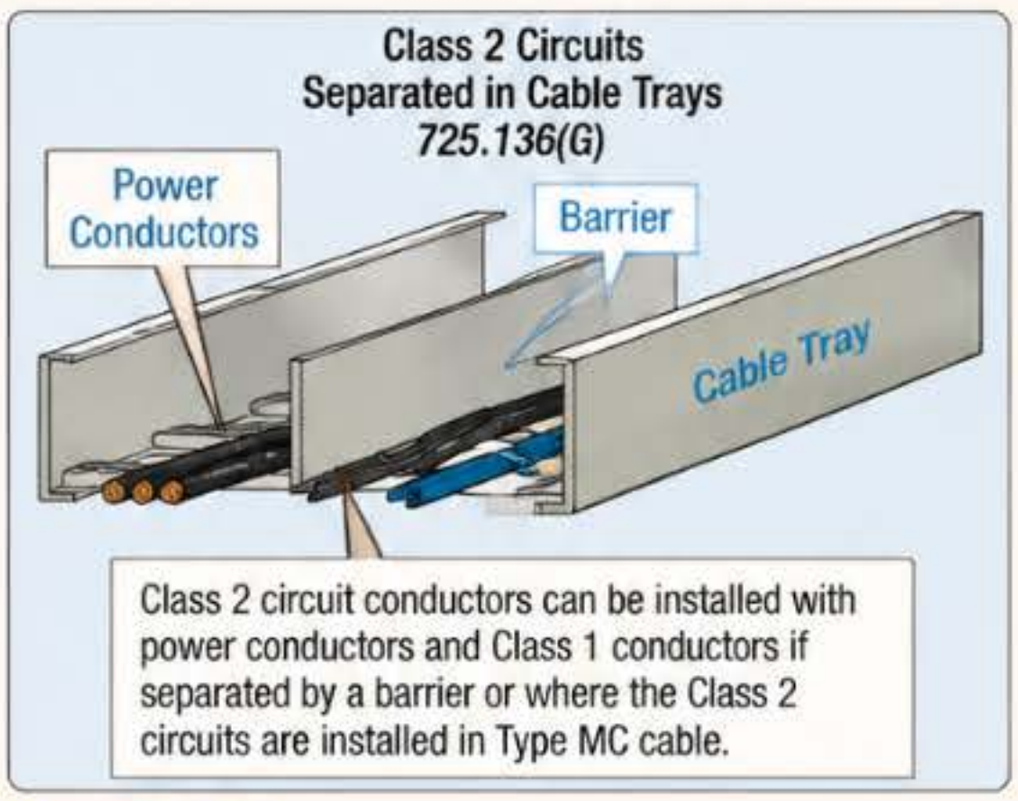


▸ Figure 725–40



▸ Figure 725–42

(G) Cable Trays. Class 2 circuit conductors can be installed with power conductors and Class 1 conductors if separated by a barrier or where the Class 2 circuits are installed in Type MC cable. ▸Figure 725–41



▸ Figure 725–41

(I) Other Applications. Class 2 circuit conductors cannot be installed in the same raceway or cable with power conductors unless:

(1) The Class 2 circuits are contained within a nonmetallic-sheathed cable. ▸Figure 725–42

Author's Commentary:

Keeping Class 2 wiring apart from power wiring reduces the risk of electrical noise and protects the safety of low-voltage systems.

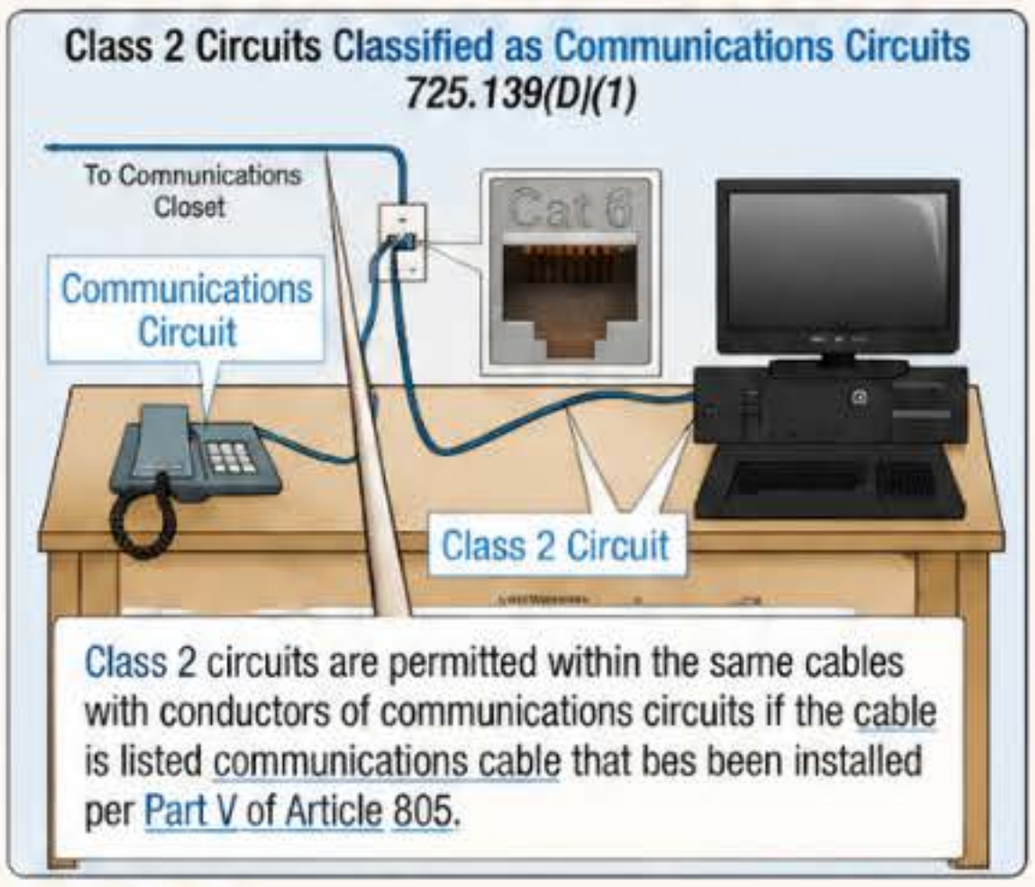
— Michael Hamilton

725.139 Conductors of Different Circuits in Same Cable, Enclosure, Cable Tray, Raceway, or Cable Routing Assembly

(A) Class 2 Conductors. Class 2 circuit conductors can be in the same cable, cable routing assembly, enclosure, or raceway with other Class 2 circuit conductors.

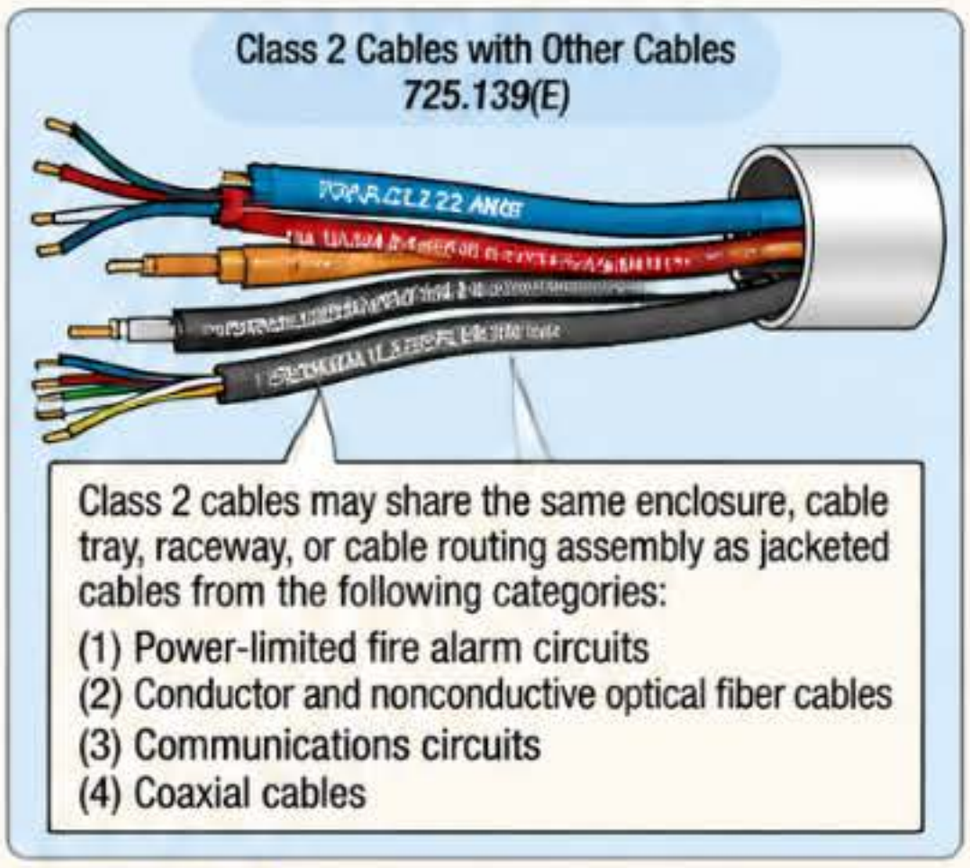
(D) Class 2 Circuits with Communications Circuits.

(1) Classified as Communications Circuits. Class 2 circuits are permitted within the same cables with conductors of communications circuits if the cable is listed communications cable that has been installed in accordance with Part V of Article 805. ▸Figure 725–43



▸ Figure 725–43

(E) Class 2 Cables with Other Cables. Jacketing for Class 2 cables is allowed to be placed within the same enclosure, cable tray, raceway, or routing assembly as jacketed cables from any of the items listed below. See Figure 725–44.



▶ Figure 725–44

(1) Power-limited fire alarm wiring systems in accordance with Parts I and III of Article 760.

(2) Nonconductive and conductive optical fiber cables in accordance with Parts I and IV of Article 770.

(3) Communications circuits in accordance with Parts I and IV of Article 805.

(4) Coaxial cables in accordance with Parts I and IV of Article 820.

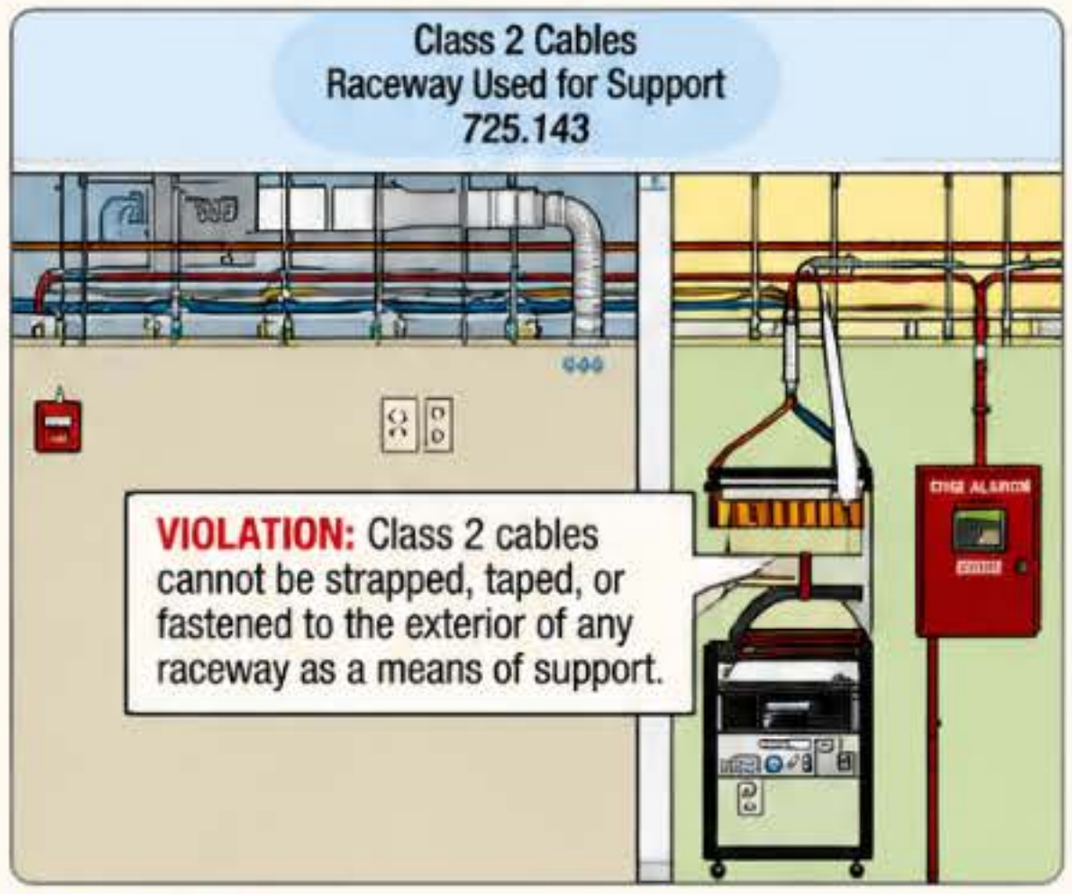
(F) Class 2 Circuits with Audio System Circuits. Audio output circuits [640.9(C)] that use Class 2 wiring practices from 725.133 and 725.154 are not permitted to be installed within any cable routing assembly, raceway, or cable together with Class 2 cables.

Author's Commentary:
Audio circuits are considered Class 2 wiring systems only when they comply with 640.9(C). These same circuits are not treated as Class 2 circuits.

— Michael Hamilton

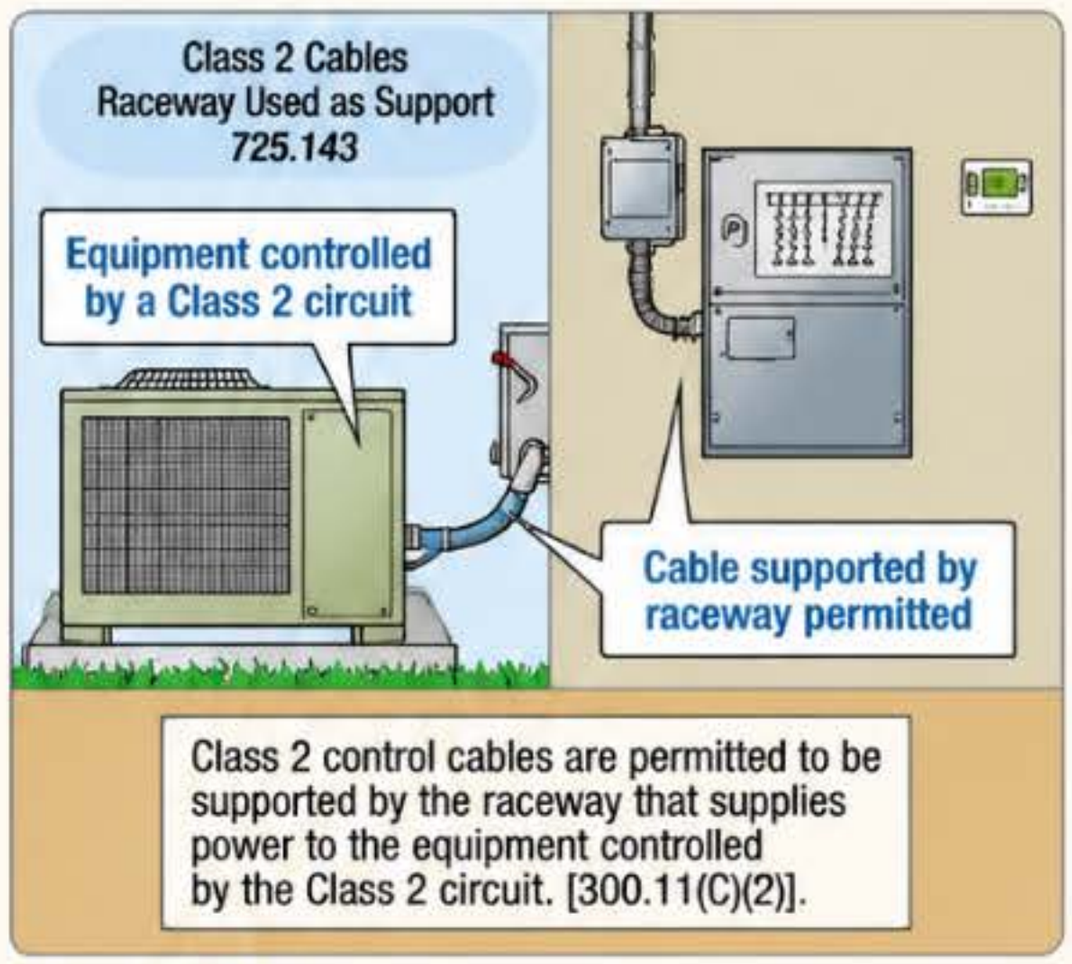
725.143 Support

Class 2 cables may not be strapped, taped, or otherwise fastened to the outside of any raceway as a support method. See Figure 725–45.



▶ Figure 725–45

Raceways that provide power to equipment controlled by a Class 2 circuit can also be used to support the Class 2 control cables. [300.11(C)(2)]. See Figure 725–46.



▶ Figure 725–46

725.144 Transmission of Power and Data

This section covers Class 2 circuits that deliver both power and data to a powered device. Section 300.11 and Parts I and III of Article 725 apply to Class 2 circuits that transport both power and data.

Any conductors that carry power and data must be copper and the current must remain under the connector's listed maximum current rating.

REMOTE-CONTROL, SIGNALING, AND POWER-LIMITED CIRCUITS 725.144

Note 1: Examples of cable assemblies that convey energy and information include closed-circuit television cameras (CCTV).

Note 2: The 8P8C connector is widely used on communications cables that draw power. See 60603-7, *Connectors for Electronic Equipment—Part 7-1: Detailed specification for 8-way, unshielded, free and fixed connectors*, for details regarding the connectors' ability to carry current at a maximum conductor temperature of 60°C. Refer to the same standard for information on current-carrying capacity at higher and lower temperatures.

Note 3: The requirements in 725.144 were developed for cable assemblies that deliver power and data over four-pair copper balanced twisted-pair cabling. This cable type is defined in ANSI/TIA 568-C.2, *Commercial Building Telecommunications Cabling Standard—Part 2: Balanced Twisted-Pair Telecommunications Cabling and Components.*

Note 4: See TIA-TSB-184-A, *Guidelines for Supporting Power Delivery Over Balanced Twisted-Pair Cabling*, for guidance on installing and maintaining balanced twisted-pair cables that support power transfer.

Note 5: Refer to ANSI/NEMA C137.3, *American National Standard for Lighting Systems—Minimum Requirements for Installation of Energy Efficient Power over Ethernet (PoE) Lighting Systems*, for requirements related to the installation of cables used in PoE lighting systems.

Note 6: The rated current of power sources listed in 725.144 represents the output current per conductor intended to be delivered under all normal operating conditions, as declared by the manufacturer. Actual current in any conductor may differ from the rated value by as much as 20 percent. A cable's current will decrease as conductor size decreases or as more conductive elements are present within the same cable.

Table 725.144 Copper Conductor Ampacity in 4-Pair Class 2 Power/Data Cables with All Conductors Carrying Current

See 2023 NEC Table 725.144 for details.

Table 725.144 Note 1: For cable bundles exceeding 192 cables, or for conductors smaller than 26 AWG, ampacity values must be determined under qualified supervision.

Table 725.144 Note 2: If at least half the conductors in a cable are current-carrying, multiply the table values by 1.40.

Note 1 to Table 725.144: Elevated conductor temperatures may diminish a cable's data transmission capability. Refer to TIA-TSB-184-A and Annex G (see 6.4.7, 6.6.3, and Annex G of ANSI/TIA-568-C.2) for information that helps adjust operating temperatures between 20°C and 60°C.

Note 2 to Table 725.144: The contact current rating of connectors can limit the maximum current permitted below the ampacity shown in Table 725.144.

(A) Use of Class 2 Cables to Transmit Power and Data. Cables of Types CL3P, CL2P, CL3R, CL2R, CL3, or CL2 may convey power and data, provided the power source's rated current per conductor does not exceed the values in Table 725.144 at an ambient temperature of 30°C. For environments up to 30°C, adjustment factors from Table 310.15(B)(1) must also be used.

Author's Commentary:

Compliance with Table 725.144 is not required for conductors that are 24 AWG or larger, or when the calculated current per conductor of the power source does not exceed 0.30A.

— *Michael Hamilton*

Note: One example is closed-circuit TV cameras using 24 AWG, 60°C-rated, Type CL2R, Category 5e balanced twisted-pair cabling.

(B) Use of Class 2-LP Cables to Transmit Power and Data. Cable Types CL3P-LP, CL2P-LP, CL3R-LP, CL2R-LP, CL3-LP, or CL2-LP may deliver power from a source whose rated current per conductor does not exceed the limit shown immediately below the suffix "-LP" in Table 725.144. These cables may also carry data to equipment. When ten or fewer unbundled LP cables are used, and their ampacity per conductor per the table is met or exceeded, the ampacity listed is permitted.

For ambient temperatures up to 30°C, apply the correction factors in Table 310.15(B)(1) or Equation 310.15(B)(2) as needed. Type 2-LP cables must also meet the following.

(1) Cables with the suffix "-LP" may be installed in bundles, raceways, cable trays, communications raceways, and cable routing assemblies.

(2) Cables marked "-LP" and subject to a marked current limit must follow the substitution rules of Table 725.154 and Figure 725.154(A) in the 2023 *NEC* for the cable type without the "-LP" marking and without the current limit.

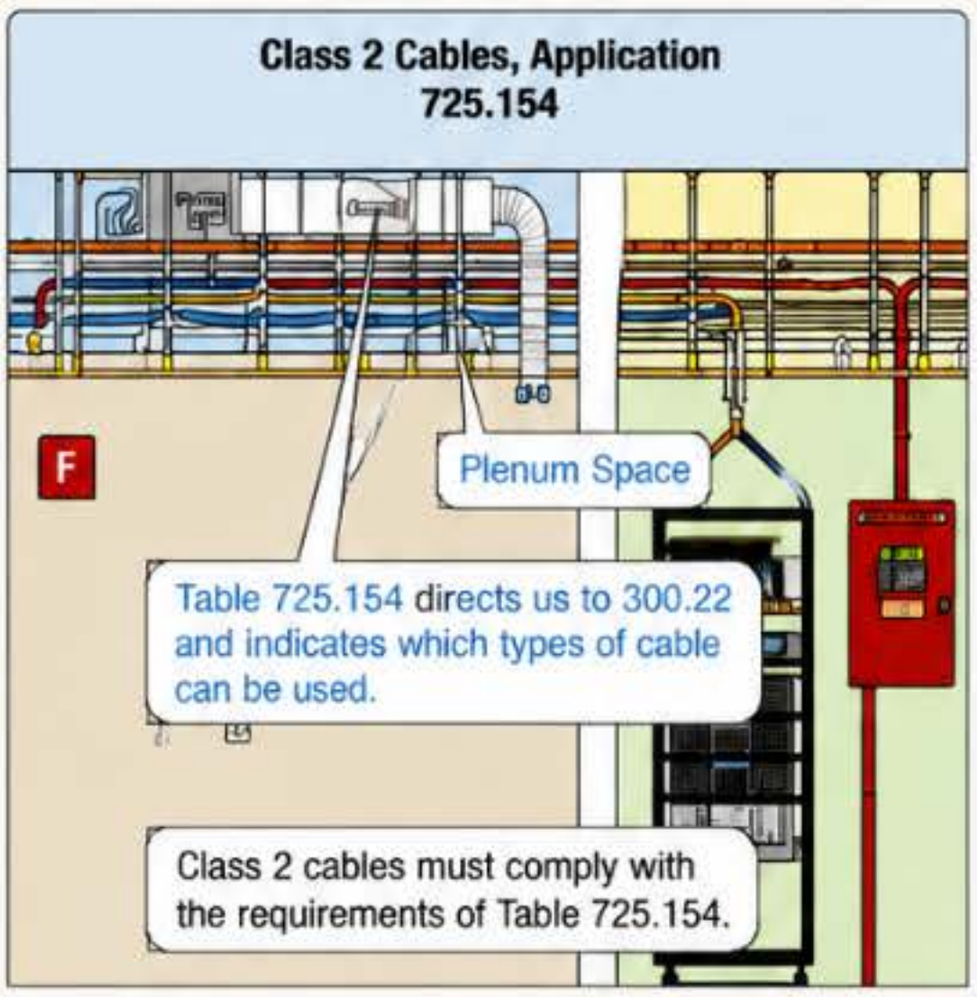
(3) System design is allowed when performed by qualified persons under engineering supervision.

Note: An example of a limited power (LP) cable is a cable marked Type CL2-LP (0.5A), 23 AWG.

725.154 | Remote-Control, Signaling, and Power-Limited Circuits

725.154 Applications of Class 2 Cables

Class 2 cables must meet the conditions of 725.154(A) through (C) and those in Table 725.154. ▸ Figure 725–47



▸ Figure 725–47

(A) Class 2 Cable Substitutions. Cable substitutions may be made in accordance with Table 725.154(A) and *NEC* Figure 725.154(A) Cable Substitution Hierarchy.

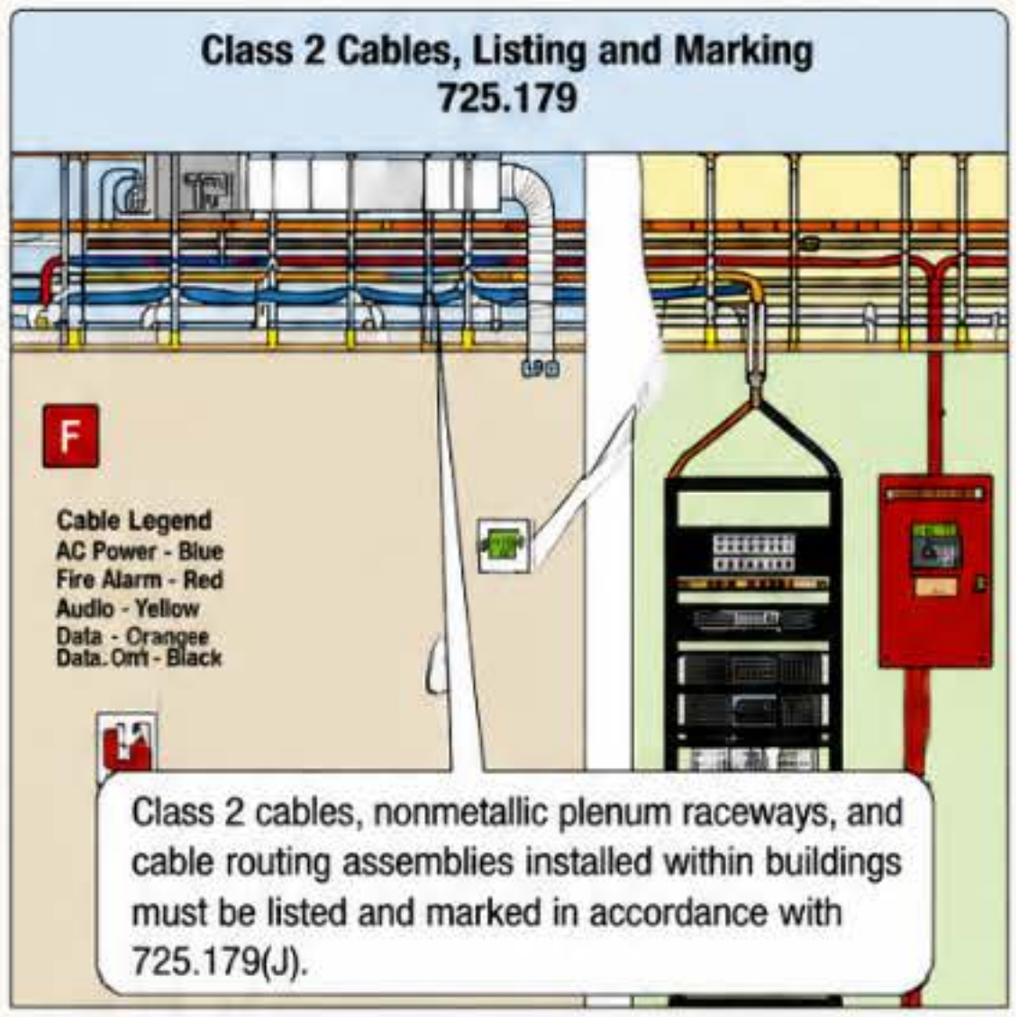
Part IV. Listing Requirements

725.179 Listing and Marking of Equipment for Power and Data Transmission

Power sources listed for circuits that deliver power and data over Class 2 cables to remote equipment must comply with 725.121, and the marking of equipment output connections must satisfy 725.121(C).

725.179 Listing and Marking of Class 2 Cables

Class 2 cables, nonmetallic plenum raceways, and cable routing assemblies installed within buildings must be listed and marked in accordance with 725.179(J). ▸ Figure 725–48



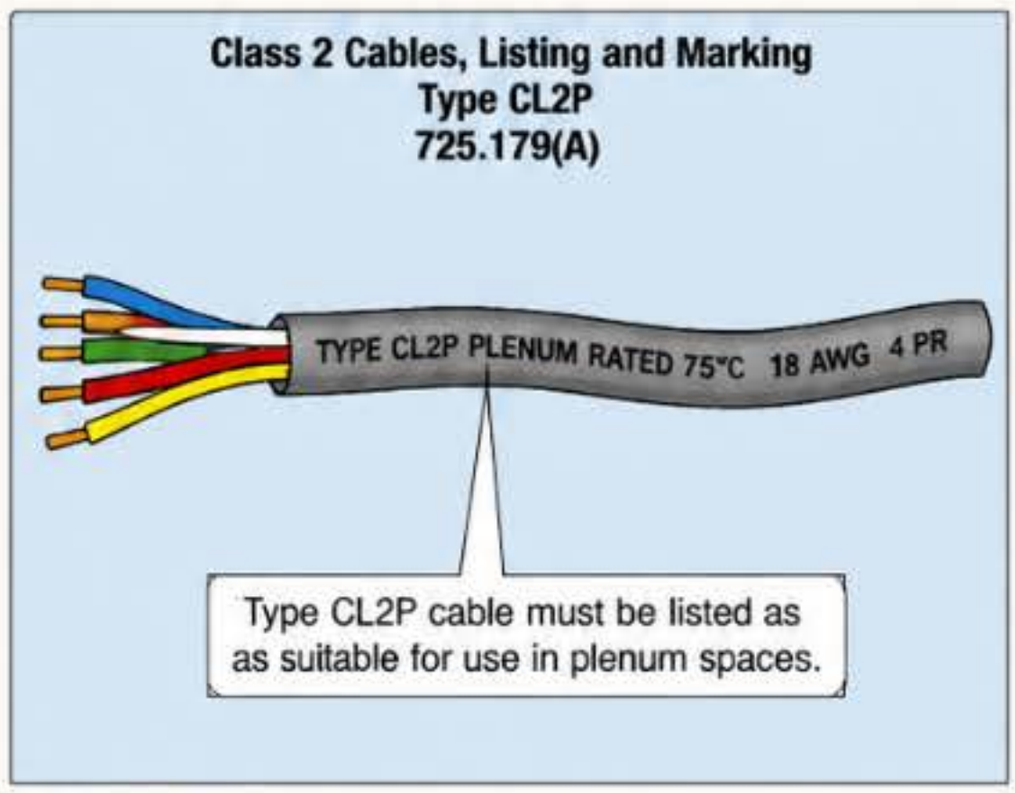
▸ Figure 725–48

Author's Commentary:

In corrosive, damp, or wet environments, or where Class 2 cables will be installed, you must identify them per 110.11 and 310.10(F). Conductors and cables placed in underground raceways [300.5(B)], or in raceways below grade in wet locations [300.9], must also be identified for those conditions. When corrosion may occur, follow 300.8's requirements for listed items [725.3(L)].

— Michael Hamilton

(A) Types CL2P and CL3P. Types CL2P and CL3P cable must be listed as suitable for use in plenum spaces. ▸ Figure 725–49



▸ Figure 725–49

Remote-Control, Signaling, and Power-Limited Circuits 725.179

(G) Cable Voltage Rating. Class 2 cables must be designed for at least 150 volts, while Class 3 cables are required to be rated for not less than 300 volts.

(I) Limited Power (LP) Cables. Cables classified as limited power (LP) must be listed for the purpose of carrying power and data conductors—up to a stated conductor size. These cables must be identified with the suffix "-LP (XXA)" where "XXA" indicates the permissible ampacity for the listed conductors.

Note: A typical example of the marking on a Class 2 cable that is LP rated is "CL2-LP, (75°C) 23 AWG 4-pair," which indicates a 4-pair plenum cable with 23 AWG conductors, a 75°C temperature rating, and a maximum current of 0.60 amp per conductor.

(J) Marking. Class 2 cables must be labeled in accordance with Table 725.179(J), and their voltage ratings must not be displayed on the cable.

Note: Voltage markings on cables can help indicate suitability for Class 1 (line-voltage) or lighting applications, which Class 2 cables are not intended for.

Table 725.179(J) Cable Marking

Cable Marking	Type
CL3P	Class 3 plenum cable
CL2P	Class 2 plenum cable
CL3R	Class 3 riser cable
CL2R	Class 2 riser cable
PLTC	Power-limited tray cable
CL3	Class 3 cable
CL2	Class 2 cable
CL3X	Class 3 cable, limited use
CL2X	Class 2 cable, limited use

Note: Class 2 cable types are listed in order from highest fire-resistance rating to lowest. Class 3 cables are shown first because they may be used in place of Class 2 cables. However, Class 3 cable cannot be used where Class 2 is specified.

Notes |

ARTICLE 760

FIRE ALARM SYSTEMS

Introduction to Article 760—Fire Alarm Systems

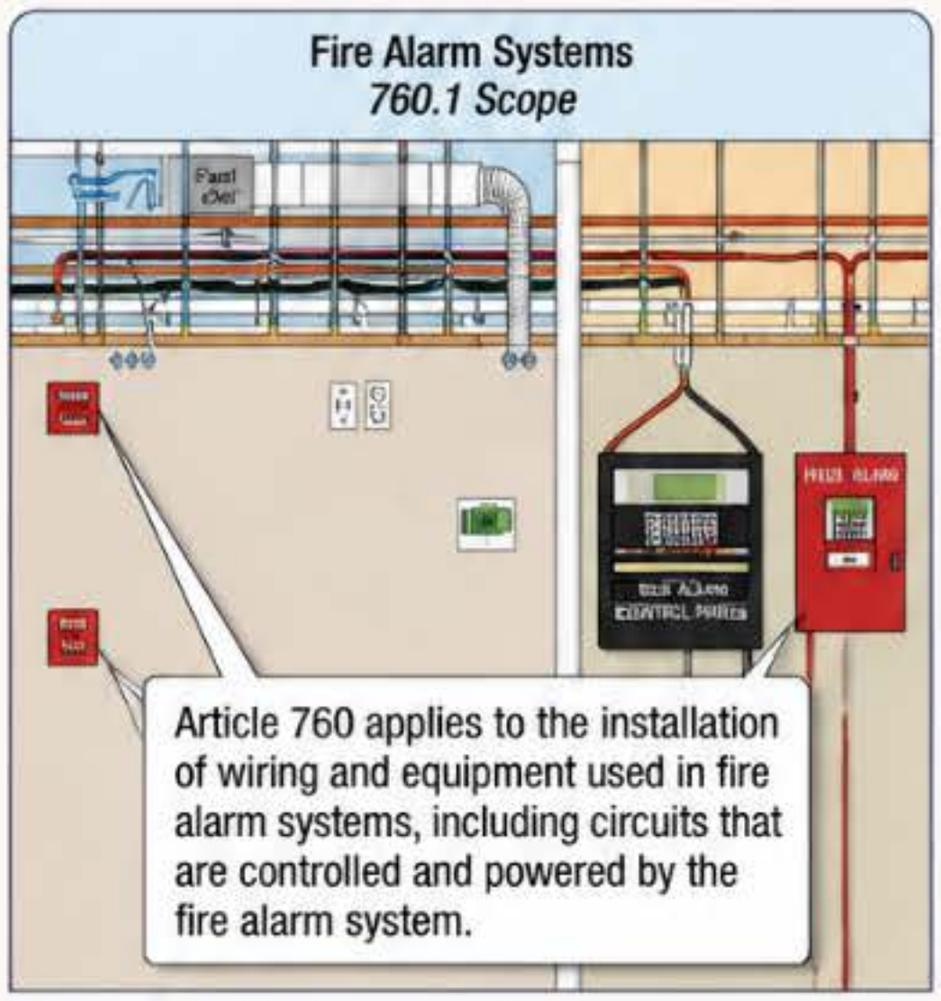
This article addresses how wiring and related equipment are installed for fire alarm systems, including circuits that are operated or supplied by the fire alarm. These systems consist of components such as fire detection and alarm signaling, guard tours, sprinkler waterflow monitoring, and sprinkler supervisory functions. The **2023** edition of NFPA 72, *National Fire Alarm and Signaling Code*, outlines the criteria for selecting, installing, performing, using, testing, and maintaining fire alarm systems.

Part I. General

760.1 Scope

Article 760 applies to the installation of wiring and equipment used in fire alarm systems, including circuits that are controlled and powered by the fire alarm system.

▶ Figure 760-1



▶ Figure 760-1

> ***Author's Commentary:***
> Residential smoke alarm systems that use interconnecting wiring fall outside the scope of Article 760. These systems are addressed elsewhere in NFPA 72, *National Fire Alarm and Signaling Code*.
>
> ***— Michael Hamilton***

Note 1: Fire alarm systems include fire detection and alarm notification, guard's tour, sprinkler waterflow, and sprinkler supervisory systems. Other circuits that might be controlled or 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. The **2023** edition of NFPA 72, *National Fire Alarm and Signaling Code*, provides the requirements for the selection, installation, performance, use, testing, and maintenance of fire alarm systems.

> ***Author's Commentary:***
> - Building control circuits tied to the fire alarm system, such as elevator capture and fan shutdown, must comply with Article 725 [760.3(E)]. Article 760 applies if those components are powered and directly controlled by the fire alarm system.
> - NFPA 101, *Life Safety Code*, or the applicable building code determines when and where a fire alarm system is required.
>
> ***— Michael Hamilton***

760.2 Definitions

The definitions in this section apply specifically to this article.

Abandoned Fire Alarm Cable. A cable that is not terminated on equipment and not identified for future use with a tag.

▶ Figure 760-2

760.3 | Fire Alarm Systems

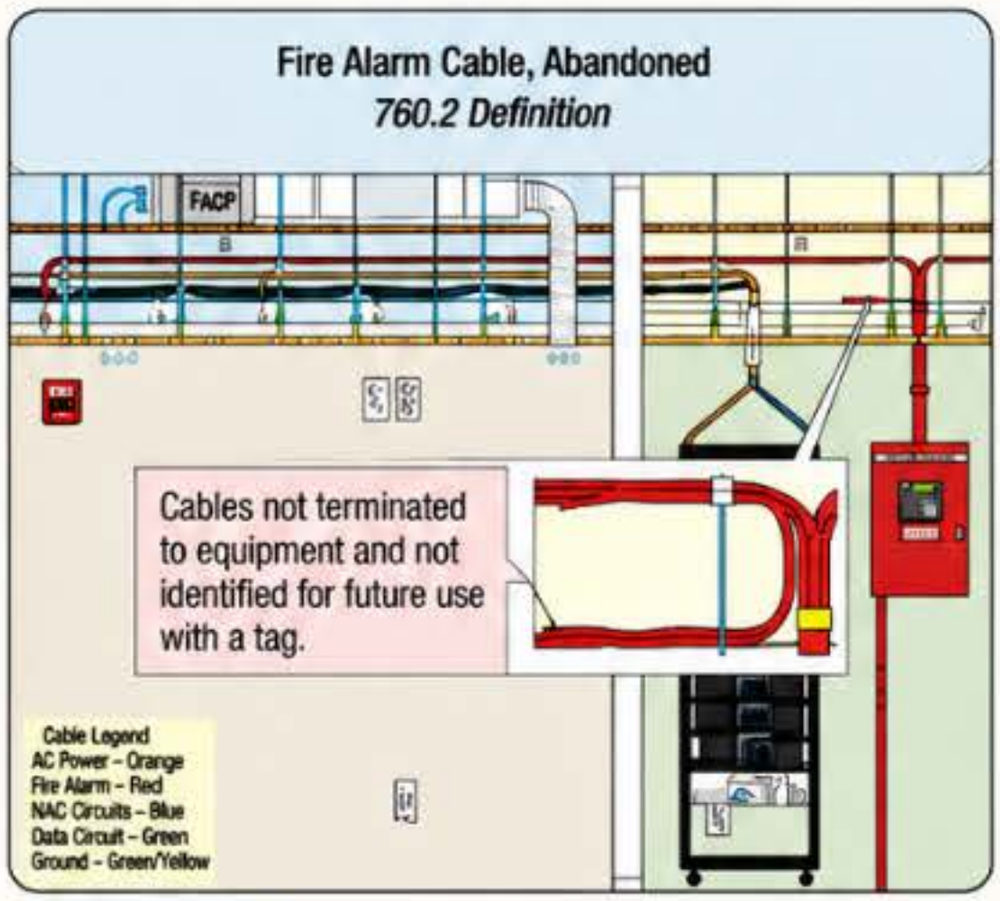


Figure 760-2

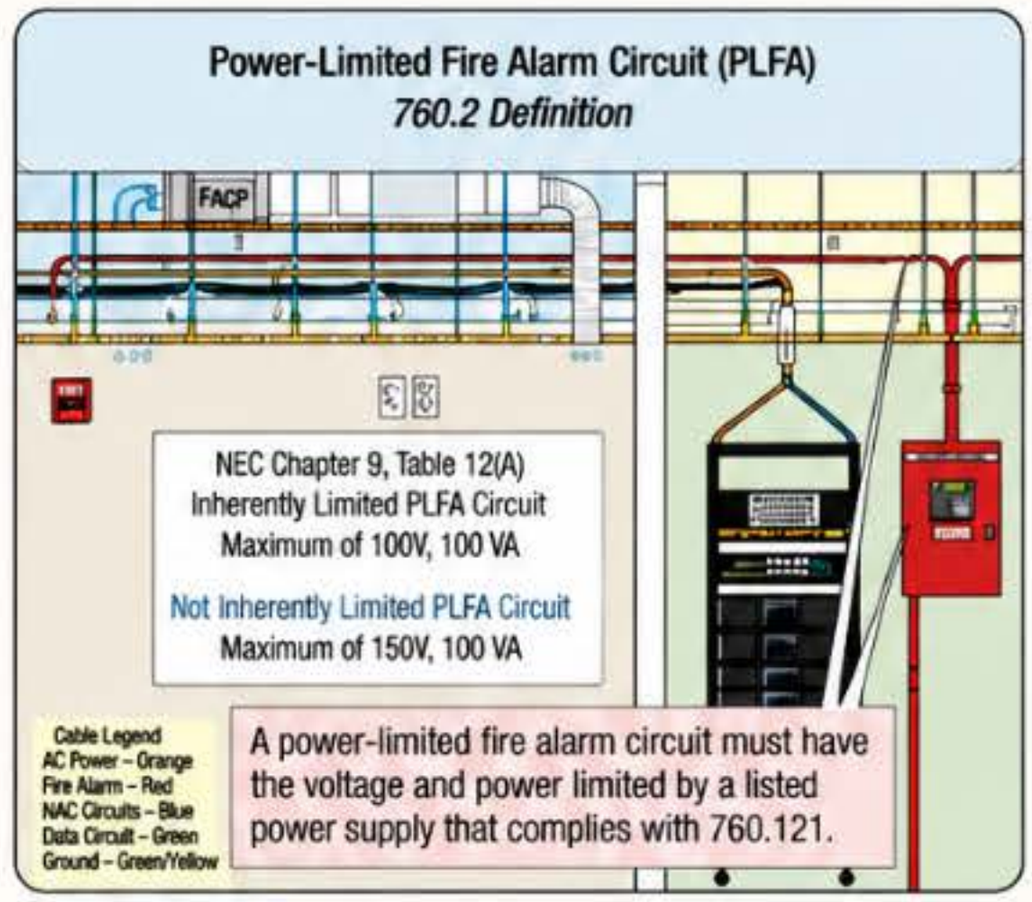


Figure 760-4

Author's Commentary:

Section 760.25 requires the accessible portion of abandoned cables to be removed.

— Michael Hamilton

Fire Alarm Circuit. The portion of the wiring system and connected equipment powered and controlled by the fire alarm system. ▸ **Figure 760-3**

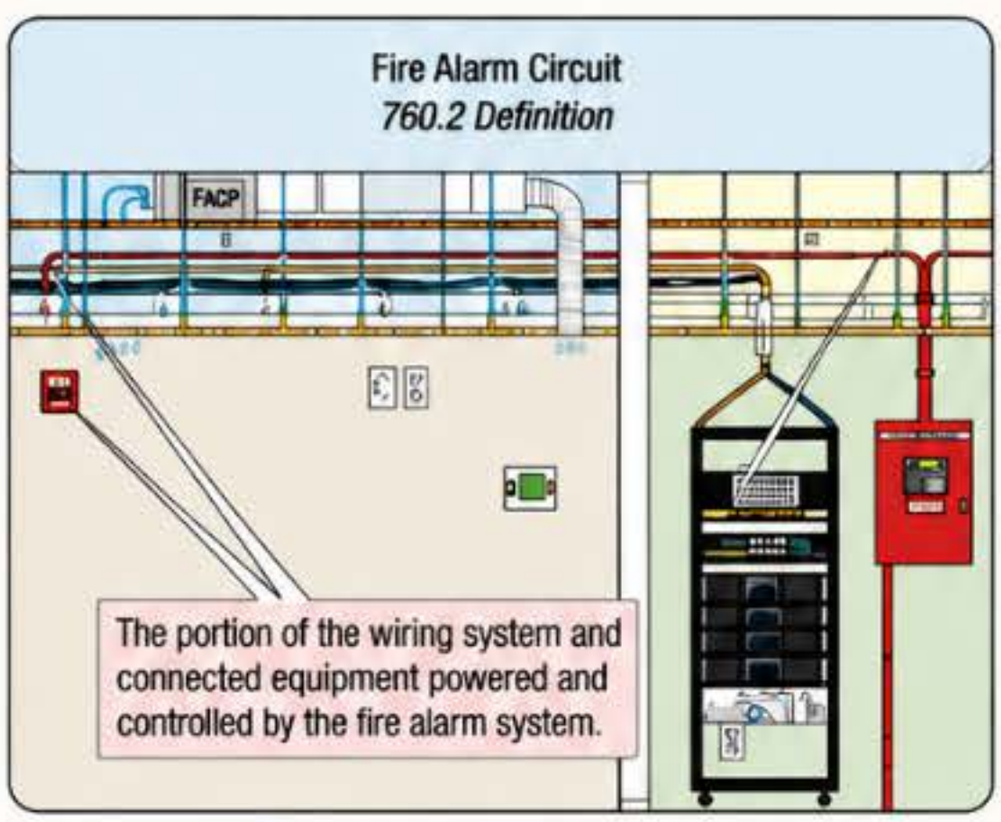


Figure 760-3

Power-Limited Fire Alarm Circuit (PLFA). A power-limited fire alarm circuit must have the voltage and power limited by a listed power supply that complies with 760.121. ▸ **Figure 760-4**

760.3 Other Articles

Fire alarm circuits and equipment must comply with 760.3(A) through (I). Only those sections contained in Article 300 specifically referenced applly to fire alarm systems.

(A) Spread of Fire or Products of Combustion. Installation of fire alarm circuits must comply with 300.21. ▸ **Figure 760-5**

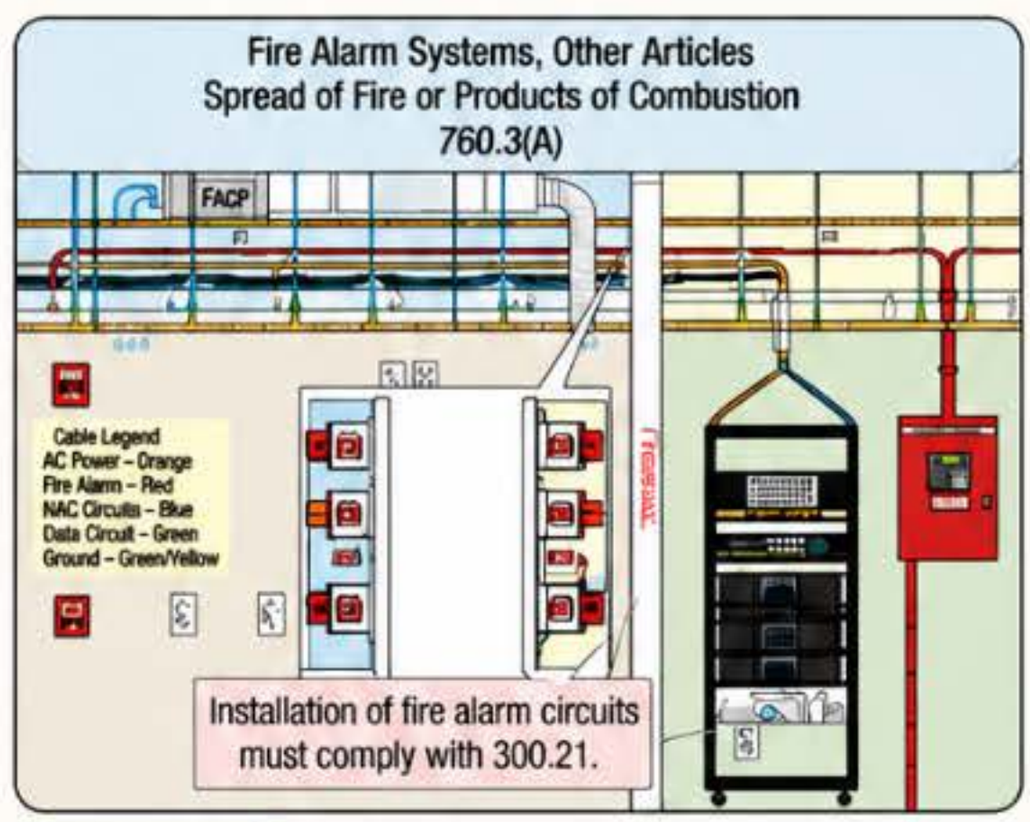
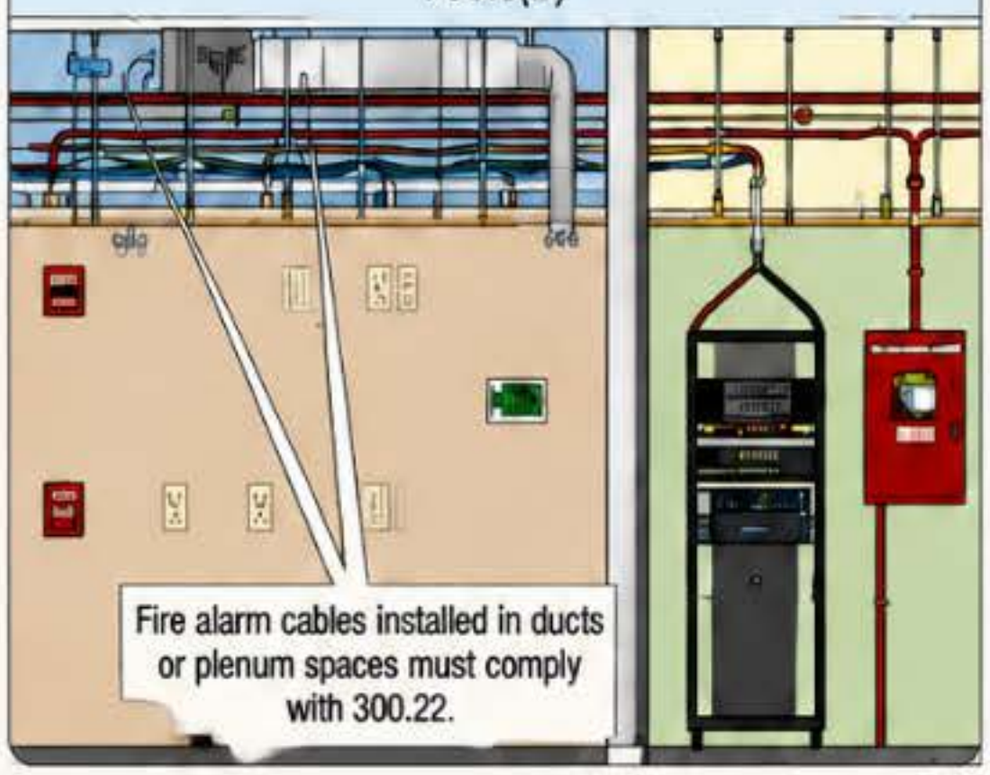


Figure 760-5

(B) Ducts and Plenum Spaces. Fire alarm cables installed in ducts or plenum spaces must comply with 300.22. ▸ **Figure 760-6**

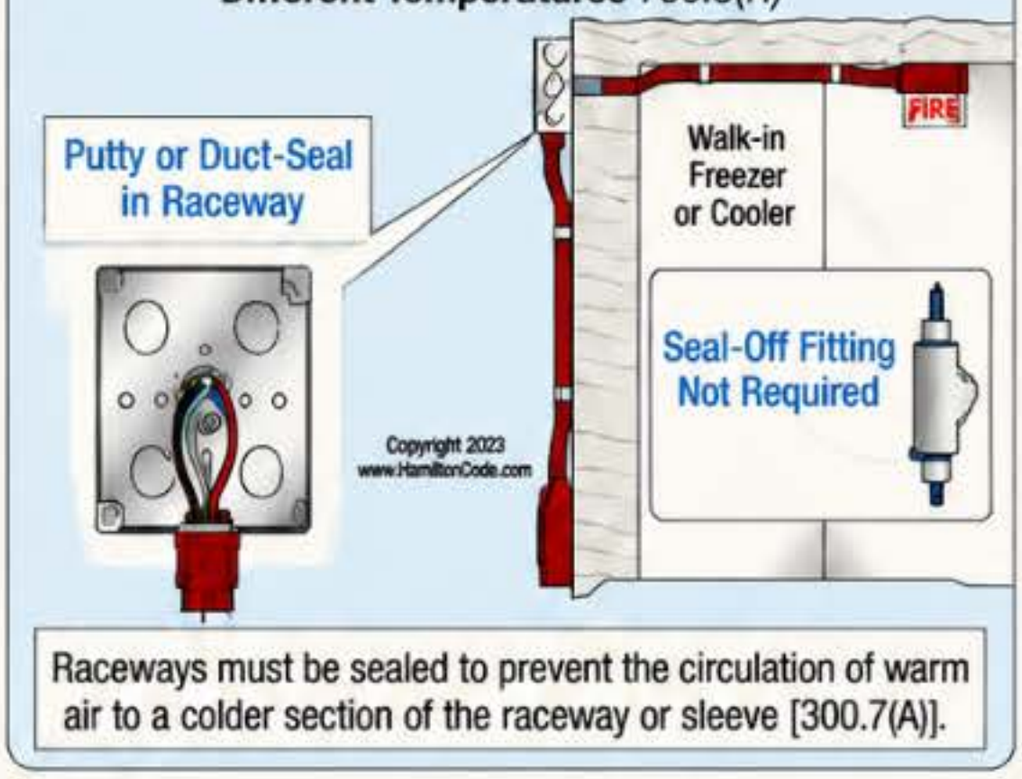
Ex 1: Power-limited fire alarm cables selected in accordance with Table 760.154 and installed in accordance with 760.135(B) and 300.22(B) Ex are permitted to be installed in ducts specifically fabricated for environmental air.

Fire Alarm Systems
Other Articles, Ducts and Plenum Spaces
760.3(B)



▶ Figure 760–6

Fire Alarm Systems, Other Articles
Raceways or Sleeves Exposed to Different Temperatures *760.3(H)*



▶ Figure 760–7

Ex 2: Power-limited fire alarm cables selected in accordance with Table 760.154 and installed in accordance with 760.135(C) are permitted to be installed in plenum spaces.

(D) Corrosive, Damp, or Wet Locations. Fire alarm circuits installed in corrosive, damp, or wet environments must be identified for use in the operating environment [110.11], must be of materials suitable for the environment in which they are to be installed, and must be of a type suitable for the application [300.5(B), 300.6, 300.9, and 310.10(F)].

(E) Building Control Circuits. Class 1, 2, and 3 circuits used for building controls (elevator capture, fan shutdown, and so on) associated with the fire alarm system, but not controlled and powered by the fire alarm system, must be installed in accordance with Article 725.

(F) Optical Fiber Cables. Optical fiber cables utilized for fire alarm circuits must be installed in accordance with Article 770.

(H) Raceways or Sleeves Exposed to Different Temperatures. If a raceway or sleeve is subjected to different temperatures, and where condensation is known to be a problem, the raceway or sleeve must be filled with a material approved by the authority having jurisdiction that will prevent the circulation of warm air to a colder section of the raceway in accordance with 300.7(A). ▶ Figure 760–7

(J) Number and Size of Conductors in a Raceway. Raceways must be large enough to permit the installation and removal of conductors without damaging conductor insulation [300.17].

Author's Commentary:

- When all conductors within a raceway are the same size and insulation, the number of conductors permitted can be found in Annex C for the raceway type.

— Michael Hamilton

Author's Commentary:

- For conductors not included in Chapter 9 (such as multiconductor cable), the actual dimensions must be used. If one multiconductor cable is used inside a raceway the single conductor percentage fill area must be used [Chapter 9, Notes to Tables, Note 5 and 9].

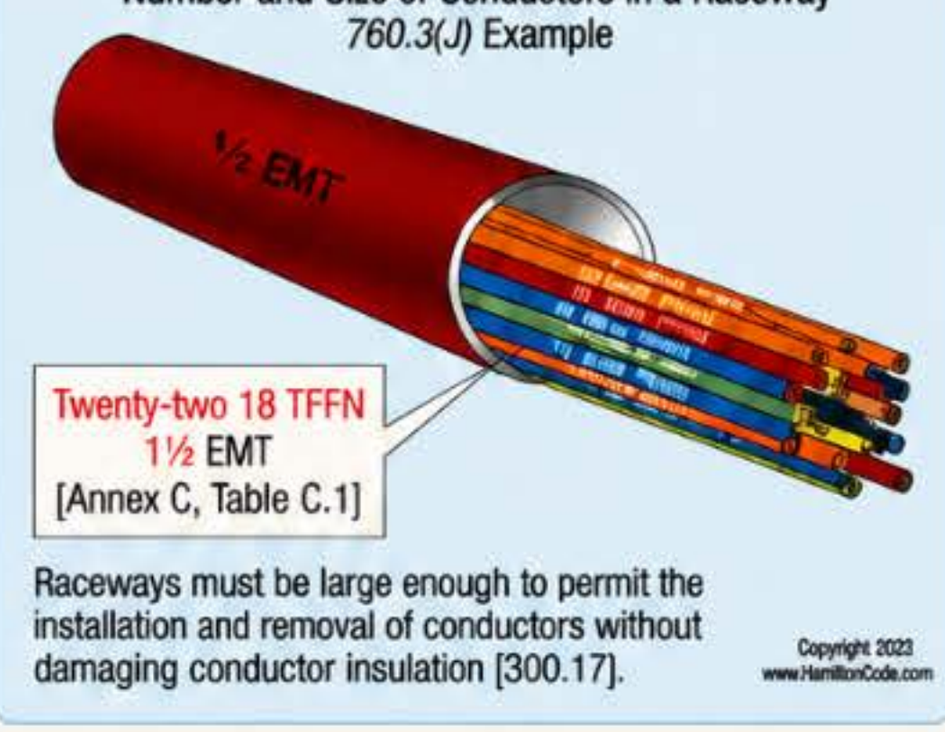
— Michael Hamilton

▶ Example

Question: *How many 18 TFFN fixture wires can be installed in trade size ½ electrical metallic tubing?* ▶ Figure 760–8

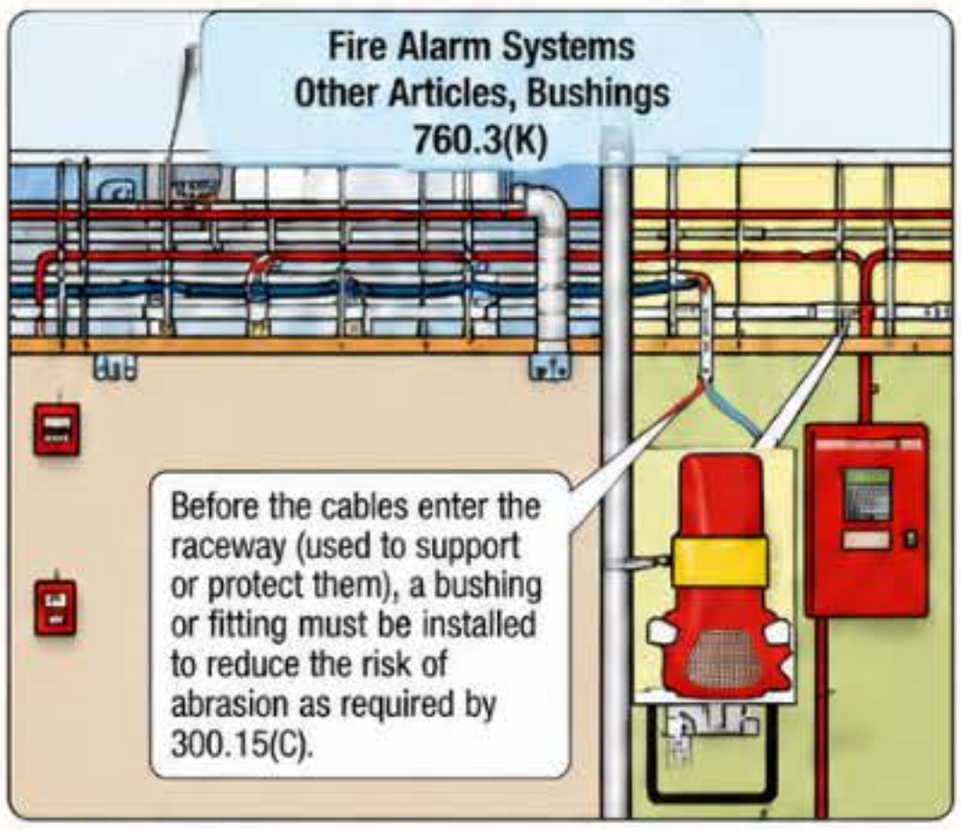
(a) 16 *(b) 18* *(c) 22* *(d) 38*

Fire Alarm Systems, Other Articles
Number and Size of Conductors in a Raceway
760.3(J) Example



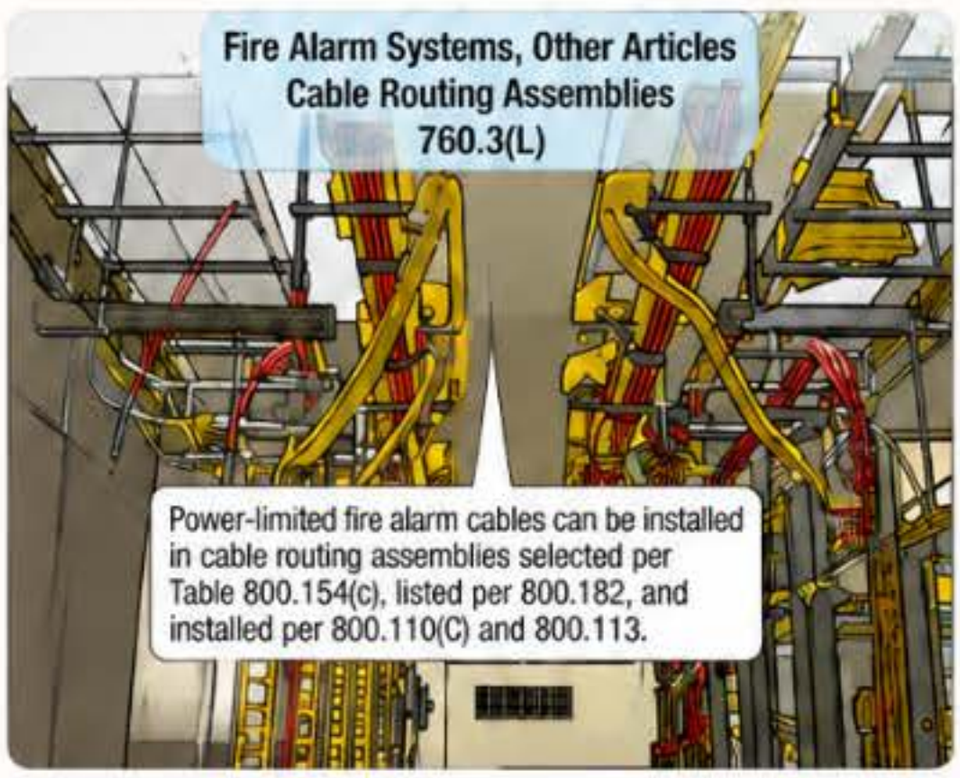
Answer: *(c) 22*
[Annex C, Table C.1]

(K) Bushing. Whenever a raceway is used to support or protect cables, a bushing or similar fitting must be used to minimize abrasion. The bushing or fitting shall be installed at the location where the cables enter the raceway as required by 300.15(C). **Figure 760–9**



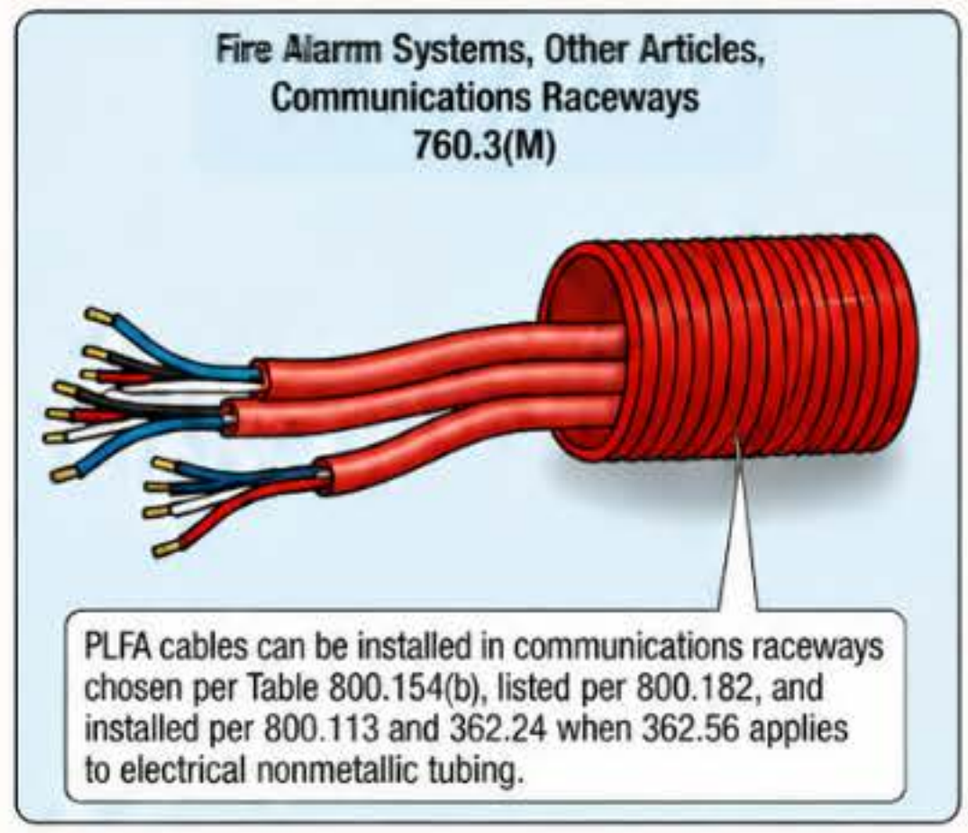
▶ **Figure 760–9**

(L) Cable Routing Assembiies. Power-limited fire alarm cables can be installed in cable routing assemblies that are selected using Table 800.154(c), listed in accordance with 800.182, and installed in accordance with 800.110(C) and 800.13.. **Figure 760–10**



▶ **Figure 760–10**

(M) Communications Raceways. Power-limited fire alarm cables may be placed in communications raceways that are selected in accordance with 800.154(b), listed in accordance with 800.182, and installed per 800.113 and 362.24 through 362.56 where the applicable requirements for electrical non-metallic tubing are found. **Figure 760–11**



▶ **Figure 760–11**

(N) Temperature Limitations. The temperature limits in 310.14(A)(3) apply to the conductors of power-limited fire alarm cables and non-power-limited fire alarm cables.

(O) Identification of Equipment Grounding Conductors. Electrical equipment grounding conductors must be identified according to 250.119.

Example: *Green-insulated conductors may be used as underground signal conductors for Types FPLP, FPLR, FPL, and substitute cables installed according to 760.154(A).*

760.21 Access to Electrical Equipment Behind Panels Designed to Allow Access

Access to equipment is not allowed if it would require building up an accumulation of cables that would interfere with the removal of suspended-ceiling panels.

Author's Commentary:
Use of cable above a ceiling must not interfere with removing panels so equipment can be reached.

— ***Michael Hamilton***

760.24 Mechanical Execution of Work

(A) General. Electrical equipment and cabling must be installed with a clean, workmanlike appearance.

Exposed cables must be supported by the structure of the building. Normal building use must not damage the cables. Use straps, staples, hangers, cable ties, and similar hardware. Install them in a way that will not harm the cable. Installations must meet the requirements of 300.4. **Figure 760–12**

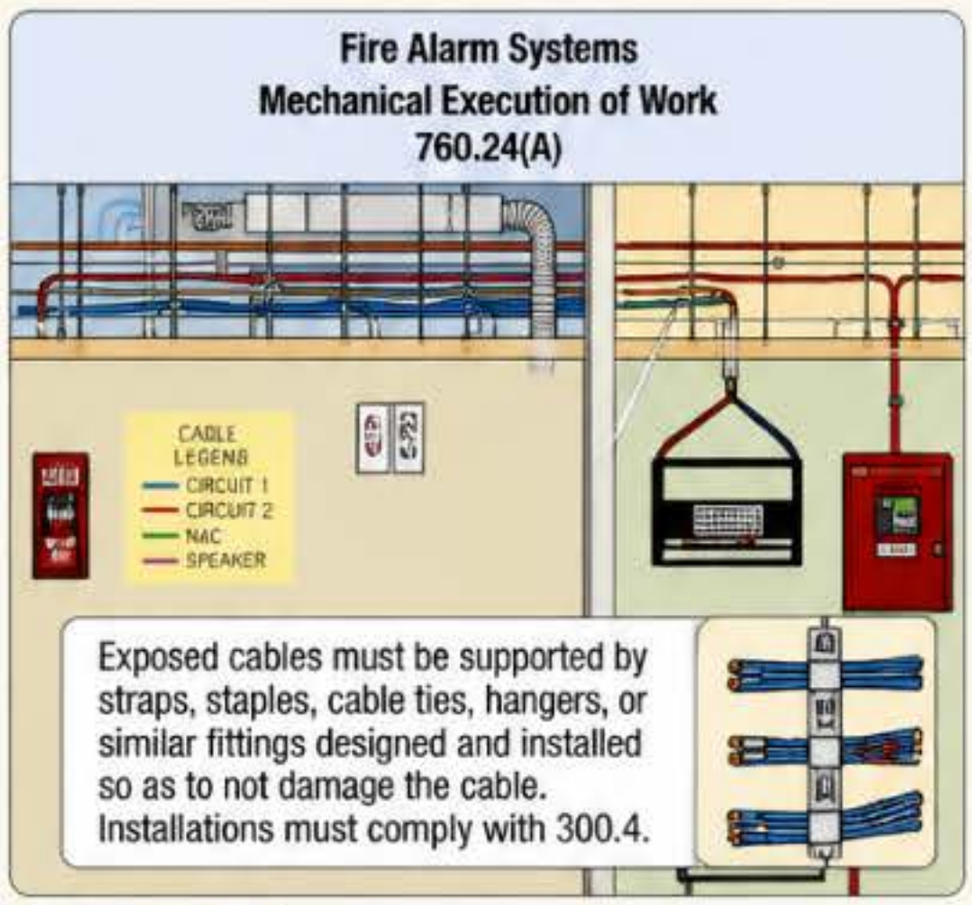


Figure 760–12

Author's Commentary:

- Raceways and cables may be supported by independent support wires attached to the suspended ceiling in accordance with 300.11(B) [760.130(B)]. — *Michael Hamilton*

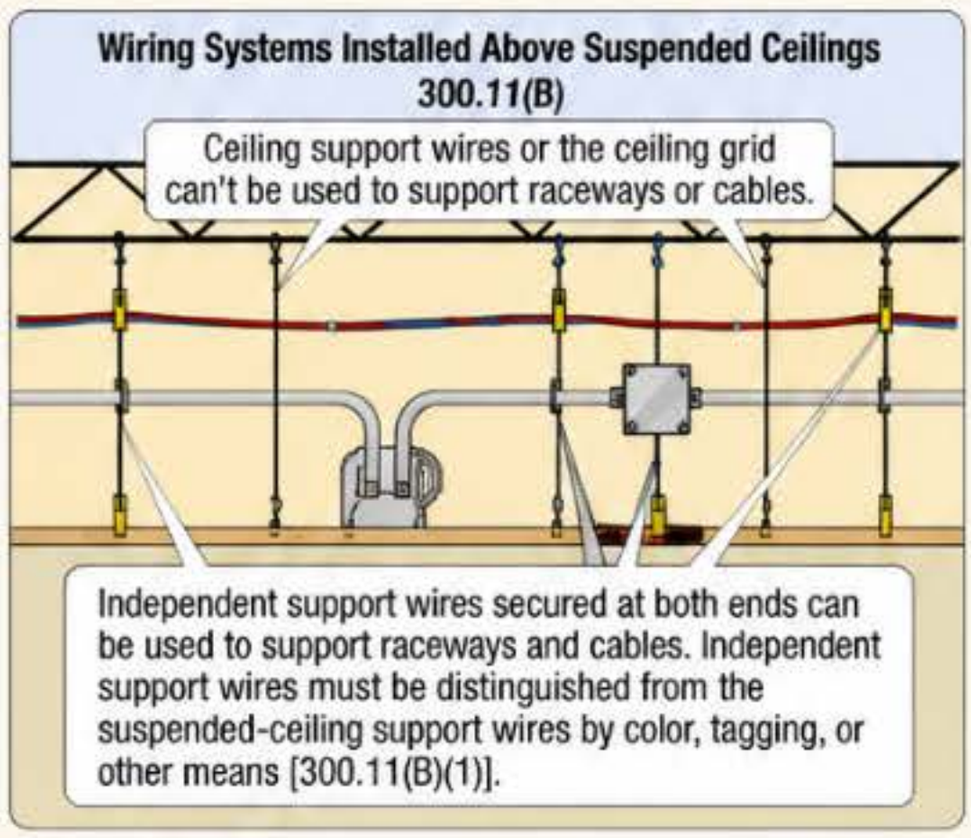


Figure 760–13

Note: Paint, plaster, cleaners, abrasives, corrosive residues, or other contaminants might result in an undetermined alteration of PLFA and NPLFA cable properties.

Cables installed through or parallel to framing members or furring strips must be protected where they are likely to be penetrated by nails or screws by installing the wiring method so it is not less than 1¼ in. from the nearest edge of the framing member or furring strips, or by protecting them with a 1¼ in. thick steel plate or the equivalent [300.4]. Figure 760–14

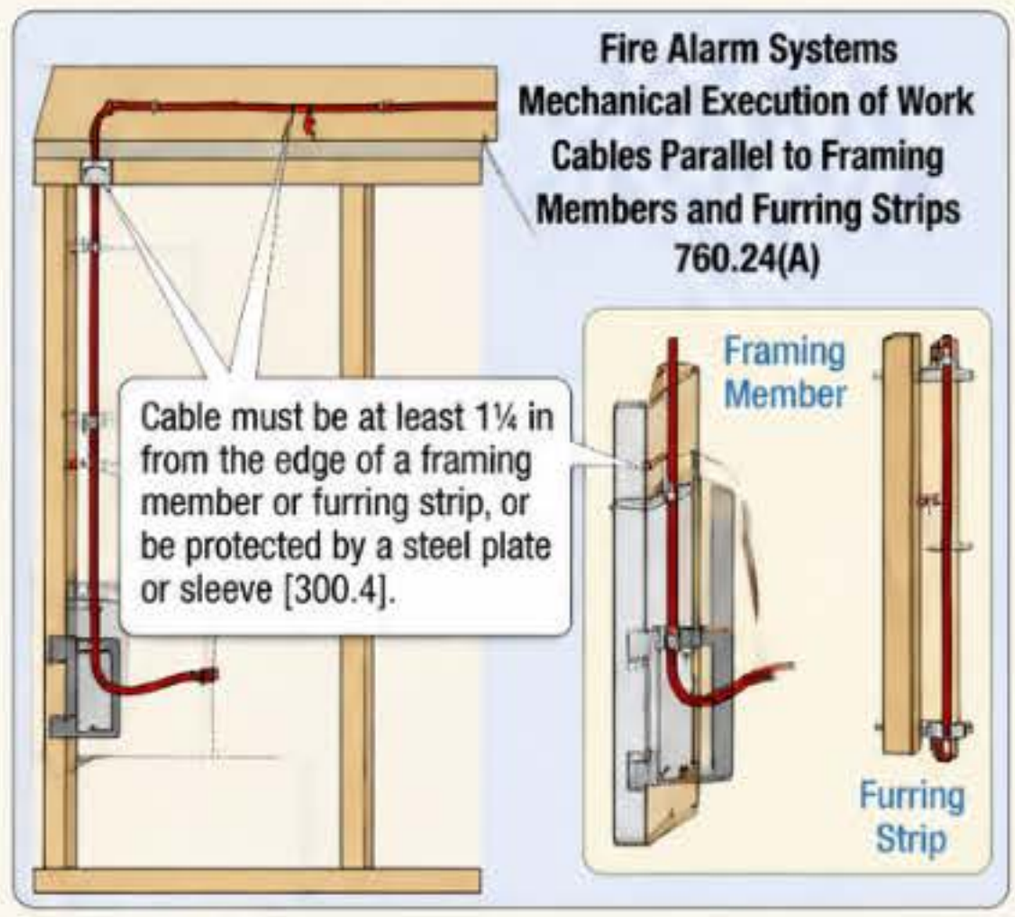


Figure 760–14

760.25 Abandoned Cables

To limit the spread of fire or products of combustion within a building, the accessible portion of cable that is not terminated at equipment and not tagged for future use must be removed. Figure 760–15

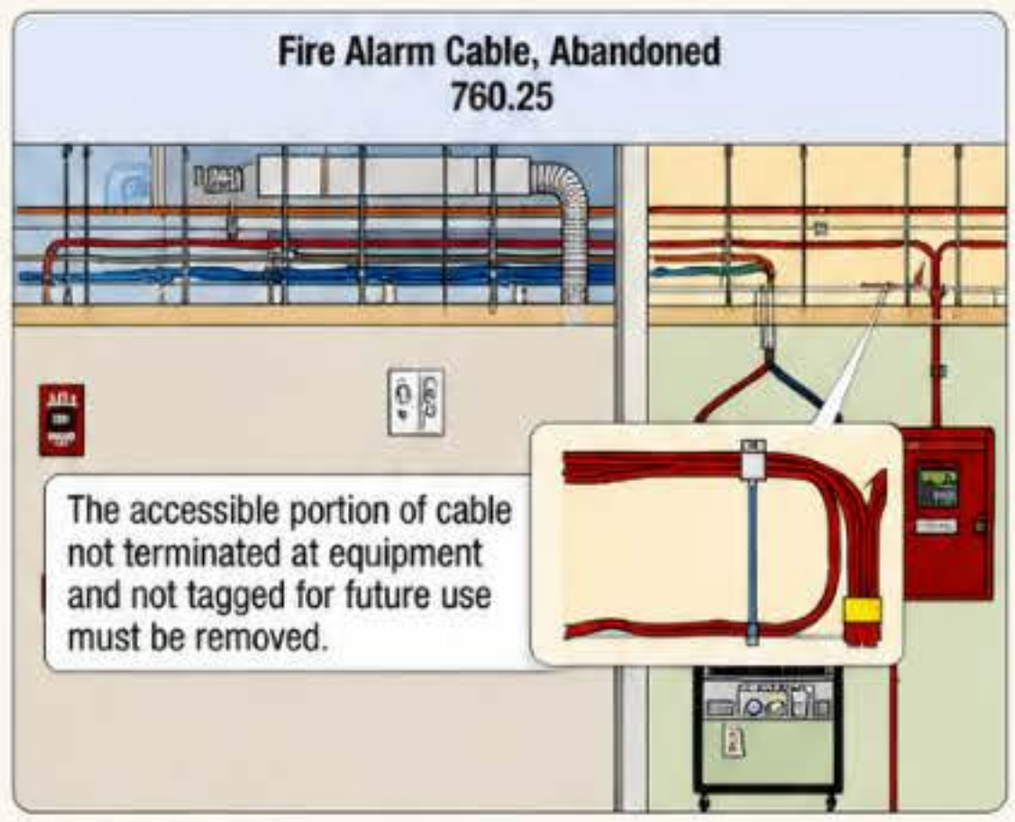


Figure 760–15

Tags identifying cables for future use must be able to withstand the environment involved.

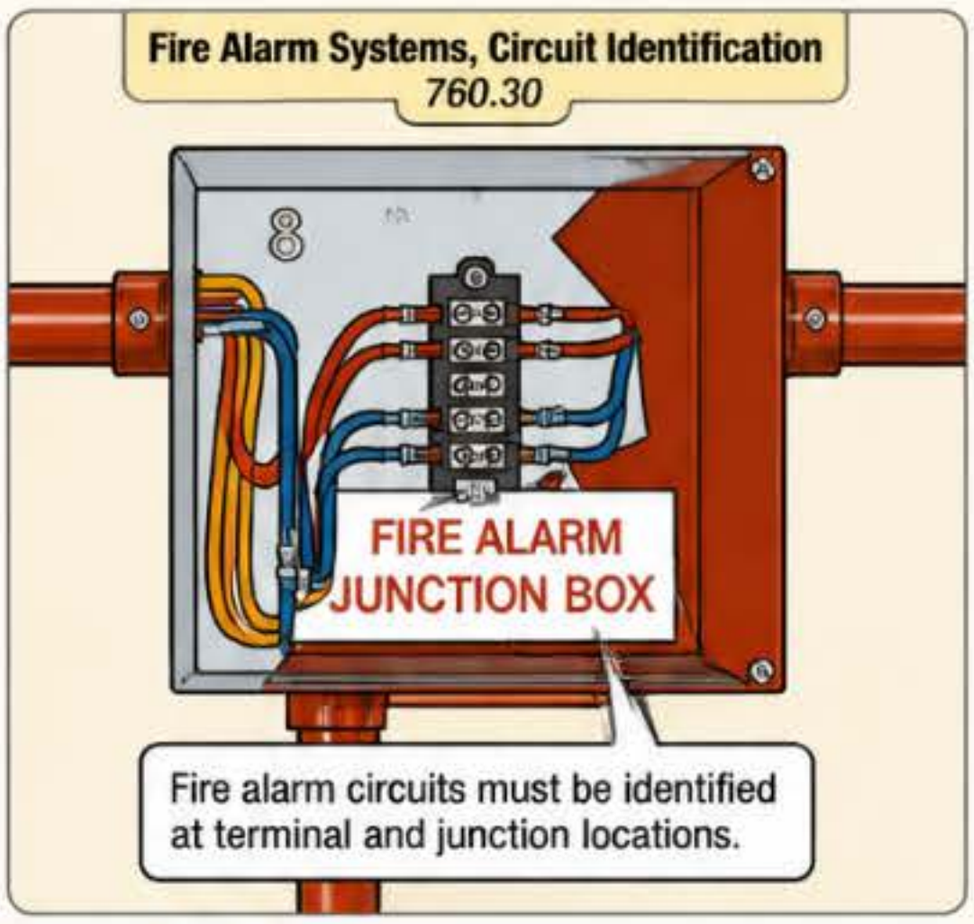
Author's Commentary:

- Cables installed in concealed raceways are not considered accessible; therefore, they are not required to be removed. See the definition of "Abandoned Fire Alarm Cable" in 760.2.

— *Michael Hamilton*

760.30 Fire Alarm Circuit Identification

Fire alarm circuits must be labeled at every terminal and junction point.
▶ Figure 760–16

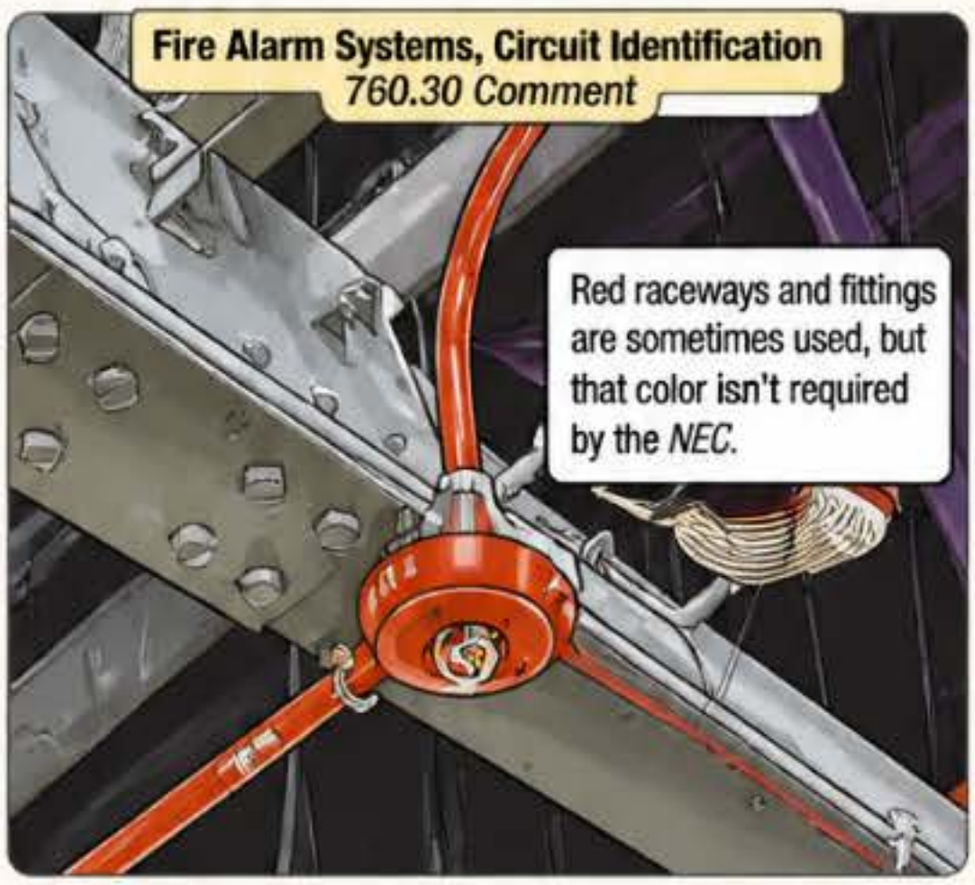


▶ Figure 760–16

The identification should be clear and placed where it can help avoid false signals on fire alarm system circuits during testing and while servicing other systems.

Author's Commentary:
Wiring and fittings may be used with red raceways, but color is optional per the *NEC*.
— *Michael Hamilton*

▶ Figure 760–17



▶ Figure 760–17

760.35 Fire Alarm Circuit Requirements

(B) Power-Limited Fire Alarm Circuits. Power-limited fire alarm (PLFA) circuits must comply with Parts I and III of this article.

Part III. Power-Limited Fire Alarm (PLFA) Circuits

760.121 Power Sources for Power-Limited Fire Alarm Circuits

(A) Power Source. The power source for a power-limited fire alarm circuit must be:

(1) A listed PLFA transformer, or

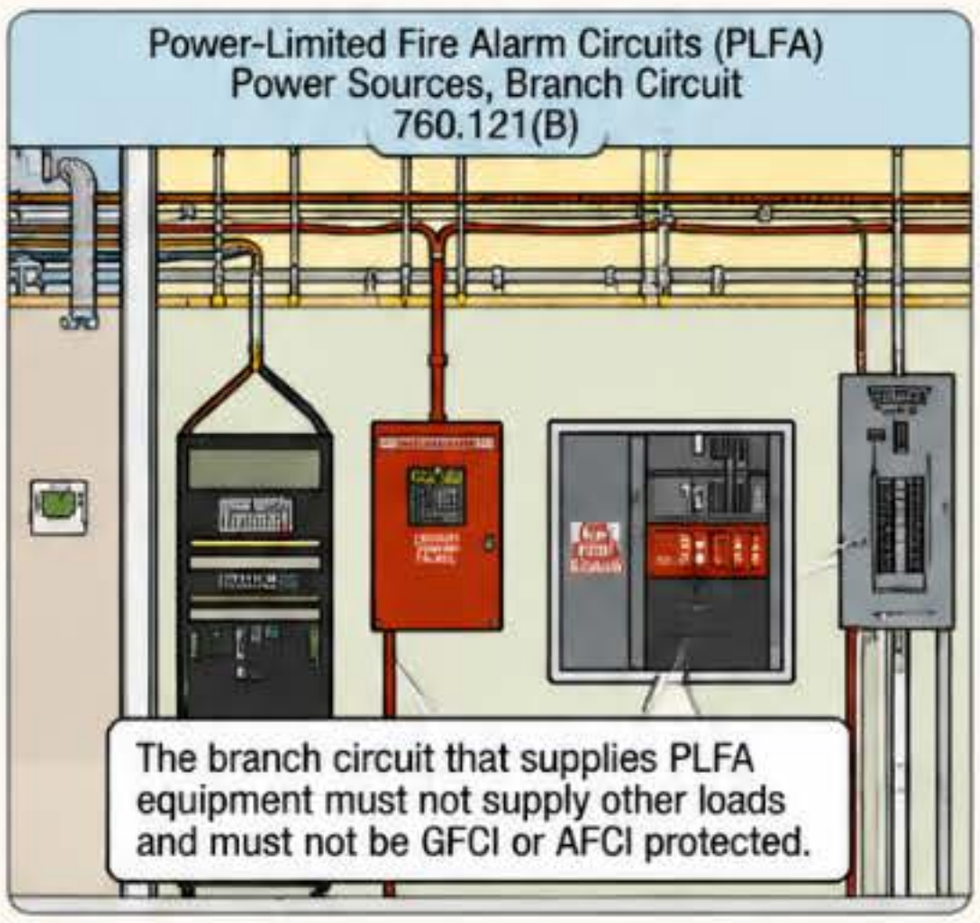
(2) A listed PLFA power supply, or

(3) Listed equipment marked to identify the PLFA power source.

Note: Examples of listed equipment are:

- A fire alarm control panel with integral power source.
- A circuit card listed for use as a PLFA source, where used as part of a listed assembly.
- A current-limiting impedance, listed for the purpose or part of a listed product, used with a nonpower-limited transformer or stored energy source, for example, storage battery, to limit the output current.

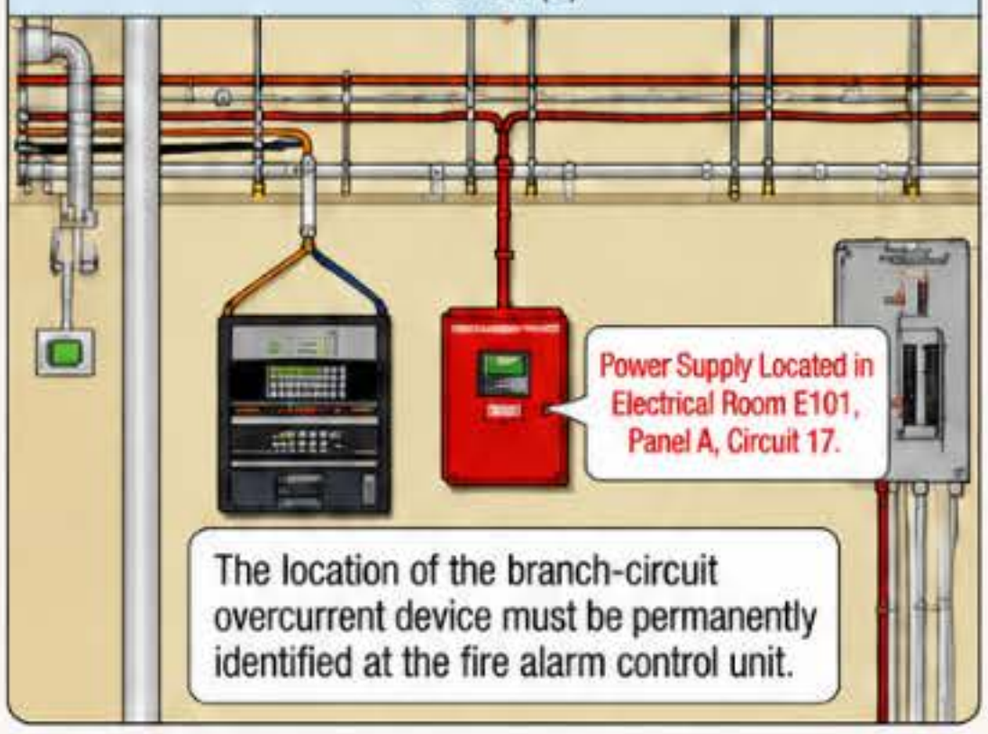
(B) Branch Circuit. Power-limited fire alarm equipment must be supplied by a branch circuit that supplies no other load and is not GFCI or AFCI protected. ▶ Figure 760–18



▶ Figure 760–18

The location of the branch-circuit overcurrent protective device for the power-limited fire alarm equipment must be permanently identified at the fire alarm control unit. ▸ Figure 760–19

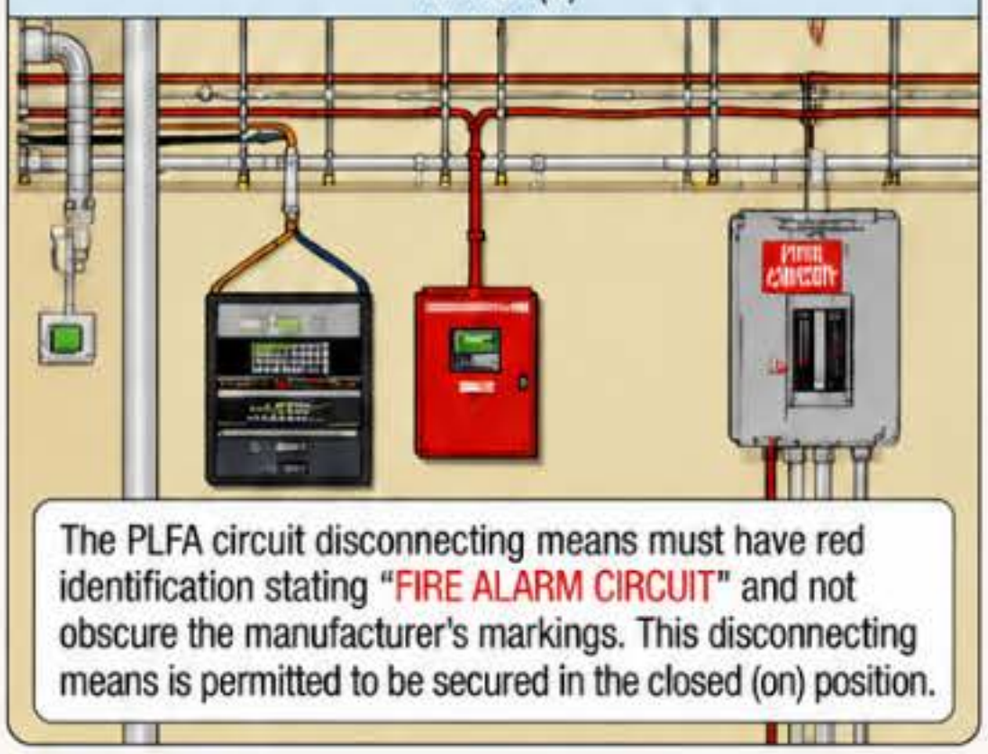
Power-Limited Fire Alarm Circuits (PLFA), Power Sources
Branch-Circuit Overcurrent Protective Device Location
760.127(B)



▸ Figure 760–19

The branch-circuit overcurrent protective device must be identified in red, be accessible only to qualified personnel, and be identified as the "FIRE ALARM CIRCUIT." The red identification must not damage the overcurrent protective device or obscure any manufacturer's markings. The fire alarm branch-circuit disconnecting means is permitted to be secured in the closed (on) position. ▸ Figure 760–20

PLFA Circuits, Power Sources
Branch-Circuit Disconnecting Means Identification
760.127(B)



▸ Figure 760–20

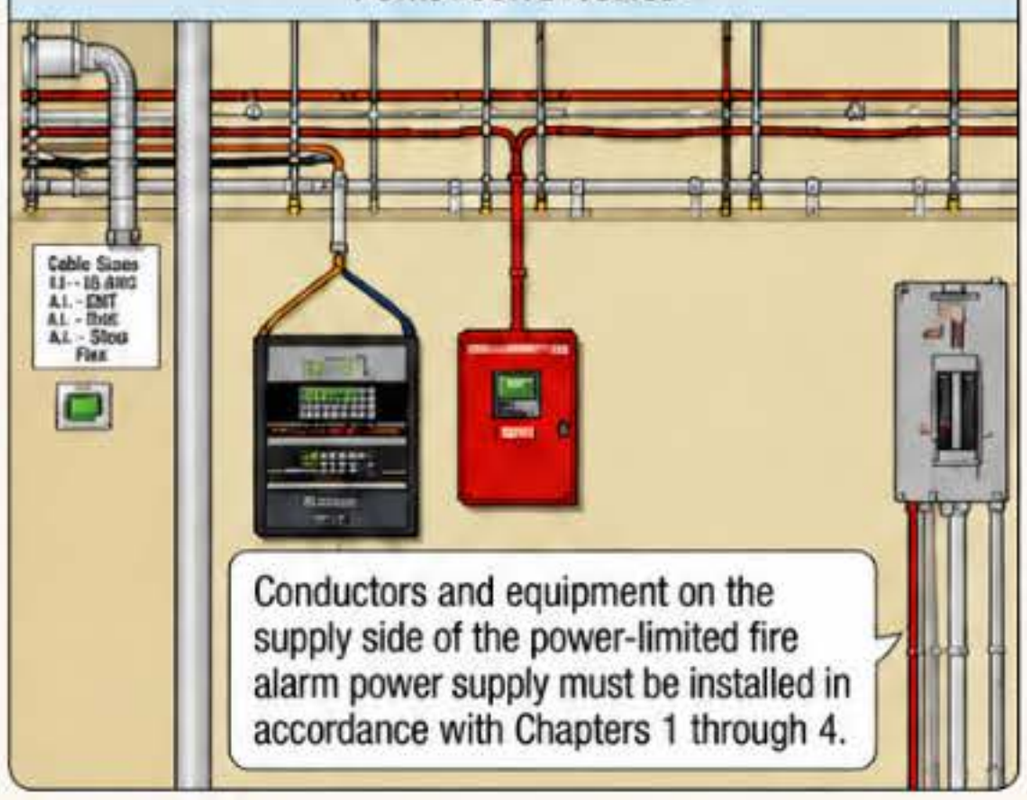
760.124 Marking

Fire alarm equipment supplying power-limited fire alarm cable circuits must be durably marked to indicate each circuit that is a power-limited fire alarm circuit.

760.127 Wiring Methods on Supply Side of the Power-Limited Fire Alarm Source

Conductors and equipment on the supply side of the power-limited fire alarm power supply must be installed in accordance with Chapters 1 through 4. ▸ Figure 760–21

PLFA Circuits, Wiring Methods on
Supply Side of the Power-Limited Fire Alarm Slice
Power 760.127 Source

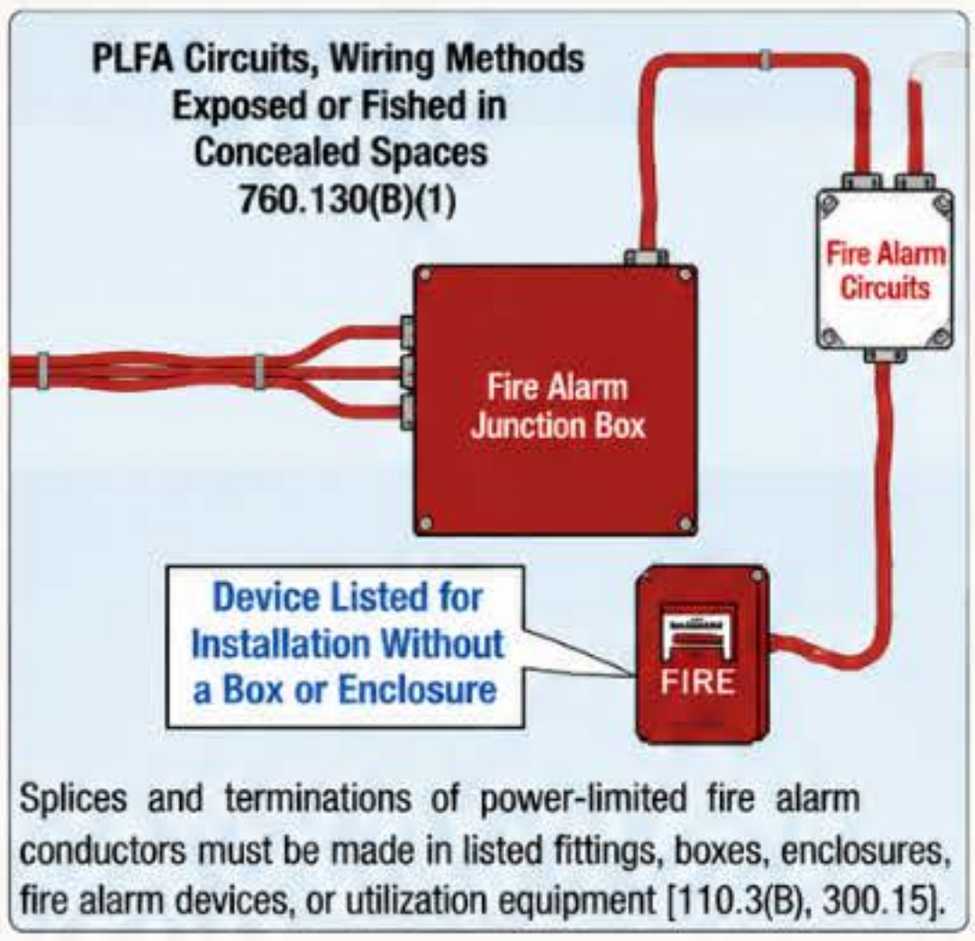


▸ Figure 760–21

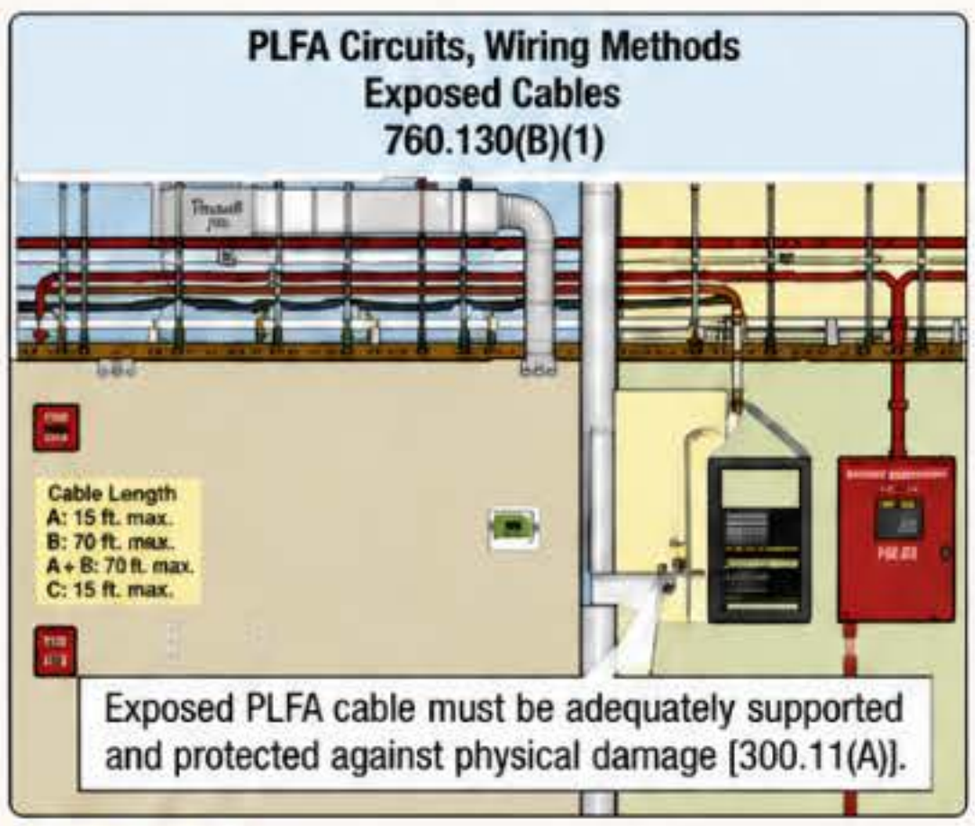
760.130 Wiring Methods on Load Side of the Power-Limited Fire Alarm Power Source

(B) PLFA Wiring Methods and Materials.

(1) Cable splices and terminations of power-limited fire alarm conductors must be made in listed fittings, boxes, enclosures, fire alarm devices, or utilization equipment [110.3(B) and 300.15]. ▸ Figure 760–22 Exposed power-limited fire alarm cable(s) must be adequately supported and protected against physical damage [300.11(A)]. ▸ Figure 760–23



▶ Figure 760–22



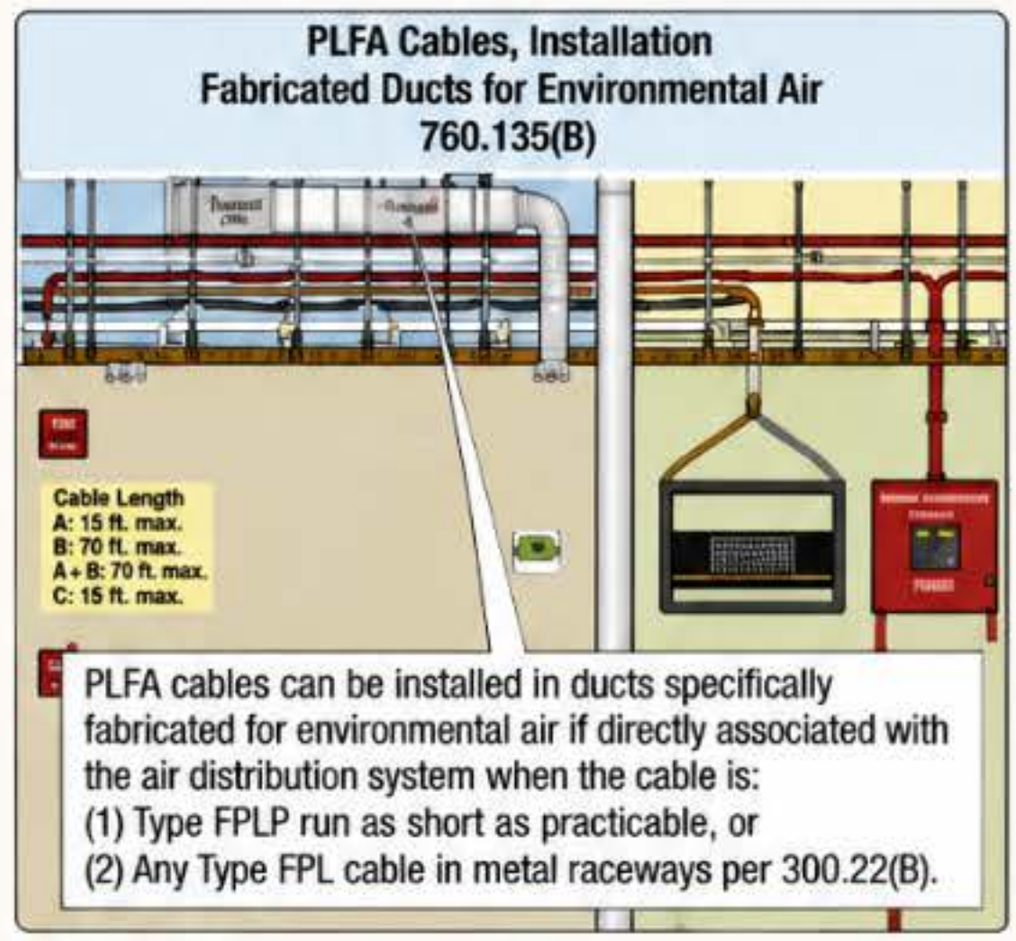
▶ Figure 760–23

760.135 Installation of PLFA Cables in Buildings

Installation of power-limited fire alarm cables in buildings must comply with 760.135(A) through (J).

(A) Listing. Power-limited fire alarm (PLFA) cables installed in buildings must be listed.

(B) Ducts Specifically Fabricated for Environmental Air Spaces. Plenum rated power-limited fire alarm (PLFA) cables are permitted to be installed within ducts specifically fabricated for environmental air spaces in accordance with 760.3(B) Ex 1 if the cable is directly associated with the air distribution system and complies with (1) or (2): ▶ Figure 760–24

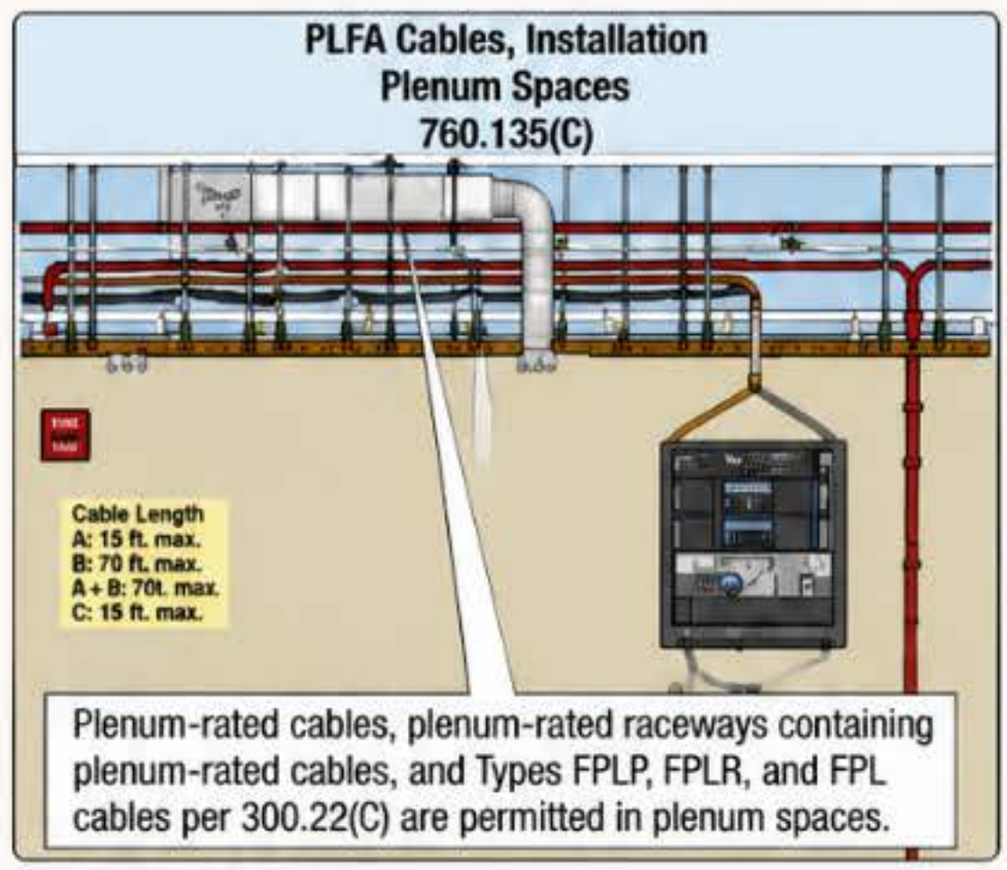


▶ Figure 760–24

(1) Type FPLP cables are permitted where the length is as short as practicable to perform the required function.

(2) Any Type FPL cable installed in metal raceways in compliance with 300.22(B).

(C) Plenum Spaces. Plenum-rated cables, plenum-rated raceways containing plenum-rated cables, and Types FPLP, FPLR, and FPL cables in accordance with 300.22(C) are permitted in plenum spaces. ▶ Figure 760–25



▶ Figure 760–25

(H) Other Building Locations. The following power-limited fire alarm cables are permitted to be installed in building locations:

(1) Types FPLP, FPLR, and FPL cables.

(2) Types FPLP, FPLR, and FPL cables installed in:

Fire Alarm Systems | 760.154

a. Plenum communications raceways.

b. Plenum cable routing assemblies.

c. Riser communications raceways.

d. Riser cable routing assemblies.

e. General-purpose communications raceways.

f. General-purpose cable routing assemblies.

(3) Types FPLP, FPLR, and FPL cables installed within a raceway of a type recognized in Chapter 3.

760.136 Separation from Power Conductors

(A) General. Power-limited fire alarm conductors are not allowed to be placed in any enclosure, raceway, or cable with power conductors.

(B) Separated by Barriers. If separated by a barrier, power-limited fire alarm circuits are permitted with electric power conductors.

Author's Commentary:
Separation is required to prevent a fire or shock danger that can occur from a short between the fire alarm circuit and the higher-voltage circuits.
— Michael Hamilton

(D) Associated Systems. Power-limited fire alarm conductors are permitted to be installed with power conductors where introduced solely to connect to equipment associated with power circuit conductors; and:

(1) A minimum of 1/4 in. separation is maintained from the power-limited fire alarm conductors to the power conductors.

(G) Other Applications. In other applications, power-limited fire alarm circuit conductors must be separated by not less than 2 in. from power conductors unless:

(1) The power and power-limited fire alarm conductors are within separate Chapter 3 wiring methods. ▸Figure 760–26

760.143 Support of PLFA Cables

Power-limited fire alarm cables are not permitted to be strapped, taped, or attached to the exterior of any raceway as a means of support. ▸Figure 760–27

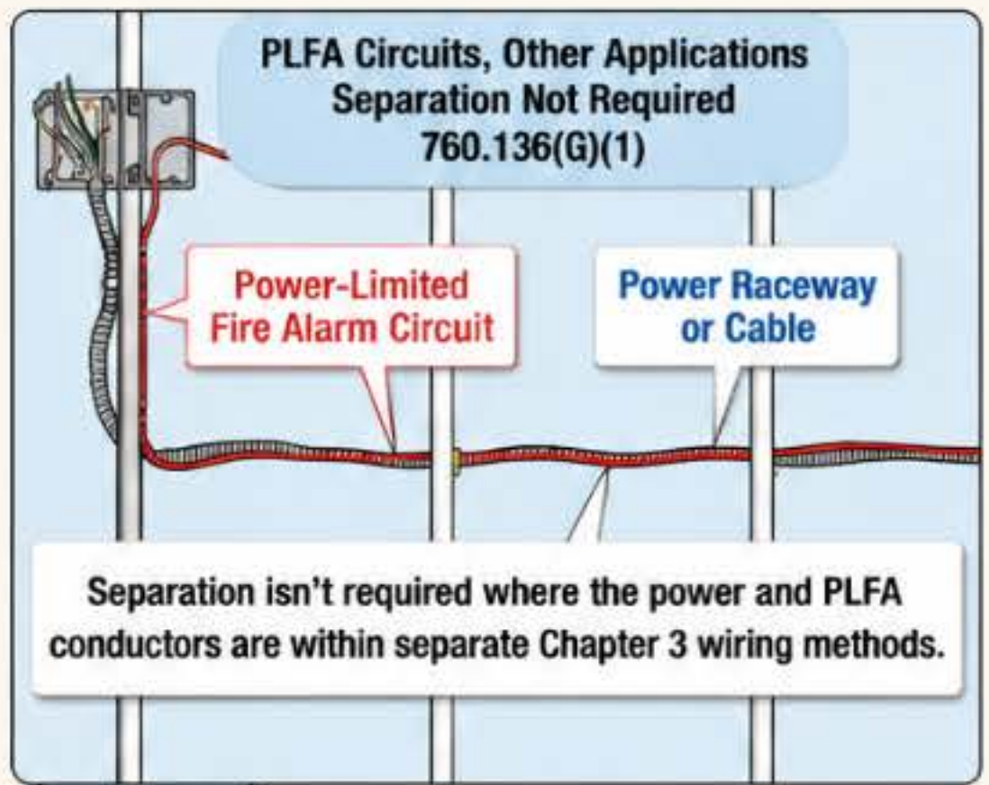


Figure 760–26

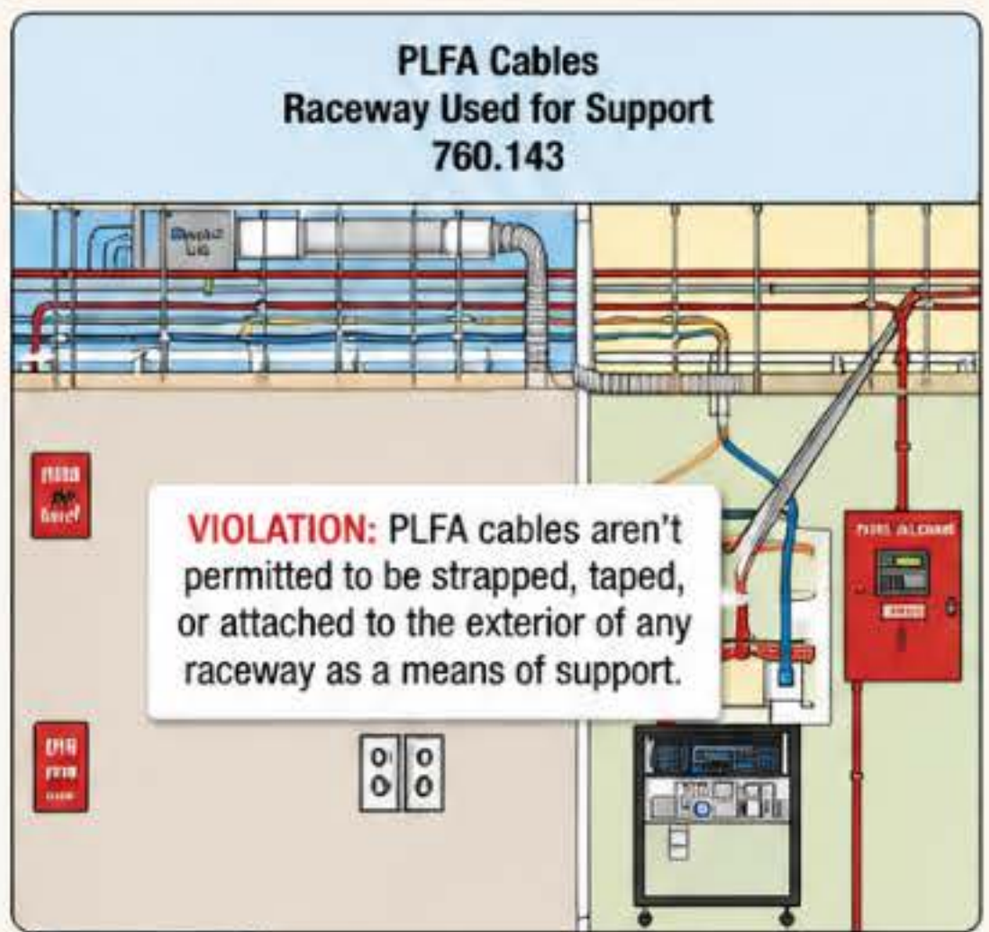
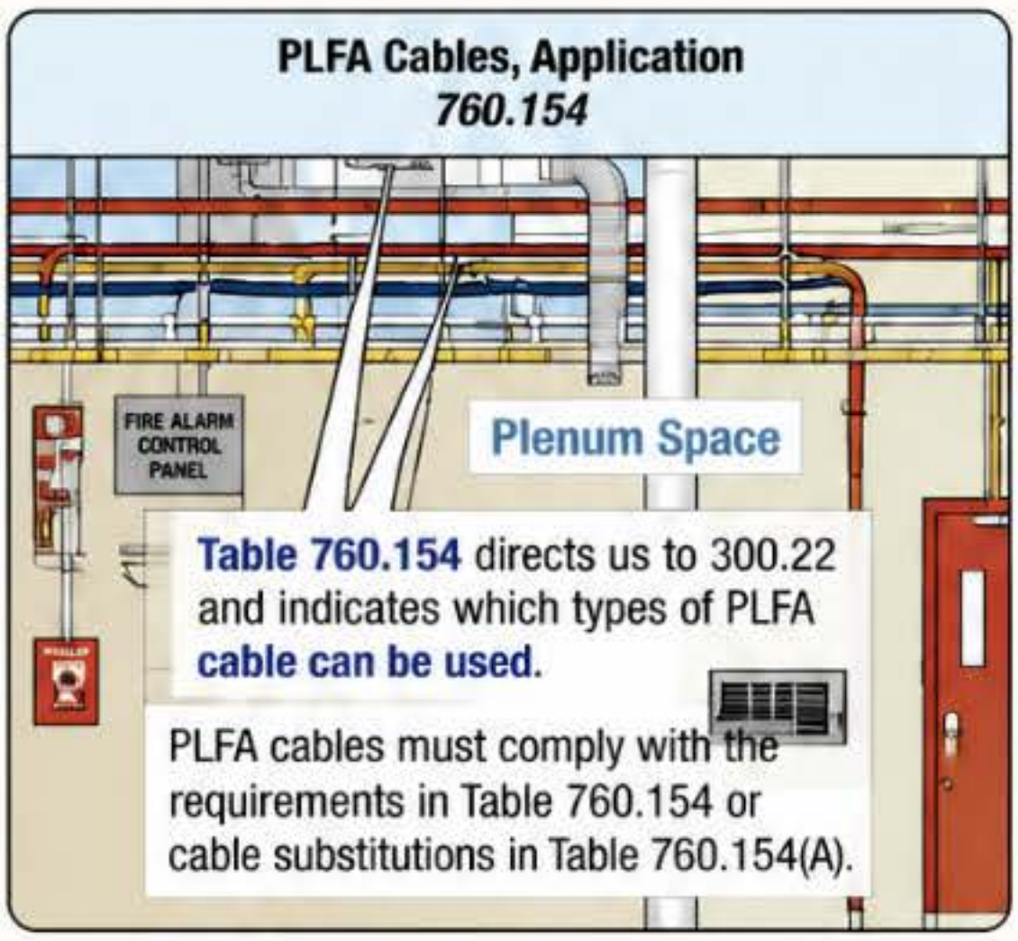


Figure 760–27

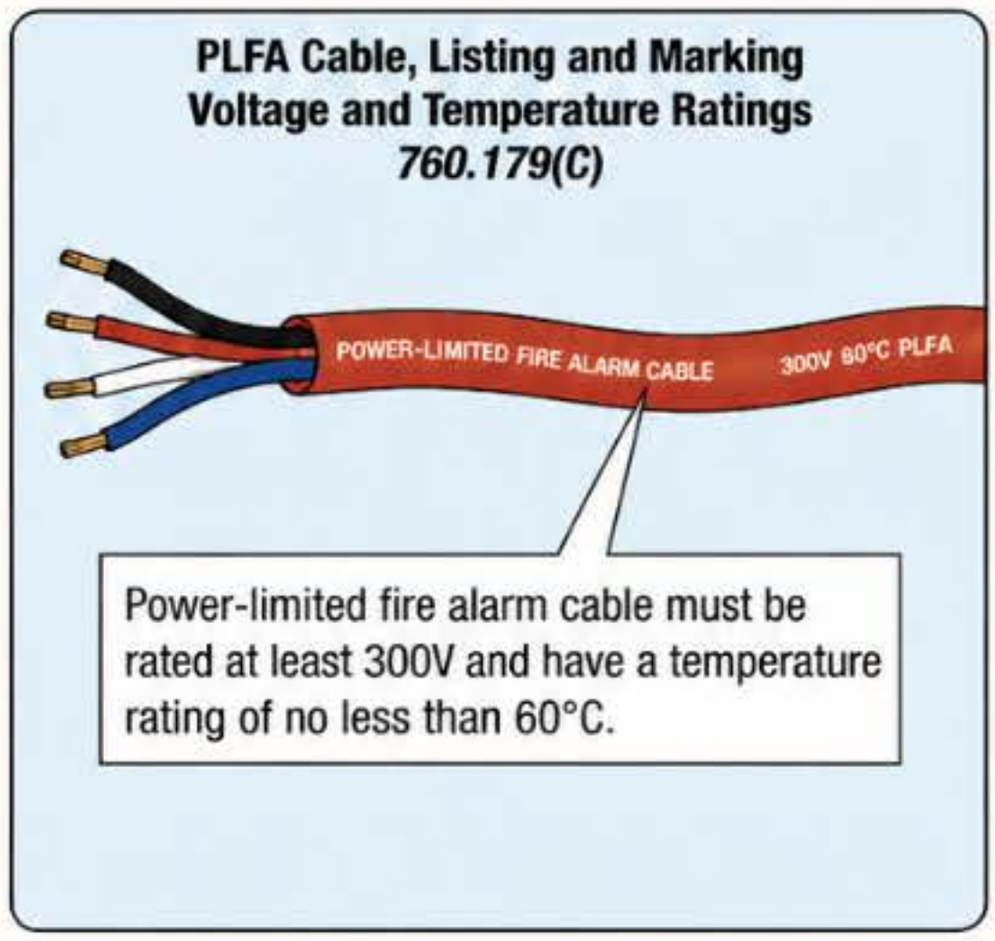
760.154 Applications of Power-Limited Fire Alarm Cables (PLFA)

PLFA cables must comply with the requirements in Table 760.154 or for cable substitutions in Table 760.154(A). ▸Figure 760–28

(A) Fire Alarm Cable Substitutions. Cable substitutions shown in Table 760.154(A) and in *NEC* Figure 760.154(A) *Cable Substitution Hierarchy* are permitted.



▸ Figure 760–28



▸ Figure 760–29

Part IV. Listing Requirements

760.179 Listing and Marking of Power-Limited Fire Alarm Cables (PLFA)

PLFA cables installed as wiring within buildings must be listed in accordance with 760.179(A) through (H) and be marked in accordance with 760.179(I). Cable in a wet location must be listed for use in wet locations or have a moisture-impervious metal sheath.

(C) Voltage and Temperature Ratings. Power-limited fire alarm cable must have a voltage rating of not less than 300V and have a temperature rating of not less than 60°C. ▸ **Figure 760–29**

(I) Marking. Cables must be marked in accordance with Table 760.179(I) and are listed in order of fire performance starting with best cable type.

Table 760.179(I) Cable Markings

Cable Marking	Type
FPLP	Power-limited fire alarm plenum cable
FPLR	Power-limited fire alarm riser cable
FPL	Power-limited fire alarm cable

Author's Commentary:

The voltage and temperature requirements help ensure the cable maintains its performance and integrity under fire alarm system operating conditions.

— Michael Hamilton

Author's Commentary:

Use the best-performing cable that meets your installation requirements. The table lists the acceptable markings from highest performance down.

— Michael Hamilton

ARTICLE 770 OPTICAL FIBER CABLES

Introduction to Article 770—Optical Fiber Cables

Article 770 sets out the rules for installing optical fiber cables and the related raceways that carry them. It also includes the requirements for composite cables, often called "hybrid" cables, which combine optical fibers with electrical conductors.

While most wiring methods you use are covered in Article 300, you turn to Article 770 for optical fiber cables—except in the rare stiuations referenced in Article 300 [770.3]. For example, 770.113 points to Article 300.22, which applies when installing fiber cables and raceways in ducts and plenum spaces.

Article 90 makes clear that the *NEC* is not a design guide or installation manual. Therefore, Article 770 does not address how well fiber systems perform. It doesn't explain how to calculate bend radii or how to install and test cables safely. If you don't read an optical fiber cable, even if you can't see any light coming through it, the light in those crrcuits is typically invisible but can still injure your eyes.

Author's Commentary:

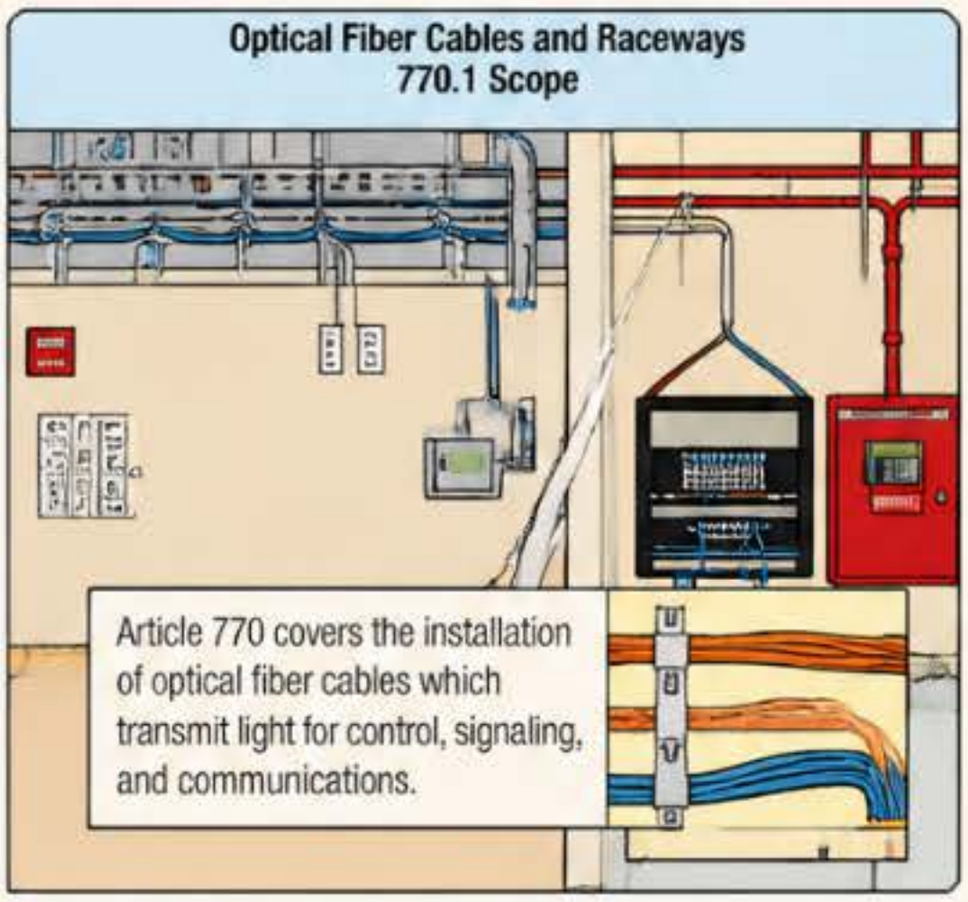
As optical fiber technology continues to advance, its role across many industries has expanded significantly. Because fiber cables are immune to electromagnetic interference, they are increasingly used to move voice, data, video, and automation signals in both communications and industrial control systems.

— Michael Hamilton

Part I. General

770.1 Scope

Article 770 covers the installation of optical fiber cables which transmit light for control, signaling, and communications. This article does not cover the construction of optical fiber cables. ▸Figure 770–1



▸Figure 770–1

Author's Commentary:

The growth of high-speed applications and the need for reliable data transfer have driven widespread adoption of optical fiber systems. Since fiber cables do not pick up electromagnetic noise, they support a large variety of uses in communications networks and in devices that process, manage, and control data in information systems, machines, and equipment.

— Michael Hamilton

770.2 Definitions

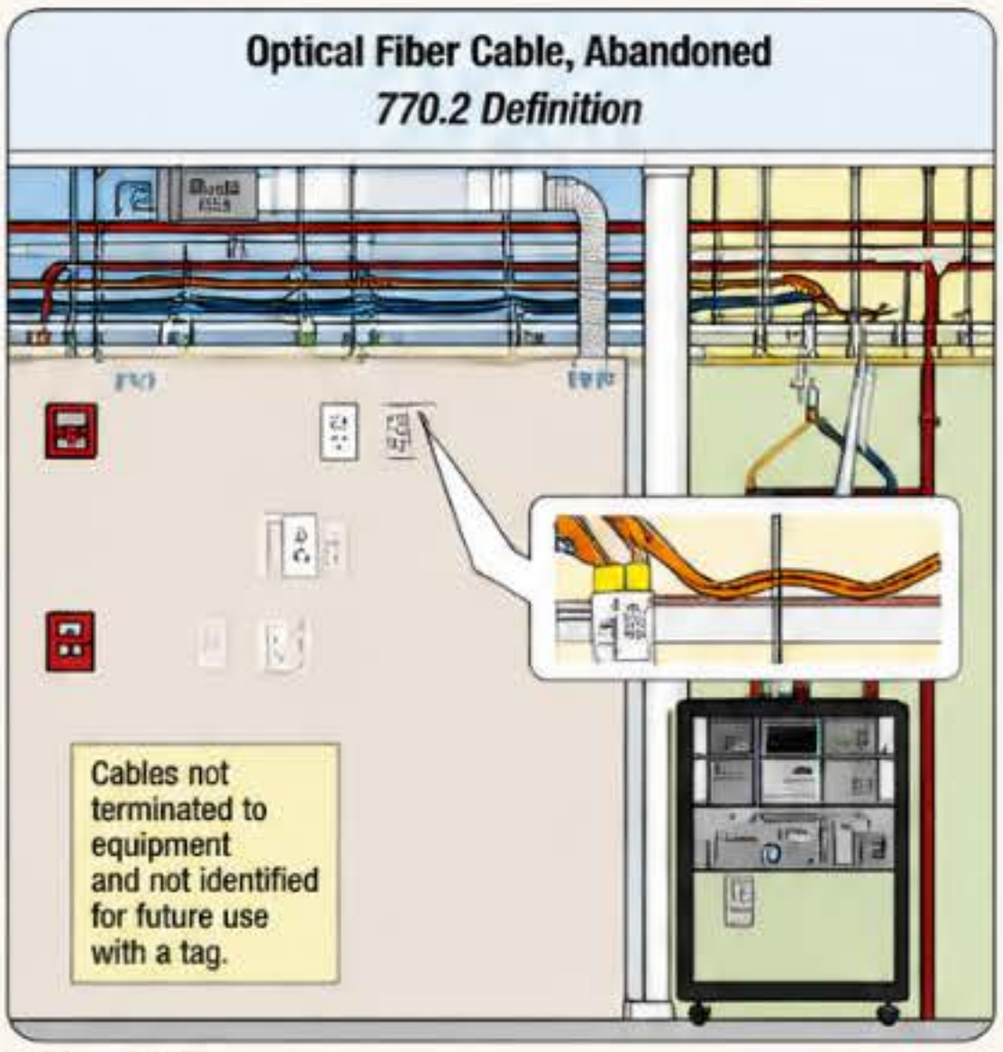
See Part 1 of Article 100 for common term definitions. The definitions in this section apply only to Article 770.

Abandoned Optical Fiber Cable. A cable that is not terminated to any equipment and is set aside for possible future use. ▸Figure 770–2

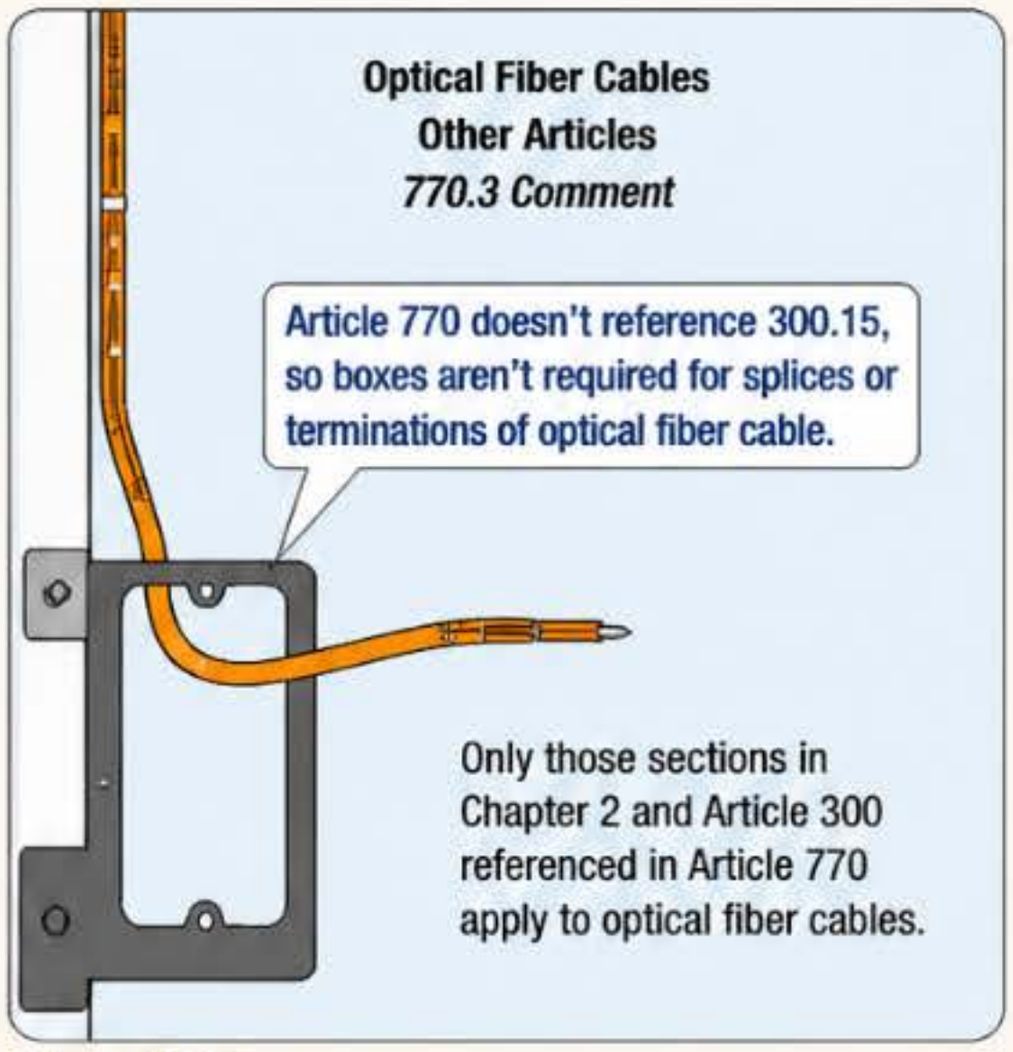
Author's Commentary:

Section 770.25 requires that any accessible portion of an abandoned cable must be taken out or removed.

— Michael Hamilton



▸ Figure 770-2



▸ Figure 770-3

Exposed (to Accidental Contact). A conductive optical fiber cable that, in the case of failure of supports or insulation, the cable's noncurrent-carrying conductive members can come into contact with an electrical circuit.

Author's Commentary:

Also see Article 100 for the definitions of "Cable, Optical Fiber," "Cable, Optical Fiber, Composite," "Cable, Optical Fiber, Conductive," "Cable, Optical Fiber, Nonconductive," and "Optical Fiber Cable."

— Michael Hamilton

770.3 Other Articles

Only those sections in Chapter 2 and Article 300 referenced in Article 770 apply to optical fiber cables.

Author's Commentary:

Article 770 does not reference 300.15, so boxes are not required for splices or terminations of optical fiber cable.

— Michael Hamilton

▸ Figure 770-3.

770.21 Access to Electrical Equipment Behind Panels Designed to Allow Access

Access to equipment is not permitted to be denied by an accumulation of optical fiber cables that prevents the removal of suspended-ceiling panels.

Author's Commentary:

Cables must be located so suspended-ceiling panels can be moved to provide access to electrical equipment.

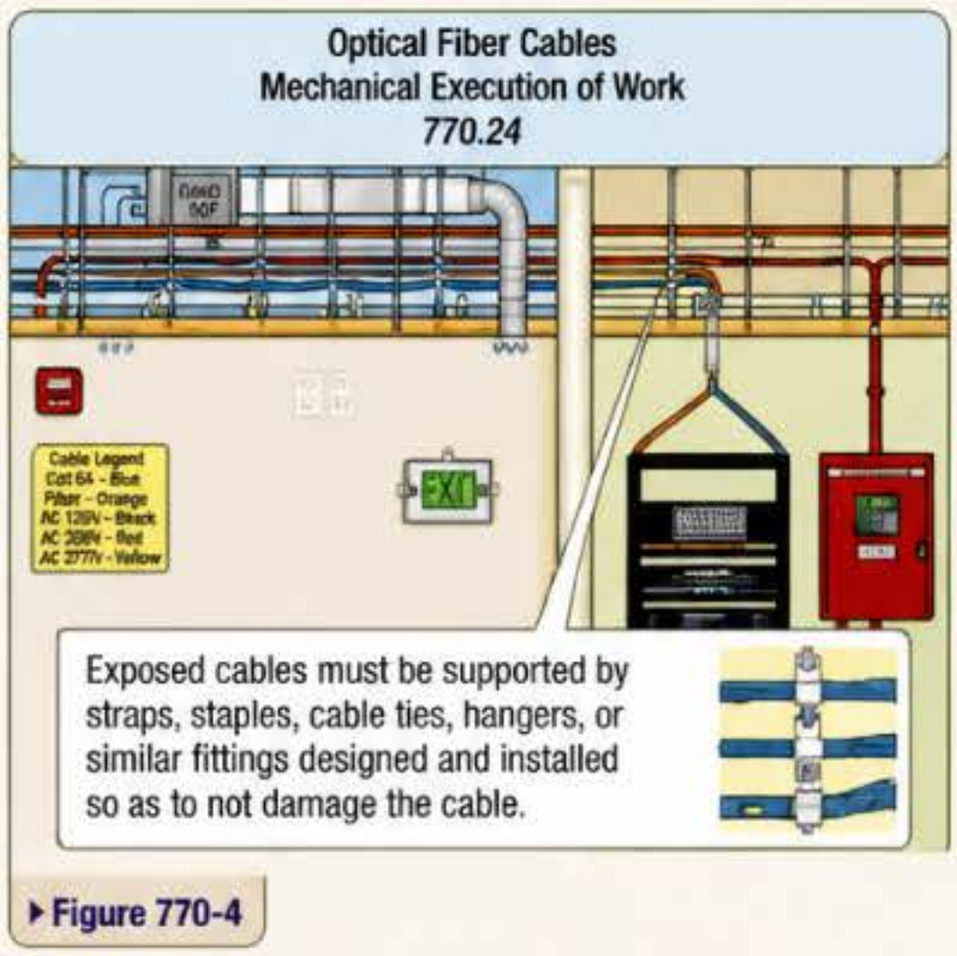
— Michael Hamilton

770.24 Mechanical Execution of Work

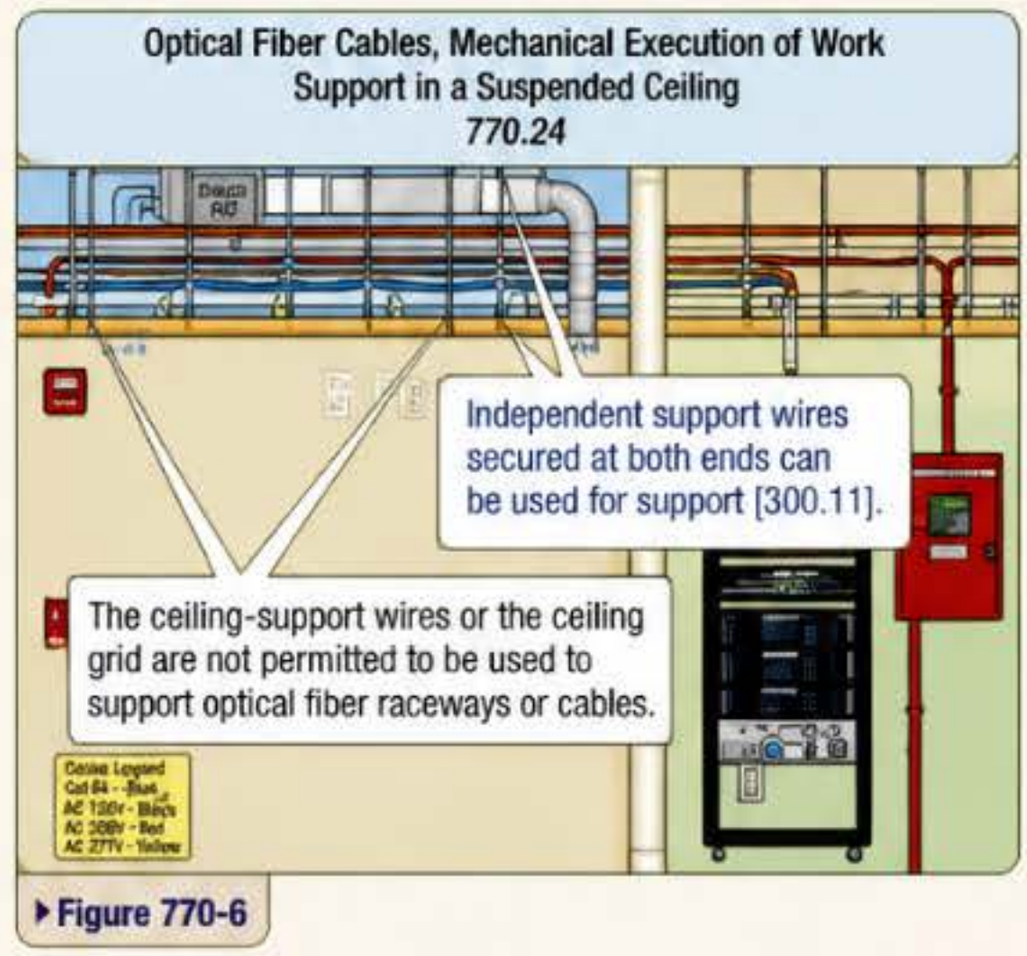
Equipment and cabling must be installed in a neat and workmanlike manner and comply with 300.4 and 300.11.

Exposed cables must be supported by the structural components of the building so the cable will not be damaged by normal building use. Support must be by straps, staples, hangers, cable ties, or similar fittings designed and installed in a manner that will not damage the cable. ▸ Figure 770-4.

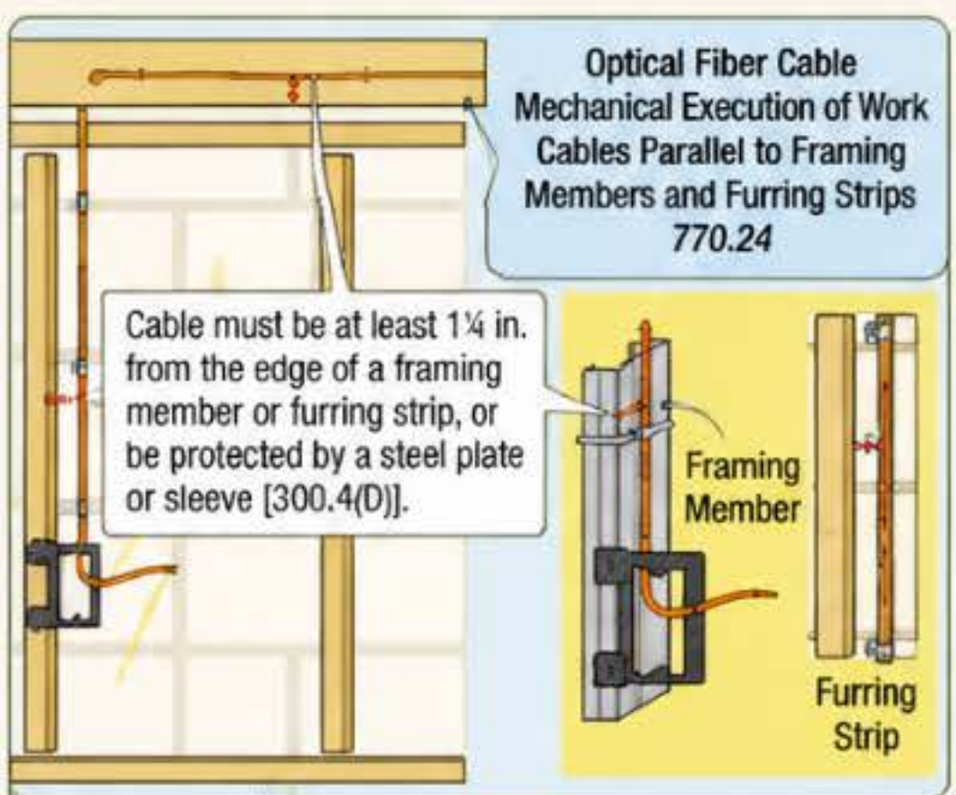
Cables installed through or parallel to framing members or furring strips must be protected where they are likely to be penetrated by nails or screws by installing the wiring method so it is not less than 1¼ in. from the nearest edge of the framing member or furring strips, or by protecting it with a ⅛ in. thick steel plate or equivalent [300.4(A)(1) and (D)]. ▸ Figure 770-5.



▸ Figure 770-4



▸ Figure 770-6



▸ Figure 770-5

Communications raceways and cable assemblies must be securely fastened in place. The ceiling-support wires or the ceiling grid are not permitted to be used to support optical fiber raceways or cables [300.11(B]. ▸Figure 770-6

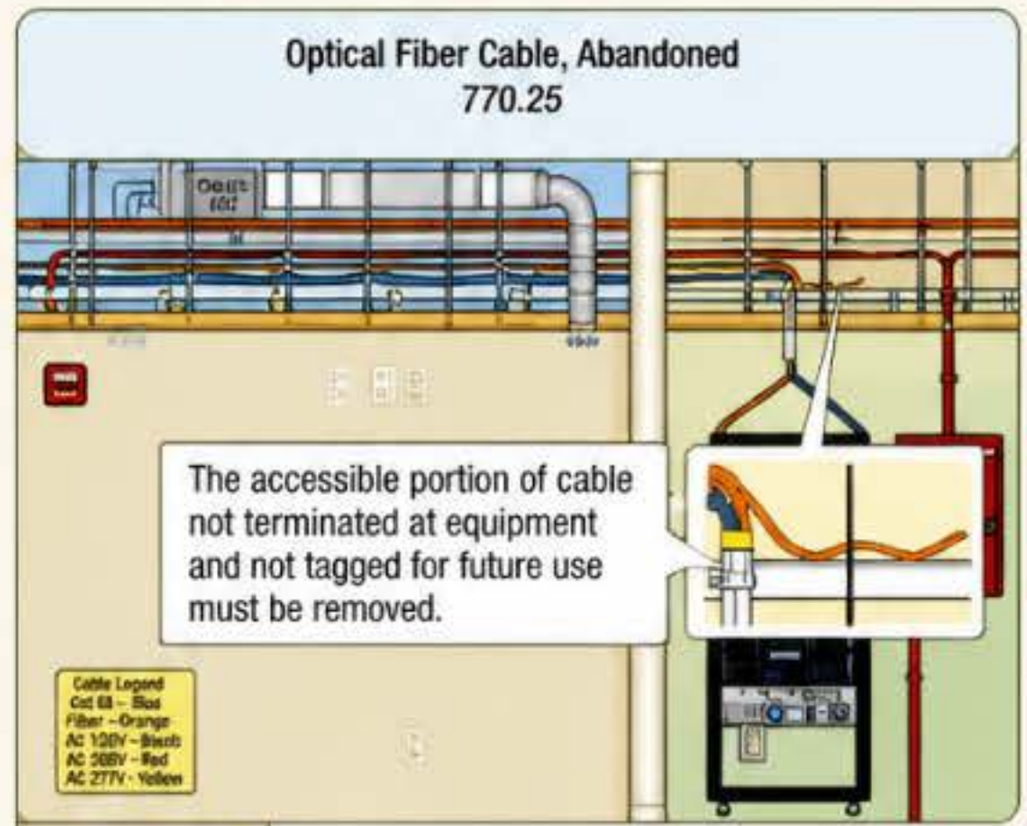
Cable ties used to secure or support optical fiber cables in plenums must be listed for use in a plenum space in accordance with 300.22(C).

Note 1: Industry practices are described in ANSI/NECA/FOA 301, *Standard for Installing and Testing Fiber Optic Cables*; ANSI/TIA-568.0-D, *Generic Telecommunications Cabling for Customer Premises*; and ANSI/TIA 568.3-D, *Optical Fiber Cabling and Components Standard.*

Note 3: Paint, plaster, cleaners, abrasives, corrosive residues, or other contaminants can result in an undetermined alteration of optical fiber cable properties.

770.25 Abandoned Cable

To limit the spread of fire or products of combustion within a building, the accessible portion of cable that is not terminated at equipment and not identified for future use with a tag must be removed [770.2]. ▸Figure 770-7



▸ Figure 770-7

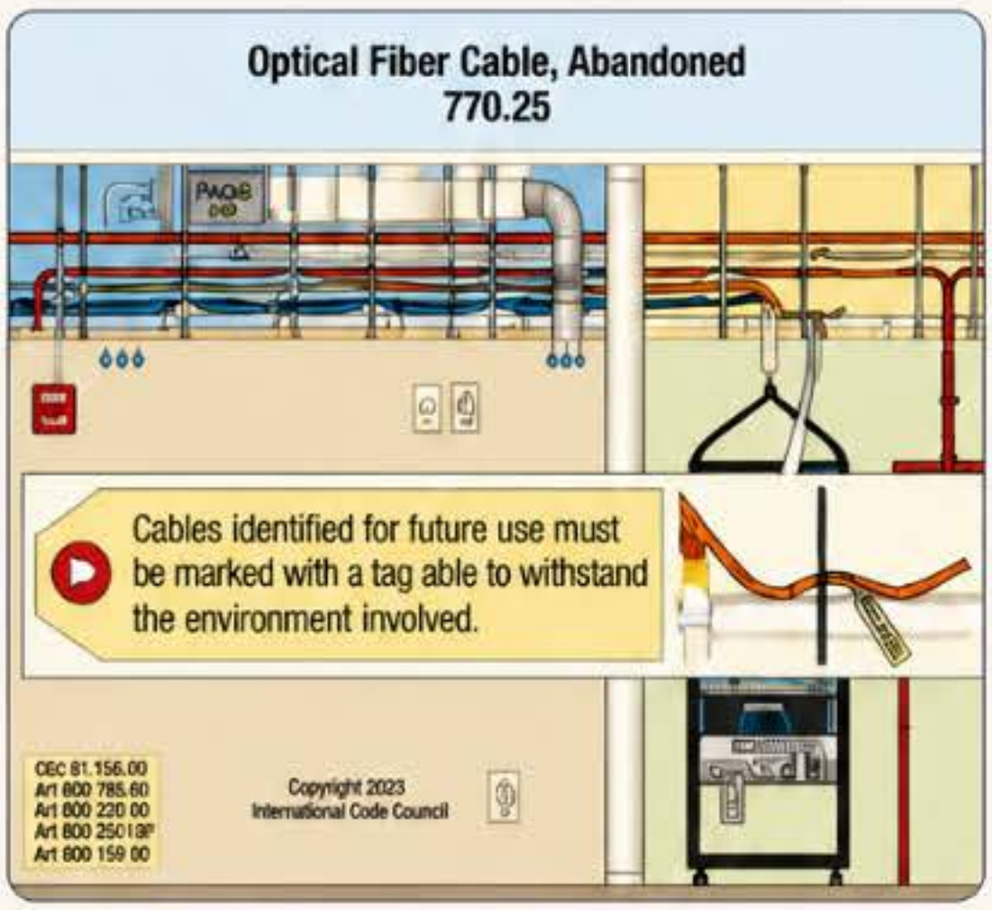
Tags identifying cables for future use must be able to withstand the environment involved. ▸Figure 770-8

Author's Commentary:

Cables installed in concealed raceways are not considered accessible; therefore, they are not required to be removed.

— Michael Hamilton

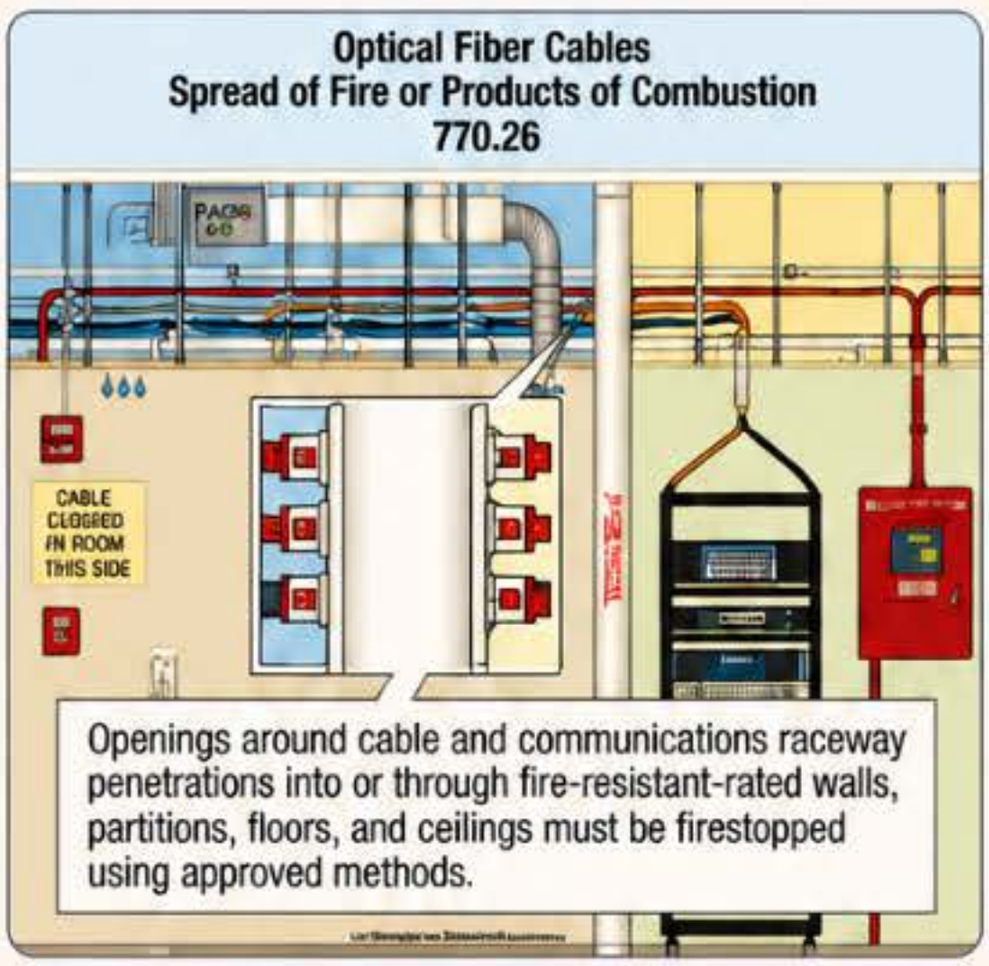
770.26 | Optical Fiber Cables



▶ Figure 770-8

770.26 Spread of Fire or Products of Combustion

Optical fiber cables and communications raceways must be installed in such a way that the spread of fire or products of combustion will not be substantially increased. Openings in fire-resistant-rated walls, floors, and ceilings for optical fiber cables and communications raceways must be firestopped using methods approved by the authority having jurisdiction to maintain the fire-resistance rating of the fire-resistive assembly. ▶ Figure 770-9



▶ Figure 770-9

Author's Commentary:

- Firestop material is listed for the specific types of wiring methods and construction structures.
- Visit International Firestop Council's website (www.firestop.org) for additional information on firestop system training complying with ASTM E2174, *Standard Practice for On-Site Inspection of Installed Firestops*, and ASTM E2393, *Standard Practice for On-Site Inspection of Installed Fire Resistive Joint Systems and Perimeter Fire Barriers.*

— ***Michael Hamilton***

Note: Directories of electrical construction materials published by qualified testing laboratories contain many listing installation restrictions necessary to maintain the fire-resistive rating of assembiles. Outlet boxes must have a horizontal separation of not less than 24 in. when installed on opposite sides in a fire-resistive assembly, unless an outlet box is listed for closer spacing or protected by fire-resistant "putty pads" in accordance with manufacturer's instructions.

Part V. Installation Methods Within Buildings

770.110 Raceways and Cable Routing Assemblies, and Cable Trays for Optical Fiber Cables

(A) Types of Raceways.

(1) Chapter 3 Raceways. Optical fiber cables can be installed in any Chapter 3 raceway that is installed in accordance with the requirements of Chapter 3.

(2) Communications Raceways. Optical fiber cables can be installed in listed communications raceways in accordance with Table 800.154(b). ▶ Figure 770-10

(B) Raceway Fill for Optical Fiber Cables.

(1) Without Electric Light or Power Conductors. If optical fiber cables are installed within a raceway without current-carrying conductors, the raceway fill tables of Chapters 3 and 9 do not apply.

(2) Nonconductive Optical Fiber Cables with Electric Light or Power Conductors. Where nonconductive optical fiber cables are installed with electric light or power conductors in a raceway, the raceway fill requirements of Chapters 3 and 9 apply.

OPTICAL FIBER CABLES

770.113

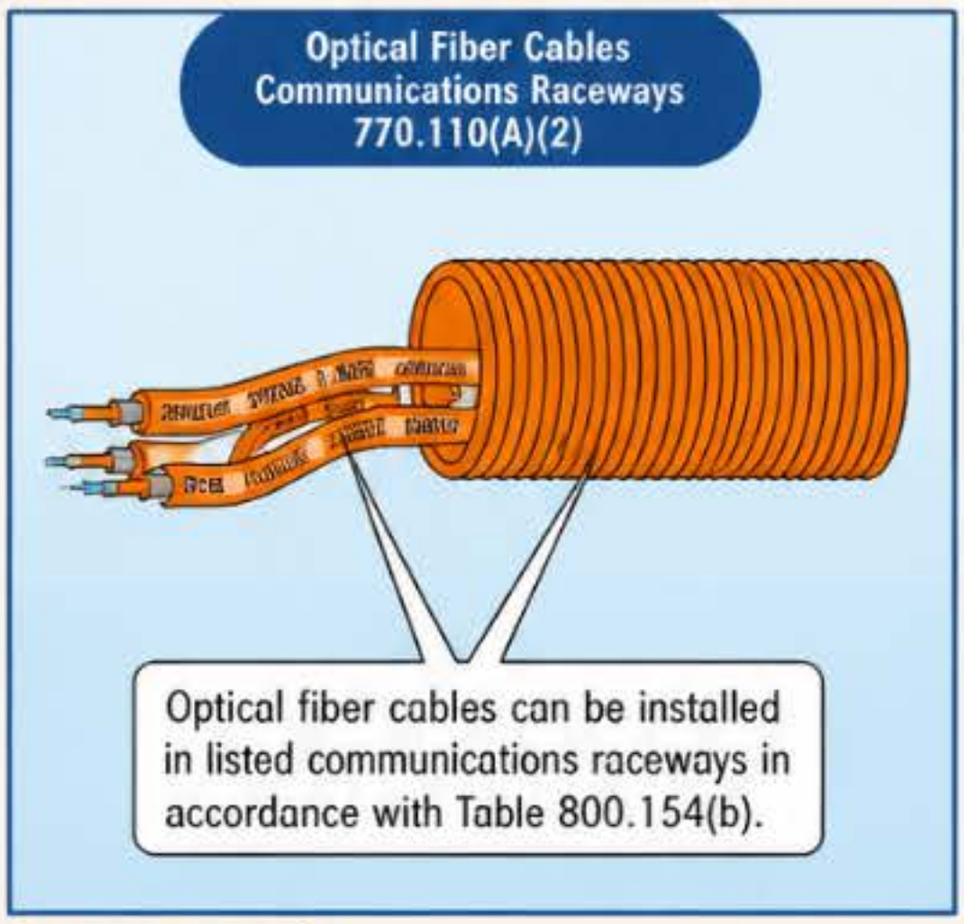


Figure 770-10

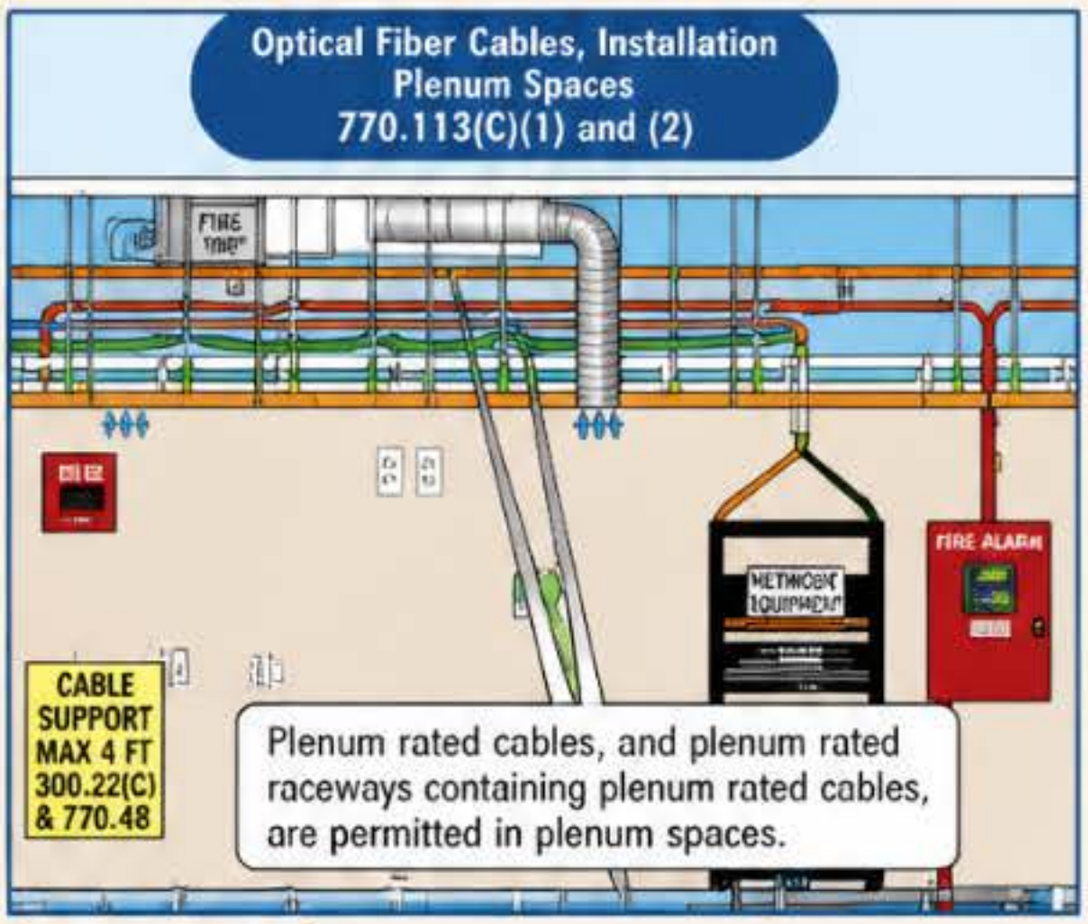


Figure 770-11

770.113 Installation of Optical Fiber Cables

(A) Listing. Optical fiber cables installed within buildings must be listed in accordance with 770.179 and installed within the limitations of the listing.

Example: Optical fiber cables installed in compliance with 770.48 are not required to be listed.

(B) Ducts Specifically Fabricated for Environmental Air Spaces. Plenum rated optical fiber cables are permitted to be installed within ducts specifically fabricated for environmental air spaces in accordance with 300.22(B) if the cable is directly associated with the air distribution system and complies with (1) and (2):

(1) The cable is plenum rated with a length up to four feet.

(2) The cable is installed within a metal raceway or plenum rated raceway in compliance with 300.22(B).

(C) Plenum Spaces. The following optical fiber cables are permitted in plenum spaces as described in 300.22(C): ▶**Figure 770-11**

(1) Plenum rated optical fiber cables.

(2) Plenum rated optical fiber cables installed in plenum rated communications raceways.

(3) Plenum rated optical fiber cables installed in plenum rated cable routing assemblies.

(4) Plenum optical fiber cables supported by open metal cable tray systems.

(5) Any type of optical fiber cables installed in metal raceways in accordance with 300.22(C).

(H) Cable Trays. The following cables can be installed in cable trays:

(1) Types OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN, and OFC cables.

(2) Types OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN, and OFC cables installed in:

a. Plenum communications raceways.

b. Riser communications raceways.

c. General-purpose communications raceways.

(J) Other Building Locations. The following cables are permitted in the spaces not described in 770.113(B) through (I):

(1) Types OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN, and OFC cables.

(2) Types OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN, and OFC cables installed in:

a. Plenum communications raceways.

b. Plenum cable routing assemblies.

c. Riser communications raceways.

d. Riser cable routing assemblies.

e. General-purpose communications raceways.

f. General-purpose cable routing assemblies.

(3) Types OFNP, OFCP, OFNR, OFCR, OFNG, OFCG, OFN, and OFC cables installed in a Chapter 3 type raceway.

770.114 Grounding

Nonconductive parts of optical fiber cables that do not carry current must be bonded to the facilities bonding termination of the system [250.94(A)].

770.133 Installation of Optical Fiber Cables and Electrical Conductors

(B) In Cabinets, Outlet Boxes, and Similar Enclosures. Optical fiber cables that are not intended to carry electricity cannot be placed in the same cabinet, outlet box, or similar enclosure that contains electric light, power, Class 1, nonpower-limited fire alarm, or medium-power network-powered broadband communications circuits unless one or more of the following situations apply:

1. The optical fiber cable is used only with electric light, power, Class 1, nonpower-limited fire alarm, or medium-power network-powered broadband communications circuits.
2. The conductors for electric light, power, Class 1, nonpower-limited fire alarm, Type ITC, or medium-power network-powered broadband communications circuits operate at 1,000 volts or less.
3. The optical fiber cable and the electrical terminations for electric light, power, Class 1, nonpower-limited fire alarm, or medium-power network-powered broadband communications circuits are installed in a factory- or field-assembled control center.
4. The optical fiber cable is installed in an industrial building where the conditions of maintenance and supervision ensure that only qualified persons perform the installation.

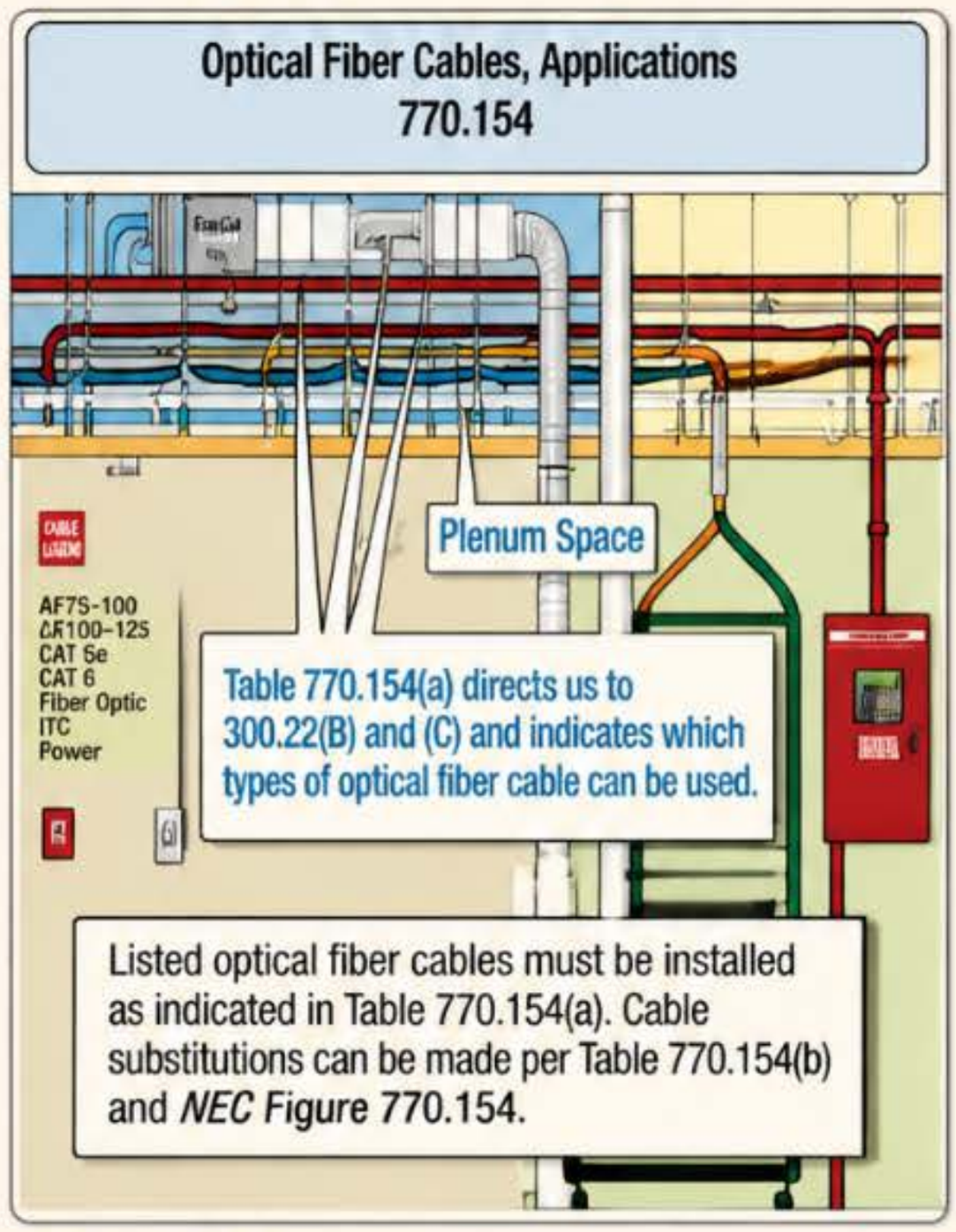
When optical fibers are within the same composite cable as electric light, power, Class 1, nonpower-limited fire alarm, or medium-power network-powered broadband communications conductors operating at 1,000 volts or less, installation is allowed only where the functions of the optical fibers and the electrical conductors are linked.

Optical fibers embedded in composite cables that include current-carrying conductors for electric light, power, or Class 1 circuits rated 1,000 volts or less may be placed in the same cabinet, cable tray, outlet box, panel, raceway, or other enclosure with conductors for electric light, power, or Class 1 circuits operating at 1,000 volts or less.

Composite optical fiber cables containing current-carrying conductors for electric light, power, or Class 1 circuits rated 1,000 volts or less are permitted to occupy the same cabinet, cable tray, outlet box, panel, raceway, or other enclosure with conductors for electric light, power, or Class 1 circuits in industrial buildings where upkeep and oversight conditions ensure that only qualified personnel perform the installation.

770.154 Applications of Listed Optical Fiber Cables

Listed optical fiber cables must be installed as indicated in Table 770.154(a), as limited by 770.110 and 770.113. Cable substitutions in accordance with Table 770.154(b) and *NEC* Figure 725.154 are permitted. ▶ **Figure 770–12**



▶ **Figure 770–12**

CHAPTER 7

PRACTICE QUESTIONS

Please use the 2023 *Code* book to answer the following questions.

CHAPTER 7—SPECIAL CONDITIONS

Article 700—Emergency Systems

1. Article ____ applies to the electrical safety of the installation, operation, and maintenance of emergency systems intended to supply, distribute, and control electricity for illumination, power, or both, to required facilities when the normal electrical supply or system is interrupted.
   (a) 500
   (b) 600
   (c) 700
   (d) 800

2. "Emergency systems" are those systems legally required and classed as emergency by a governmental agency having jurisdiction. These systems are intended to automatically supply illumination and/or power essential for ____.
   (a) community activity
   (b) safety to human life
   (c) public recreation
   (d) police and emergency services exclusively

3. Emergency systems are generally installed where artificial illumination is required for safe exiting and for panic control in buildings occupied by large numbers of persons, such as ____ and similar institutions.
   (a) hotels
   (b) theaters and sports arenas
   (c) health care facilities
   (d) all of these

4. Emergency systems may provide power for ventilation where essential to maintain life, fire detection and alarm systems, elevators, fire pumps, public safety communications systems, industrial processes where current interruption would produce serious ____.
   (a) production slowdowns
   (b) life safety or health hazards
   (c) equipment failure
   (d) structural damage

5. The ____ shall conduct or witness a test of the complete emergency system upon installation and periodically afterward.
   (a) electrical engineer
   (b) authority having jurisdiction
   (c) qualified person
   (d) manufacturer's representative

6. Emergency system equipment shall be maintained in accordance with ____.
   (a) the authority having jurisdiction
   (b) UL listing(s)
   (c) manufacturer instructions and industry standards
   (d) OSHA regulations

7. A written record shall be kept of required tests and maintenance on emergency systems.
   (a) True
   (b) False

Article 700 | Practice Questions

8. The emergency system equipment shall be suitable for the _____ current at its terminals.

(a) demand load
(b) available fault current
(c) peak-demand
(d) shaved-load

9. An emergency system shall have adequate _____ in accordance with Article 220 or by another approved method.

(a) lighting
(b) capacity
(c) water flow
(d) ambient temperature

10. For emergency systems, transfer equipment shall be _____ for emergency use and approved by the authority having jurisdiction.

(a) automatic
(b) listed
(c) marked
(d) all of these

11. Automatic transfer switches for emergency systems shall be _____.

(a) able to be remotely operated
(b) able to be locked in the "closed" position
(c) permitted to be reconditioned
(d) electrically operated and mechanically held

12. An emergency transfer switch for emergency systems shall supply only _____.

(a) emergency loads
(b) computer equipment
(c) UPS equipment
(d) all of these

13. Where used for emergency systems, the short-circuit current rating of the transfer equipment, based on the specific overcurrent protective device type and settings protecting the transfer equipment, shall be field marked on the _____ of the transfer equipment.

(a) exterior
(b) top
(c) interior
(d) underside

14. In locations containing an emergency system, a sign shall be placed at the service-entrance equipment indicating the type and location of each on-site emergency power source.

(a) True
(b) False

15. A listed surge protective device shall be installed in or on all emergency systems switchboards and panelboards.

(a) True
(b) False

16. Emergency circuits shall be permanently marked so they will be readily identified as a _____ of an emergency circuit or system.

(a) segment
(b) section
(c) component
(d) critical branch

17. Emergency circuits shall be permanently marked so they will be readily identified as a component of an emergency circuit or system and receptacles supplied from the emergency system shall have a(an) _____ color or marking on the receptacle cover plates or the receptacles.

(a) approved
(b) distinctive
(c) legible
(d) luminescent

18. Wiring from an emergency source or emergency source distribution overcurrent protection to emergency loads shall be kept entirely independent of all other wiring and equipment unless wiring _____.

(a) from the normal power source is located in transfer equipment enclosures
(b) is supplied from two sources in exit or emergency luminaires
(c) is from two sources in a listed load control relay supplying exit or emergency luminaires, or in a common junction box, attached to exit or emergency luminaires
(d) all of these

19. If power from an emergency source is used to feed critical emergency systems and other equipment, then which switchboard sections or switchgear sections—with or without a shared bus—or individual disconnects mounted in separate cabinets must be used to supply all other loads during an emergency?

(a) separate vertical
(b) separate horizontal
(c) combined vertical and horizontal
(d) identified

20. Connections from an emergency source to supply emergency and other (nonemergency) loads must be allowed in the common bus of separate switchboards or switchgear, in separate sections of the switchboard, or in individual enclosures. These enclosures may be fed through one feeder or several feeders, with or without _____.

(a) overcurrent protection at the source
(b) ground-fault protection at the source
(c) a current-limiting device at the source
(d) load-shavling monitoring

21. Emergency system circuit wiring arrangements should be planned and located as needed to reduce risks of complete failure due to _____.

(a) flooding
(b) fire
(c) icing
(d) all of these

22. When the normal feeder to a building or structure fails, emergency power must become available within _____ seconds.

(a) 5
(b) 10
(c) 30
(d) 60

23. Emergency equipment used in emergency systems should be _____ and placed to lower the possibility of total failure caused by flooding, fires, icing, and vandalism.

(a) approved
(b) listed
(c) installed
(d) designed

24. Emergency system equipment must be engineered and installed so it reduces hazards that could lead to total failure from _____ and vandalism.

(a) flooding
(b) fires
(c) icing
(d) all of these

25. The storage battery that powers emergency lighting and other life-safety systems must keep normal voltage within 87½ percent of its rated value for a minimum of _____ hour(s).

(a) 1
(b) 1½
(c) 2
(d) 2½

26. Emergency system equipment has to be on the same branch circuit that supplies the normal lighting in the area and is connected _____ any local switches.

(a) with
(b) ahead of
(c) after
(d) downstream of

27. In emergency systems, the only appliances and lamps that may get power are those supplied by _____.

(a) emergency lighting circuits
(b) multiwire branch circuits
(c) HID-rated circuit breakers
(d) only load-shadding circuits

28. Emergency lighting must be designed and installed so that if one individual luminaire, such as a lamp, burns out, the room remains at least somewhat lit.

(a) True
(b) False

29. A branch circuit that powers emergency lighting and power outlets may be part of a multiwire branch circuit.

(a) True
(d) False

Article 701 Practice Questions

30. Emergency system(s) overcurrent devices shall be selectively coordinated with all _____ overcurrent protective devices.

(a) supply-side
(b) load-side
(c) downstream
(d) reconditioned

Article 701—Legally Required Standby Systems

1. Article 701 applies to the electrical safety of the installation, operation, and maintenance of _____ intended to supply, distribute, and control electricity to required facilities for illumination or power, or both, when the normal electrical supply or system is interrupted.

(a) emergency systems
(b) legally required standby systems
(c) optional standby systems
(d) dwelling standby systems

2. A "legally required standby system" is intended to automatically supply power to _____ in the event of failure of the normal source.

(a) those systems classed as emergency systems
(b) selected loads
(c) critical branch circuits
(d) essential circuits

3. The _____ shall conduct or witness a test of the complete legally required standby system upon installation.

(a) electrical engineer
(b) authority having jurisdiction
(c) qualified person
(d) manufacturer's representative

4. Legally required standby systems shall be tested _____ on a schedule and in a manner approved by the authority having jurisdiction to ensure the systems are maintained in proper operating condition.

(a) monthly
(b) quarterly
(c) annually
(d) periodically

5. Legally required standby system equipment shall be maintained in accordance with _____.

(a) UL listing(s)
(b) local emergency services requirements
(c) manufacturer instructions and industry standards
(d) local jurisdictional requirements

6. A written record shall be kept of required tests and maintenance on legally required standby systems.

(a) True
(b) False

7. Legally required standby system equipment shall be suitable for _____ at its terminals.

(a) the available fault current
(b) the maximum overload current only
(c) the minimum fault current
(d) a one-hour rating

8. A legally required standby system shall have adequate capacity in accordance with Article _____ or by another approved method.

(a) 210
(b) 220
(c) 230
(d) 700

9. Transfer equipment for legally required standby systems, including automatic transfer switches, shall be _____.

(a) automatic
(b) listed and marked for standby use
(c) approved by the authority having jurisdiction
(d) all of these

10. Automatic transfer switches on legally required standby systems shall be electrically operated and _____ held.

(a) electrically
(b) mechanically
(c) gravity
(d) any of these

11. Where used for legally required standby systems, the short-circuit current rating of the transfer equipment, based on the specific overcurrent protective device type and settings protecting the transfer equipment, shall be field marked on the ____ of the transfer equipment.

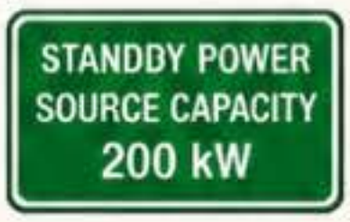
(a) exterior
(b) top
(c) interior
(d) underside

12. Audible and visual signal devices shall be provided, where practicable, for legally required standby systems to indicate ____.

(a) a malfunction of the emergency source
(b) that the emergency source is carrying load
(c) that the battery charger is not functioning
(d) all of these

13. A sign shall be placed at the service entrance indicating the ____ of each on-site legally required standby power source.

(a) capacity
(b) date of last testing
(c) manufacturer
(d) type and location

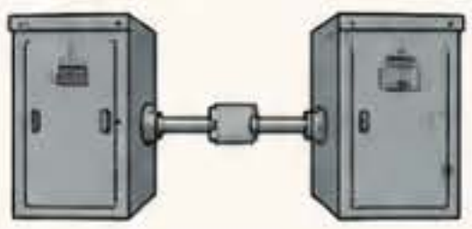


14. Legally required standby system wiring shall be permitted to occupy the same raceways, cables, boxes, and cabinets with other general wiring.

(a) True
(b) False

15. Where approved by the authority having jurisdiction, connections ahead of and not within the same cabinet, enclosure, vertical switchgear section, or vertical switchboard section as the service disconnecting means shall be permitted for ____ standby service.

(a) emergency
(b) legally required
(c) optional
(d) all of these



16. The branch-circuit overcurrent devices for legally required standby systems shall be accessible only to ____.

(a) the authority having jurisdiction
(b) authorized persons
(c) the general public
(d) qualified persons

17. Overcurrent devices for legally required standby systems shall be ____ with all supply-side overcurrent devices.

(a) series rated
(b) selectively coordinated
(c) installed in parallel
(d) labeled

Article 702—Optional Standby Systems

1. Optional standby systems are typically installed to provide an alternate source of power for ____.

(a) data processing and communication systems
(b) emergency systems for health care facilities
(c) emergency systems for hospitals
(d) emergency systems for fire houses

2. Where manual transfer equipment is used, an optional standby system shall have adequate ____ for the supply of all equipment intended to be operated at one time.

(a) ventilation
(b) supervision
(c) fuel supply
(d) capacity and rating

3. Where manual transfer equipment is used, an optional standby system shall have adequate capacity and rating for the supply of all ____.

(a) equipment intended to be operated at the same time
(b) equipment where life safety is dependent
(c) emergency and egress lighting
(d) fire and security systems

4. Where manual transfer equipment is used in an optional standby system, the ____ of the optional standby system shall be permitted to select the load connected to the system.

(a) installer
(b) designer
(c) user
(d) inspector

Article 702 | Practice Questions

5. Where automatic transfer equipment is used, an optional standby system shall be capable of supplying ____.

   (a) the full load that is transferred by the automatic transfer equipment
   (b) all equipment upon which life safety is dependent
   (c) all emergency and egress lighting
   (d) all fire and security systems

6. Where a load management system is employed that will automatically manage the connected load of an optional standby system, the standby source shall have a capacity sufficient to supply ____ load that will be connected by the load management system.

   (a) 80 percent of the
   (b) 115 percent of the
   (c) 125 percent of the
   (d) the maximum

7. Transfer equipment shall be required for all optional standby systems subject to the requirements of ____ and for which an electric utility supply is either the normal or standby source.

   (a) the authority having jurisdiction
   (b) Article 702
   (c) the equipment manufacturer
   (d) the owner of the facility

8. For optional standby systems, the temporary connection of a portable generator without transfer equipment shall be permitted where conditions of maintenance and supervision ensure that only qualified persons will service the installation, and where the normal supply is physically isolated by ____.

   (a) a lockable disconnecting means
   (b) the disconnection of the normal supply conductors
   (c) an extended power outage
   (d) a lockable disconnecting means, or the disconnection of the normal supply conductors

9. Optional standby system transfer switches installed between the ____ and the meter enclosure shall be listed meter-mounted transfer switches.

   (a) service connection point
   (b) utility meter
   (c) utility transformer
   (d) cold sequence disconnect

10. Meter-mounted transfer switches shall be of the ____ type unless rated as determined by 702.4(B)(2).

    (a) automatic
    (b) manual
    (c) monitoring
    (d) remote

11. Where used for optional standby systems in other than dwelling units, the short-circuit current rating of the transfer equipment, based on the specific overcurrent protective device type and settings protecting the transfer equipment, shall be field marked on the ____ of the transfer equipment.

    (a) exterior
    (b) top
    (c) interior
    (d) underside

12. Optional standby system transfer equipment shall be suitable for the intended use and shall be ____ so as to prevent the inadvertent interconnection of all sources of supply in any operation of the transfer equipment.

    (a) listed
    (b) designed
    (c) installed
    (d) all of these

13. Optional standby system transfer equipment and electric power production systems installed to permit operation in parallel with the ____ shall also meet the requirements of Article 705.

    (a) PV system
    (b) generator
    (c) normal source
    (d) battery storage system

14. Audible and visual signal devices shall be provided, where practicable, for optional standby systems to indicate a malfunction of the emergency power source and ____.

    (a) that the emergency source is carrying load
    (b) that the battery charger is not functioning
    (c) a ground fault has occurred
    (d) all of these

ARTICLE 705—INTERCONNECTED ELECTRIC POWER PRODUCTION SOURCES

15. A sign shall be placed at the service-entrance equipment for commercial and industrial installations indicating the _____ of each on-site optional standby power source.

(a) type
(b) date of installation
(c) date of last testing
(d) type and location

16. For _____, a sign shall be placed at the disconnecting means required in 230.85 that indicates the location of each permanently installed on-site optional standby power source disconnector or means to shut down the prime mover as required in 445.18(D).

(a) schools
(b) hospitals
(c) hotels
(d) one- and two-family dwellings

17. For one- and two-family dwellings, a sign shall be placed at the disconnecting means required in 230.85 that indicates the location of each permanently installed on-site optional standby power source disconnector or means to shut down the _____ as required in 445.18(D).

(a) prime mover
(b) utility supply
(c) secondary source
(d) primary source

Article 705—Interconnected Electric Power Production Sources

1. Article 705 covers installations of one or more electric power production sources operating in parallel with a _____ source(s) of electricity.

(a) secondary
(b) alternate
(c) primary
(d) stand-alone

2. The definitions in Article 705 shall apply only within Article 705.

(a) True
(b) False

3. In accordance with Article 705, a premises wiring system that has generation, energy storage, and load(s), or any combination thereof, that includes the ability to disconnect from and parallel with the primary source is known as a "_____ system."

(a) tandem
(b) primary
(c) microgrid
(d) dual function

4. Interactive equipment intended to operate in parallel with electric power production sources shall be listed for interactive function or be _____ for interactive function and have a field label applied, or both.

(a) tested
(b) evaluated
(c) approved
(d) licensed

5. For interconnected power production source(s), installation of one or more electrical power production sources operating in parallel with a primary source(s) of electricity shall be performed only by _____.

(a) qualified persons
(b) utility company persons
(c) the authority having jurisdiction
(d) utility company persons or the authority having jurisdiction

6. Interconnected power production installations with multiple co-located power production sources shall be permitted to be identified as a group(s).

(a) True
(b) False

7. Interconnected power production source(s) are permitted to be connected to the supply side of the service disconnecting means when in compliance with 705.11.

(a) True
(b) False

Article 705 Practice Questions

8. To determine the rating of the overcurrent device protecting the supply-side connected, interconnected power production source(s), total the continuous current output ratings of all interconnected power sources providing service. That total must not be greater than the ampacity of the _____.

(a) service conductors
(b) power production source output current
(c) service disconnect rating
(d) sum of all overcurrent protective devices

9. When supply-side power source output circuit conductors leave a building, they must be shielded by overcurrent devices in a(n) _____ outside the structure or at a location that can be reached without entering the building, where the power source conductors enter.

(a) location
(b) readily accessible location
(c) accessible location
(d) secured location

10. Supply-side connected, interconnected power production source(s) must have all metal raceways and metal parts linked with the supply-side source output conductors in accordance with 250.92(B) by being _____.

(a) bonded
(b) grounded
(c) bonded and grounded
(d) bonded or grounded

11. The grounding terminal or bus for the supply-side disconnecting means must be connected to a(n) _____ sized in accordance with 250.102, based on the conductor size in 705.11(B).

(a) supply-side bonding jumper
(b) equipment grounding conductor
(c) grounded service conductor
(d) grounding electrode

12. Supply-side connected, interconnected power production source(s) equipment requires a grounded conductor. A connection must be made between the supply-side bonding jumper and the grounded conductor at the supply-side disconnecting means in accordance with 705.11(F).

(a) True
(b) False

13. For supply-side connected, interconnected power production source(s), connections from power source output circuit conductors to service conductors must use connectors described in 110.14 and comply with all enclosure fill requirements.

(a) listed
(b) marked
(c) identified
(d) all of these

14. Interconnected power production source(s) may be connected to the load side of the service disconnecting means at any distribution equipment on the premises.

(a) True
(b) False

15. Where an interconnected power source connection is made to a feeder, the feeder must have an ampacity _____ percent of the power source output circuit current.

(a) equal to 125
(b) greater than 125
(c) not greater than 125
(d) equal to 125 percent of the power source output circuit current, or greater than 125

16. Interconnected power production source output connections are made at feeders. All taps must be sized on the basis of the sum of _____ percent of all power source output circuit current(s) and the rating of the overcurrent device protecting the feeder conductors for sizing tap conductors using the calculations in 240.21(B).

(a) 100
(b) 115
(c) 125
(d) 175

Author's Commentary: *Article 705 keeps power production systems safe by setting rules for sizing, grounding, bonding, and protecting the conductors that connect to the supply side of the service. Know these details well to ensure that installations are code compliant and remain safe for everyone.*

— Michael Hamilton

17. A group of interconnected power production sources is connected to output buses. Two feeding sources are used—one primary (main) power source and one additional (secondary) source. The secondary source is positioned at the far side of a busbar that has connected loads. The combined current from all sources feeding the output circuit may not be greater than 125% of the busbar's ampacity.
What percentage of the busbar ampacity is the maximum allowed for that overcurrent device?

(a) 110
(b) 120
(c) 125
(d) 150

18. Several interconnected power production sources are tied to output buses. A primary source and a secondary source feed at the opposite ends of a busbar that has connected loads. The sum of the ampacity ratings of all overcurrent devices on panelboards, load banks, and supply equipment fed from that busbar may not exceed what percentage of the busbar's ampacity?

(a) 80
(b) 100
(c) 120
(d) 125

19. Multiple sources feed either end of a center-fed panelboard located in a building. The main power source provides 125% of the output circuit current. The total rating of the overcurrent device protecting the busbar must not be greater than what percentage of the current rating of the busbar?

(a) 110
(b) 115
(c) 120
(d) 125

20. Interconnected power production sources are connected to circuit breakers that are not designated as "line" or "load." Under these conditions, is the circuit breaker considered acceptable for backfeed?

(a) True
(b) False

21. When interconnected power production sources are connected to circuit breakers labeled "line" and "load," is the circuit breaker appropriate for backfeed if it is specifically designed for that purpose?

(a) not marked
(b) marked
(c) identified as
(d) listed for

22. Plug-in style circuit breakers intended for interconnected power production sources that are listed and designated as _____ do not require a mounting fastener as required by 408.36(D).

(a) interactive
(b) active
(c) reactive
(d) interactive or active

23. Per Article 705 of the 2023 NEC, the total of all interconnected power production system-controlled currents plus all monitored currents from other sources of supply must not be more than _____ percent of the ampacity of any busbar or conductor fed by the power production sources.

(a) 100
(b) 115
(c) 125
(d) 150

24. According to Article 705 of the 2023 NEC, the contribution of _____ currents from all interconnected power production source(s) must not exceed the interrupting and short-circuit current ratings of equipment in interactive systems.

(a) demand
(b) load
(c) monitored
(d) limited

25. A means must be provided to isolate power source output circuit conductors of interconnected electrical power production equipment from conductors of other systems. The disconnecting means must be a _____.

(a) manually operable switch or circuit breaker
(b) load-break-rated pull-out switch
(c) device listed or approved for the intended application
(d) any of these

Author's Commentary:

These questions focus on the limits and requirements for interconnected power production systems—busbar loading, breaker suitability, source contributions, and disconnecting means per Article 705.

— Michael Hamilton

Article 705 Practice Questions

26. All raceway and cable wiring methods included in Chapter _____ of this *Code* and other wiring systems and fittings specifically listed, intended, and identified for use with interconnected electric power production systems and equipment shall be permitted.

(a) 1
(b) 2
(c) 3
(d) 4

27. Circuit conductors for interconnected power production systems shall _____.

(a) be sized to carry the maximum currents in 705.28(A) multiplied by 125 percent without adjustment or correction factors
(b) be sized to carry the maximum currents in 705.28(A) with adjustment and correction factors
(c) where connected to feeders if smaller than the feeder conductors (feeder tap), the conductor ampacity shall be calculated in accordance with 240.21(B) based on the overcurrent device protecting the feeder
(d) all of these

28. Neutral conductors for interconnected power production systems used solely for instrumentation, voltage detection, or phase detection can be sized in accordance with _____.

(a) 250.66
(b) 250.102
(c) 250.122
(d) 310.16

29. In accordance with Article 705, transformers with power sources on each side (primary and secondary) of the transformer shall be provided with primary overcurrent protection in accordance with 450.3. The primary shall be the side of the transformer connected to the largest source of _____ current.

(a) available fault
(b) short-circuit
(c) output power source
(d) available fault current or short-circuit

Author's Commentary:
Article 705 focuses on safe and reliable interconnection of distributed energy resources. These questions highlight key requirements for wiring methods, conductor sizing, neutral conductors, transformer protection, risk considerations, reconnection procedures, voltage limits, and microgrid operation.

— Michael Hamilton

30. For interconnected power production systems, risks to personnel and equipment associated with the _____ could occur if an interactive electric power production source can operate as an intentional island.

(a) primary source of power
(b) power production system
(c) primary source of power or power production system
(d) possibility of a lightning strike

31. For interconnected power production systems, when the primary source supply system is restored, special detection methods are typically required to limit exposure of power production sources to _____ reconnection.

(a) out-of-phase
(b) primary power
(c) secondary power
(d) utility

32. For interconnected power production systems, single-phase power sources in interactive systems shall be connected to three-phase power systems in order to limit unbalanced voltages at the point of interconnection to not more than _____ percent.

(a) 2
(b) 3
(c) 5
(d) 10

33. In accordance with Article 705, microgrid systems shall be permitted to disconnect from the primary source of power or other interconnected power production source(s) and operate as an isolated microgrid system operating in _____ mode.

(a) isolated
(b) island
(c) standby
(d) shutdown

34. In accordance with Article 705, microgrid interconnect devices shall _____.

(a) be required for any connection between a microgrid system and a primary power source
(b) be listed or field labeled for the application
(c) have a sufficient number of overcurrent devices located to provide protection from all sources
(d) all of these

Article 706—Energy Storage Systems

1. Energy storage systems are devices that can either modify current levels through conversion, or shift energy from one form—such as direct current—to another, such as alternating current.
   (a) True
   (b) False

2. A means of isolation must be provided for every source derived from an energy storage system (ESS).
   (a) branch circuits
   (b) phase conductors
   (c) supply circuits
   (d) combiners

3. The energy storage technology must include adequate measures for air movement and gas management to minimize the buildup of any gas that could be produced (if present). This is to help prevent the accumulation of _____.
   (a) noxious gases
   (b) toxic gases
   (c) an explosive mixture
   (d) fumes

4. Energy storage systems serving one- or two-family dwellings are not allowed to produce a direct-current voltage above _____ between conductors or between a conductor and ground.
   (a) 100V
   (b) 120V
   (c) 240V
   (d) 300V

Article 710—Stand-Alone Systems

1. Article 710 addresses electric power production systems that operate in _____ mode and whose installations are not connected to any electric power production and distribution network.
   (a) island
   (b) standby
   (c) tandem
   (d) generating

2. Stand-alone systems are capable of operating in _____ with other power sources.
   (a) island mode, independent from the electric utility
   (b) isolated microgrid systems
   (c) interactive mode
   (d) all of these

3. All stand-alone system equipment must be approved for the intended use by being _____.
   (a) listed for the application
   (b) evaluated for the application and having a field label applied
   (c) listed for the application, or being evaluated for the application and having a field label applied
   (d) listed for the application, and being evaluated for the application and having a field label applied

4. A permanent _____ must be installed at any building supplied by a stand-alone system at each service equipment location or at an approved, easily visible location. This _____ identifies where each power source that connects to the building or other onsite sources is located.
   (a) plaque
   (b) directory
   (c) marking
   (d) plaque or directory

5. For stand-alone systems with multiple supply sources to the building, the plaque or directory must _____.
   (a) be marked with the wording "CAUTION: MULTIPLE SOURCES OF POWER"
   (b) have the marking permanently affixed
   (c) have markings with sufficient durability to withstand the environment involved
   (d) all of these

6. The output from stand-alone or isolated microgrid power sources that feed wiring systems on the premises may be allowed to have less capacity than the calculated load.
   (a) True
   (b) False

7. What is the total available output capacity from all independent supplies of the stand-alone system? It must be _____ the load set by the largest single piece of utilization equipment tied to that system.

(a) less than
(b) the lowest demand load on
(c) equal to or greater than
(d) the highest demand on

8. To determine the stand-alone system capacity for general-use loads, use the total capacity from the company's sources, such as _____.

(a) generators
(b) energy storage system inverters
(c) generators and energy storage system inverters
(d) PV combiners

9. Circuit conductors that connect a stand-alone source to a building or structure disconnecting means must be sized and protected based on the combined output ratings of the stand-alone source(s).

(a) True
(b) False

10. Stand-alone and isolated microgrid systems may supply 120V single-phase, 3-wire, 120/240V service to distribution panels when there are no 240V outlets and no multiwire circuits.

(a) True
(b) False

11. Stand-alone systems require either energy storage or backup power supplies.

(a) True
(b) False

12. Plug-in type backfed circuit breakers used in stand-alone systems and connected to an interconnected supply must be installed per 408.36(D).

(a) True
(b) False

Article 725—Remote-Control, Signaling, and Power-Limited Circuits

1. Article 725 covers _____ circuits that are not an integral part of a device or of utilization equipment.

(a) remote-control
(b) signaling
(c) power-limited
(d) all of these

2. Class 2, Class 3, and PLTC cable that is not terminated at equipment and not identified for future use with a tag is considered _____.

(a) reconditioned
(b) abandoned
(c) demolished
(d) reusable

3. Class 1, 2, and 3 circuits installed through fire-resistant-rated walls, partitions, floors, or ceilings shall be firestopped to limit the possible spread of fire or products of combustion.

(a) True
(b) False

4. If remote-control, signaling, and power-limited circuits are installed in a raceway that is subjected to different temperatures, and where condensation is known to be a problem, the raceway shall be filled with an approved material that will prevent the circulation of warm air to a colder section of the raceway. An explosionproof seal _____.

(a) is required for this purpose
(b) that has been proven effective for this purpose is not required
(c) is not required for this purpose
(d) is the only method of doing this

5. When a raceway is used for the support or protection of cables for remote-control, signaling, and power-limited circuits, a bushing to reduce the potential for abrasion shall be placed at the location the cables emerge from the raceway.

(a) True
(b) False

6. Class 2, Class 3, and Type PLTC cables may be installed in plenums, in riser cable-routing assemblies, in general-purpose cable-routing assemblies, and for other general applications when _____.

(a) selected in accordance with Table 800.154(C)
(b) listed in accordance with the provisions of 800.182
(c) installed in accordance with 800.110(D) and 800.113
(d) all of these

7. Class 2, Class 3, and Type PLTC cables are permitted to be installed in plenum communications raceways, riser communications raceways, and general-purpose communications raceways when _____, where the requirements that apply to electrical nonmetallic tubing (ENT) are met.

(a) selected in accordance with the provisions of Table 800.154(B)
(b) listed in accordance with 800.182
(c) installed in accordance with 800.113 and 362.24 through 362.56
(d) all of these

8. The temperature limitations for conductors, as specified in 310.14(A)(3), apply to Class 1, Class 2, and Class 3 cables.

(a) True
(b) False

9. Class 1, Class 2, and Class 3 cables' _____ conductors must be identified in accordance with 250.119.

(a) ungrounded
(b) grounded
(c) equipment grounding
(d) shielded

10. Access to electrical equipment may not be denied by excessive bundles of remote-control, signaling, or power-limited wiring and cables that would prevent removal of panels, including suspended-ceiling panels.

(a) True
(b) False

Author's Commentary:

Always create pathways for maintenance and service. Crowded wiring that blocks panel or ceiling access can lead to code violations and complicate future work.

— Michael Hamilton

11. Class 1, Class 2, and Class 3 circuits installed _____ on the surface of ceilings and walls must be supported by the structure so that the cable will not be damaged by normal building use.

(a) exposed
(b) concealed
(c) hidden
(d) in raceways

12. Exposed Class 1, Class 2, and Class 3 cables shall be supported by straps, staples, hangers, or similar fittings designed and installed so as not to damage the cable.

(a) True
(b) False

13. _____ or other contaminants can result in an undetermined alteration of Class 1, 2, and 3 cable properties.

(a) Paint and plaster
(b) Cleaners and abrasives
(c) Corrosive residues
(d) all of these

14. Accessible portions of abandoned Class 2 and Class 3 cables shall be removed.

(a) True
(b) False

15. Class 2 cables set aside for future use shall be marked with a tag of sufficient durability to withstand _____.

(a) moisture
(b) humidity
(c) the environment involved
(d) temperature fluctuations

16. Remote-control circuits for safety-control equipment must be classified as _____ if failure of the equipment to operate introduces a direct fire or life hazard.

(a) Class 1
(b) Class 2
(c) Class 3
(d) Class I, Division 1

Article 725 | Practice Questions

17. Class 1 circuits are reserved for power-limited applications. They must be supplied from a source whose rated output does not exceed _____ or 1,000 VA.
    (a) 12V
    (b) 24V
    (c) 30V
    (d) 50V

18. Class 1 circuits include remote-control and signaling systems used for remote operation or communication. Their purpose must not go beyond _____.
    (a) 30V
    (b) 125V
    (c) 250V
    (d) 600V

19. Class 1 circuits must be installed in accordance with Part I of Article 300. They are exempt from the wiring methods described in Chapter 3.
    (a) True
    (b) False

20. Class 1 circuits and the circuits that feed equipment may share the same cable, enclosure, or raceway without a barrier _____.
    (a) when the equipment's power is tied to its operation
    (b) where the circuits involved are not a combination of ac and dc
    (c) under no circumstances
    (d) only where the equipment is essential for life safety

21. Class 1 circuits may be installed in the same raceway as conductors of _____ and medium power network-powered broadband communications circuits, provided a barrier separates them.
    (a) electric light
    (b) power
    (c) nonpower-limited fire alarm
    (d) all of these

22. The source of power for a Class 2 circuit shall be _____.
    (a) a listed Class 2 transformer
    (b) a listed Class 2 power supply
    (c) other listed equipment identified to indicate the Class 2 power source
    (d) any of these

23. _____ audio/video information technology (computer), communications, and industrial equipment limited-power circuits are allowed as the power source for a Class 2 or Class 3 circuit.
    (a) Listed
    (b) Labeled
    (c) Identified
    (d) Approved

24. The power sources for limited-power circuits in 725.121(A)(3) and for listed audio/video information technology equipment and listed industrial equipment in 725.121(A)(4) shall have a label indicating the maximum voltage and _____ output for each connection point.
    (a) fault current
    (b) rated current
    (c) overcurrent
    (d) running current

25. Rated current for Class 2 and Class 3 power sources for conductors that transmit _____ is the output current per conductor the power source is designed to deliver to an operational load at normal operating conditions, as declared by the manufacturer.
    (a) power and data
    (b) emergency signaling
    (c) fire signaling
    (d) alarm signaling

26. Rated current for _____ power sources for conductors covered in 725.144 is the output current per conductor the power source is designed to deliver to an operational load at normal operating conditions, as declared by the manufacturer.
    (a) Class 1
    (b) Class 2
    (c) Class 3
    (d) Class 2 and Class 3

27. Equipment supplying Class 2 or Class 3 circuits shall be durably marked where plainly visible to indicate _____.
    (a) each circuit that is a Class 2 or Class 3 circuit
    (b) the circuit VA rating
    (c) the size of conductors serving each circuit
    (d) all of these

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28. Class 2 and Class 3 circuits reclassified and installed as Class 1 circuits are no longer Class 2 or Class 3 circuits, unless there is a continued connection to a Class 2 or Class 3 power source.

(a) True
(b) False

29. Cables and conductors of Class 2 and Class 3 circuits may be installed alongside conductors of electric light, power, Class 1, nonpower-limited fire alarm, security, and medium-power network-powered broadband communications circuits.

(a) may be permitted to
(b) shall not
(c) shall
(d) shall be required to

30. Conductors of Class 2 and Class 3 circuits shall not be placed in any enclosure, raceway, cable, or similar fittings with conductors of Class 1 or electric light or power conductors, unless ____.

(a) insulated for the maximum voltage present
(b) totally comprised of aluminum conductors
(c) separated by a barrier
(d) all of these

31. Audio system circuits using Class 2 or Class 3 wiring methods are not permitted in the same cable, raceway, or cable routing assembly with ____.

(a) other audio system circuits
(b) Class 1 conductors or cables
(c) Class 3 conductors or cables
(d) Class 2 conductors or Class 3 conductors or cables

32. The exterior portion of raceways shall not be used as a means of support for Class 2 or Class 3 cables.

(a) True
(b) False

33. Sections 725.144(A) and (B) shall apply to ____ that transmit power and data to a powered device.

(a) all circuits
(b) Class 1, 2, and 3 circuits
(c) Class 2 and 3 circuits
(d) low voltage circuits

34. The requirements of Parts I and III of Article 725 and 300.11 shall apply to Class 2 and Class 3 circuits that transmit power and data.

(a) True
(b) False

35. The conductors for Class 2 and Class 3 circuits that carry power for the data circuits shall be copper and the current in the power circuit shall not exceed the current limitation of the ____.

(a) conductors
(b) connectors
(c) wiring method
(d) equipment served

36. One example of the use of cables for Class 2 or Class 3 circuits that transmit power and data is the connection of closed-circuit TV cameras (CCTV).

(a) True
(b) False

37. The 8P8C connector is in widespread use with powered communications systems using Class 2 or Class 3 circuits and these connectors are typically rated at ____ maximum.

(a) 0.50A
(b) 1.00A
(c) 1.20A
(d) 1.30A

38. When using Table 725.144, bundle sizes over ____ cables, or conductor sizes smaller than 26 AWG, capacities shall be permitted to be determined by qualified personnel under engineering supervision.

(a) 129
(b) 178
(c) 187
(d) 192

39. Where only half of the conductors in each cable are carrying current, the values in Table 725.144 shall be permitted to be increased by a factor of ____.

(a) 1.00
(b) 1.20
(c) 1.40
(d) 1.60

40. Where Types CL3P, CL2P, CL3R, CL2R, CL3, or CL2 transmit power and data, the rated current per conductor of the power source shall not exceed the ampacities in Table 725.144 at an ambient temperature of ____.

(a) 30°C
(b) 60°C
(c) 75°C
(d) 90°C

41. One example of the use of Class 2 cables is a network of closed-circuit TV cameras using 24 AWG, 60°C rated, Type CL2R, Category 5e balanced twisted-pair cabling.

(a) True
(b) False

42. Where Types CL3P-LP, CL2P-LP, CL3R-LP, CL2R-LP, CL3-LP, or CL2-LP transmit power and data, the rated current per conductor of the power source installed at temperatures above 86°F, the correction factors in Table _____ shall apply to the ampacities in Table 725.144.

(a) 310.15(B)(3)(a)
(b) 310.15(B)(7)
(c) 310.15(B)(1)
(d) 310.16

43. Class 2-LP and Class 3-LP cables shall comply with which of the following, as applicable?

(a) Cables with the suffix "-LP" shall be permitted to be installed in bundles, raceways, cable trays, communications raceways, and cable routing assemblies.
(b) Cables with the suffix "-LP" and a marked ampere level shall follow the substitution hierarchy of Table 725.154 and *NEC* Figure 725.154(a) for the cable type without the suffix "-LP" and without the marked ampere level.
(c) System design shall be permitted by qualified persons under engineering supervision.
(d) any of these

44. Class 2, Class 3, and Type PLTC cables, installed as wiring methods within buildings, shall be _____ as resistant to the spread of fire and other criteria in accordance with 725.179(A) through (I) and shall be marked in accordance with 725.179(J).

(a) listed
(b) labeled
(c) identified
(d) approved

45. Types CL2P and CL3P plenum cable shall be ____ as suitable for use in ducts, plenums, and other space for environmental air and shall be listed as having adequate fire-resistant and low-smoke producing characteristics.

(a) marked
(b) labeled
(c) listed
(d) approved

46. Class 2 and Class 3 plenum cables listed as suitable for use in ducts, plenums, and other spaces used for environmental air shall be Type _____.

(a) CL2P and CL3P
(b) CL2R and CL3R
(c) CL2 and CL3
(d) PLTC

Article 760—Fire Alarm Systems

1. Article 760 covers the requirements for the installation of wiring and equipment of _____.

(a) communications systems
(b) antennas
(c) fire alarm systems
(d) fiber optics

2. Fire alarm systems include _____.

(a) fire detection and alarm notification
(b) guard's tour
(c) sprinkler waterflow
(d) all of these

3. Fire alarm cables that are not terminated at equipment other than a connector and not identified for future use with a tag are considered abandoned.

(a) True
(b) False

4. _____ fire alarm cables installed in ducts, plenums, or other spaces used for environmental air shall comply with 300.22.

(a) Fire rated
(b) Metal-clad
(c) Power-limited and nonpower limited
(d) Line-voltage

Author's Commentary:
Practice with these questions is one of the best ways to strengthen your grasp of Articles 725 and 760. Review each topic carefully and refer back to the Code sections mentioned for a complete understanding.

— Michael Hamilton

5. Fire alarm cables selected in accordance with Table 760.154 and installed in accordance with 760.135(B) and 300.22(B) Exceth shall be permitted to be installed in ducts specifically fabricated for environmental air.

   (a) Power-limited
   (b) Nonpower-limited
   (c) Power-limited and nonpower-limited
   (d) Line-voltage

6. Fire alarm cables selected in accordance with Table 760.154 and installed in accordance with 760.135(C) shall be permitted to be installed in other spaces used for environmental air (plenums).

   (a) Fire-rated
   (b) Metal-clad
   (c) Power-limited and nonpower-limited
   (d) Line-voltage

7. Where _____ cables are utilized for fire alarm circuits, the cables shall be installed in accordance with Article 770.

   (a) Class 1
   (b) Class 2
   (c) Class 3
   (d) Optical fiber

8. If fire alarm conductors are installed in a raceway that is subjected to different temperatures, and where condensation is known to be a problem, the raceway shall be filled with a material approved by the authority having jurisdiction that will prevent the circulation of warm air to a colder section of the raceway. An explosionproof seal _____.

   (a) Is required for this purpose
   (b) Has been proven effective for this purpose
   (c) Is not required for this purpose
   (d) Is the only method of doing this

9. Raceways enclosing cables and conductors for fire alarm systems shall be large enough to permit the _____ of conductors without damaging conductor insulations limited by 300.17.

   (a) Concealment
   (b) Bending space
   (c) Splicing
   (d) Installation and removal

10. When a raceway is used for the support or protection of cables for fire alarm circuits, a bushing to reduce the potential for abrasion shall be placed at the location the cables emerge from the raceway.

    (a) True
    (b) False

11. Power-limited fire alarm cables shall be permitted to be installed in plenum cable routing assemblies, riser cable routing assemblies, and general-purpose cable routing assemblies where _____.

    (a) Selected in accordance with Table 800.154(c)
    (b) Listed in accordance with the provisions of 800.182
    (c) Installed in accordance with 800.110(c) and 800.113
    (d) All of these

12. Power-limited fire alarm cables shall be permitted to be installed in plenum communications raceways, riser communications raceways, and general-purpose communications raceways where _____, and where the requirements applicable to electrical nonmetallic tubing apply.

    (a) Selected in accordance with Table 800.154(B)
    (b) Listed in accordance with the provisions of 800.182
    (c) Installed in accordance with 800.113 and 362.24 through 362.56
    (d) All of these

13. The requirements of 310.14(A)(3) on the temperature limitation of conductors shall apply to nonpower-limited fire alarm cables only.

    (a) True
    (b) False

14. Power-limited and nonpower-limited fire alarm cables with green insulation shall be permitted to be used as ungrounded signal conductors.

    (a) True
    (b) False

15. Fire alarm circuit cables and conductors installed exposed on the surface of ceilings and sidewalls shall be supported by _____, hangers, or similar fittings designed and installed so as not to damage the cable.

    (a) Straps
    (b) Staples
    (c) Cable ties
    (d) Any of these

Article 760 PRACTICE QUESTIONS

16. Accessible portions of abandoned fire alarm cable shall be removed.

(a) True
(b) False

17. Fire alarm cables identified for future use shall be marked with a tag of sufficient durability to withstand ____.

(a) moisture
(b) humidity
(c) the environment involved
(d) temperature fluctuations

18. Fire alarm circuits shall be identified at all terminal and junction locations in a manner that helps prevent unintentional signals on fire alarm system circuits during ____ of other systems.

(a) installation
(b) testing and servicing
(c) renovations
(d) all of these

19. The fire alarm circuit disconnecting means for a power-limited fire alarm system shall ____.

(a) have red identification
(b) be accessible only to qualified personnel
(c) be identified as "FIRE ALARM CIRCUIT"
(d) all of these

20. The power source for a power-limited fire alarm circuit can be supplied through a ground-fault circuit interrupter or an arc-fault circuit interrupter.

(a) True
(b) False

21. The fire alarm branch-circuit disconnecting means shall be permitted to be secured in the "on" position.

(a) True
(b) False

22. Fire alarm equipment supplying power-limited fire alarm circuits shall be durably marked where plainly visible to indicate each circuit that is ____.

(a) supplied by a nonpower-limited fire alarm circuit
(b) a power-limited fire alarm circuit
(c) a fire alarm circuit
(d) supervised

23. Cable splices or terminations in power-limited fire alarm systems shall be made in listed ____ or utilization equipment.

(a) fittings
(b) boxes or enclosures
(c) fire alarm devices
(d) any of these

24. Power-limited fire alarm circuit cables and conductors shall not be placed in any cable, cable tray, compartment, enclosure, manhole, ____, or similar fitting with conductors of electric light, power, Class 1, nonpower-limited fire alarm circuits, and medium-powerer, network-powered broadband communications circuits unless permitted by 760.136(B) through (G).

(a) outlet box
(b) device box
(c) raceway
(d) any of these

25. Generally speaking, conductors for lighting or power may occupy the same enclosure or raceway with conductors of power-limited fire alarm circuits.

(a) True
(b) False

26. Power-limited fire alarm cables can be supported by strapping, taping, or attaching to the exterior of a conduit or raceway.

(a) True
(b) False

27. Power-limited fire alarm cables installed within buildings shall be ____ as being resistant to the spread of fire.

(a) marked FR
(b) listed
(c) identified
(d) color coded

28. Power-limited fire alarm cable used in a ____ location shall be listed for use in ____ locations or have a moisture-impervious metal sheath.

(a) dry
(b) damp
(c) wet
(d) hazardous

29. Cables used in power-limited fire alarm systems must have a voltage rating of al least ____.

(a) 100V
(b) 300V
(c) 600V
(d) 1,000V

30. Cables used in power-limited fire alarm systems must have a temperature rating of a least ____.

(a) 60°C
(b) 75°C
(c) 90°C
(d) 100°C

Article 770—Optical Fiber Cables

1. Article 770 governs the installation of optical fiber cables. This article does not address the construction of ____.

(a) coaxial cables
(b) tray cables
(c) optical fiber cables
(d) industrial trolley cables

2. Optical fiber cables left unterminated at equipment or any connection point, and not labeled for future use with a tag, are considered abandoned.

(a) True
(b) False

3. Access to electrical equipment cannot be refused due to gathered optical fiber cables that ____ removal of panels, including suspended-ceiling panels.

(a) prevents
(b) hinders
(c) blocks
(d) requires

4. Optical fiber cables installed ____ on ceilings and walls must be supported by the building so that normal building use will not damage the cable.

(a) exposed
(b) in raceways
(c) hidden
(d) exposed and concealed

5. Accepted industry practices for optical fiber installations are described in ____.

(a) ANSI/NECA/BICSI 568, *Standard for Installing Commercial Building Telecommunications Cabling*
(b) ANSI/NECA/FOA 301, *Standard for Installing and Testing Fiber Optic Cables*
(c) other ANSI-approved installation standards
(d) all of these

6. Paint, plaster, cleaners, abrasives, corrosive residues, or other contaminants may cause an unknown change in optical fiber cable performance due to ____.

(a) usefulness
(b) voltage
(c) properties
(d) reliability

7. Accessible portions of abandoned optical fiber cable must be removed.

(a) True
(b) False

8. Openings where optical fiber cables and communications pathways go through fire-resistance-rated walls, partitions, floors, or ceilings must be _____ using approved methods to keep the fire-resistance rating.

(a) closed
(b) opened
(c) draft stopped
(d) firestopped

9. When optical fiber cable is installed in a Chapter 3 raceway, that raceway must be installed according to Chapter 3 requirements.

(a) True
(b) False

10. Optical fibers may run in the same composite cable as lighting, power, and Class 1 circuits of 1,000V or less where the optical fibers and the associated electrical conductors perform the same functions.

(a) True
(b) False

Author's Commentary: Article 770 provides installation rules for optical fiber systems beyond their equipment terminations. It focuses on protecting performance, maintaining fire-resistance, and ensuring access to electrical equipment.

— Michael Hamilton

Article 770 | Practice Questions

11. Nonconductive optical fiber cables shall not be permitted to occupy the same cabinet, outlet box, panel, or similar enclosure unless the nonconductive optical fiber cables are functionally associated with the electric circuits.

(a) True

(b) False

CHAPTER 8

COMMUNICATIONS SYSTEMS

Introduction to Chapter 8—Communications Systems

Chapter 8 of the *National Electrical Code* covers the wiring rules for communications systems such as telephones, radio and antennas, satellite dishes, closed-circuit television (CCTV), coaxial cable systems, and network- and premises-powered broadband systems for voice, audio, video and data.

Communications systems are not subject to the general requirements contained in Chapters 1 through 4 or the special requirements of Chapters 5 through 7, except where a Chapter 8 rule specifically points to one of those chapters [90.3]. Also, installations of communications equipment under the exclusive control of communications utilities located outdoors, or in building spaces used exclusively for such installations, are exempt from the *NEC* [90.2(B)(4)].

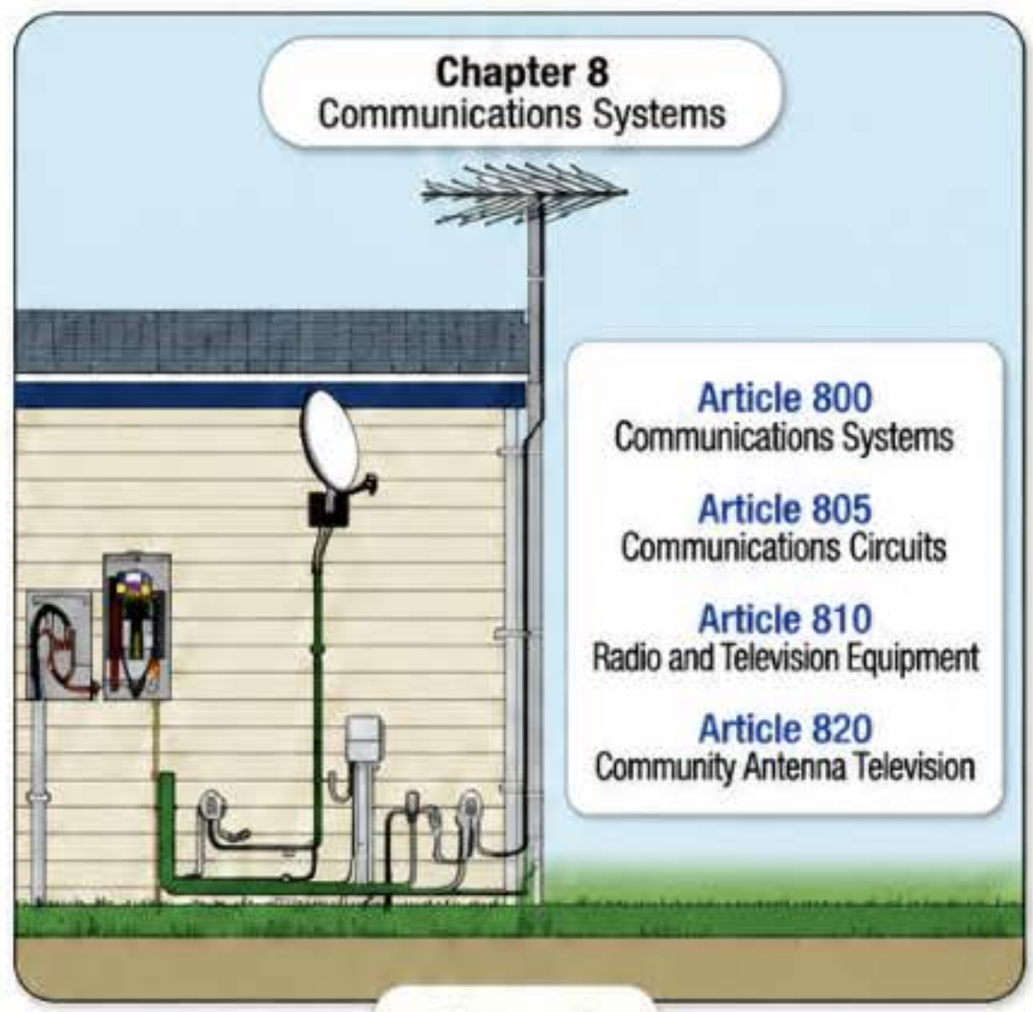


Figure 1

- **Article 800—General Requirements for Communications Systems.** This article covers general requirements for the installation of communications. and radio distribution systems, network-powered broadband communications systems, and premises-powered broadband communications systems, unless modified by Articles 805 or 820.
- **Article 805—General Requirements for Communications Circuits.** This article addresses the installation requirements for circuits and equipment used to deliver telephone wiring and other telecommunications services, such as computer local area networks (LANs), and the outside wiring for fire and burglar alarm systems connected to central monitoring stations.
- **Article 810—Radio and Television Antenna Equipment.** This article covers antenna systems for radio and television receiving equipment, amateur radio transmitting and receiving equipment, and certain features of transmitter safety. It also includes antennas such as multi-element, vertical rod and dish, and the wiring and cabling that connects them to the equipment.
- **Article 820—Community Antenna Television (CATV) and Radio Distribution Systems (Coaxial Cable).** This article addresses the installation of coaxial cables used to distribute limited-energy high-frequency signals for television, cable TV, and closed-circuit television (CCTV) for security purposes. It also covers the premises wiring of satellite TV systems where the dish antenna is outside and covered by Article 810.

Notes |

ARTICLE 800 GENERAL REQUIREMENTS FOR COMMUNICATIONS SYSTEMS

Introduction to Article 800—General Requirements for Communications Systems

Article 800 provides the foundational rules that govern the installation and use of communications systems addressed by Articles 805 and 820. Keep in mind that its coverage excludes Article 810, which deals with radio and television equipment. The material here continues independent of the rest of the *Code* and includes content from Chapter 8 including the conditions in Articles 805, 820, 830, and 840 that supplement or adjust the requirements of Article 800. This section uses the same style as 90.3 and relies on the overall guidance in Chapters 1 through 4, which may be refined further by rules in Chapters 5 through 7.

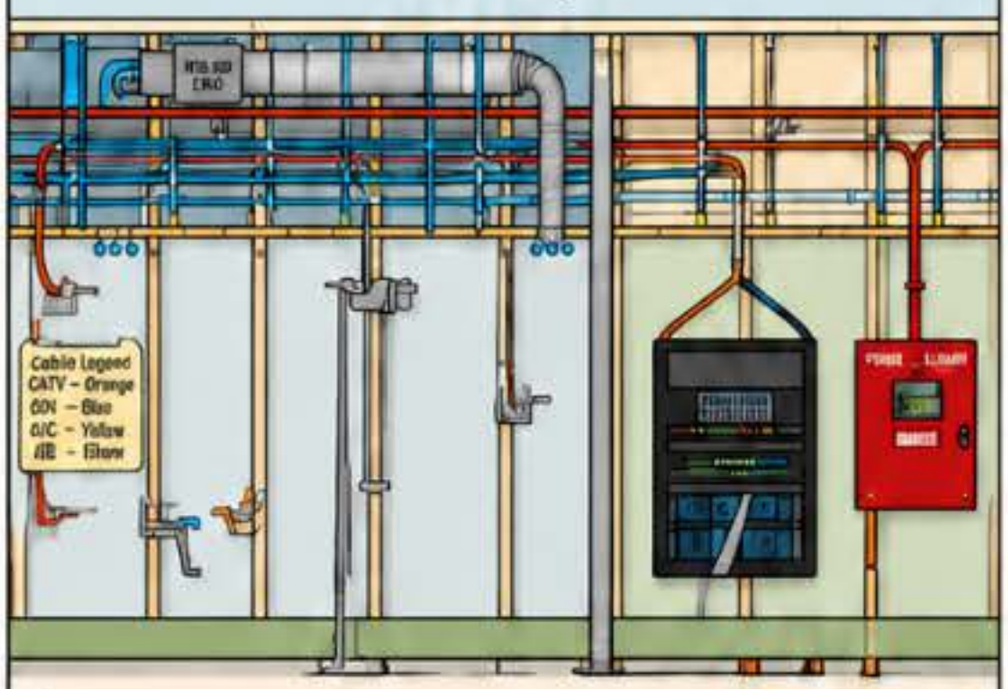
Part I. General

800.1 Scope

Article 800 outlines the overarching requirements for communications systems. These provisions apply to communications circuits, community antenna television networks, radio distribution setups, and broadband communications systems—unless another provision in Articles 805 or 820 changes the requirements.

▶ Figure 800–1

Communications Systems
800.1 Scope



Article 800 covers a variety of communications systems, such as communications circuits, community antenna television and radio distribution networks, as well as broadband communications systems—unless specifically changed by Articles 805 or 820.

▶ Figure 800–1

800.2 Definitions

The definitions of commonly used terms in Article 100 and those found here in 800.2 apply throughout Chapter 8.

Author's Commentary:

- Across the NEC, definitions tied to a specific article always appear in the xx.2 section of that article. What makes Chapter 8 unique is that it collects definitions for use across its entire scope in 800.2.
- Another distinctive aspect of Chapter 8 is that topics like wiring methods, bonding techniques, and other installation requirements are covered throughout the chapter and then consolidated within Article 800.

— ***Michael Hamilton***

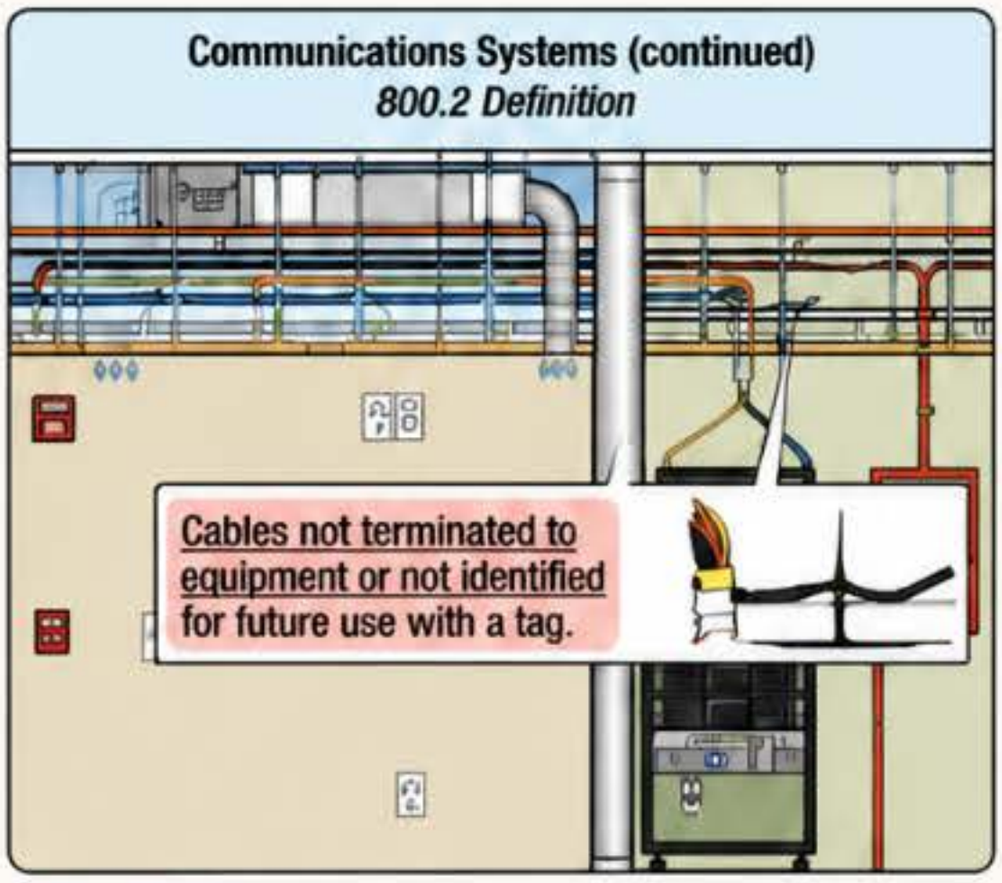
Abandoned Cable. Cable that is left disconnected from equipment and not clearly tagged to show its intended future use. ▶ Figure 800–2

Author's Commentary:

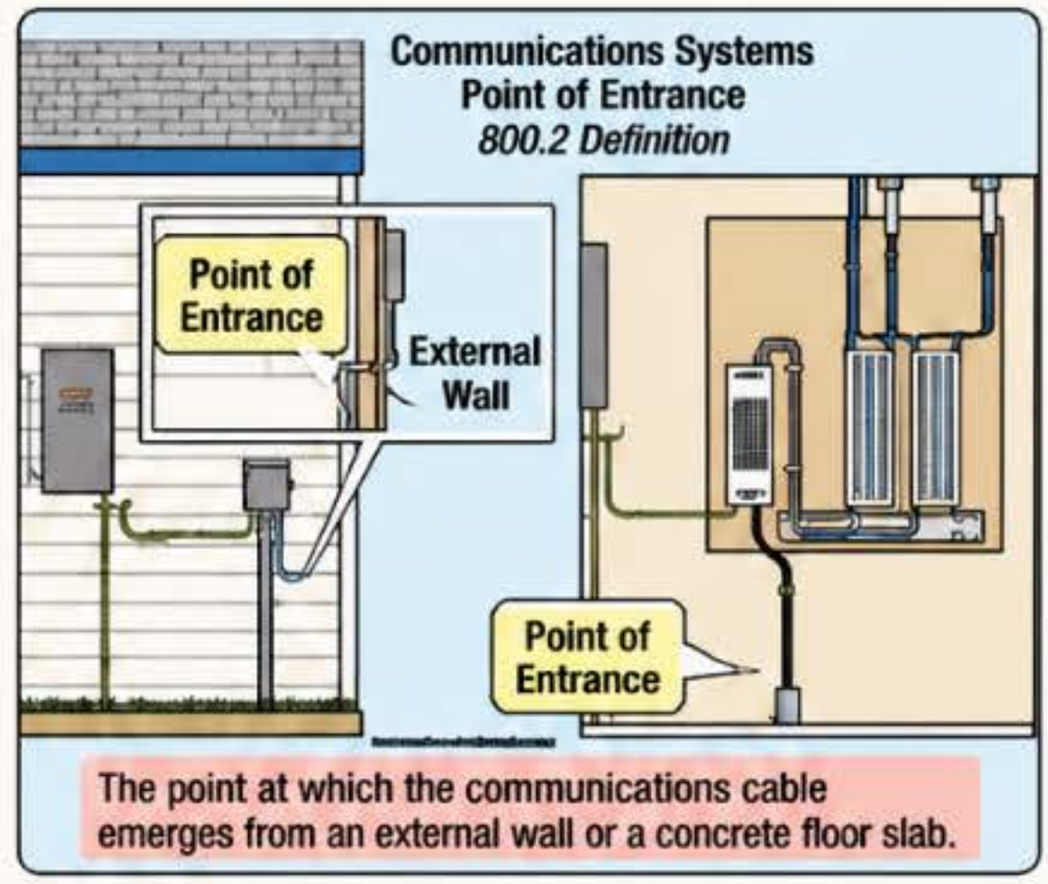
- Section 800.25 requires that any accessible segment of abandoned cable be removed.

— ***Michael Hamilton***

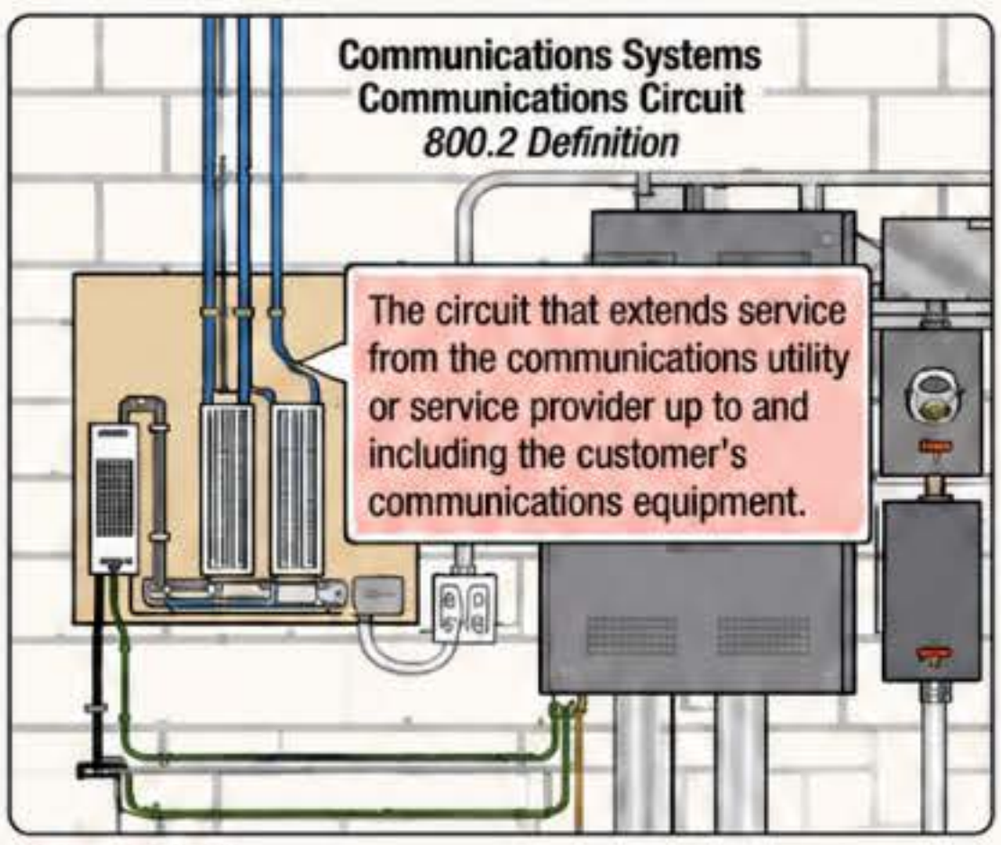
Communications Circuit. A circuit that links the communications utility or service provider to the customer and includes the customer's communications equipment. ▶ Figure 800–3



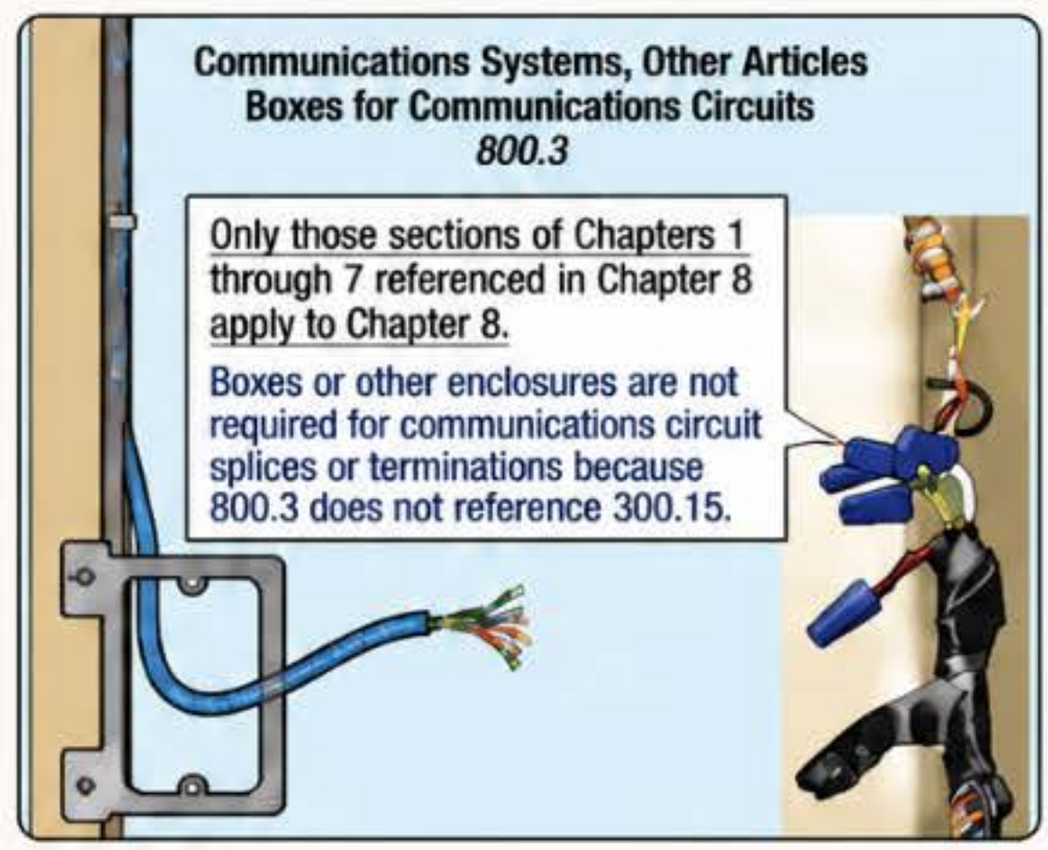
▶ Figure 800–2



▶ Figure 800–4



▶ Figure 800–3



▶ Figure 800–5

Exposed (to Accidental Contact). A situation where failure of support or insulation can cause the circuit to touch another circuit.

Point of Entrance. The location on a building where the cable comes through an exterior wall or concrete floor slab. ▶Figure 800–4

800.3 Other Articles

Only those sections of Chapters 1 through 7 referenced in Chapter 8 apply to Chapter 8. ▶Figure 800–5

(A) Hazardous (Classified) Locations. For circuits and equipment installed in a location that is classified in accordance with 500.5 and 505.5, the applicable requirements of Chapter 5 apply.

(B) Wiring in Ducts for Dust, Loose Stock, or Vapor Removal. The requirements of 300.22(A) apply.

(C) Equipment in Plenum Spaces. Equipment installed in plenum spaces must comply with 300.22(C)(3).

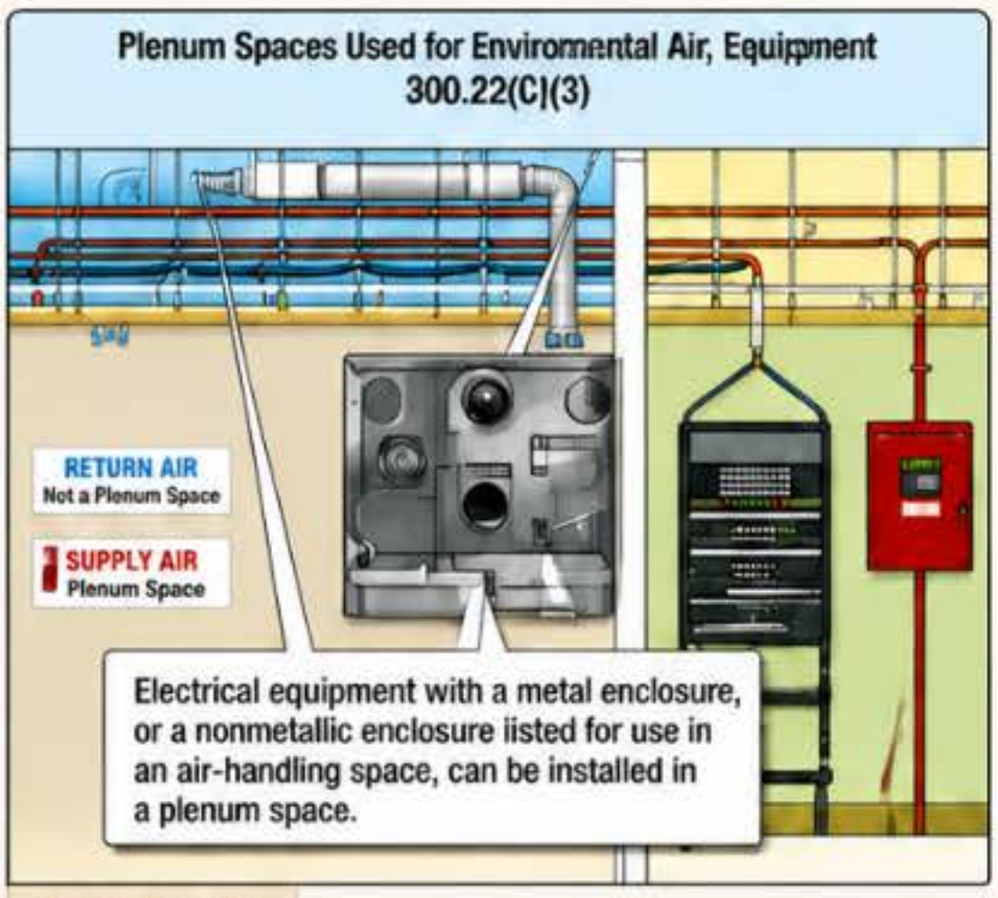
Author's Commentary:

Under 300.22(C)(3), electrical equipment that has a metal enclosure, or a nonmetallic enclosure listed for air handling spaces, can be mounted in a plenum space.

— Michael Hamilton

(D) Installation and Use. Communications equipment must bie installed and used according to manufacturers' instructions in accordance with 110.3(B).

General Requirements for Communications Systems | 800.24



▸ Figure 800–6

▸ Figure 800–7

(E) Optical Fiber Cable. Where optical fiber cable is used to provide a communications circuit within a building, Article 770 applies.

(F) Other Communications Systems. Communications systems must comply with the following requirements:

(1) Communications Circuits—Article 805

(2) Antennas—Article 810

(3) Caaxial Cable Systems—Article 820

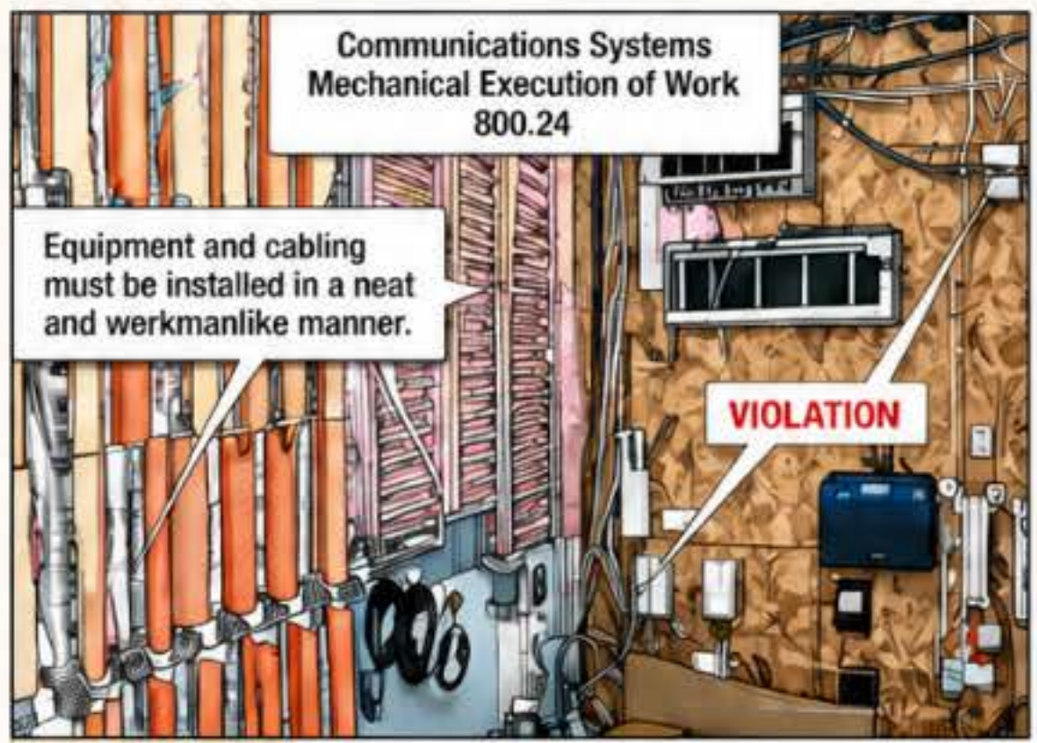
800.21 Access to Electrical Equipment Behind Panels Designed to Allow Access

Access to equipment must not be prohibited by an accumulation of cables that prevents the removal of suspended-ceiling panels ▸ **Figure 800–7**

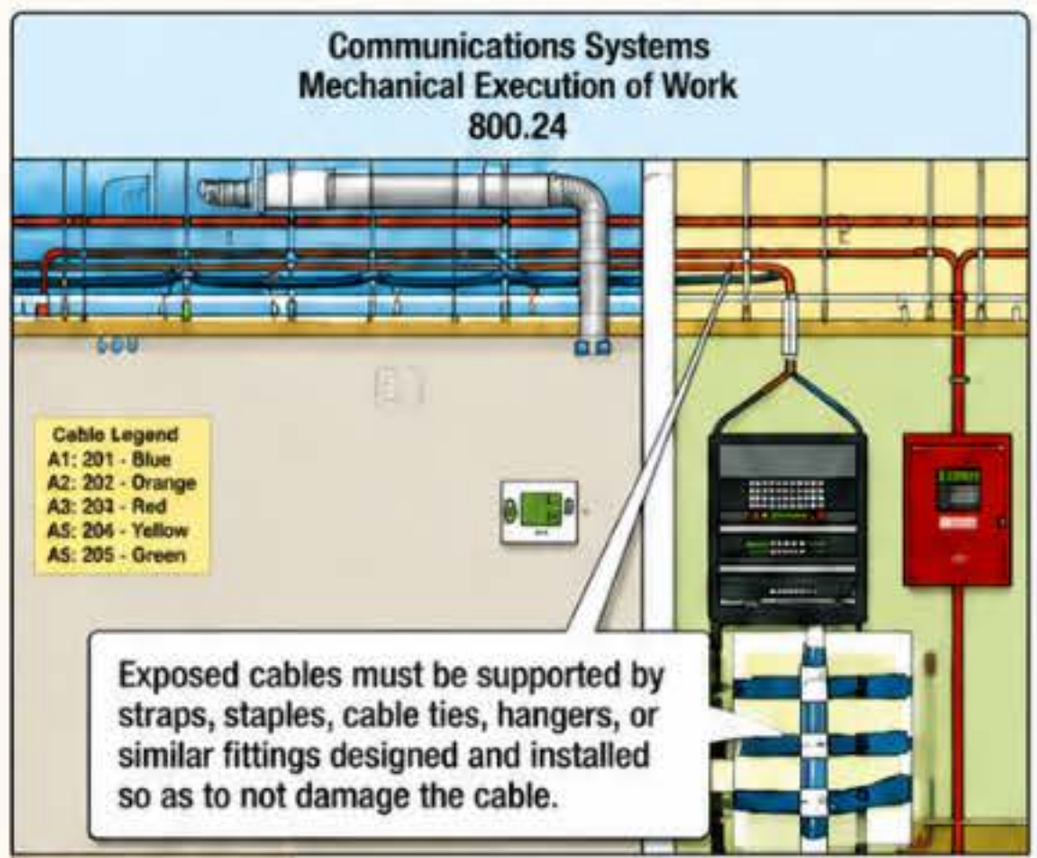
800.24 Mechanical Execution of Work

Equipment and cabling must be installed in a neat and workmanlike manner. ▸ **Figure 800–8**

Exposed cables must be supported by the structural components of the building so the cable will not be damaged by normal building use. Support must be by straps, staples, hangers, cable ties, or similar fittings designed and installed in a manner that will not damage the cable. ▸ **Figure 800–9**

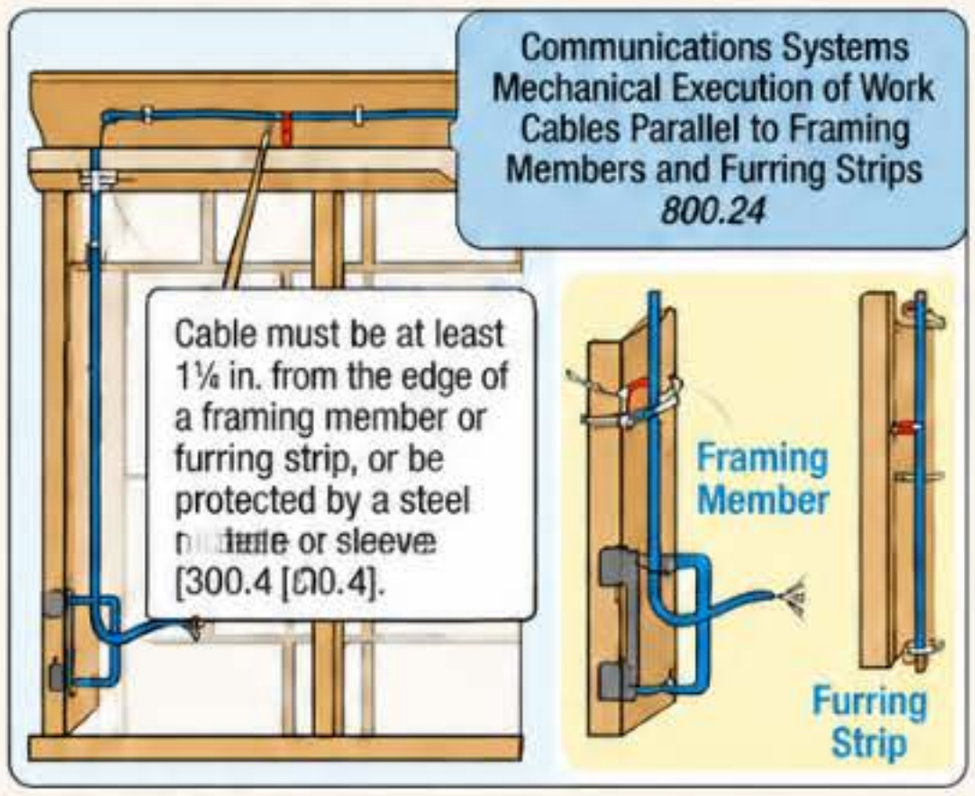


▸ Figure 800–8

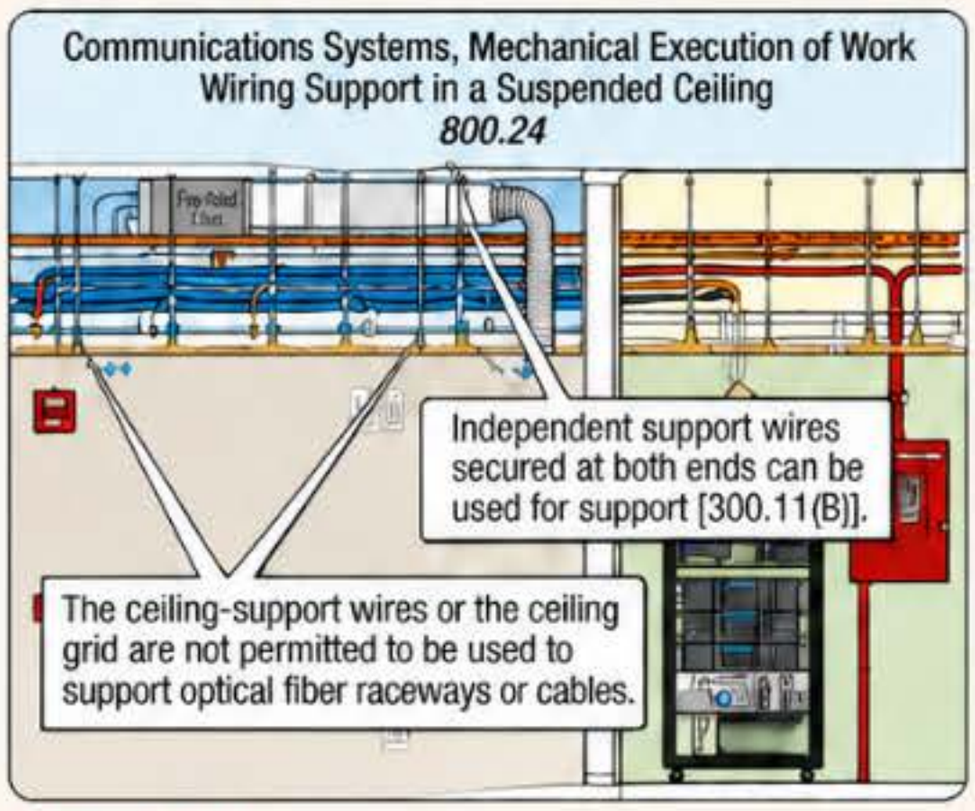


▸ Figure 800–9

Exposed cables must comply with 300.4 and 300.11. Nonmetallic cable ties in plenum spaces must comply with 805.170(C). **Figure 800–10** and **Figure 800–11**



▶ **Figure 800–10**



▶ **Figure 800–11**

Author's Commentary:

- Section 300.4 protects against physical damage from nails and screws penetrating wood and metal members, and from other trades working in parallel with the framing. Section 300.11 lays out how to secure and support wiring.

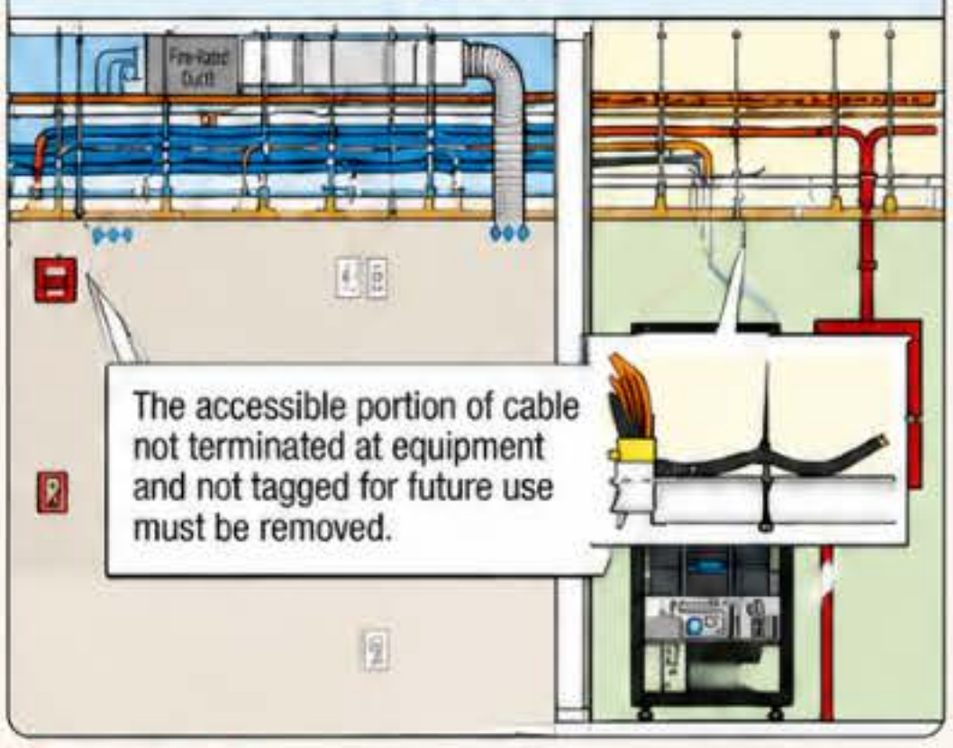
— Michael Hamilton

Note 1: Accepted industry practices are described in ANSI/TIA-568, *Commercial Building Telecommunications Infrastructure Standard;* ANSI/TIA-569-D, *Telecommunications Pathways and Spaces;* ANSI/TIA-570-C, *Residential Telecommunications Infrastructure Standard;* ANSI/TIA-1005-A, *Telecommunications Infrastructure Standard for Industrial Premises;* ANSI/TIA-1179, *Healthcare Facility Telecommunications Infrastructure Standard;* ANSI/TIA-4966, *Telecommunications Infrastructure Standard for Educational Facilities;* and other ANSI-approved installation standards.

Note 3: Paint, plaster, cleaners, abrasives, corrosive residues, or other contaminants may change the electrical characteristics of wire and cable in ways that could be unpredictable.

800.25 Abandoned Cable

To limit the spread of fire or products of combustion within a building, tiber accessibls portion of cable that is not terminated at equipment and not identified for future use with a tag must be removed [800.2]. Tags identifying cables for future use must be able to withstand the environment involved. ▶ **Figure 800–12**



▶ **Figure 800–12**

800.26 Spread of Fire or Products of Combustion

Communications circuits and equipment must be installed so the spread of fire or products of combustion will not be greatly increased. Openings into or through fire-resistant walls, floors, and ceilings for electrical equipment must be firestopped using methods approved by the authority having jurisdiction to keep the fire-resistance rating of the assembly equal to that of the fire-rated assembly. ▶ **Figure 800–13** and ▶ **Figure 800–14**

— Michael Hamilton

General Requirements for Communications Systems | 800.26

Communications Systems
Spread of Fire or Products of Combustion
800.26

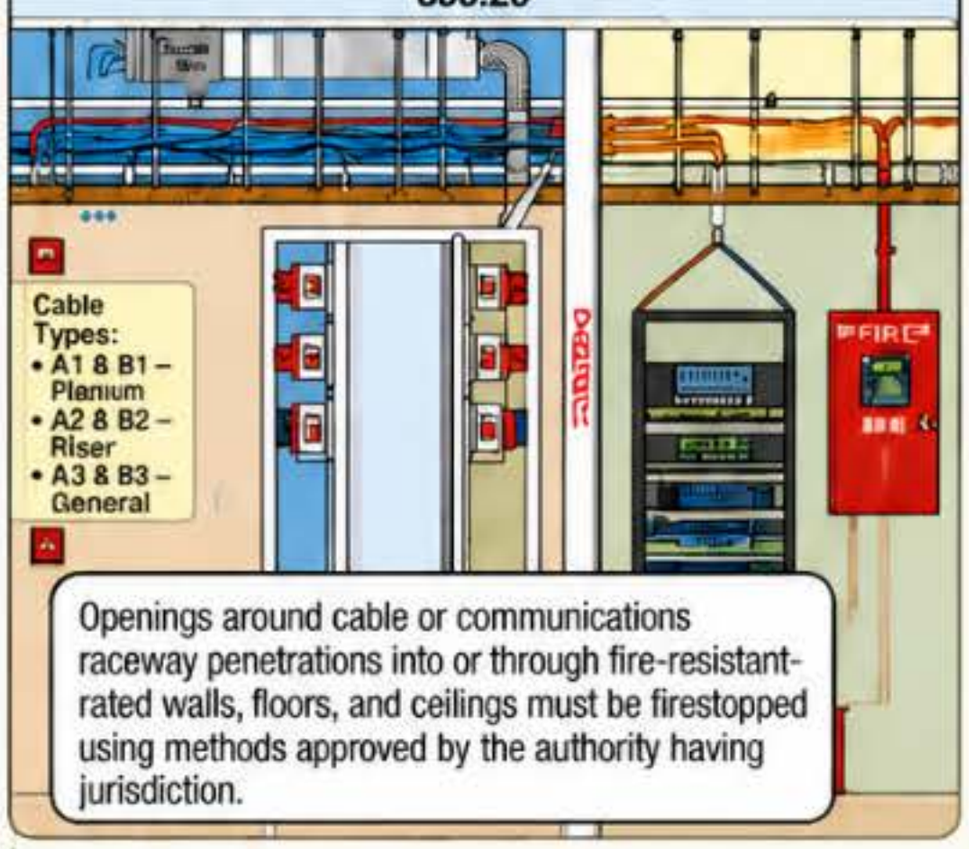


Figure 800-13

Spread of Fire or Products of Combustion
Examples of Approved Firestopping Methods.
300.21 Comment

Firestopping materials are listed for the specific types of wiring methods and the construction of the assembly they penetrate.

Figure 800-15

Communications Systems
Spread of Fire or Products of Combustion
800.26

Figure 800-14

Author's Commentary:

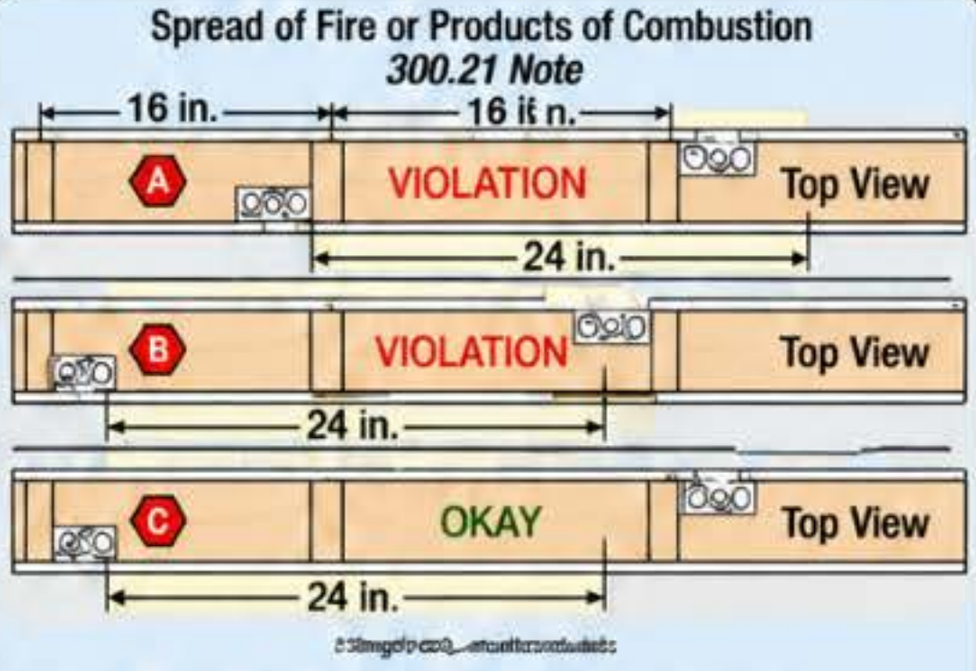
- Firestopping materials are listed for the specific types of wiring methods and the construction of the assembly they penetrate.

— Michael Hamilton

Figure 800-15

Note: Directorres of electrical construction materials published by recognized testing laboratories contain listing and installation restrictions necessary to maintain the fire-resistive rating of assemblies. Building codes also have restrictions on penetrations on opposite sides of a fire-resistance-rated wall. Outlet boxes must have a horizontal separation of not less than 24 in. when installed on opposite sides in a fire-rated assembly, unless an outlet box is listed for closer spacing or protected by fire-resistant "putty pads" in accordance with the manufacturer's instructions. **Figure 800-16** and **Figure 800-17**

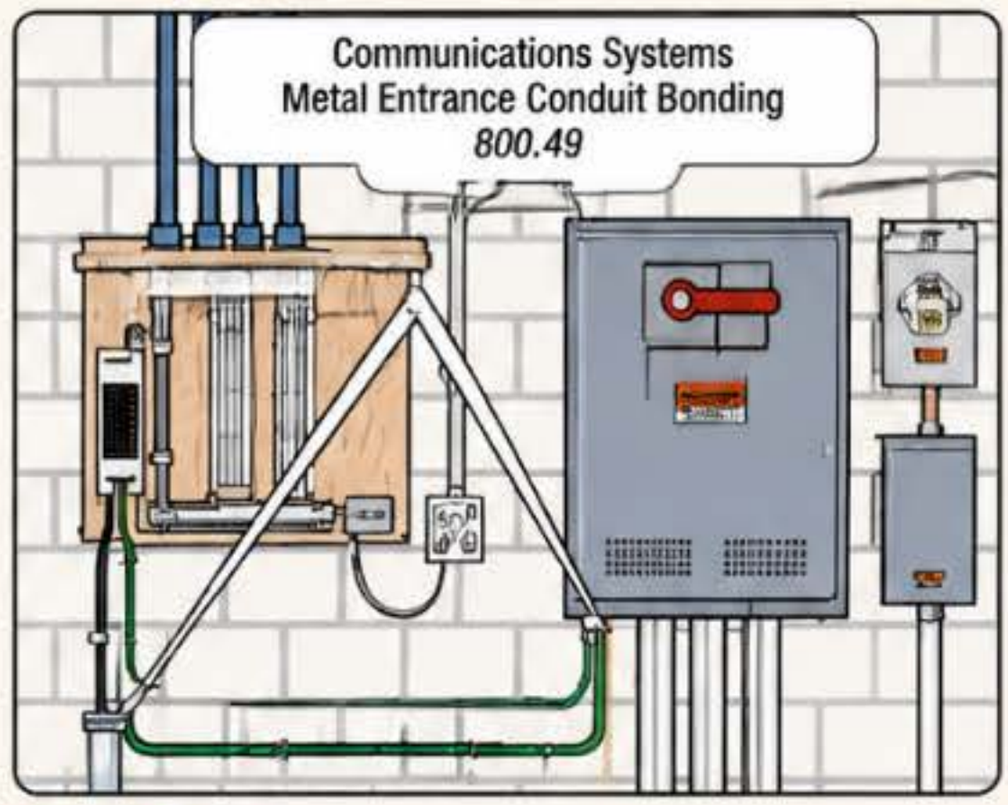
Spread of Fire or Products of Combustion
300.21 Note



3 examples (top view of wall) of outlet boxes installed on opposite sides of studs in a fire-rated assembly, a 24-in. minimum horizontal separation is required unless protected by fire-resistant "putty pads."

Figure 800-16

▶ Figure 800–17



▶ Figure 800–18

Author's Commentary:
Although boxes in fire-resistance-rated assemblies serve a purpose, rules still apply. When steel boxes are used, they must be anchored to the framing. Nonmetallic, cut-in boxes are limited to the types allowed by code. Every model and any optional insert must be listed for that exact box location.

— Michael Hamilton

- Boxes installed in fire-resistance-rated assemblies exist for a reason. If steel boxes are used, they must be fastened to the framing members. Nonmetallic, cut-in boxes are not permitted (see *NEC 2023, Guide Information for Electrical Equipment*). Firestop "putty pads" are typically applied on the exterior, but many manufacturers also provide inserts intended for installation on the interior of the box.

Part II. Wires and Cables Outside and Entering Buildings

800.49 Metal Entrance Conduit Bonding

Metal raceways that contain entrance cable must be bonded to a grounding electrode conductor, grounding electrode, or (where present) the building grounding electrode system in accordance with 800.100(B). ▶ Figure 800–18

800.53 Separation from Lightning Conductors

Where applicable, maintain a separation of at least 6 ft between communications circuits and lightning protection conductors.

Part III. Bonding Methods

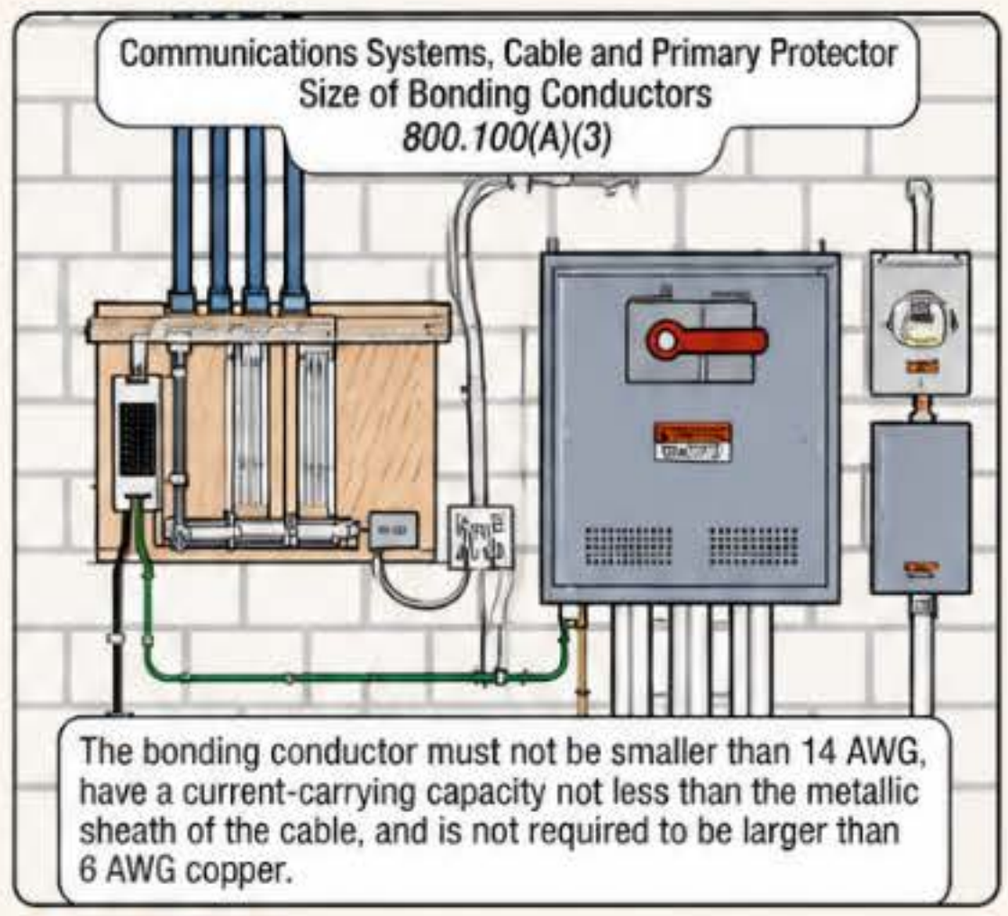
800.100 Cable and Primary Protector Bonding

(A) Bonding Conductor.

(1) Insulation. The bonding conductor must be listed and may be insulated, covered, or bare.

(2) Material. The bonding conductor must be copper or another corrosion-resistant conductor and can be solid or stranded.

(3) Size. The bonding conductor is not required to be larger than 14 AWG, has a current-carrying capacity not less than the metallic sheath of the cable, and does not need to be larger than 6 AWG copper. ▶ Figure 800–19



▶ Figure 800–19

(4) Length. Keep the bonding conductor as short as possible. For one- and two-family dwellings, the bonding conductor must not exceed 20 ft in length. ▶ Figure 800–20

800.100 GENERAL REQUIREMENTS FOR COMMUNICATIONS SYSTEMS

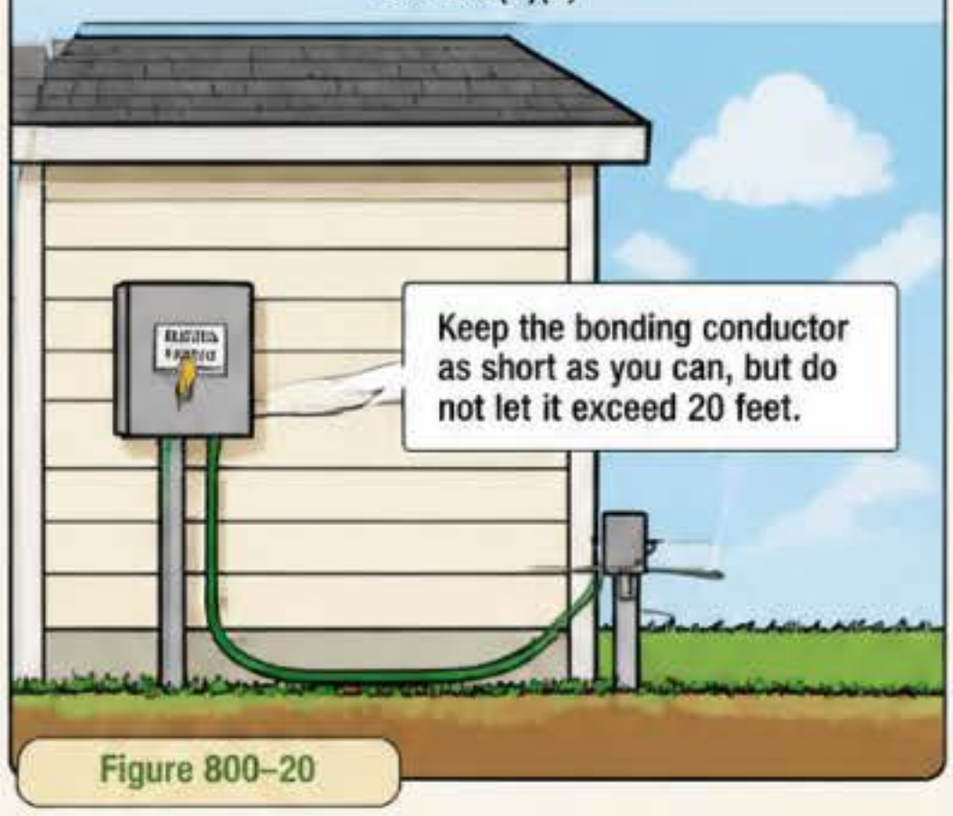


Figure 800–20

Author's Commentary:
Lightning prefers not to travel around corners or through loops. That's why the bonding jumper should be laid out in the straightest route possible.
— Michael Hamilton

(6) Physical Protection. The bonding conductor must be shielded from physical damage. When installed in a metal raceway, both ends of the raceway must be bonded to the bonding conductor or to the same terminal or electrode to which the bonding conductor is connected.

Author's Commentary:
Using PVC conduit for the bonding conductor is often a wiser choice.
— Michael Hamilton

Note: Restricting the bonding conductor length helps minimize voltage differences between the building's electrical power system and communications conductors during lightning events.

Ex: For one- and two-family dwellings, if the bonding conductor is longer than 20 feet, you must install a separate ground rod or a rod shorter than 8 feet [800.100(B)(3)(3)] and ensure it suits the application [800.100(C)], with fittings appropriate for the listed outdoor use [800.100(C)]. Additionally, connect the extra ground rod to the structure's grounding electrode system with at least 6 AWG copper wire [800.100(D)].

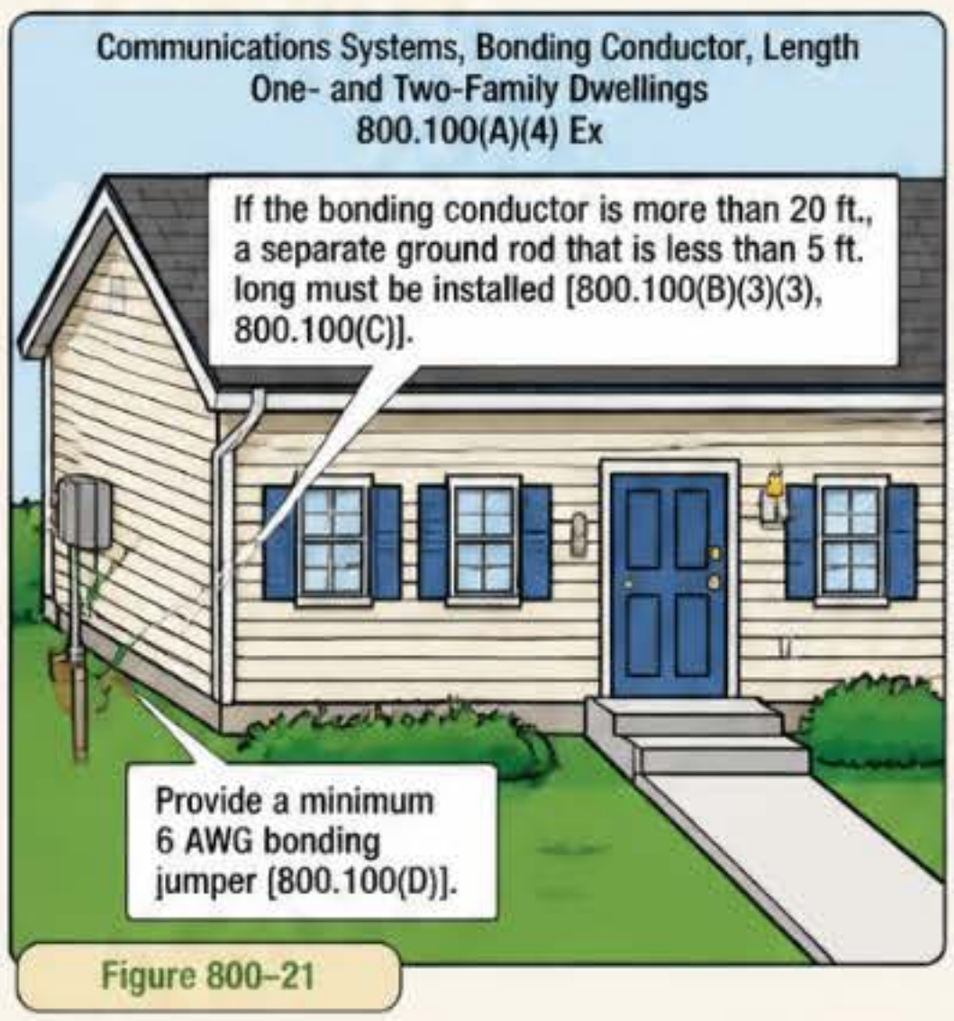


Figure 800–21

(5) Run in Straight Line. Install the bonding conductor in a direct, straight path whenever it is reasonably possible.

(B) Electrode. Connect the bonding conductor to an electrode in accordance with (B)(1), (B)(2), or (B)(3).

(1) Buildings with an Intersystem Bonding Termination. Terminate the bonding conductor at the designated intersystem bonding termination as required by 250.94. ▸ Figure 800–22

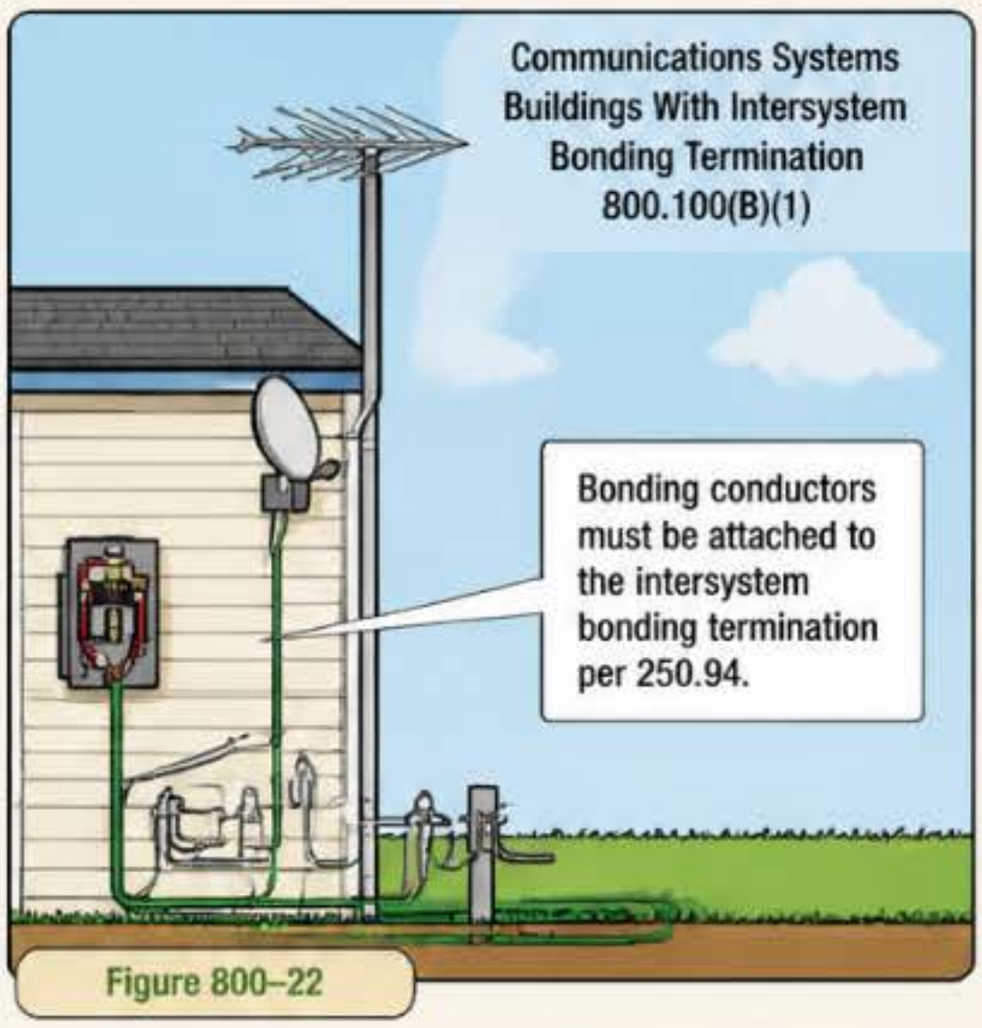
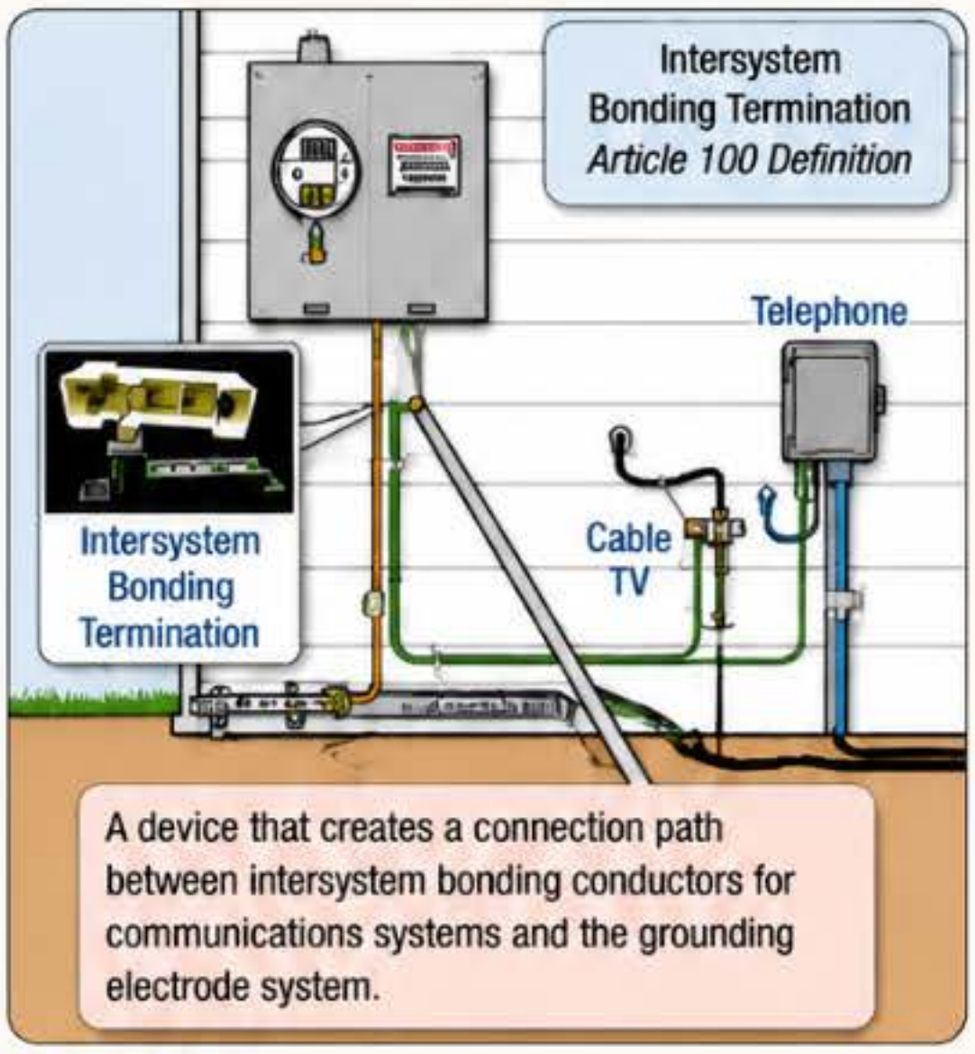


Figure 800–22

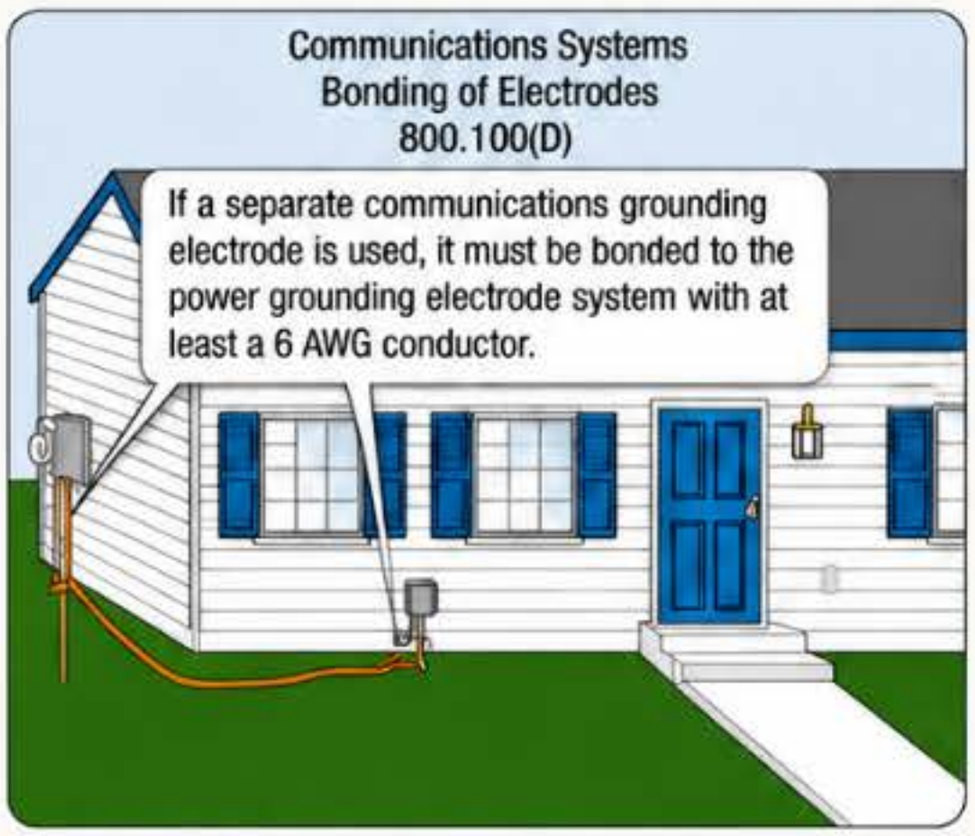
Author's Commentary:
Per definition 100, an "intersystem bonding termination" links the intersystem bonding conductor for communications systems to the grounding electrode system.
— Michael Hamilton



▸ Figure 800–23

Note: Figure 800.100(B)(1) in the 2023 *NEC* depicts how the bonding conductor is connected in buildings or structures equipped with an intersystem bonding termination.

(D) Bonding of Electrodes. When a separate grounding electrode (such as a rod) is installed for a communications system, it must be bonded to the building's power grounding electrode system with at least a 6 AWG copper conductor. ▸ Figure 800–24



▸ Figure 800–24

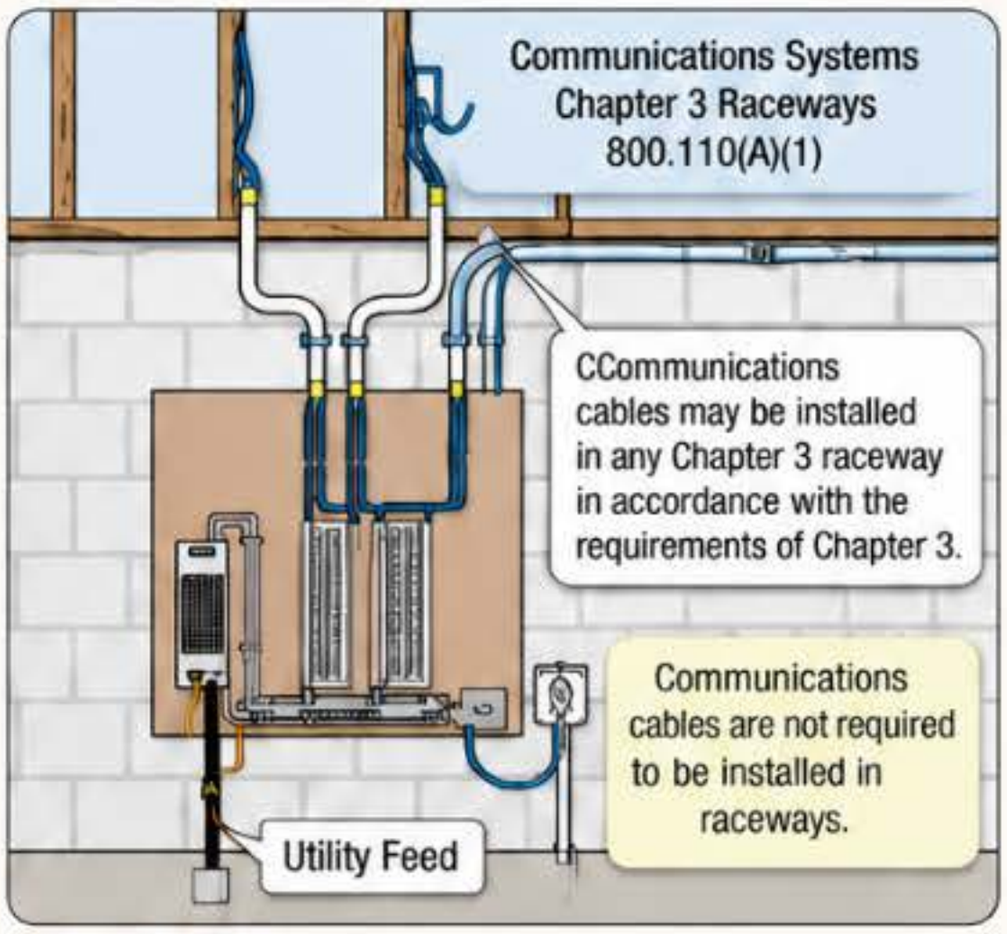
Note 2: Bonding separate electrodes together helps reduce voltage differences between the power and communications systems during lightning events.

Part IV. Installation Methods Within Buildings

800.110 Raceways and Cable Routing Assemblies

(A) Types of Raceways.

(1) Chapter 3 Raceways. Communications cables may be installed in any Chapter 3 raceway in accordance with the requirements of Chapter 3. ▸ Figure 800–25



▸ Figure 800–25

Author's Commentary:

Communications cable is not required to be installed in a Chapter 3 raceway; however, when it is, the installation must comply with the requirements for that raceway.

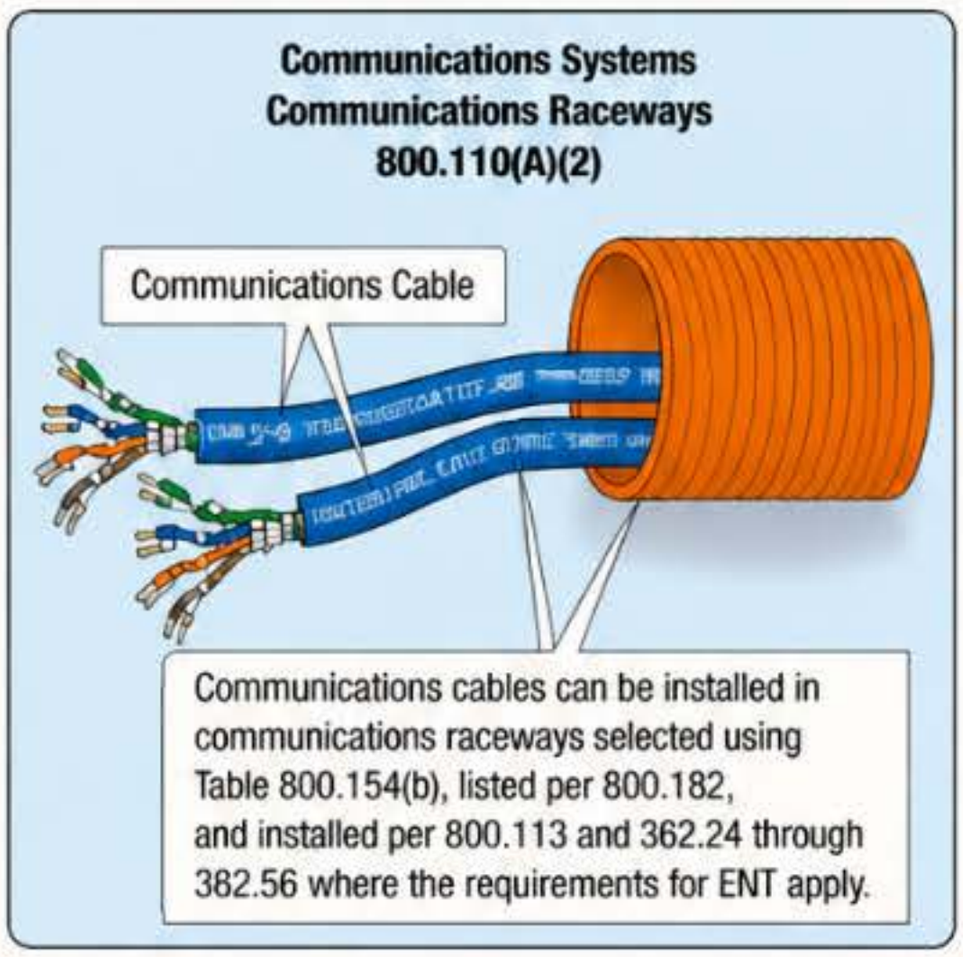
— Michael Hamilton

(2) Communications Raceways. Communications cables may be installed in communications raceways chosen using Table 800.154(b), in accordance with 800.182, and installed per 800.113 and 362.24 through 362.56 where the requirements for electrical nonmetallic tubing (ENT) apply. ▸ Figure 800–26

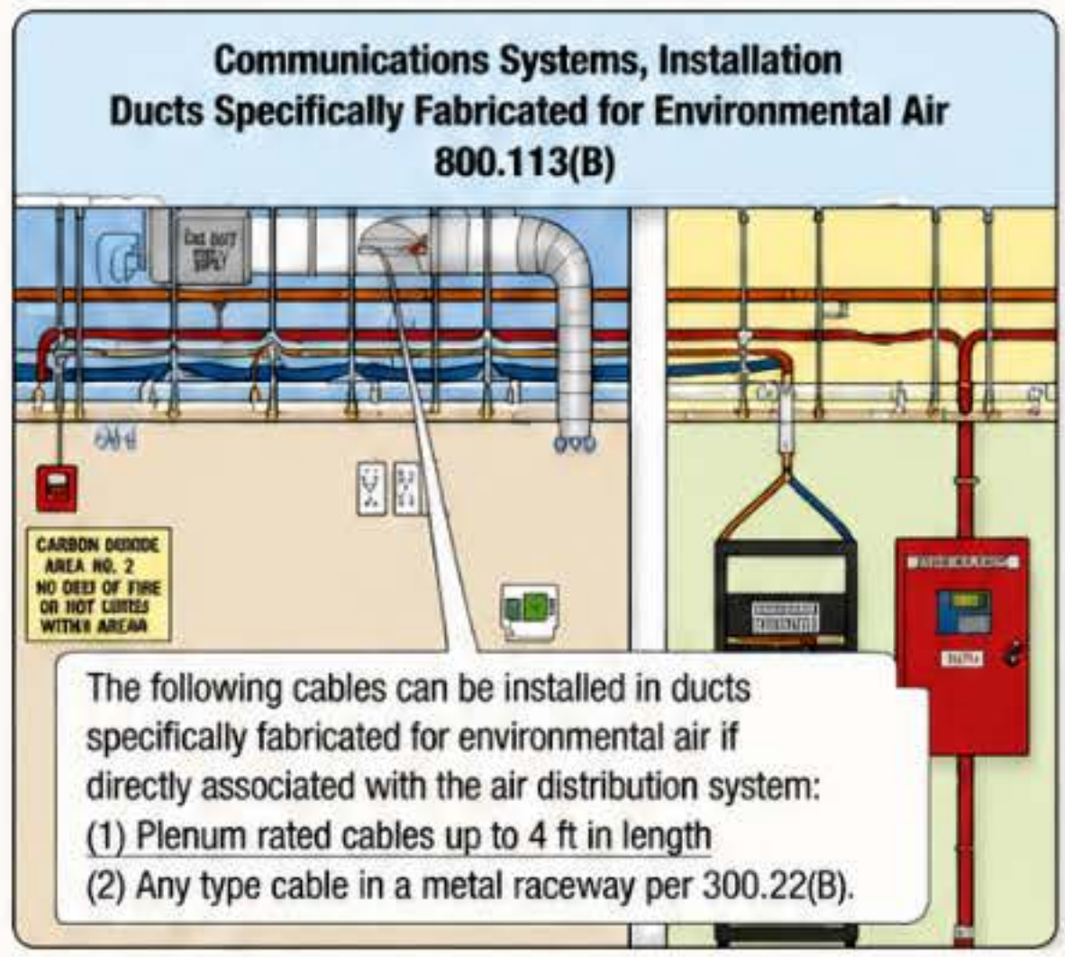
(3) Innerduct for Communications Wires and Cables, or Coaxial Cables. Listed plenum communications raceways, listed riser communications raceways, and listed general-purpose communications raceways selected per Table 800.154(b) may be used as an innerduct in any raceway type permitted in Chapter 3.

(B) Raceway Fill for Communications Wires and Cables. The raceway fill limits of 300.17 do not apply to communications cables installed within a raceway.

General Requirements for Communications Systems | 800.113



▶ Figure 800–26



▶ Figure 800–27

(C) Cable Routing Assemblies. Communications cables can be installed in cable routing assemblies selected in accordance with Table 800.154(c), listed in accordance with 800.182, and installed in accordance with 800.110(C)(1) and (C(2), and 800.113.

(1) Horizontal Support. Where installed horizontally, cable routing assemblies must be supported every 3 ft and at each end or joint, unless listed otherwise. The distance between supports can never exceed 10 ft.

(2) Vertical Support. Where installed vertically, cable routing assemblies must be supported every 4 ft, unless listed otherwise, and are not permitted to have more than one joint between supports.

800.113 Installation of Communications Wires, Cables, Raceways, and Cable Routing Assemblies

The installation of cables, cable routing assemblies, and communications raceways must comply with 800.110 and the following:

(A) Listing. Cables, cable routing assemblies, and communications raceways installed in buildings must be listed.

Ex: Outside plant cables installed per 805.48 and 820.48 are not be required to be listed.

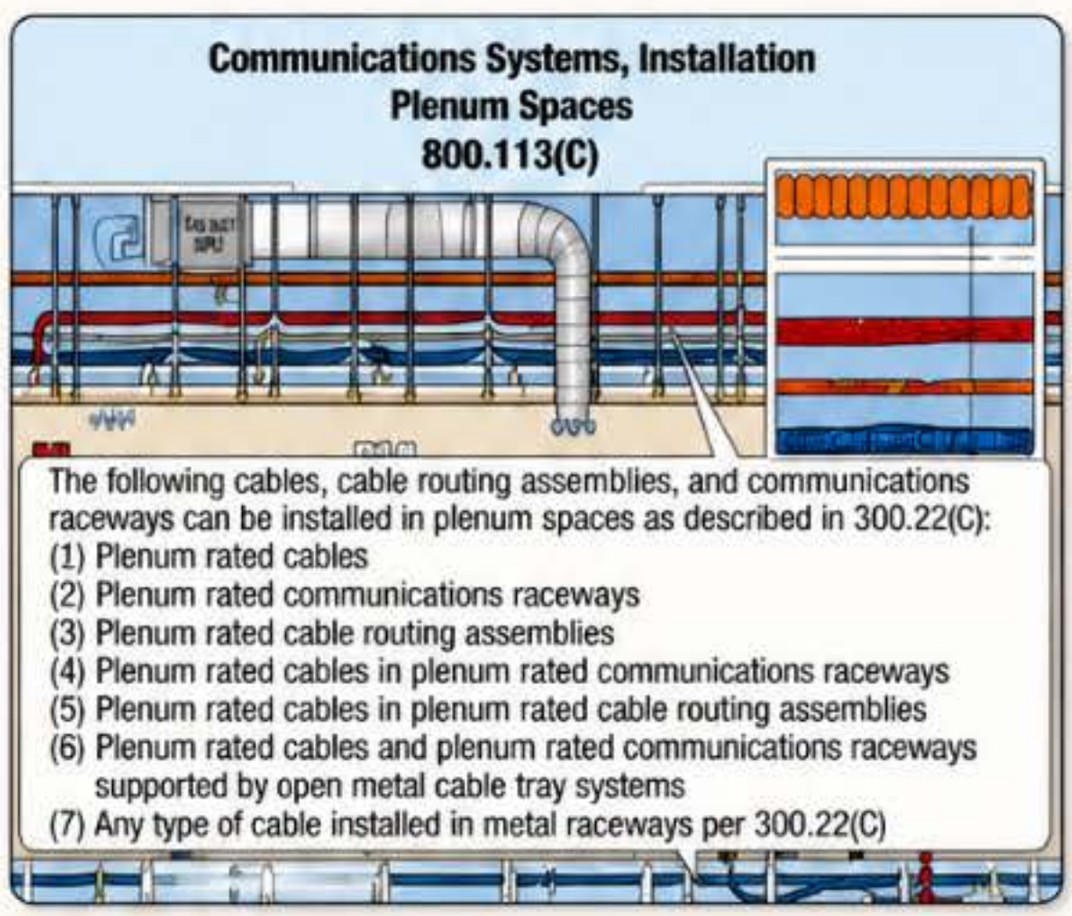
(B) Ducts Specifically Fabricated for Environmental Air. The following cables are permitted in ducts specifically fabricated for environmental air as described in 300.22(B) if they are directly associated with the air distribution system: ▶ Figure 800–27

(1) Plenum-rated cables up to 4 ft in length

(2) Any type of cable in a metal raceway in accordance with 300.22(B)

Note: For information on fire protection of wiring installed in fabricated ducts, see NFPA 90A, *Standard for the Installation of Air-Conditioning and Ventilating Systems*.

(C) Plenum Spaces. The following cables, cable routing assemblies, and communications raceways can be installed in plenum spaces as described in 300.22(C): ▶ Figure 800–28



▶ Figure 800–28

(1) Plenum-rated cables

(2) Plenum-rated communications raceways

(3) Phenum-rated cable routing assemblies

(4) Plenum-rated cables installed in plenum-rated communications raceways

(5) Plenum-rated cables installed in plenum-rated cable routing assemblies

(6) Plenum-rated cables and plenum-rated communications raceways supported by open metal cable tray systems

(7) Any type of cable installed in metal raceways in compliance with 300.22(C)

800.154 Applications of Listed Communications Wires, Cables, and Raceways, and Listed Cable Routing Assemblies

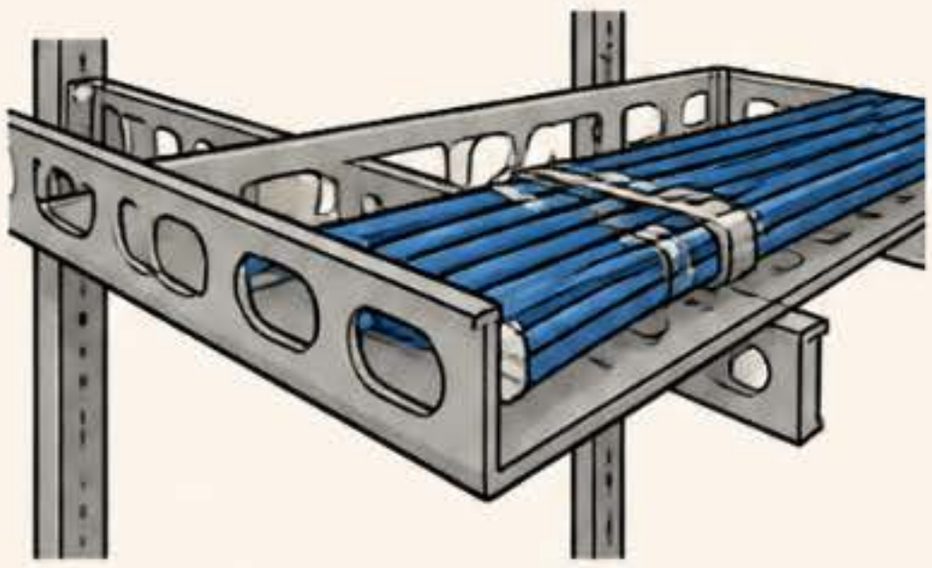
Permitted and nonpermitted uses of listed communications wires, cables, coaxial cables and raceways, and listed cable routing assemblies must comply with one of the following:

(1) Listed communications wires and cables as indicated in Table 800.154(a)

(2) Listed communications raceways as indicated in Table 800.154(b)

(3) Listed cable routing assemblies as indicated in Table 800.154(c)

The permitted applications are subject to the installation requirements of 800.110 and 800.113.



800.179 Plenum, Riser, General-Purpose, and Limited-Use Cables

Plenum, riser, general-purpose, and limited-use cables must be listed in accordance with 800.179(A) through (D). The cable voltage rating must not be marked on the cable.

(A) Plenum Cables. Type CMP (communications plenum cables) and Type CATVP (community antenna television plenum coaxial cables) must be listed as being suitable for use in ducts, plenums, and other spaces used for environmental air and also be listed as having adequate fire-resistant and low smoke-producing characteristics.

(B) Riser Cables. Type CM (communications general-purpose cables) and Type CATV (community antenna television coaxial general-purpose cables) must be listed as being suitable for general-purpose use, with the exception of risers and plenums, and also be listed as being resistant to the spread of fire.

(C) General-Purpose Cables. Type CM (communications general-purpose cables) and Type CATV (community antenna television coaxial general-purpose cables) must be listed as being suitable for general-purpose use, with the exception of risers and plenums, and also be listed as being resistant to the spread of fire.

ARTICLE 805 GENERAL REQUIREMENTS FOR COMMUNICATIONS CIRCUITS

Introduction to Article 805—General Requirements for Communications Circuits

The overarching provisions for Chapter 8 installations, other than Article 810 systems, are compiled in Article 800. Article 805 contains the detailed requirements that govern communications circuits. These rules either add to or revise the provisions in Article 800. The structure parallels the 90.3 language, which states that the rules in Chapters 1 through 4 can be altered by the particular rules found in Chapters 5 through 7.

Article 805 has its foundation in telephone technology. As a result, it addresses telephone, fax, voice, and related applications. Keep the following essential takeaways about Article 805 in mind:

- Do not connect incoming communications cables to the service-entrance power mast.
- Keep the bonding conductor for the primary protector as direct and as short as possible.
- When communications cables run above a finished ceiling, route and support them to permit easy access using a ceiling panel removal.
- Maintain cables separated from lightning protection conductors.
- If communications cables are installed in a Chapter 3 raceway, you must do so in accordance with the 2023 *NEC* requirements for the type of raceway in use.
- Follow all special identification and marking rules carefully.

Part I. General

805.1 Scope

Article 805 covers communications circuits and equipment.

▶ *Figure 805–1*

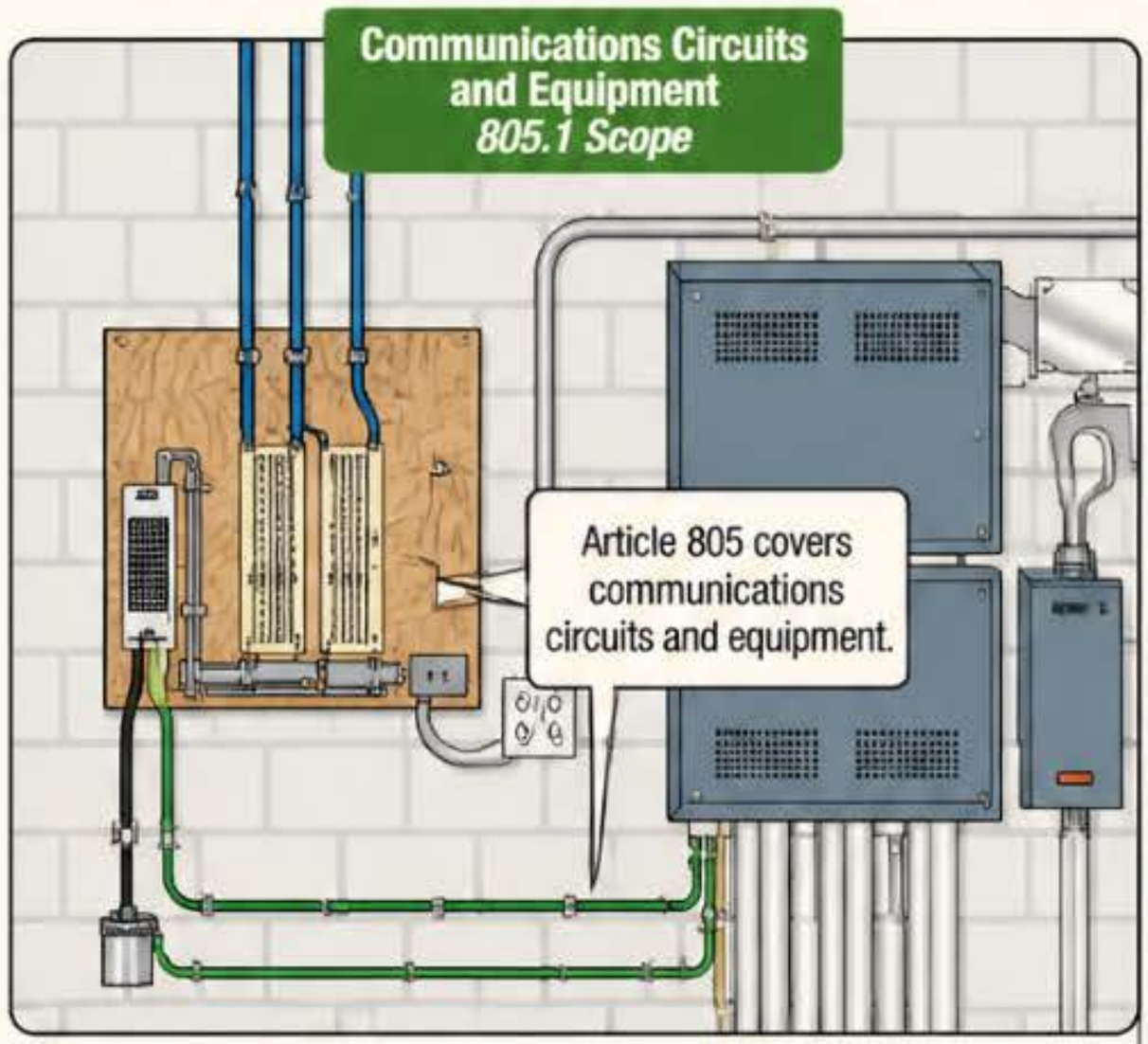
805.2 Definitions

This definition applies only to Article 805.

Communications Circuit Integrity (CI) Cable. Cable used in communications systems to maintain the continuous operation of vital circuits for a specified duration during fire conditions.

805.18 Installation of Equipment

Communications equipment must be listed in accordance with 805.170.



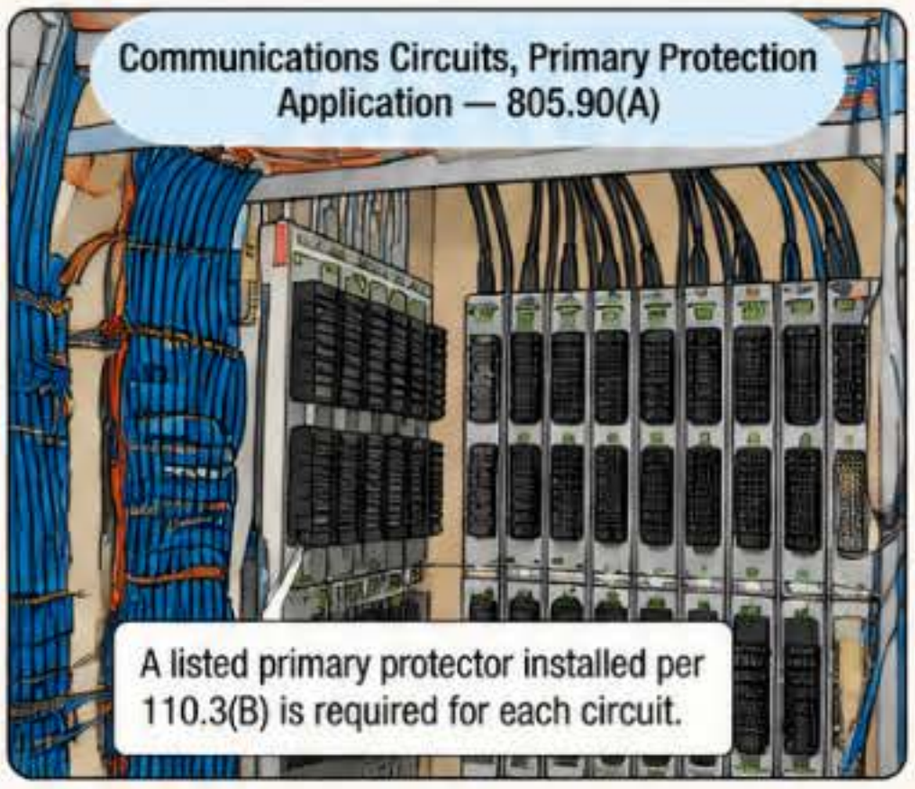
▶ *Figure 805–1*

Part III. Protection

805.90 Primary Protection

(A) Application. Every circuit must have a listed primary protector installed in compliance with 110.3(B).

▶ Figure 805–2



▶ Figure 805–2

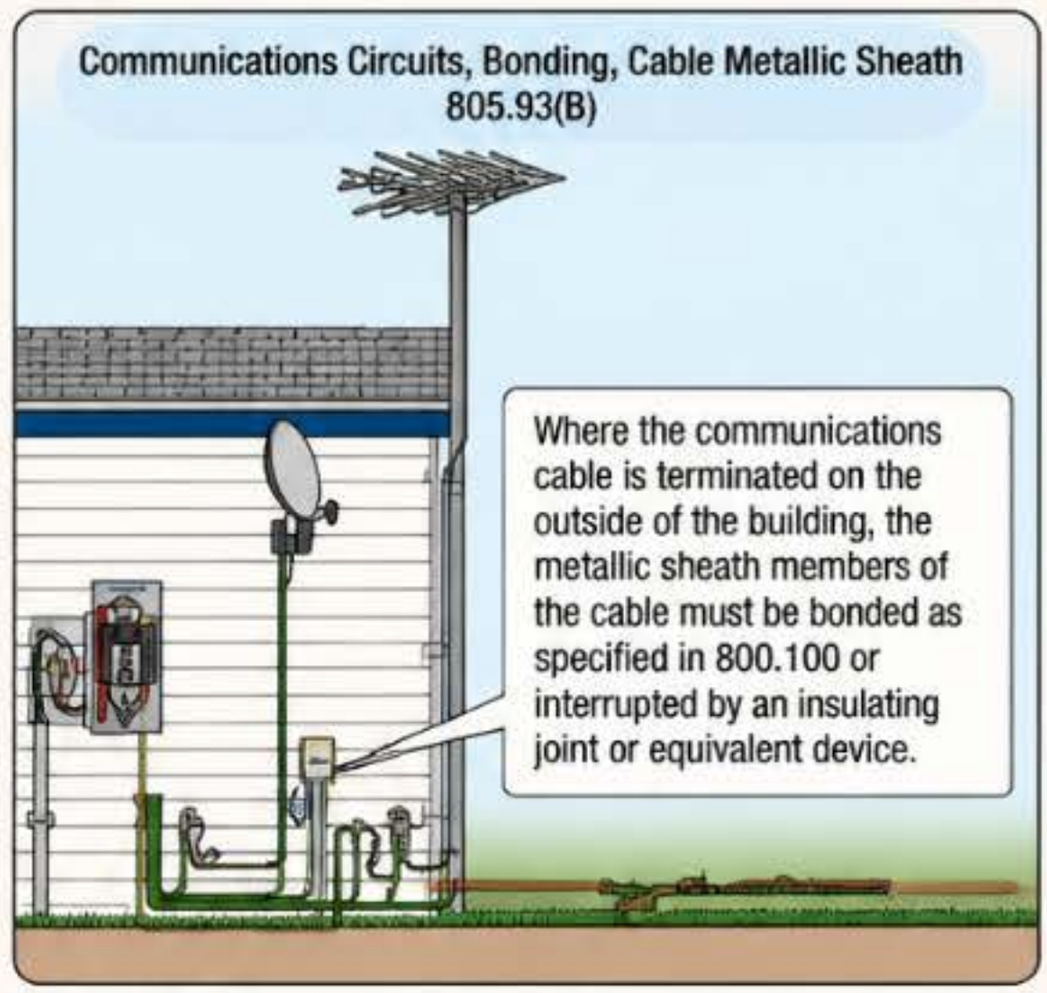
> **Author's Commentary:**
> You may choose the location for the primary protector or use one with the shortest bonding conductor available. Keeping this conductor short reduces voltage differences during lightning strikes and other metal system faults.
> *— Michael Hamilton*

805.93 Bonding or Interruption

(A) Entering Buildings. When communications cables enter a structure, the metallic sheath or armor of the cable must be connected (bonded) as specified in 800.100 or must be separated (interrupted) by an insulating joint or equivalent device. The separation or bonding must be as near as possible to the building entrance.

(B) Terminating on the Outside of Buildings. When communications cables end on the exterior of a building, the metallic sheath of the cable must be bonded (per 800.100) or interrupted with an insulating joint or equivalent device. The connection point should be as close as feasible to the location where the cable terminates.

▶ Figure 805–3



▶ Figure 805–3

Part IV. Installation Methods Within Buildings

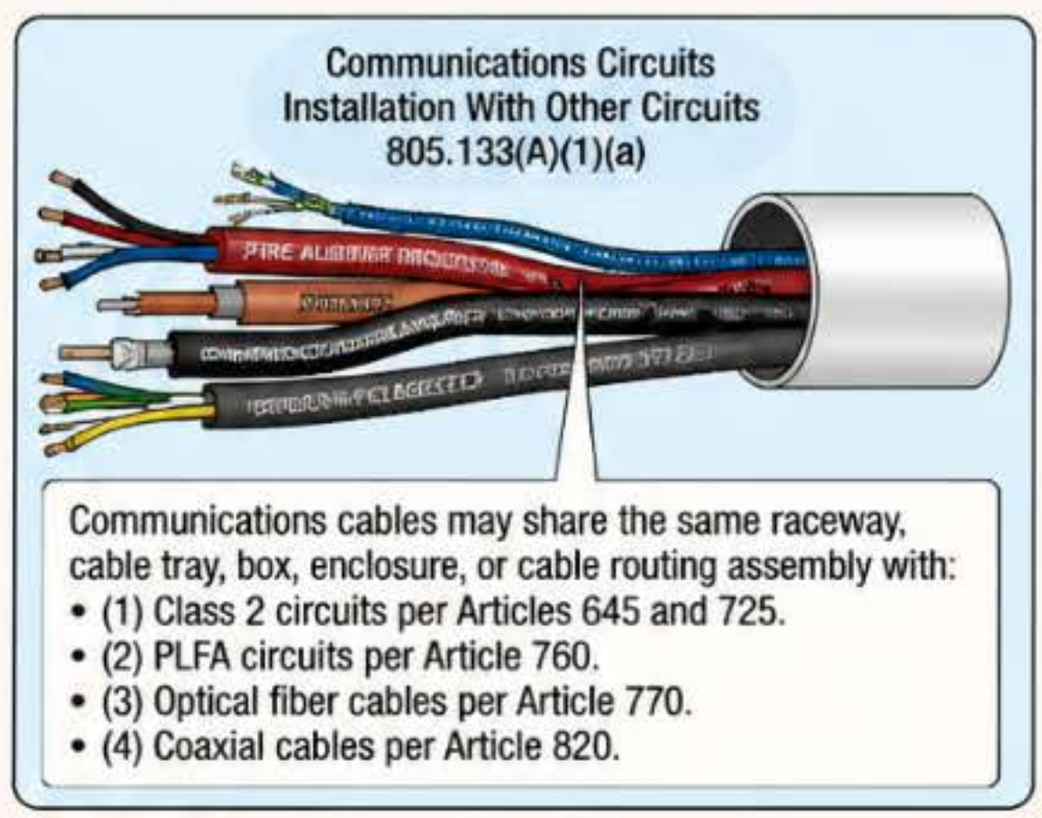
805.133 Installation of Communications Wires, Cables, and Equipment

(A) Separation from Power Conductors.

(1) In Raceways, Cable Trays, Boxes, Enclosures, and Cable Routing Assemblies.

(a) With Other Circuits. Communications cables can be in the same raceway, cable tray, cable routing assembly, box, or enclosure with cables of any of the following:

▶ Figure 805–4



▶ Figure 805–4

805.156 DEFINITIONS | From Michael Hamilton Publications

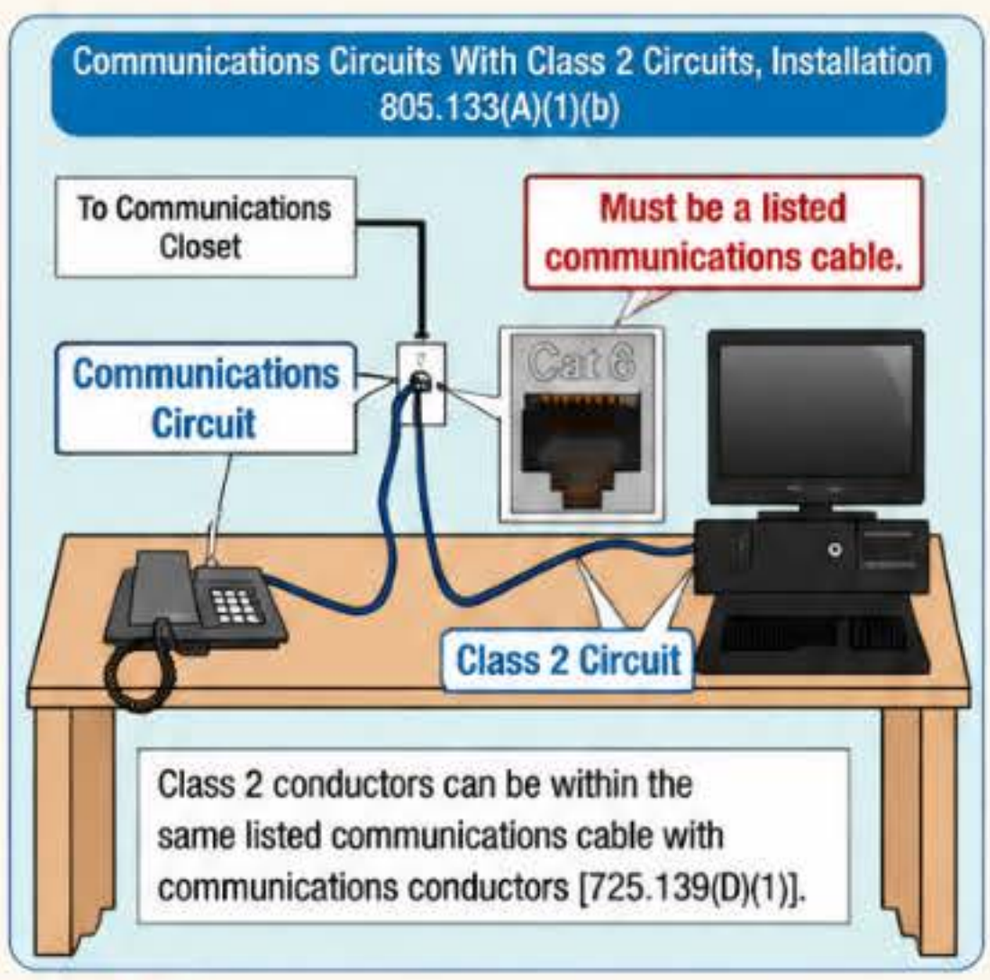
(1) Class 2 circuits in accordance with Articles 645 and 725.

(2) Power-limited fire alarm circuits in accordance with Article 760.

(3) Optical fiber cables in accordance with Article 770.

(4) Coaxial cables in accordance with Article 820.

(b) Class 2 Circuits. Class 2 conductors can be within the same listed communications cable with communications conductors [725.139(D)(1)].
▸ Figure 805–5



▸ Figure 805–5

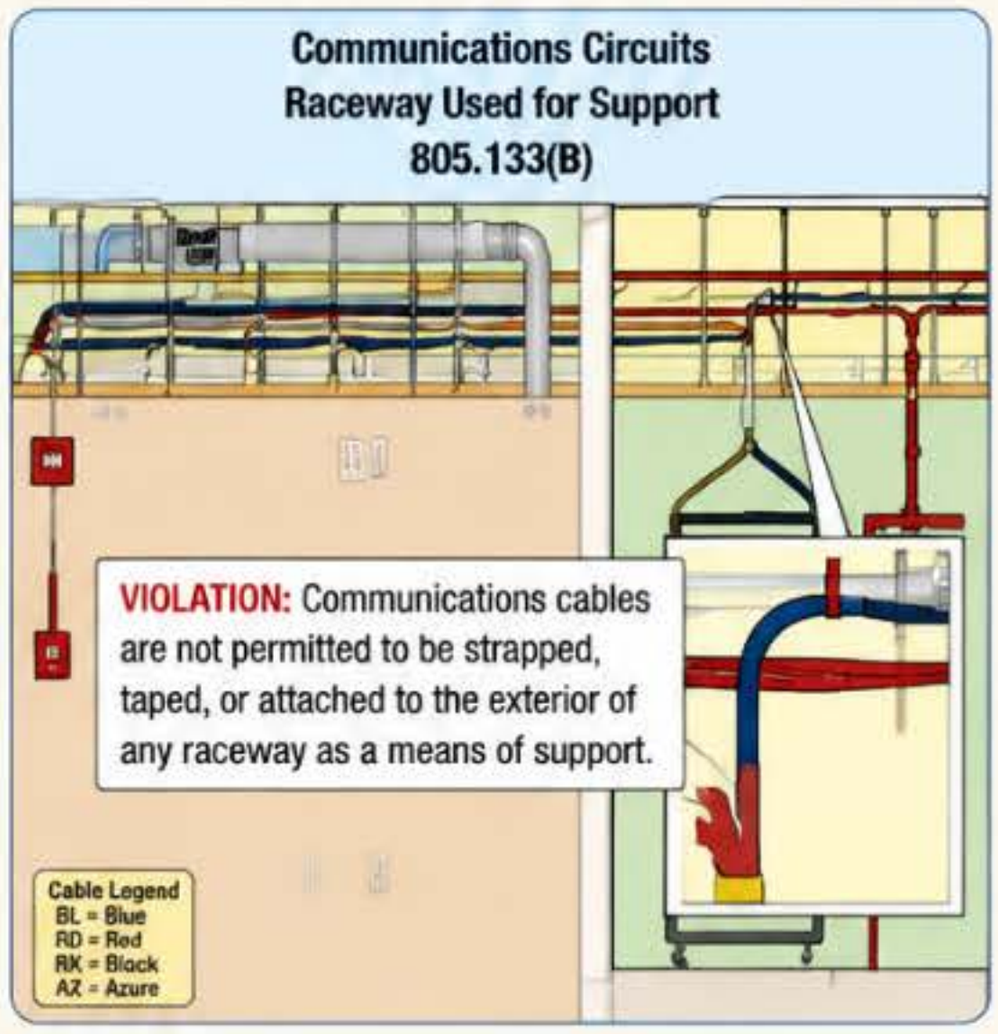
> ***Author's Commentary:***
> - A common application of this requirement is when a single cable is used for both voice communications and data.
> - Listed Class 2 cables have a voltage rating of not less than 150V [725.179(G)], whereas communications cables have a voltage rating of at least 300V [800.179].
>
> — *Michael Hamilton*

(c) With Power Conductors in Same Raceway or Enclosure. Communications conductors are not permitted to be placed in any raceway, compartment, outlet box, junction box, or similar fitting with conductors of electric power or Class 1 circuits.

Ex 1: Power conductors can be in the same enclosure with communications conductors if separated by a barrier.

Ex 2: Power conductors that supply communications equipment must maintain a ¼ in. separation from communications conductors within the enclosure.

(B) Support of Communications Cables. Communications cables are not permitted to be strapped, taped, or attached to the exterior of any raceway as a means of support. ▸ Figure 805–6



▸ Figure 805–6

> ***Author's Commentary:***
> - Exposed cables must be supported by the structural components of the building so the cable will not be damaged by normal building use. The cables must be secured by straps, staples, cable ties, hangers, or similar fittings designed and installed in a manner that will not damage the cable [800.24].
>
> — *Michael Hamilton*

805.154 Communications Cable(s) Substitutions

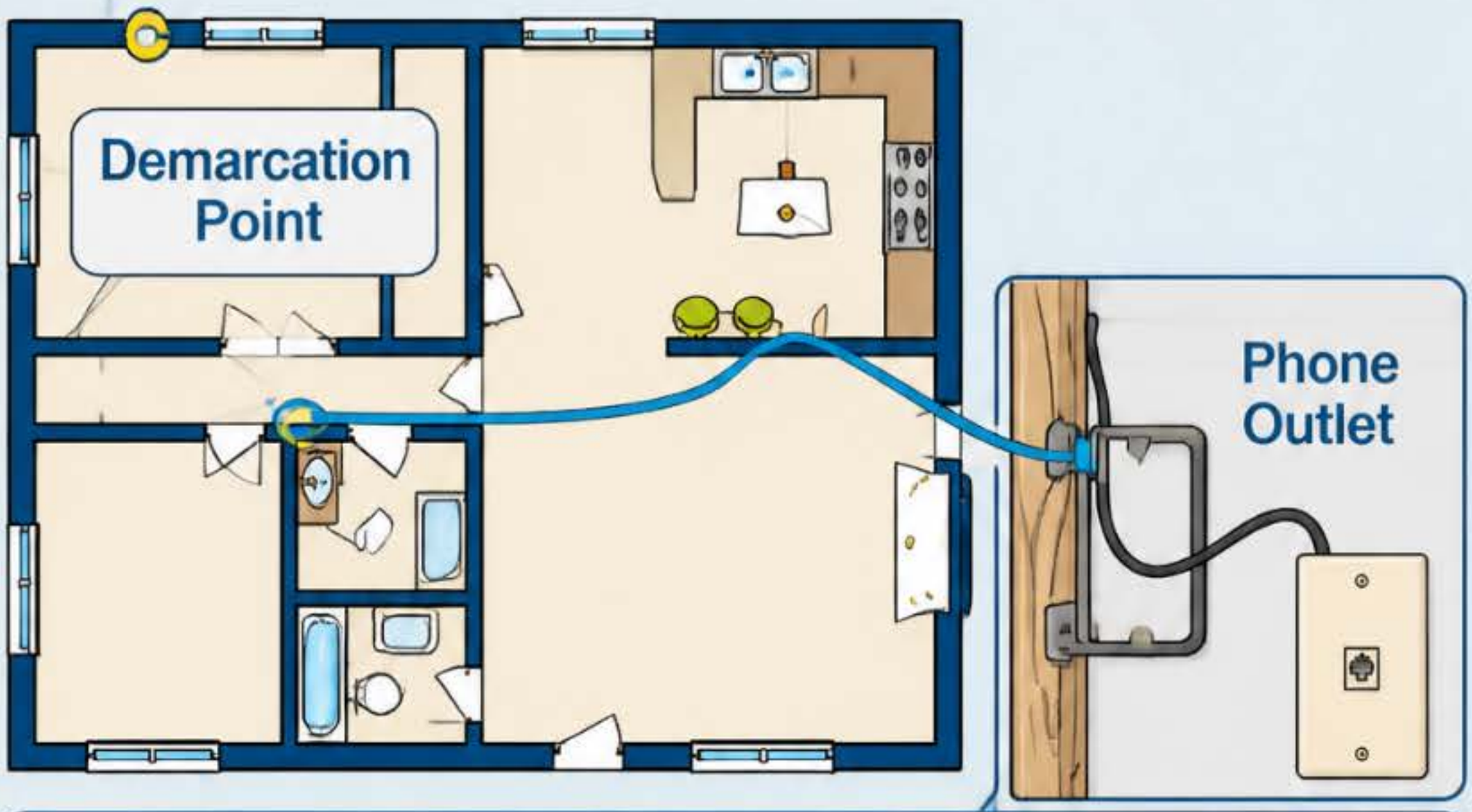
Cable substitutions are permitted provided that the substitute is more fire resistant than the original as indicated in the Cable Substitution Hierarchy in NEC figure 805.154.

805.156 Dwelling Unit Communications Outlet

For new construction, at least one communications outlet must be installed in a readily accessible area within each dwelling unit and cabled to the service provider's demarcation point. ▸ Figure 805–7

805.156 | General Requirements for Communications Circuits

Communications Circuits, Communications Outlet, Dwelling 805.156



For new construction, at least one communications outlet must be installed in a readily accessible area within each dwelling unit and cabled to the service provider's demarcation point.

Figure 805-7

ARTICLE 810 RADIO AND TELEVISION ANTENNA EQUIPMENT

Introduction to Article 810—Radio and Television Antenna Equipment

Unlike other articles in this chapter, Article 810 is not covered by the general rules in Article 800; as a result, it stands completely alone in the *Code* unless a rule in 810 references a specific rule elsewhere in the *NEC 2023*.

This article addresses transmitter and receiver (satellite dish and antenna) equipment, along with the wiring and cabling that support that equipment. Keep these key points in mind when working with Article 810:

- Avoid contact with conductors from other electrical systems.
- Do not connect satellite dishes, antennas, or other equipment to the service-entrance power mast.
- Maintain bonding conductors as short as practical and protect them from physical harm.
- If the mast is not properly bonded, you risk flashovers and possible electrocution.
- Remember that bonding helps equalize voltage differences between metallic parts and other conductive items, such as swimming pool structures.
- Clearances are critical, and Article 810 includes specific clearance requirements. For example, it sets out separate clearance rules for indoor and outdoor locations.

See Figure 800.100(B)(1) and Figure 800.100(B)(2) in the *NEC 2023* for examples of bonding conductors and grounding electrode conductors.

Part I. General

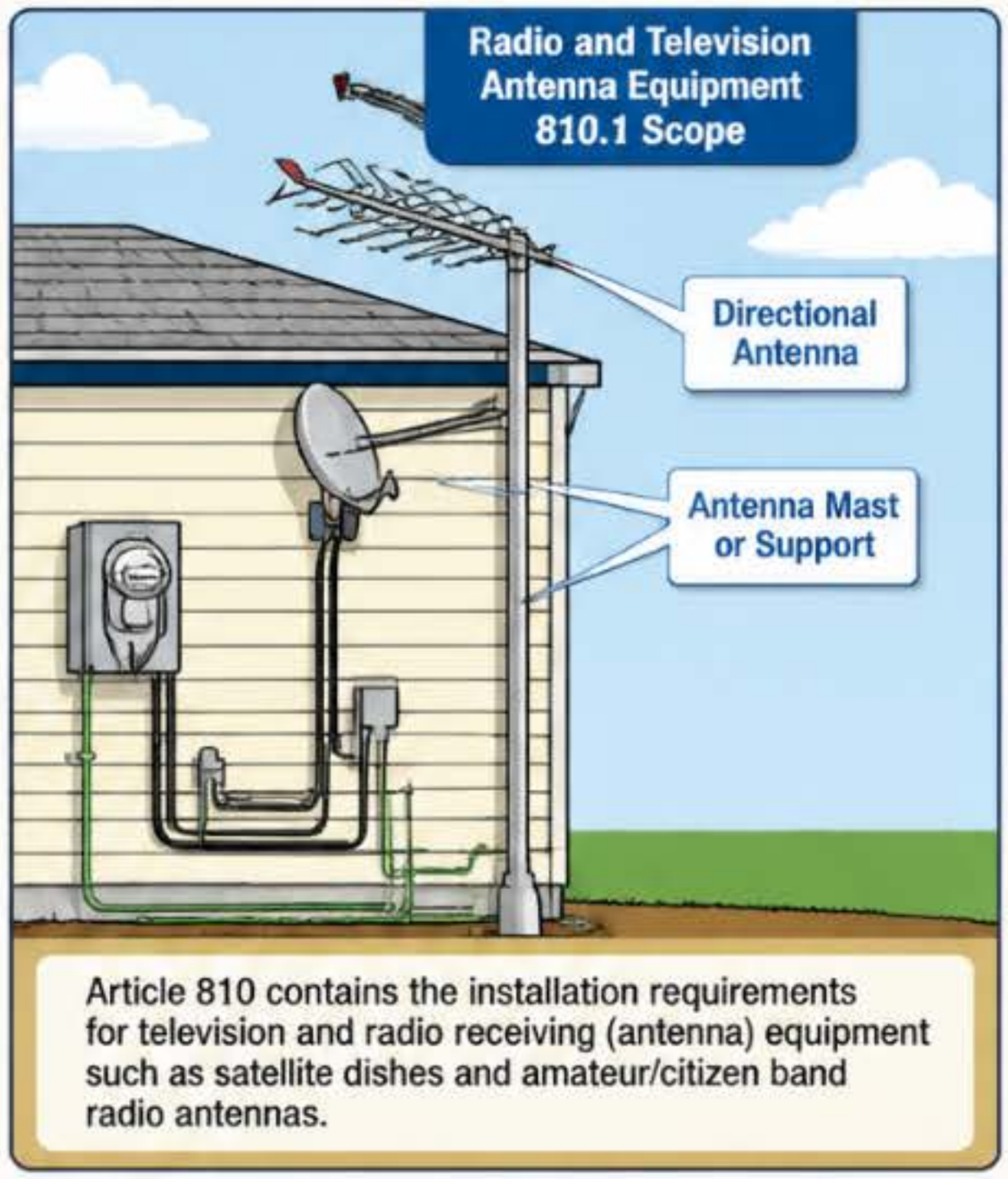
810.1 Scope

Article 810 contains the installation requirements for television and radio receiving (antenna) equipment, including satellite dishes and amateur/citizen band radio antennas. ▶Figure 810–1

Author's Commentary:

- Article 810 covers:
  - Antennas that receive local television signals.
  - Satellite antennas, which are commonly referred to as satellite dishes.
  - Roof-mounted antennas for AM/FM/XM radio reception.
  - Amateur radio transmitting and receiving equipment, including HAM radio equipment (a noncommercial [amateur] communications system).

— Michael Hamilton



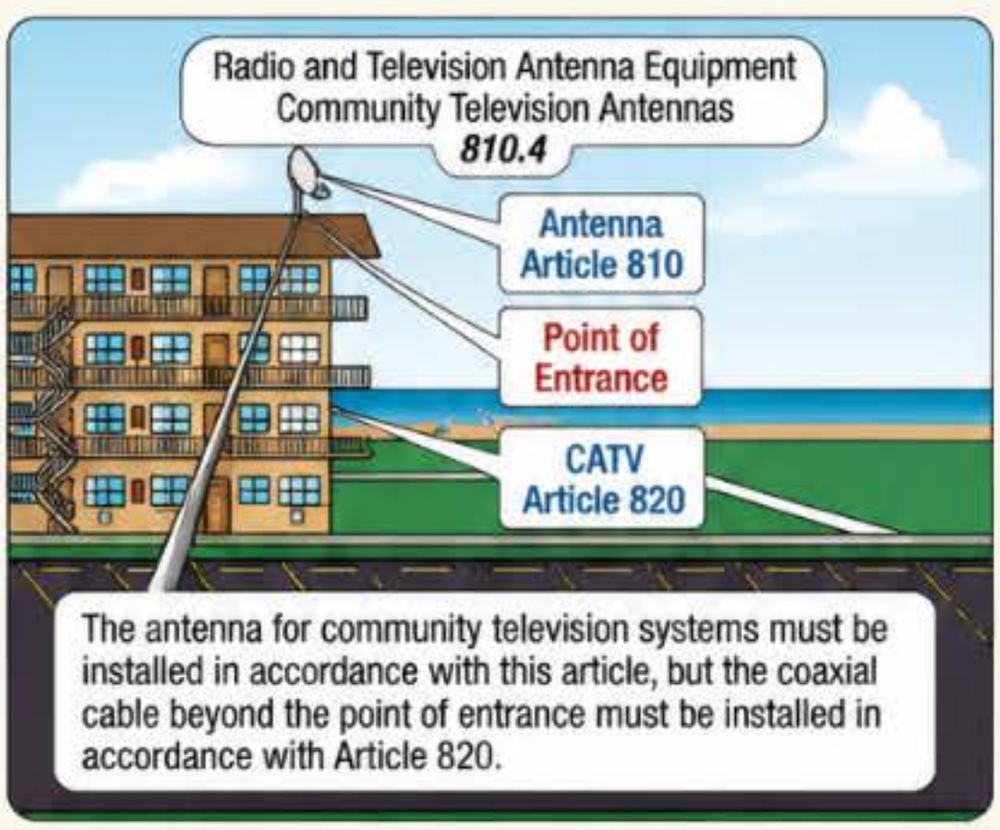
Article 810 contains the installation requirements for television and radio receiving (antenna) equipment such as satellite dishes and amateur/citizen band radio antennas.

Figure 810–1

▶ Figure 810-2

810.4 Community Television Antenna

The antenna for community television systems must be installed in accordance with this article, but the coaxial cable beyond the point of entrance must be installed in accordance with Article 820. ▶Figure 810-3



▶ Figure 810-3

Author's Commentary:

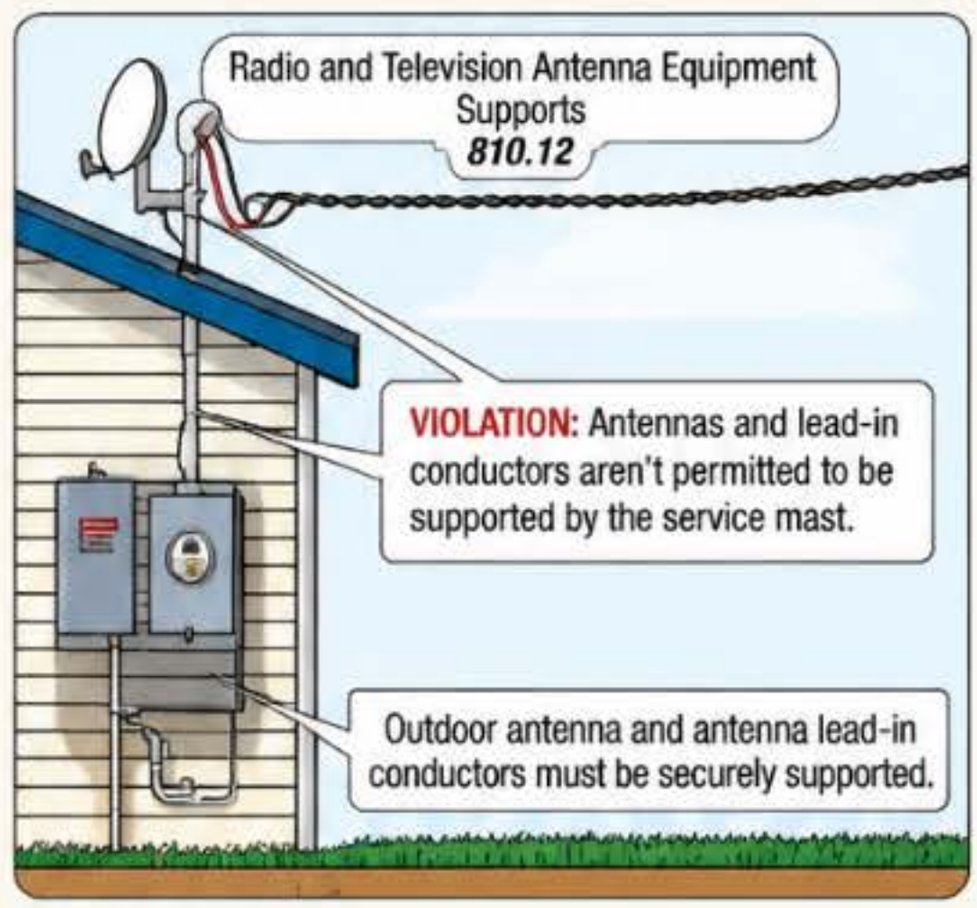
A community TV antenna is used for serving multiple-occupancy buildings like apartment complexes, condominiums, motels, and hotels.

— Michael Hamilton

Part II. Receiving Equipment—Antenna Systems

810.12 Supports

Outdoor antennas and lead-in conductors must be safely supported, and the lead-in conductors must be securely attached to the antenna. The antennas or lead-in conductors are not permitted to be attached to the electric service mast. ▶Figure 810-4



▶ Figure 810-4

810.13 Avoid Contact with Conductors of Other Systems

Outdoor antennas and lead-in conductors must be kept at least 2 ft away from exposed electric power conductors to avoid the possibility of accidental contact.

Author's Commentary:

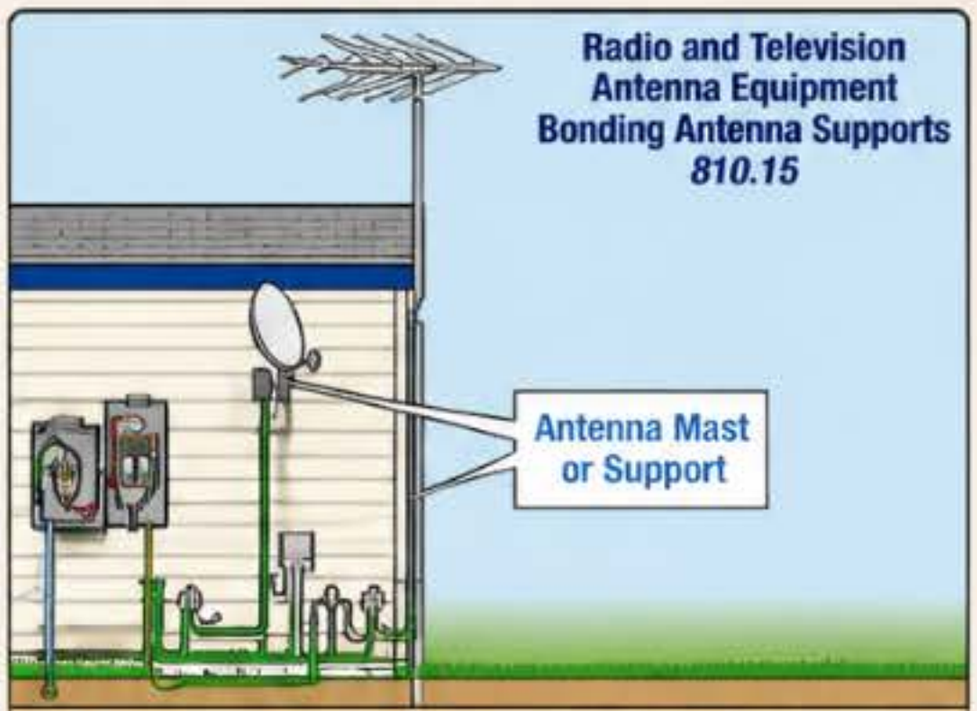
- According to the *National Electrical Code Handbook*, "One of the leading causes of electrical shock and electcrocution is the accidental contact of radio, television, and amateur radio transmitting and receiving antennas, and equipment with light or power conductors. Extreme caution should therefore be exercised during this type of installation, and periodic visual inspections should be conducted thereafter."

— Michael Hamilton

Radio and Television Antenna Equipment

810.15 Metal Antenna Supports—Bonding

Exterior masts and metal supports used to hold antennas must be connected per 810.21, unless the antenna and its support structure are located within a protected zone defined by a 150-ft radius rolling sphere. ▶ Figure 810–5



Outdoor masts and metal structures that support antennas must be bonded per 810.21, unless the antenna and its related supporting mast or structure are within a zone of protection defined by a 150-ft radius rolling sphere.

▶ Figure 810–5

Note: See NFPA 780, *Standard for the Installation of Lightning Protection Systems* (4.8.3.1), for the application of the term "Rolling Sphere."

810.18 Clearances

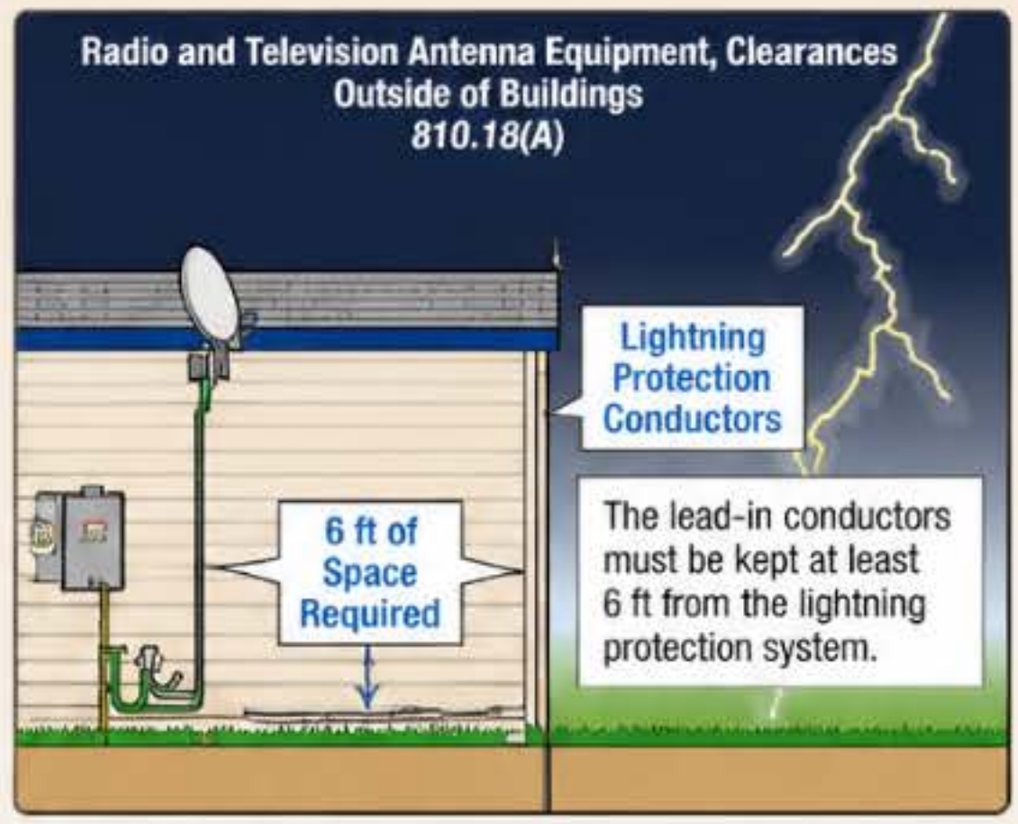
(A) Outside of Buildings. Lead-in conductors attached to buildings must be installed so they cannot swing any closer than 2 ft to the conductors of circuits of 250V or less, or closer than 10 ft to the conductors of circuits of over 250V.

Lead-in conductors must be kept at least 6 ft from the lightning protection system, and underground antenna lead-in conductors must maintain a separation not less than 12 in. from electric power conductors. ▶ Figure 810–6

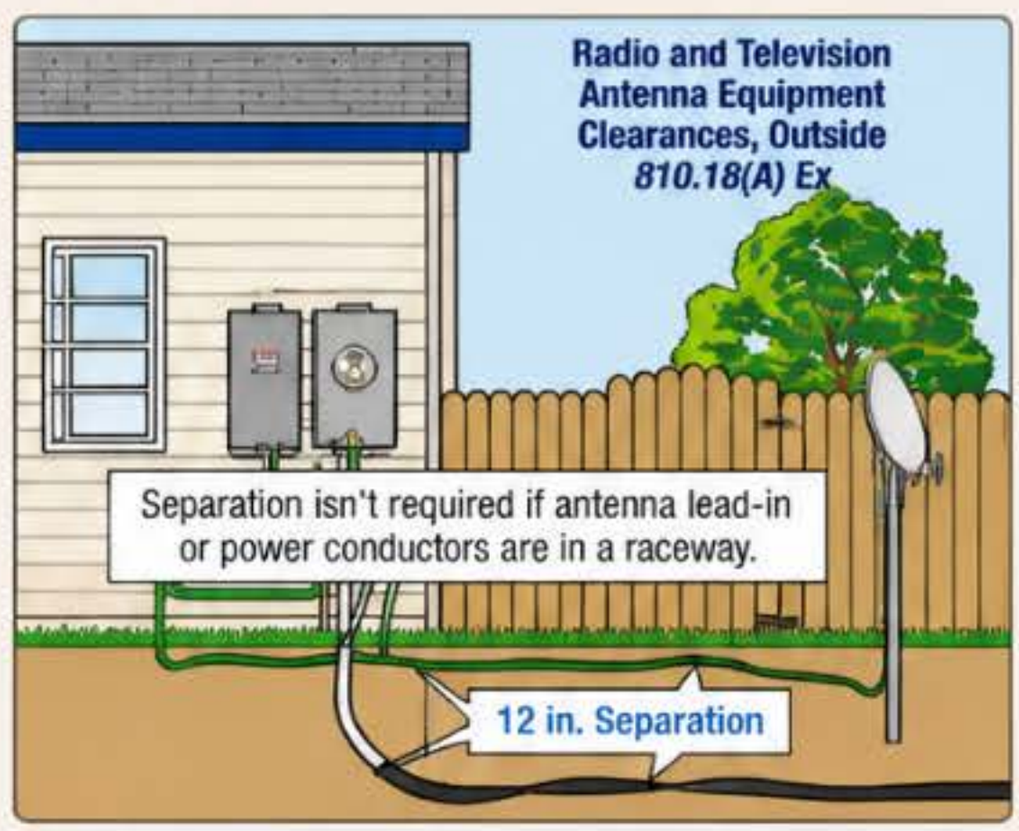
Ex: Separation is not required where the underground antenna lead-in conductors or the electric power conductors are installed in raceways or metal cable armor. ▶ Figure 810–7

(B) Indoors. Indoor antenna and lead-in conductors are not permitted to be less than 2 in. from electric power conductors.

Ex 1: Separation is not required if the antenna lead-in conductors or the electric power conductors are installed within a metal raceway or metal cable armor.



▶ Figure 810–6



▶ Figure 810–7

(C) Boxes and Enclosures. Indoor antenna lead-in conductors can be in the same box or enclosure with electric power conductors where separated by an effective, permanently installed barrier. ▶ Figure 810–8

810.20 Antenna Discharge Unit

(A) Listed. Each lead-in conductor from an outdoor antenna must be provided with a listed antenna discharge unit. ▶ Figure 810–9

(B) Location. The antenna discharge unit must be located outside or inside the building, nearest the point of entrance, but not near combustible material or in a hazardous (classified) location as defined in Article 500.

810.21 | Radio and Television Antenna Equipment

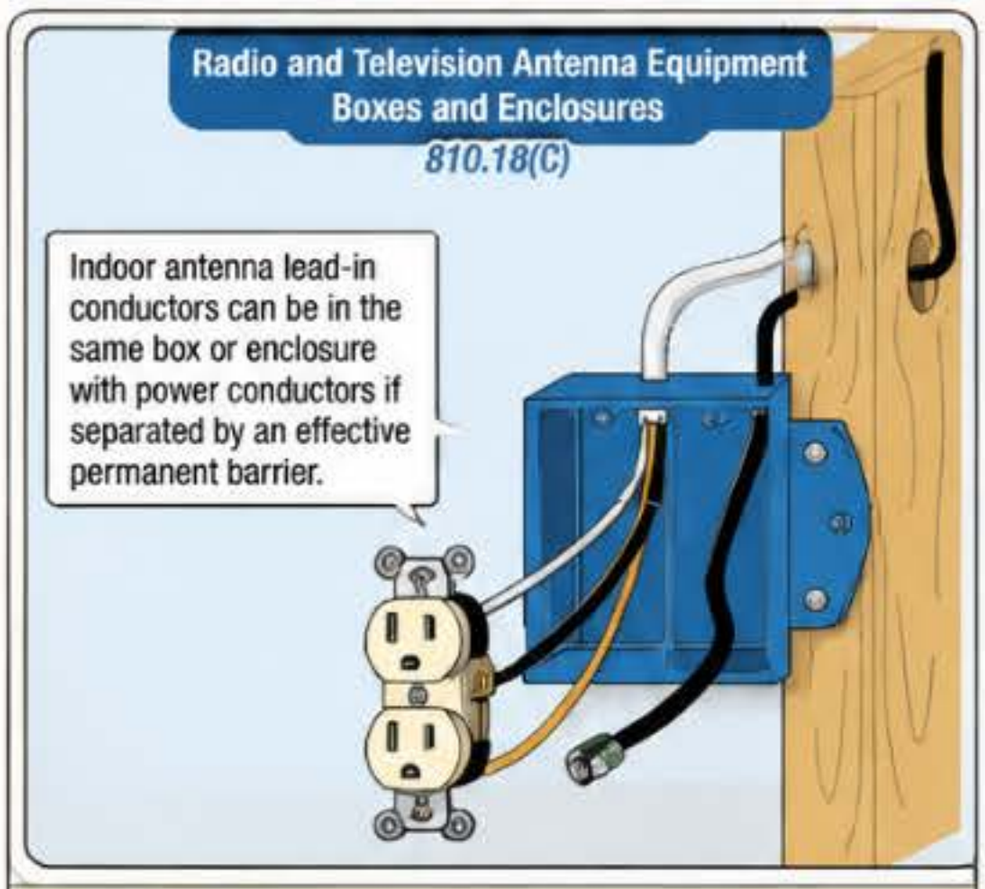


Figure 810–8

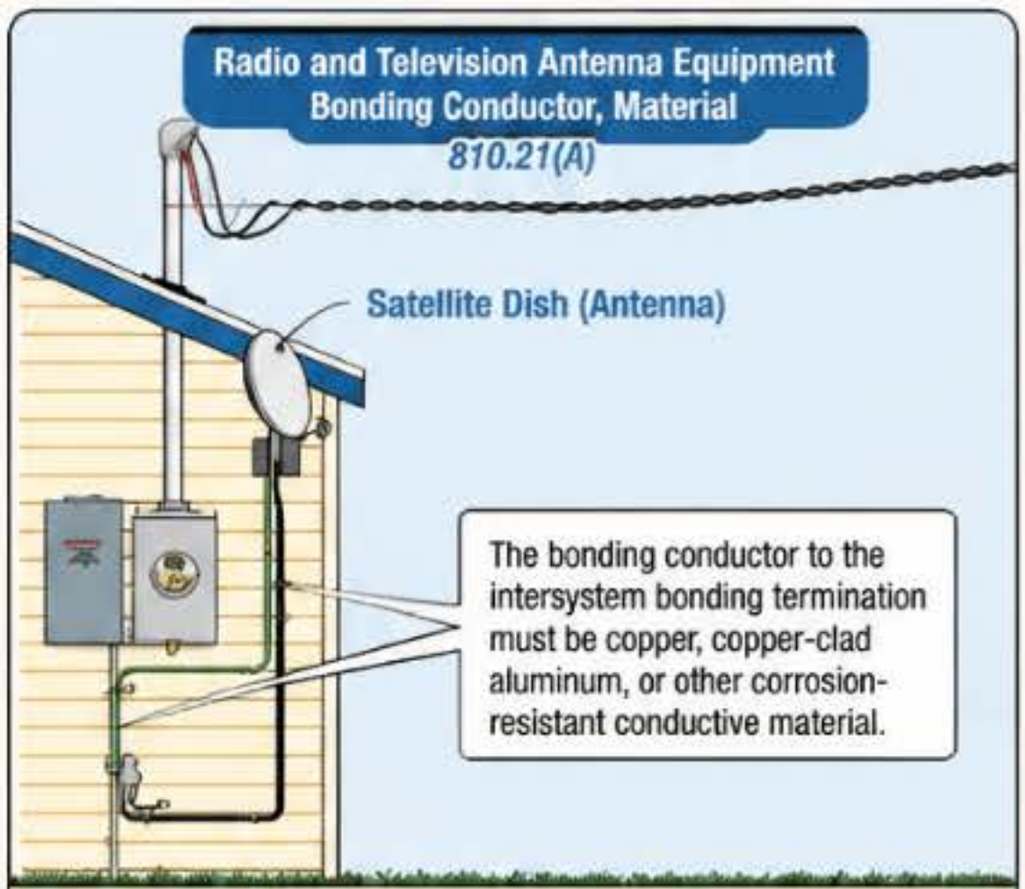


Figure 810–10

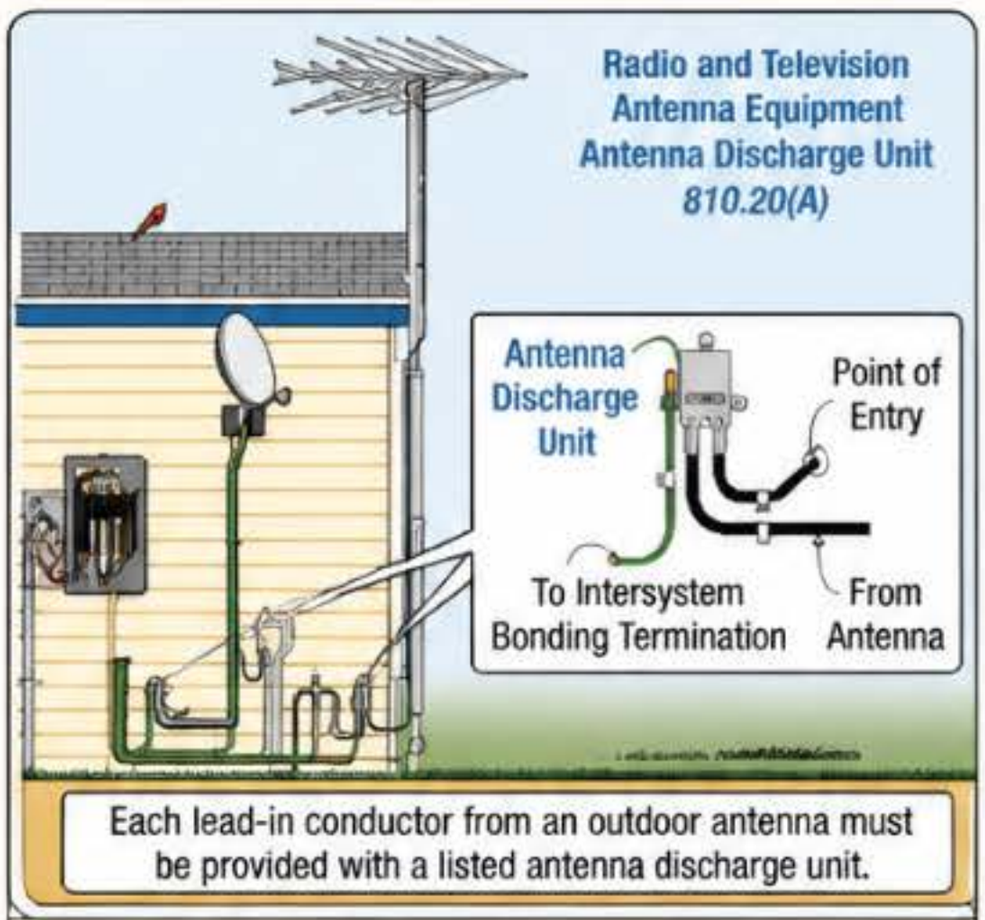


Figure 810–9

(C) Bonding. The antenna discharge unit must be bonded in accordance with 810.21.

810.21 Bonding Conductors and Grounding Electrode Conductors

Bonding conductors must meet the following requirements:

(A) Material. The bonding conductor to the intersystem bonding termination must be copper, copper-clad aluminum, copper-clad steel, aluminum, bronze, or other corrosion-resistant conductive material. ▸ Figure 810–10

Where aluminum or copper-clad aluminum is used, it must not be installed outside within 18 in. from the Earth or where subject to corrosive conditions.

(B) Insulation. Insulation on bonding conductors is not required.

(C) Supports. The bonding conductor must be securely fastened in place.

(D) Physical Protection. Bonding conductors must be mechanically protected where subject to physical damage; and where installed in a metal raceway, both ends of the raceway must be bonded to the bonding conductor.

Author's Commentary:

- Installing the bonding conductor in PVC conduit is a better practice.

— Michael Hamilton

(E) Run in Straight Line. The bonding conductor must be run in as straight a line as practicable.

Author's Commentary:

- Lightning does not like to travel around corners or through loops, which is why the bonding conductor must be run as straight as practicable.

— Michael Hamilton

(F) Electrode. The bonding conductor must terminate in accordance with (1), (2), or (3).

(1) Buildings with an Intersystem Bonding Termination. The bonding conductor for the antenna mast and antenna discharge unit must terminate to the intersystem bonding termination [Article 100] as required by 250.94. ▸ Figure 810–11

(G) Inside or Outside Building. The bonding conductor can be installed either inside or outside the building.

810: Radio and Television Antenna Equipment | 810.21

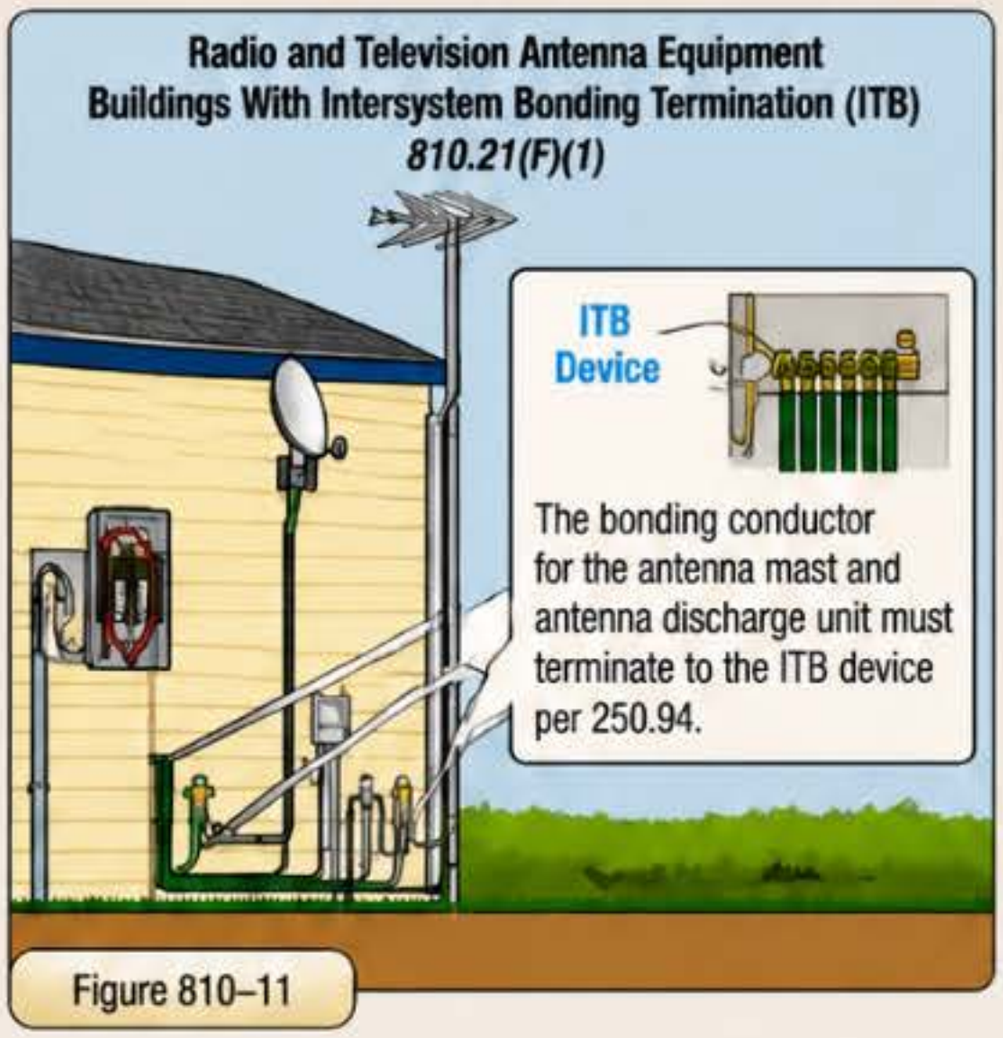


Figure 810–11

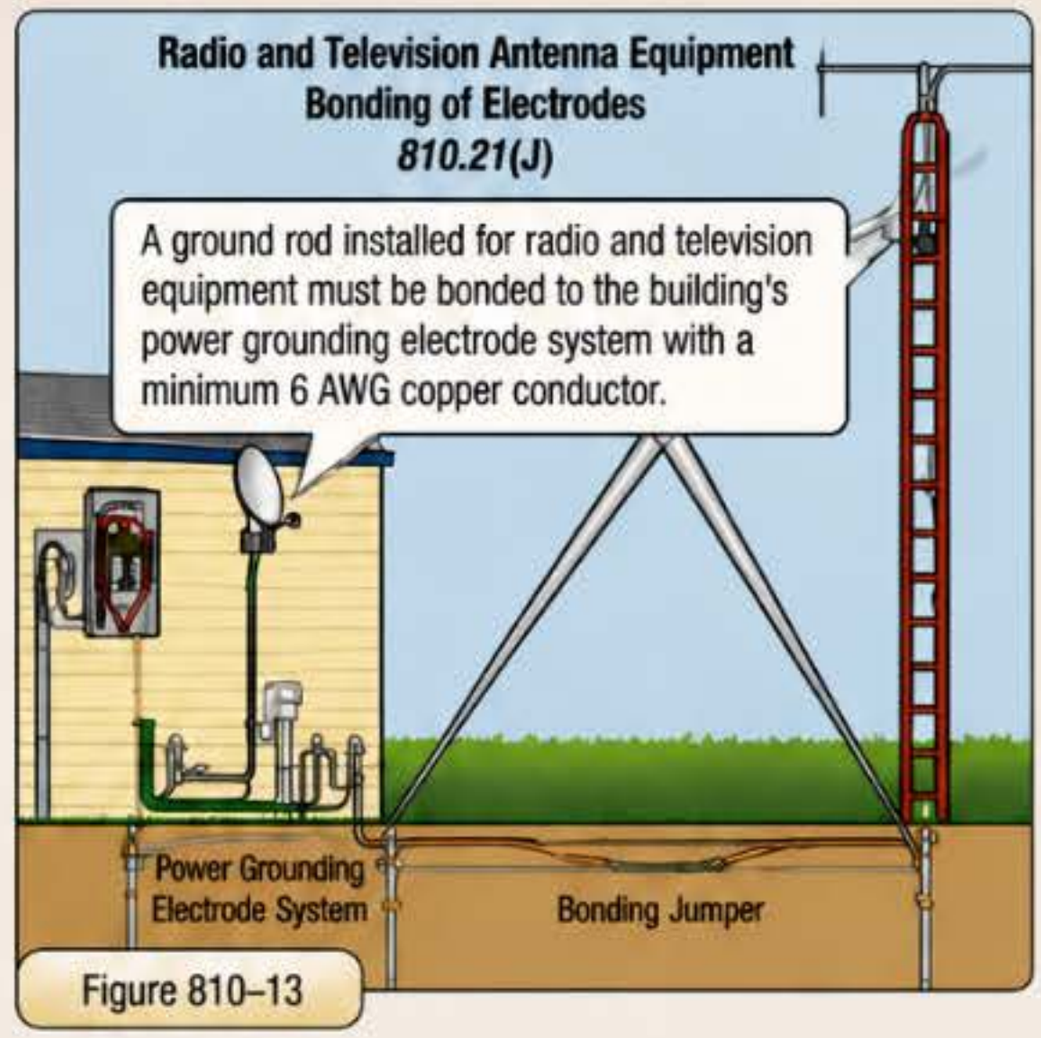


Figure 810–13

(H) Size. The bonding conductor is not permitted to be smaller than 10 AWG copper, 8 AWG aluminum, or 17 AWG copper-clad steel or bronze. ▸Figure 810–12

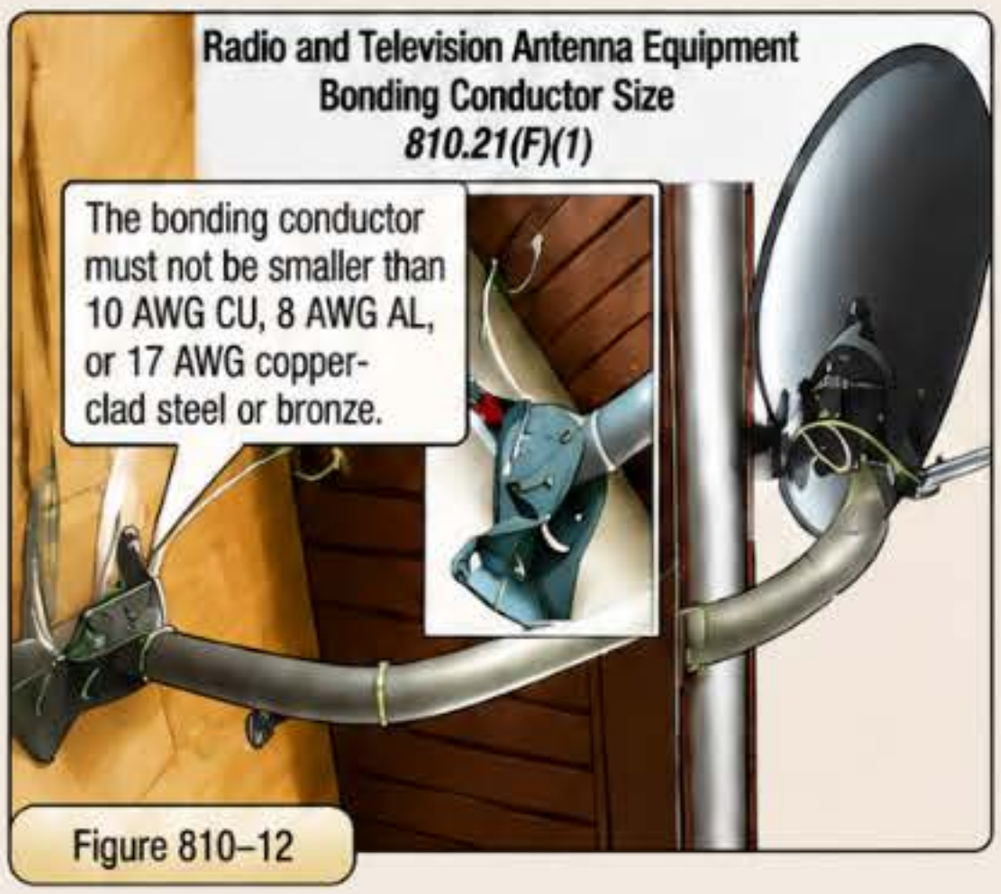


Figure 810–12

(J) Bonding of Electrodes. A ground rod installed for the radio and television equipment must be bonded to the building's power grounding electrode system with a minimum 6 AWG copper conductor. ▸Figure 810–13

Author's Commentary:

- A separate grounding electrode is not required for radio and TV equipment, but if it is installed, then it must be bonded to the building's power grounding electrode system with a minimum 6 AWG copper conductor.
- Bonding of electrodes helps reduce induced voltage differences between the power and communications systems during lightning events.

— Michael Hamilton

(K) Electrode Connection. Termination of the bonding conductor must be by exothermic welding, listed lugs, listed pressure connectors, or listed clamps. Grounding fittings that are concrete-encased or buried in the Earth must be listed for direct burial in accordance with 250.70. ▸Figure 810–14

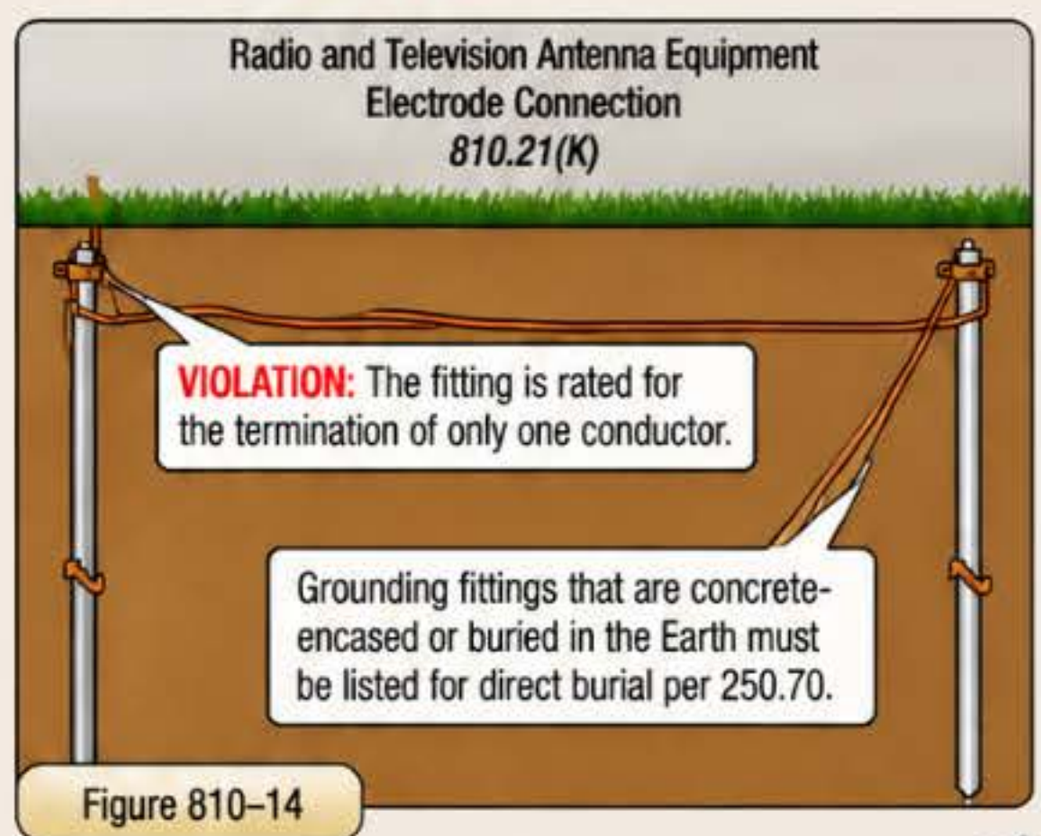


Figure 810–14

Author's Commentary:

- Bonding the lead-in lines and the mast assembly helps block high-voltage spikes caused by static discharges or nearby lightning that may reach the antenna or satellite dish. Since the dish is outdoors, wind can build up static electricity on both the antenna and the cable it connects to. This static charge can jump through the cable over small gaps in internal parts like a low noise block (LNB) or a receiver.
  Tying the antenna or dish to the building's grounding electrode system (grounding) allows that static energy to safely discharge.
- Grounding alone won't stop damage from a direct lightning strike, but it can reduce the impact by working with proper surge protection to protect the satellite dish and nearby equipment from lightning surges.

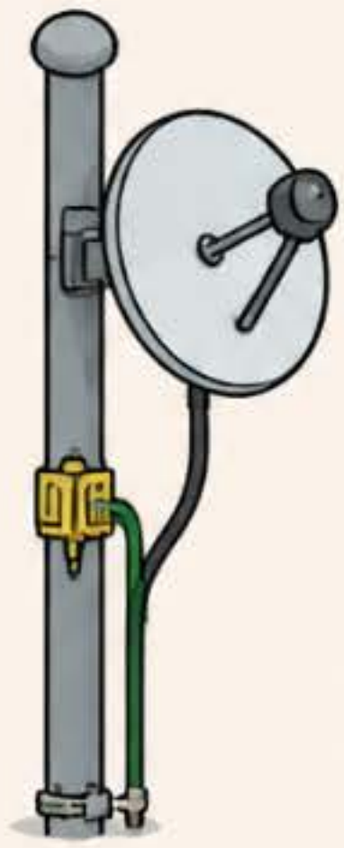
— Michael Hamilton

Part III. Amateur and Citizen Band Transmitting and Receiving Stations—Antenna Systems

810.51 Other Sections

In addition to the requirements found in Part III, the antenna systems for amateur and citizen band transmitting and receiving stations must also comply with 810.11 through 810.15.

810.57 Antenna Discharge Units—Transmitting Stations



Each outdoor lead-in conductor must be equipped with an antenna discharge unit or another approved method to drain static charges from the antenna system.

Example 1: If the lead-in is shielded continuously with metal that is bonded per 810.58, an antenna discharge unit or other approved means isn't needed.

Example 2: If the antenna system is bonded in accordance with 810.58, an antenna discharge unit or other suitable means isn't required.

810.58 Bonding Conductors and Grounding Electrode Conductors—Amateur and Citizen Band Transmitting and Receiving Stations

Bonding conductors must meet 810.58(A) through 810.58(C).

(A) Other Sections. Bonding conductors for amateur and citizen band transmitting and receiving stations must comply with 810.21(A) through 810.21(C).

(B) Size of Protective Bonding Conductor. The protective bonding conductor used for transmitting stations must be at least as large as the lead-in but not smaller than 10 AWG copper, bronze, or copper-clad steel.

ARTICLE 820 COMMUNITY ANTENNA TELEVISION (CATV) AND RADIO DISTRIBUTION SYSTEMS (COAXIAL CABLE)

Introduction to Article 820—Community Antenna Television (CATV) and Radio Distribution Systems (Coaxial Cable)

This article addresses how television and radio signals are delivered within a facility or onto a property using cable instead of antenna reception. These signals carry limited power, yet operate at high frequencies.

- Article 820 identifies the "Point of Entrance" for these circuits and specifies the general rules for installing all communication wiring.
- The incoming coaxial cable should be routed as directly as feasible to the point of entrance.
- If coaxial cables must cross above a dropped ceiling, they need adequate support for access to the ceiling panel system.
- Adequate clearance is mandatory, and Article 820 provides detailed spacing requirements. For example, allow at least 6 ft (1.8 m) between coaxial cables and lighthing conductors.
- The bonding conductor must be connected to the intersystem bonding termination if the system is within or attached to the building.
- When a separate grounding electrode is used, a bonding jumper is required to the power grounding electrode system.

Part I. General

820.1 Scope

Article 820 covers the installation of coaxial cables for distributing high-frequency signals typically employed in community antenna television systems (CATV).

▶ Figure 820–1

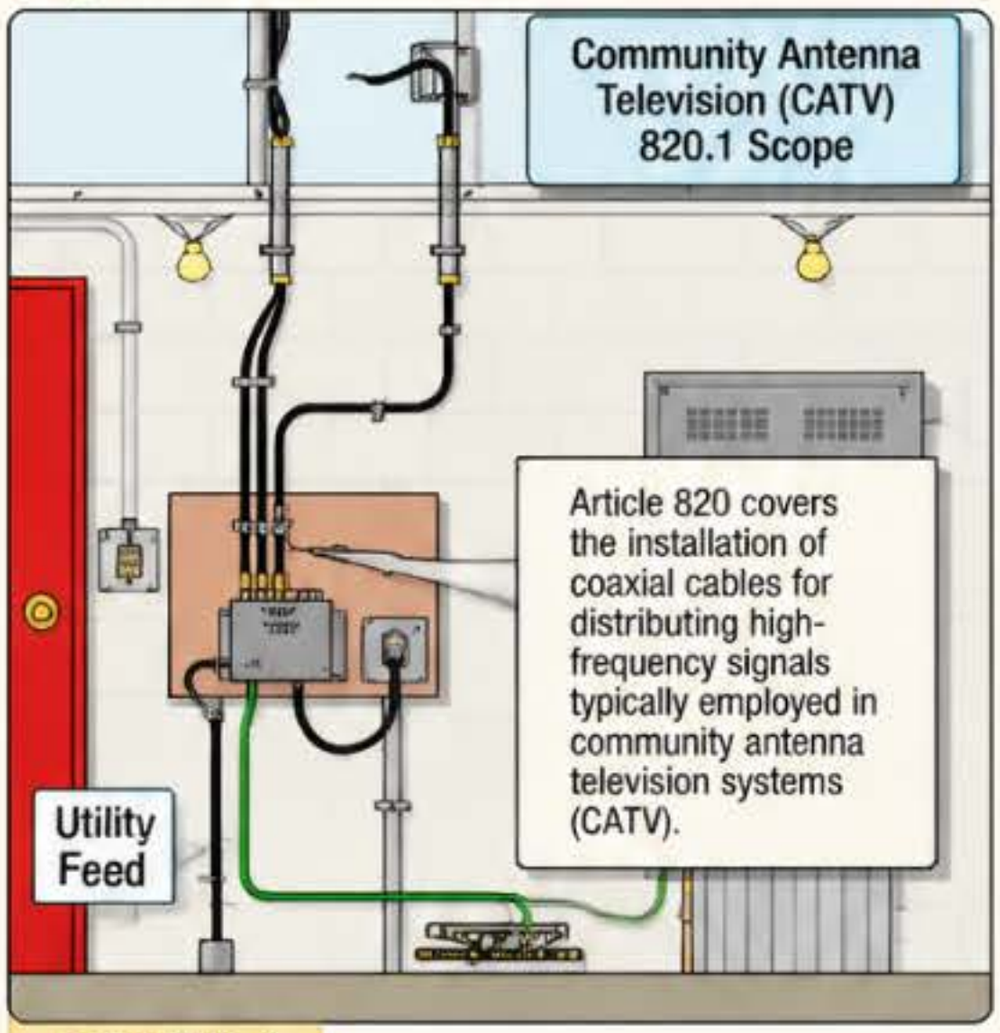


Figure 820–1

Author's Commentary:

- Article 820 governs the installation of coaxial cables used for cable television, closed-circuit television, security cameras, and radio and television receiving equipment.
- Coaxial cables that link antennas to television and radio receiving equipment [810.3] and community television systems [810.4] must be installed in accordance with this article.

— Michael Hamilton

Part III. Protection

820.93 Grounding of the Outer Conductive Shield of Coaxial Cables

(A) Coaxial Cables Entering Building. Coaxial cables supplied to a building must have the metallic sheath members bonded as close as practicable to the point of entrance in accordance with 820.100.

▶ Figure 820–3

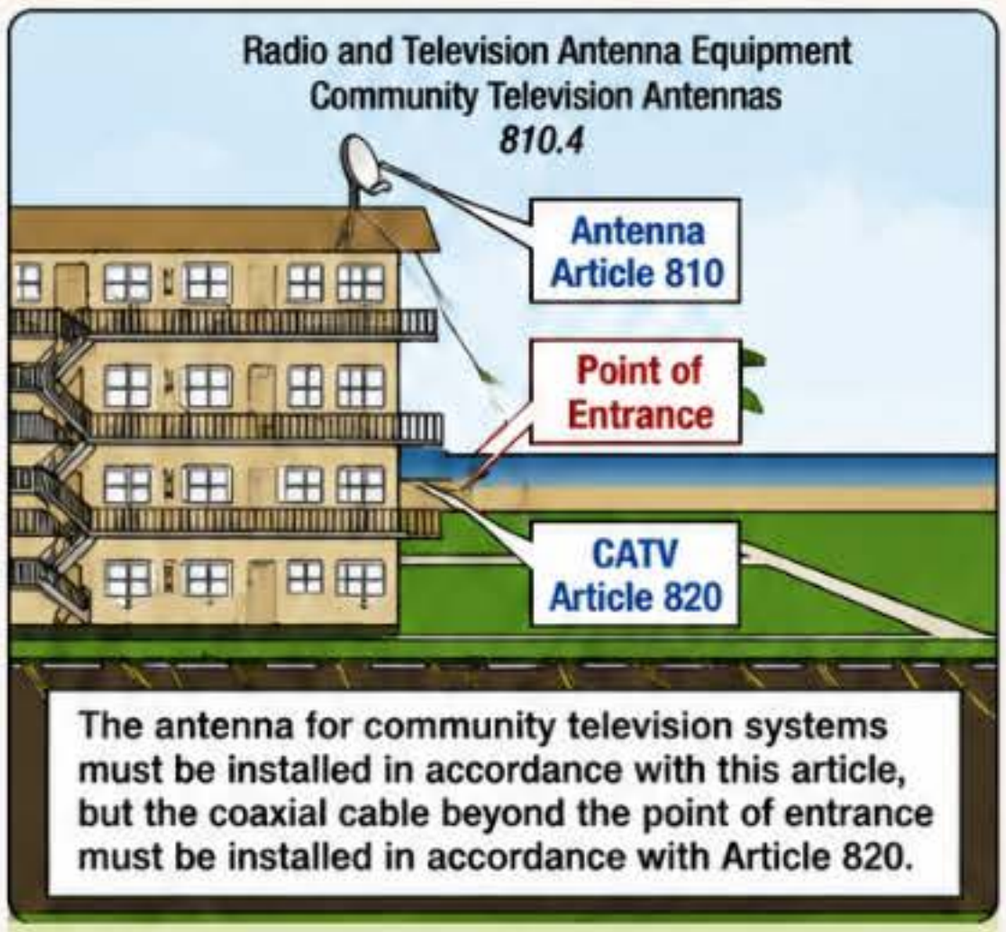


Figure 820–2

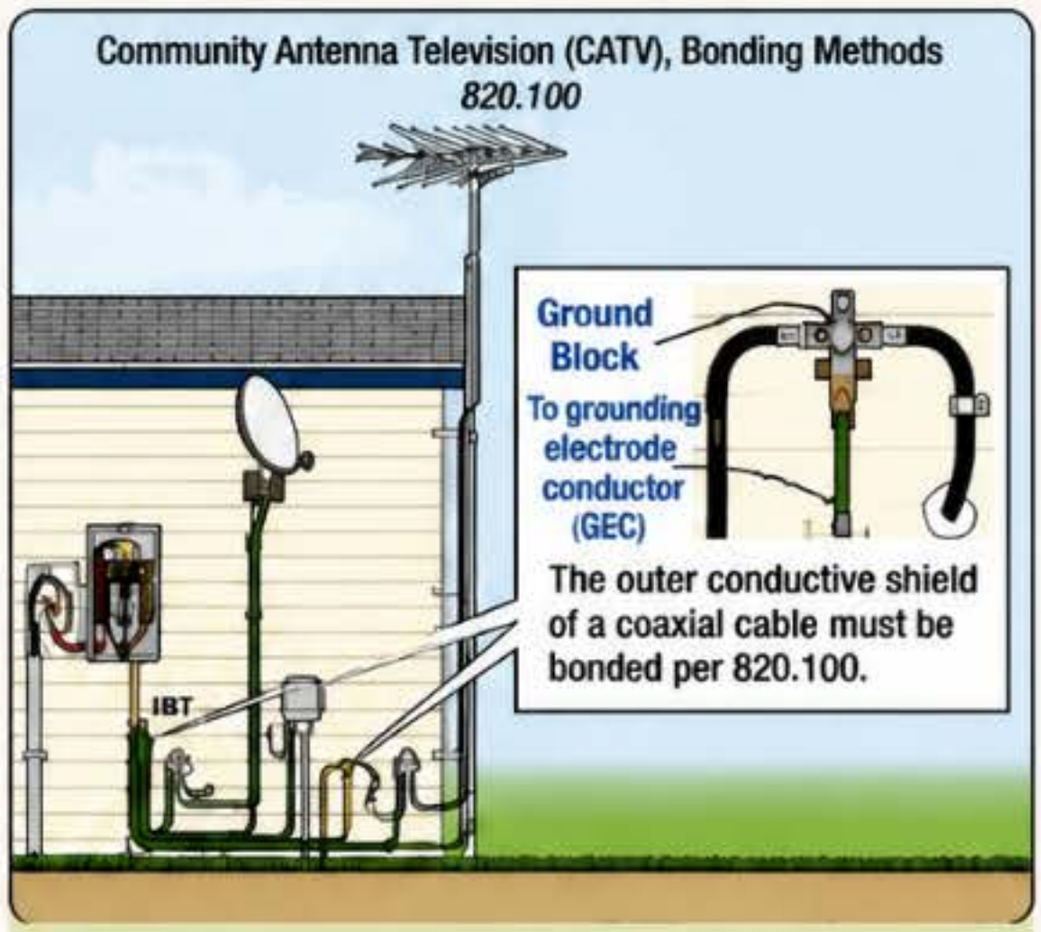


Figure 820–4

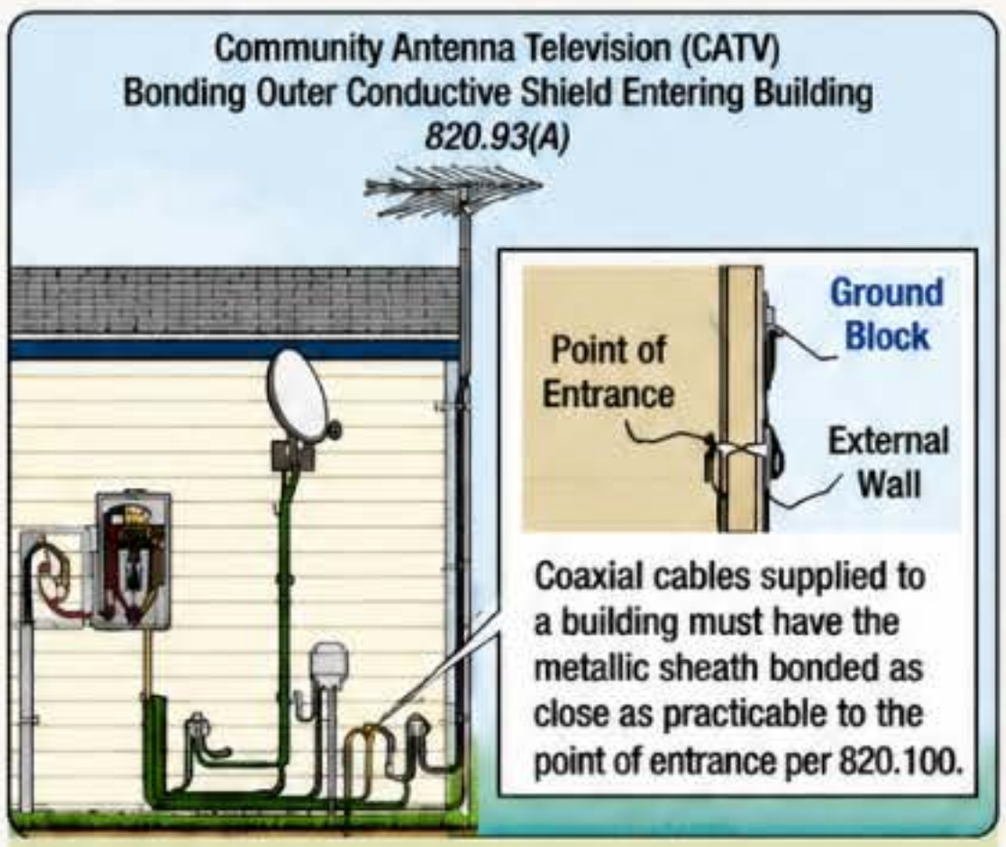


Figure 820–3

Part IV. Grounding Methods

820.100 Bonding and Grounding Methods

The outer conductive shield of a coaxial cable must be bonded in accordance with 820.100. ▸Figure 820–4

Part V. Installation Methods Within Buildings

820.133 Installation of Coaxial Cables and Equipment

(A) Separation from Power Conductors.

(1) In Raceways, Cable Trays, Boxes, Enclosures, and Cable Routing Assemblies.

(a) Other Circuits. Coaxial cables are permitted in the same raceway, cable tray, box, enclosure, or cable routing assembly with jacketed cables of any of the following. ▸Figure 820–5

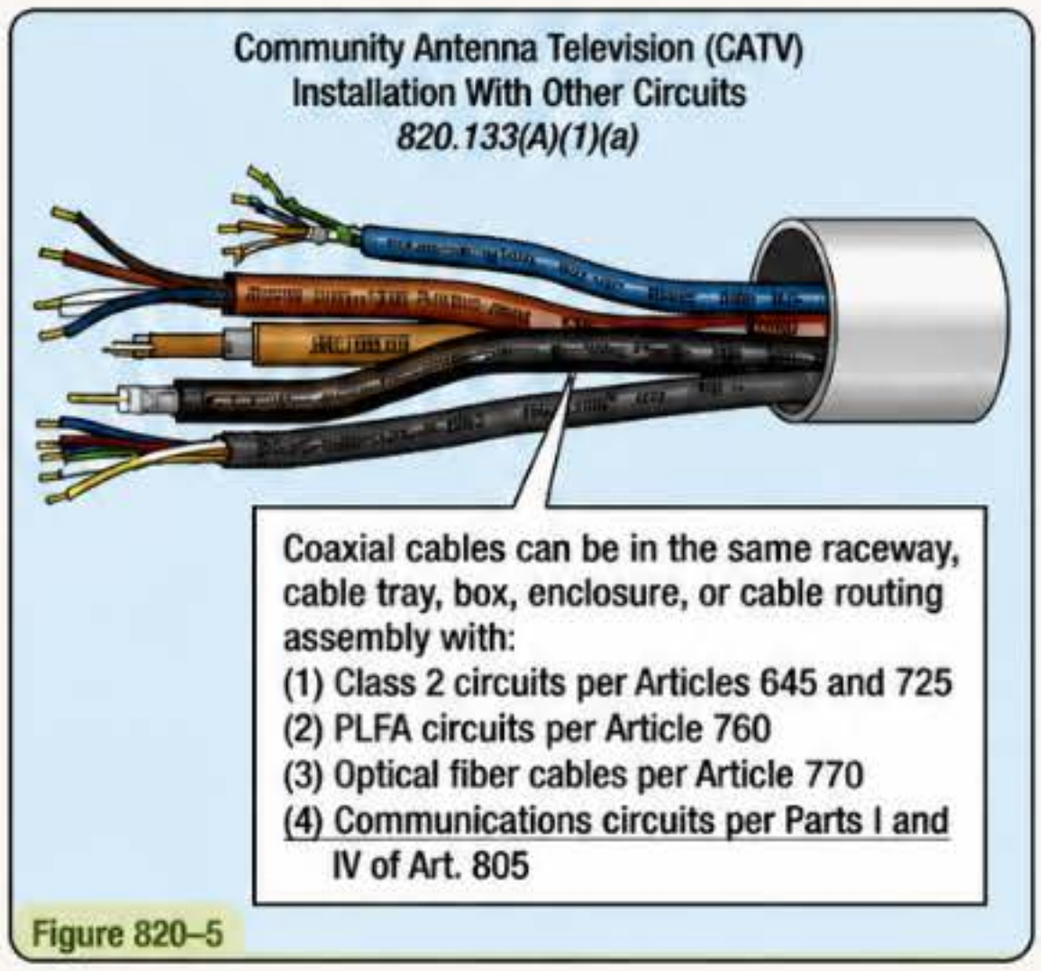


Figure 820–5

(1) Class 2 remote control, signaling, and power-limited circuits in compliance with Article 645 or Parts I and III of Article 725

(2) Power-limited fire alarm systems in compliance with Parts I and III of Article 760

(3) Nonconductive and conductive optical fiber cables in compliance with Parts I and V of Article 770

DEFINITIONS | From Michael Hamilton Publications

(4) **Communications circuits in compliance with Parts I and IV of Article** 805.

(5) **Low-power network-powered broadband communications circuits in compliance with Parts I and V of Article 830.**

(b) With Power Conductors in Same Raceway or Enclosure. Coaxial cables are not allowed in the same raceway, compartment, outlet box, junction box, or similar enclosure as conductors of electric power or Class 1 circuits.

Ex 1: Power conductors may be run in the same enclosure with coaxial cables if they are separated by a barrier.

Ex 2: Power conductors that feed coaxial cable distribution equipment must keep a ¼ in. separation from coaxial cables inside the enclosure.

(2) Other Applications. Coaxial cable must be separated by at least 2 in. from conductors of any of the following: electric light, power, Class 1, nonpower-limited fire alarm, or medium-power network-powered broadband communications circuits.

Ex 1: Separation is not required where either (1) all conductors of electric light, power, Class 1, nonpower-limited fire alarm, and medium-power network-powered broadband communications circuits are in a raceway, or in metal-sheathed, metal-clad, nonmetallic-sheathed, Type AC or Type UF cables, or (2) all coaxial cables are encased in a raceway.

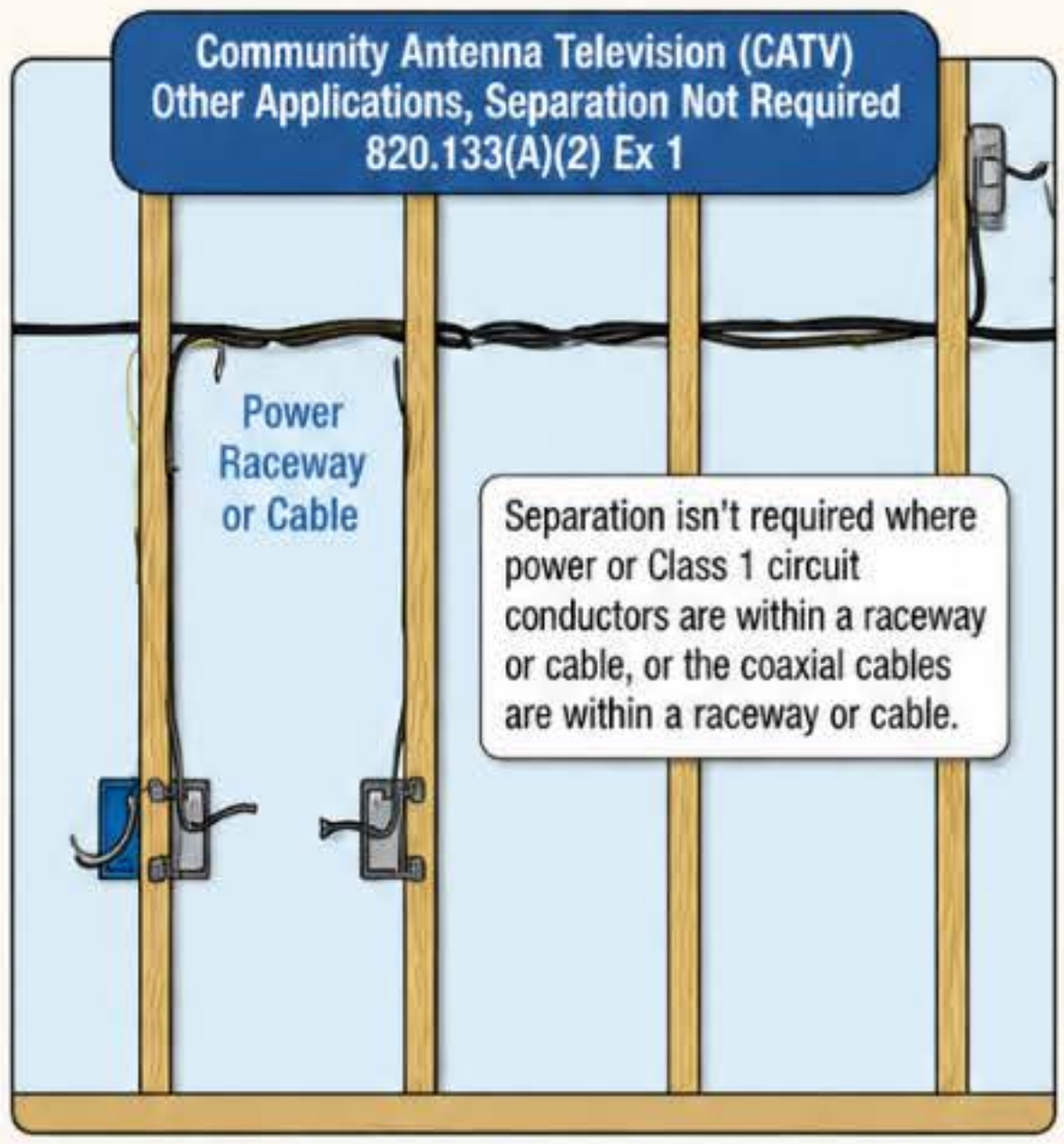


Figure 820–6

Ex 2: Separation is not required where the coaxial cables are permanently separated from the conductors of electric light, power, Class 1, nonpower-limited fire alarm, and medium-power network-powered broadband communications circuits by a continuous and firmly fixed nonconductor, such as porcelain tubes or flexible tubing, in addition to the insulation on the wire.

Author's Commentary:

Separation rules exist to prevent interference and reduce the risk of damage. When coaxial cables share space with power wiring, maintaining the required distance—or using a barrier—helps ensure clean signal integrity and code compliance.

— Michael Hamilton

Notes |

CHAPTER 8 PRACTICE QUESTIONS

Please use the 2023 *Code* book to answer the following questions.

CHAPTER 8—COMMUNICATIONS SYSTEMS

Article 800—General Requirements for Communications Systems

1. The Article 800 general requirements for communications systems apply to communications circuits, community antenna television and radio distribution systems, network-powered broadband communications systems, and premises-powered broadband communications systems, unless modified by Articles 805 or _____.

   (a) 820
   (b) 830
   (c) 840
   (d) any of these

2. The definitions in Part I of Article 100 shall apply throughout Chapter 8. The definitions in 800.2 shall apply only within Chapter 8.

   (a) True
   (b) False

3. Communications cables not terminated at equipment or not identified for future use with a tag are considered _____.

   (a) deserted
   (b) abandoned
   (c) reconditioned
   (d) reusable

4. Communications cables such as CATV cable not terminated at equipment other than a coaxial cable connector and not identified for future use with a tag are considered abandoned.

   (a) True
   (b) False

5. A "_____ circuit" is one that extends service from the communications utility or service provider up to and including the customer's communications equipment.

   (a) limited-energy
   (b) remote-signaling
   (c) power-limited
   (d) communications

6. "Communications circuits" are circuits that extend _____ and outside wiring for fire alarms and burglar alarms from the communications utility to the customer's communications equipment up to and including equipment such as a telephone, fax machine, or answering machine.

   (a) voice
   (b) audio and video
   (c) interactive services
   (d) all of these

7. A communications circuit that is in such a position that, in case of failure of supports or _____, contact with another circuit may result, and is considered to be exposed to accidental contact.

   (a) insulation
   (b) shielding
   (c) fittings
   (d) the grounding conductor

ARTICLE 800 | PRACTICE QUESTIONS

8. The point of entrance of a communications circuit is the point ____ a building at which the communications wire or cable emerges from an external wall or from a concrete floor slab.

(a) outside
(b) within
(c) on
(d) penetrating

9. The point of entrance of a communications cable such as CATV coaxial cable is the point ____ a building at which the coaxial cable emerges from an external wall or from a concrete floor slab.

(a) outside
(b) within
(c) on
(d) under

10. Only those sections of ____ referenced in Chapter 8 shall apply to Chapter 8.

(a) Chapters 1 through 4
(b) Chapters 2 and 3
(c) Chapters 1 through 7
(d) the Annexes

11. For communications circuit wiring in ____, the requirements of 300.22(A) shall apply.

(a) underfloor spaces
(b) suspended ceiling spaces
(c) plenums
(d) ducts for dust, loose stock, or vapor removal

12. For communications circuit wiring in ____, the requirements of 300.22(C)(3) shall apply.

(a) spaces for environmental air
(b) ducts for dust
(c) ducts for loose stock
(d) ducts for vapor removal

13. Where ____ cable is used to provide a communications circuit within a building, Article 770 shall apply.

(a) coaxial
(b) fire alarm
(c) low-voltage
(d) optical fiber

14. Access to electrical equipment shall not be denied by an accumulation of communications ____ that prevents the removal of suspended-ceiling panels. paiia pahels.

(a) routers
(b) amplifiers
(c) ductwork
(d) wires and cables

15. Communications cables installed ____ on the surface of ceilings and walls shall be supported by the building structure in such a manner that the cable will not be damaged by normal building use.

(a) in raceways
(b) in conduit
(c) hidden
(d) exposed and concealed

16. ____ may result in an undetermined alteration of communications wire and cable properties.

(a) Paint or plaster
(b) Cleaners or abrasives
(c) Corrosive residues or other contaminants
(d) any of these

17. Accessible portions of abandoned communications cable shall be removed.

(a) True
(b) False

18. Openings around penetrations of communications cables, communications raceways, and cable routing assemblies through fire-resistant-rated walls, partitions, floors, or ceilings shall be ____ using approved methods to maintain the fire resistance rating.

(a) closed
(b) opened
(c) draft stopped
(d) firestopped

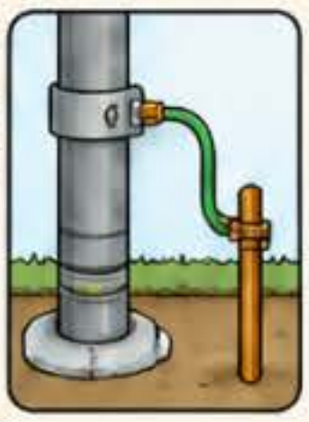
AUTHOR'S COMMENTARY: *These questions emphasize key access, protection, and installation requirements for communications wiring and cable systems. Mastering Article 800 helps ensure safe, reliable, and code-compliant low-voltage installations in all types of buildings.*

— Michael Hamilton

DEFINITIONS | From Michael Hamilton Publications

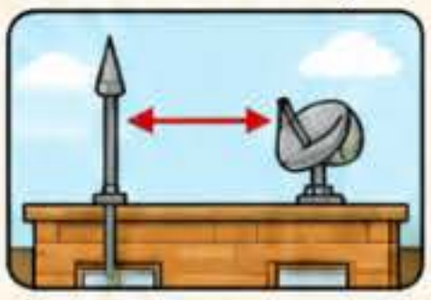
Practice Questions | **Article 800**

19. Metal conduit containing communications entrance wire or cable shall be connected by a _____ to a grounding electrode or, where present, the building grounding electrode system in accordance with 800.100(B).



(a) copper conductor
(b) steel structure
(c) metal water pipe
(d) bonding or grounding electrode conductor

20. Where practicable, a separation of at least _____ ft shall be maintained between lightning conductors and all communication wires and cables and CATV type coaxial cables on buildings.

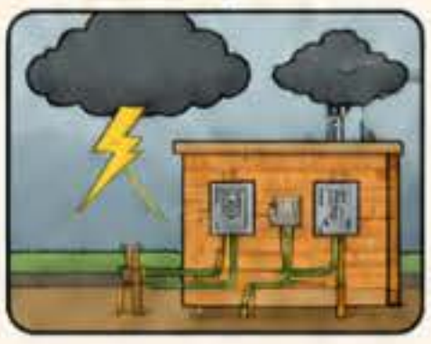


(a) 1
(b) 2
(c) 3
(d) 6

21. In one- and two-family dwellings, the primary protector conductor or conductor or grounding electrode conductor for communications systems shall be as short as practicable, not to exceed _____ ft in length.

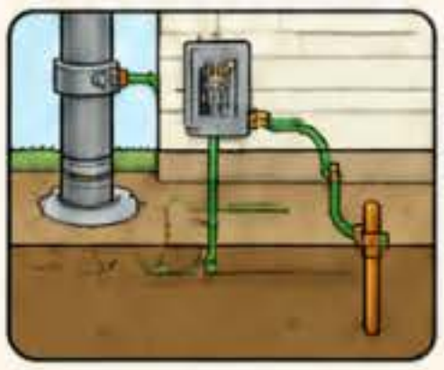
(a) 5
(b) 8
(c) 10
(d) 20

22. Limiting the length of the primary protector grounding conductors for communications circuits helps to reduce voltage between the building's _____ and communications systems during lightning events.



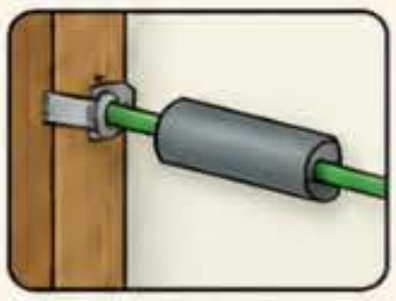
(a) power
(b) fire alarm
(c) lighting
(d) lightning protection

23. In one- and two-family dwellings where it is not practicable to achieve an overall maximum primary protector grounding electrode conductor length of _____ ft, a separate ground rod meeting the minimum dimensional criteria of 800.100(B)(3)(2) or (B)(3)(3) shall be driven, the grounding electrode conductor shall be connected to the ground rod in accordance with 800.100(C), and the ground rod shall be connected to the power grounding electrode system in accordance with 800.100(D).



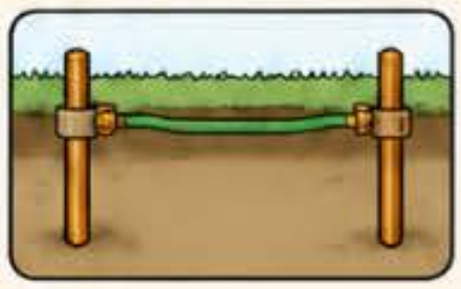
(a) 5
(b) 8
(c) 10
(d) 20

24. Communications systems bonding conductors and grounding electrode conductors shall be protected where exposed to _____.



(a) line voltage conductors
(b) soil
(c) physical damage
(d) all of these

25. Communications grounding electrodes shall be bonded to the power grounding electrode system at the building or structure served using a minimum _____ AWG copper bonding jumper.



(a) 10
(b) 8
(c) 6
(d) 4

26. Where communications wires and cables are installed in a Chapter 3 raceway, the raceway shall be installed in accordance with Chapter 3 requirements.

(a) True
(b) False

27. The raceway fill requirements of Chapters 3 and 9 shall apply to _____-power network-powered broadband communications cables.

(a) low
(b) medium
(c) high
(d) multiconductor

28. Communications systems _____ installed in buildings shall be listed.

(a) wires and cables
(b) cable routing assemblies
(c) raceways
(d) all of these

29. Communications systems wires, cables, cable routing assemblies, and communications raceways shall not be permitted in other spaces used for environmental air.

(a) True
(d) False

DEFINITIONS | From Michael Hamilton Publications

30. Communications systems wires, cables, cable routing assemblies, and communications raceways are allowed in plenum risers for either single-family or two-family dwellings.

(a) True
(b) False

31. Communications plenum cable shall be _____ when used in other areas designated for environmental air.

(a) marked
(b) identified
(c) approved
(d) listed

Author's Commentary:
Plenum-rated cable must carry a verification mark showing its compliance. That mark can be "marked," "identified," "approved," or "listed." Any of those satisfies the requirement.

— Michael Hamilton

Article 805—General Requirements for Communications Circuits

1. For communications circuits, equipment electrically connected to a communications network shall be _____ in accordance with 805.170.

(a) labeled
(b) approved
(c) field-marked
(d) labeled

2. In buildings where the communications cable terminates outside, the metal sheath of the cable must be _____ in accordance with 800.100 or insulated joint or equivalent.

(a) grounded or bonded
(b) approved and connected
(c) spliced and terminated
(d) copper or aluminum

3. To support communications circuits during new construction, at least _____ communications outlets must be provided within the residence in an easily accessible location and cabled to the demarcation point of the service provider.

(a) zero
(b) one
(c) two
(d) three

Author's Commentary:
Planning ahead with the minimum number of outlets makes it easier to add devices later and keeps wiring neat and accessible.

— Michael Hamilton

Article 810—Radio and Television Antenna Equipment

1. Article ____ covers antenna systems for television receiving equipment, amateur and citizen band radio transmitting and receiving equipment, and certain features of transmitter safety.

(a) 680
(b) 700
(c) 810
(d) 840

2. Outdoor antennas and lead-in conductors must be securely supported. Lead-in conductors shall be securely fastened to the antenna, but they must not be attached to the electric service mast.

(a) True
(d) False

3. Masts and metal structures that support antennas must be grounded per 810.21 unless the antenna and its related supporting mast or structure are located inside a zone of protection established by a _____-ft radius rolling sphere.

(a) 75
(b) 100
(c) 125
(d) 150

4. NFPA 780, *Standard for the Installation of Lightning Protection Systems*, provides information for the application of the term "rolling sphere" as used in 810.15.

(a) True
(b) False

5. Underground antenna conductors for radio and television receiving equipment must be separated by at least _____ from any light, power, or Class 1 circuit conductors.

(a) 12 in.
(b) 18 in.
(c) 5 ft
(d) 6 ft

Author's Commentary:
Keeping spacing between antenna cables and other electrical wiring reduces the likelihood of signal interference and electrical hazards.

— Michael Hamilton

PRACTICE QUESTIONS

6. Indoor antenna and lead-in conductors for radio and television receiving equipment shall be separated by at least ____ from conductors of any electric light, power, or Class 1 circuit conductors, unless otherwise permitted.
   (a) 2 in.
   (b) 12 in.
   (c) 18 in.
   (d) 6 ft

7. Indoor antenna lead-in conductors for radio and television receiving equipment can be in the same enclosure with conductors of other wiring systems where separated by an effective permanently installed barrier.
   (a) True
   (b) False

8. Antenna discharge units shall be located outside the building only.
   (a) True
   (b) False

9. Radio and television receiving antenna systems shall have bonding or grounding electrode conductors that are ____.
   (a) copper or other corrosion-resistant conductive material
   (b) insulated, covered, or bare
   (c) securely fastened in place and protected where subject to physical damage
   (d) all of these

10. The grounding electrode conductor for an antenna mast shall be ____ where subject to physical damage.
   (a) electrically protected
   (b) protected
   (c) connected
   (d) disconnected

11. The bonding conductor or grounding electrode conductor for a radio/television antenna system shall be protected where subject to physical damage, and where installed in a metal raceway, both ends of the raceway shall be bonded to the ____ conductor.
   (a) contained
   (b) grounded
   (c) ungrounded
   (d) largest

12. The bonding conductor or grounding electrode conductor for an antenna mast or antenna discharge unit shall be run to the grounding electrode in as straight a line as practicable.
   (a) True
   (b) False

13. If the building or structure served has an intersystem bonding termination, the bonding conductor for an antenna mast shall be connected to the intersystem bonding termination.
   (a) True
   (b) False

14. If the building or structure served has no radio and television equipment intersystem bonding termination, the ____ conductor or grounding electrode conductor shall be connected to the nearest accessible location on the building or structure grounding electrode system as covered in 250.50.
   (a) grounded
   (b) neutral
   (c) service equipment enclosure
   (d) bonding

15. The grounding electrode conductor for an antenna mast or antenna discharge unit, if copper, shall not be smaller than 10 AWG.
   (a) True
   (b) False

16. If a separate grounding electrode is installed for the radio and television equipment, it shall be bonded to the building's electrical power grounding electrode system with a bonding jumper not smaller than ____ AWG.
   (a) 10
   (b) 8
   (c) 6
   (d) 1/0

Article 820—Community Antenna Television (CATV) and Radio Distribution Systems (Coaxial Cable)

1. Article ____ covers the installation of coaxial cables for distributing radio frequeecy signals typically employed in community antenna television (CATV) systems.
   (a) 300
   (b) 430
   (c) 800
   (d) 820

AUTHOR'S COMMENTARY:
These questions target key rules for antenna systems—covering separation, grounding, bonding, and protection. Solid knowledge here helps ensure safe, code-compliant installations.

— Michael Hamilton

Article 820 | Practice Questions

2. The outer conductive shield of a CATV coaxial cable entering a building shall be grounded as close to the point of entrance as practicable.

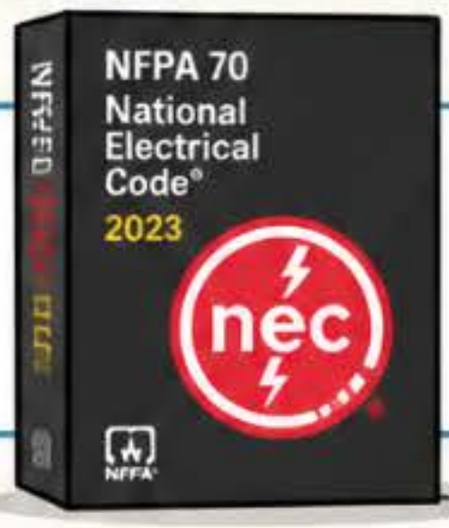
(a) True

(b) False

FINAL EXAM

A

STRAIGHT ORDER



Please use the **2023** *Code* book to answer the following questions.

1. Which of the following systems shall be installed and removed in accordance with the *NEC* requirements?

(a) Signaling conductors, equipment, and raceways
(b) Communications conductors, equipment, and raceways
(c) Electrical conductors, equipment, and raceways
(d) all of these

2. The *Code* covers underground mine installations and self-propelled mobile surface mining machinery and its attendant electrical trailing cable.

(a) True
(b) False

3. Installations shall comply with the material located in the *NEC* Annexes because they are part of the requirements of the *Code*.

(a) True
(b) False

4. Nonmandatory Informative Annexes contained in the back of the *Code* book are _____.

(a) for information only
(b) not enforceable as a requirement of the *Code*
(c) enforceable as a requirement of the *Code*
(d) for information only and not enforceable as a requirement of the *Code*

5. All _____ shall be covered with an insulation equivalent to that of the conductors or with an identified insulating device.

(a) splices
(b) joints
(c) free ends of conductors
(d) all of these

6. The required working space for access to live parts of equipment operating at 300 volts-to-ground, where there are exposed live parts on one side and grounded parts on the other side, is _____ ft.

(a) 3
(b) 3½
(c) 4
(d) 4½

7. When determining a Class I, Division 2 location, the _____ is a factor that should be considered in determining the classification and extent of the location.

(a) quantity of flammable material that might escape in case of an accident
(b) adequacy of ventilating equipment
(c) record of the industry or business with respect to explosions or fires
(d) all of these

Straight Order | Final Exam A

8. Electrical and electronic equipment in hazardous (classified) locations shall be protected by a(n) ____ technique.

(a) explosionproof
(b) dust-ignitionproof
(c) dusttight
(d) any of these

9. Wiring methods and materials permitted in Class I, Division 1 locations include ____.

(a) threaded rigid metal ordt or threaded steel IMC
(b) flexible fittings listed for Class I, Division 1 locations
(c) boxes approved for Class I, Division 1 locations
(d) all of these

10. Wiring methods permitted in Class I, Division 1 locations are permitted in Class I, Division 2 locations.

(a) True
(b) False

11. General-purpose enclosures and fittings are permitted in Class I, Division 2 locations unless the enclosure contains make-and-break contacts for ____ as required by 501.10(5)(B)(1), 501.115(B)(1), and 501.150(B)(1).

(a) meters, instruments, and relays
(b) circuit breakers or motor controllers
(c) signaling, alarm, remote-control, and communications systems
(d) all of these

12. A sealing fitting shall be permitted to be installed within ____ ft of either side of the boundary where a conduit leaves a Class I, Division 1 location.

(a) 5
(b) 6
(c) 8
(d) 10

13. In Class I, Division 1 locations, seals for cables at all terminations, shall be installed within ____ in. of the enclosure or as required by the enclosure marking.

(a) 6
(b) 12
(c) 18
(d) 20

14. Circuit breakers in Class I, Division 2 locations that are not hermetically sealed or oil-immersed shall be installed in a Class I, Division 1 enclosure.

(a) True
(b) False

15. Luminaires installed in Class I, Division 2 locations shall be protected from physical damage by a suitable ____.

(a) warning label
(b) pendant
(c) guard or by location
(d) all of these

16. In Class I, Division 1 locations, all apparatus and equipment of signaling, alarm, remote-control, and communications systems ____ shall be identified for Class I, Division 1 locations.

(a) over 50V
(b) over 100 volts-to-ground
(c) regardless of voltage
(d) except those operating at less than 24V

17. In Class I, Division 2 locations, where provision must be made for flexibiity, ____ shall apply.

(a) 502.10(A)(2)
(b) 502.10(A)(3)
(c) 502.10(B)(1)
(d) 502.10(B)(4)

18. In Class II, Division 1 locations, motors, generators, and other rotating electrical machinery shall be ____.

(a) listed for the environment
(b) explosionproof
(c) general duty
(d) identified for the location or totally enclosed pipe-ventilated

19. In Class II, Division 2 locations, flexible cord can serve as the supporting means for a pendant luminaire.

(a) True
(b) False

20. In Class III locations, locknut-bushing and double-locknut types of fittings may be depended on for bonding purposes.

(a) True
(b) False

21. In Class III locations, portable lighting equipment shall be equipped with handles and protected with substantial guards. Lampholders shall be of the unswitched type with no provision for ____.

(a) receiving attachment plugs
(b) grounding connections
(c) lamp installation
(d) hooks or hangers

22. In major repair garages where ventilation is not provided, any pit or depression below floor level shall be a Class I, Division ____ location.

(a) 1
(b) 2
(c) 1 or Division 2
(d) 1 and Division 2

23. Type NM cable can be installed above a Class I location in a commercial garage.

(a) True
(b) False

24. In patient care spaces, metal faceplates shall be directly connected to an insulated copper equipment grounding conductor by means of ____ securing the feceplate to a metal yoke or strap of a receptacle or to a metal outlet box.

(a) ground clips
(b) rivets
(c) metal mounting screws
(d) a spot weld

25. In assembly occupancies, Type NM cable, ENT, and PVC conduit shall be permitted to be installed in those portions of buildings not required to be of ____ construction by the applicable building code.

(a) Class I, Division 1
(b) fire-rated
(c) occupancy-rated
(d) aboveground

26. When installed indoors for carnivals, circuses, and fairs, flexible cords and flexible cables shall be listed for wet locations and shall be sunlight resistant.

(a) True
(b) False

27. For carnivals and fairs, receptacles of the locking type not accessible from grade level that only facilitate quick disconnecting and reconnecting of electrical equipment shall not be required to be provided with GFCI protection.

(a) True
(b) False

28. An "equipotential plane" is an area where wire mesh or other conductive elements are embedded in or placed under concrete and bonded to ____.

(a) all metal structures
(b) fixed nonelectrical equipment that could become energized
(c) the electrical grounding system
(d) all of these

29. Luminaires used in agricultural buildings shall ____.

(a) minimize the entrance of dust, foreign matter, moisture, and corrosive material
(b) be protected by a suitable guard if exposed to physical damage
(c) be listed for use in wet locations when exposed to water
(d) all of these

30. GFCI protection in a mobile home shall be provided for ____.

(a) receptacle outlets installed outdoors and in compartments accessible from outside
(b) receptacles within 6 ft of a wet bar sink, dishwasher outlets, and where installed to serve countertop surfaces
(c) all receptacles in bathrooms including receptacles in luminaires
(d) all of these

31. Article 555 covers marinas, boatyards, docking facilities but not floating buildings.

(a) True
(b) False

32. In land areas not subject to tidal fluctuation, the electrical datum plane shall be a horizontal plane that is ____ ft above the highest tide level for the area occurring under normal circumstances, based on the highest high tide.

(a) 1
(b) 1½
(c) 2
(d) 2½

33. Electrical connections must be provided at least ____ in. above the deck surface of a floating pier.

(a) 12
(b) 18
(c) 24
(d) 30

34. Shore power receptacles installed in accordance with 555.33(A) must have individual GFPE set to open at currents not exceeding _____ milliamperes.

(a) 6
(b) 30
(c) 75
(d) 100

35. A _____ shall be used to serve as the required shore power receptacle disconnecting means, and it shall be identified as to which receptacle it controls.

(a) circuit breaker
(b) switch
(c) circuit breaker or fused knife switch
(d) circuit breaker, switch, or both

36. The provisions of Article _____ apply to temporary electric power and lighting installations.

(a) 480
(b) 555
(c) 590
(d) 600

37. Types NM, NMC, and SE cables can be used for branch circuits for temporary installations without height limitation and without concealment.

(a) True
(b) False

38. Vegetation may not be used to support overhead conductor spans of _____ for temporary installations.

(a) luminaires
(b) receptacles
(c) branch circuits or feeders
(d) lighting conductors

39. Where overcurrent protective devices that have been previously used are installed in a temporary installation, these overcurrent protective devices must be examined to ensure these devices _____.

(a) have been properly installed
(b) have been properly maintained
(c) show no evidence of impending failure
(d) all of these

40. Each commercial occupancy accessible to pedestrians must have at least one sign outlet in an accessible location at each entrance to each tenant space supplied by a branch circuit rated at least _____.

(a) 15A
(b) 20A
(c) 30A
(d) 40A

41. The disconnecting means for a sign or outline lighting system may be located at the point of entry to a sign and the disconnect shall be located at the point the feeder circuit or branch circuit(s) supplying a sign or outline lighting system enters a _____.

(a) sign enclosure
(b) sign body
(c) pole in accordance with 600.5(D)(3)
(d) any of these

42. Listed flexible metal conduit or listed liquidtight flexible metal conduit that encloses the secondary circuit conductor from a transformer or power supply for use with neon tubing may be used as a bonding means if the total accumulative length of the conduit in the secondary circuit does not exceed ____ ft.

(a) 6
(b) 25
(c) 50
(d) 100

43. Ballasts, transformers, electronic power supplies, and Class 2 power sources for signs may be located above suspended ceilings, provided their enclosures are securely fastened in place and _____.

(a) are effectively bonded
(b) not dependent on the suspended-ceiling grid for support
(c) are rated at not more than 300V
(d) effectively grounded

44. Each 15A and 20A, 125V, single-phase receptacle installed in pits, in hoistways, on the cars of elevators and dumbwaiters associated with wind turbine tower elevators, on the platforms or in the runways and machinery spaces of platform lifts and stairway chairlifts, and in escalator and moving walkways shall be _____.

(a) on a GFCI-protected circuit
(b) of the GFCI type
(c) provided with GFCI protection
(d) current-limiting

45. The lighting switch for hoistway pits shall be readily accessible from the _____.

(a) pit access door
(b) elevator car
(c) floor of the pit
(d) machinery room

46. Article 625 covers the electrical conductors and equipment connecting an electric vehicle to premises wiring for the purposes of _____.

(a) charging
(b) power export
(c) bidirectional current flow
(d) all of these

47. For electric vehicle equipment rated more than _____ or more than 150 volts-to-ground, the disconnecting means shall be provided and installed in a readily accessible location.

(a) 20A
(b) 30A
(c) 50A
(d) 60A

48. Article _____ covers apparatus for electric arc welding, resistance welding, plasma cutting, and other similar welding and cutting process equipment that is connected to an electrical supply system.

(a) 600
(b) 620
(c) 630
(d) 680

49. Each resistance welder shall have an overcurrent device rated or set at not more than _____ percent of the rated primary current of the welder.

(a) 80
(b) 100
(c) 125
(d) 300

50. Class 2 and Class 3 cables for audio signal processing, amplification, and reproduction equipment installed in accordance with 725.135(B) and Table 725.154 shall be permitted to be installed in ducts specifically fabricated for environmental air.

(a) True
(d) False

51. Ventilation in the underfloor area of an information technology equipment room shall be used in that room only, unless provided with fire/smoke dampers at the point of penetration of the room boundary.

(a) True
(b) False

52. Nonmetallic raceways for branch circuit supply conductors can be installed in the area under raised floors of approved construction of information technology equipment rooms.

(a) True
(b) False

53. Installed supply circuits and interconnecting cables identified for future use in information technology equipment rooms shall be marked with a tag of sufficient durability to withstand the environment involved which shall include the _____.

(a) date the cable was identified for future use
(b) date of intended use
(c) intended future use of the cable
(d) all of these

54. All electric pool water heaters shall have the heating elements subdivided into loads not exceeding _____.

(a) 20A
(b) 35A
(c) 48A
(d) 60A

55. All receptacles supplied by branch circuits rated _____ or less to ground within a pool equipment room shall be GFCI protected.

(a) 110V
(b) 125V
(c) 150V
(d) 250V

56. Junction boxes for pool lighting shall be located not less than _____ ft from the inside wall of a pool unless separated by a fence or wall.

(a) 3
(b) 4
(c) 6
(d) 8

57. Circuits serving gas-fired swimming pool and spa water heaters operating at voltages above the low-voltage contact limit shall be provided with _____ protection for personnel.

(a) GFCI
(b) AFCI
(c) combined AFCI/GFCI
(d) a gas valve emergency shut-off

58. Fountain electrical equipment that is supplied by a flexible cord shall have all exposed noncurrent-carrying metal parts grounded by an insulated copper equipment grounding conductor that is an integral part of this _____.

(a) cord
(b) feeder circuit
(c) branch circuit
(d) fountain

59. PV system equipment and disconnecting means are permitted to be installed in a bathroom when listed for the application.

(a) True
(b) False

60. The PV maximum output circuit current shall be the sum of parallel PV source circuit maximum currents as calculated in _____.

(a) 690.8(A)(1)(a)
(b) 690.8(A)(2)
(c) 690.8(A)(3)
(d) Article 220

61. For PV system rapid shutdown systems, controlled conductors located outside the array boundary or more than 3 ft from the point of entry inside a building shall be limited to not more than _____ within 30 seconds of rapid shutdown initiation.

(a) 15V
(b) 30V
(c) 50V
(d) 80V

62. An isolating device for PV system equipment shall be which of the following?

(a) a mating connector meeting the requirements of 690.33 and listed and identified for use with specific equipment
(b) a finger-safe fuse holder or an isolating switch that requires a tool to place the device in the open (off) position
(c) an isolating device listed for the intended application
(d) any of these

63. PV systems that exceed 30V or 8A shall be provided with direct-current _____ to reduce fire hazards.

(a) arc-fault protection
(b) rectifier protection
(c) ground-fault monitors
(d) ground-fault protection

64. For buildings with rapid shutdown, the rapid shutdown switch shall have a label that reads "RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM" installed within _____ ft of the switch.

(a) 3
(b) 6
(c) 10
(d) 25

65. Feeder conductors supplying fire pump motors and accessory equipment shall be sized no less than _____ percent of the sum of the fire pump motor(s) and pressure maintenance motor(s) full-load currents, plus 100 percent of the ampere rating of the fire pump accessory equipment.

(a) 100
(b) 125
(c) 250
(d) 600

DEFINITIONS | From Michael Hamilton Publications

66. Emergency system equipment must be maintained in agreement with ____.

(a) the authority having jurisdiction
(b) UL listing(s)
(c) manufacturer instructions and industry standards
(d) OSHA regulations

67. Where used for emergency systems, the short-circuit current rating of the transfer equipment, based on the specific overcurrent protective device type and settings protecting the transfer equipment, shall be field marked on the ____ of the transfer equipment.

(a) exterior
(b) top
(c) interior
(d) underside

68. Wiring from an emergency source to supply emergency and other (nonemergency) loads shall be permitted if the common bus of separate sections of the switchgear, separate sections of the switchboard, or the individual enclosures are supplied by single or multiple feeders with or without ____.

(a) overcurrent protection at the source
(b) ground-fault protection at the source
(c) a current-limiting device at the source
(d) load-shaving monitoring

69. In emergency systems, only appliances and lamps required for emergency use shall be supplied by ____.

(a) emergency lighting circuits
(b) multiwire branch circuits
(c) HID-rated circuit breakers
(d) only load-shaved circuits

70. The ____ shall conduct or witness a test of the complete legally required standby system upon installation.

(a) electrical engineer
(b) authority having jurisdiction
(c) qualified person
(d) manufacturer's representative

71. Automatic transfer switches on legally required standby systems shall be electrically operated and ____ held.

(a) electrically
(b) mechanically
(c) gravity
(d) any of these

72. Overcurrent devices for legally required standby systems shall be ____ with all supply-side overcurrent devices.

(a) series rated
(b) selectively coordinated
(c) installed in parallell
(d) labeled

73. Where a load management system is employed that will automatically manage the connected load of an optional standby system, the standby source shall have a capacity sufficient to supply ____ load that will be connected by the load management system.

(a) 80 percent of the
(b) 115 percent of the
(c) 125 percent of the
(d) the maximum

74. Optional standby system transfer equipment and electric power production systems installed to permit operation in parallel with the ____ shall also meet the requirements of Article 705.

(a) PV system
(b) generator
(c) normal source
(d) battery storage system

75. Where supply-side power source output circuit conductors make their connection to the service outside of a building, they shall be protected by overcurrent devices in a(n) ____ outside the building or at the first readily accessible location where the power source conductors enter the building.

(a) location
(b) readily accessible location
(c) accessible location
(d) secured location

Straight Order | Final Exam A

76. When interconnected power production source output connections are made at feeders, all taps must be sized based on the total of _____ percent of the combined power source output current(s), plus the rating of the overcurrent device that protects the feeder conductors or for sizing tap conductors using the calculations in 240.21(B) of the 2023 NEC.

(a) 100
(b) 115
(c) 125
(d) 175

77. Per Article 705, the total of all interconnected power production system controlled currents, plus every monitored current from other sources of supply, may not be more than _____ percent of the ampacity of any busbar or conductor supplied by production sources.

(a) 100
(b) 115
(c) 125
(d) 150

78. In interconnected power production systems, safety hazards to personnel and equipment related to the _____ could occur if an interactive electric power source functions as an intentional island.

(a) primary source of power
(b) power production system
(c) primary source of power or power production system
(d) possibility of a lightning strike

79. A disconnecting means must be installed for all _____ received from an energy storage system (ESS).

(a) branch circuits
(b) phase conductors
(c) supply circuits
(d) combiners

80. A permanent _____ shall be installed at a building supplied by a stand-alone system at each service equipment location or at an approved, readily visible location. The _____ shall identify the location of each power source disconnect for the building or be grouped with other plaques or directories for other on-site sources.

(a) plaque
(b) directory
(c) marking
(d) plaque or directory

81. Stand-alone systems require either energy storage or backup power supplies.

(a) True
(b) False

82. When a raceway is used for the support or protection of cables for remote-control, signaling, and power-limited circuits, a bushing to reduce the potential for abrasion must be installed at the site where the cables come out of the raceway.

(a) True
(b) False

83. Exposed Class 1, Class 2, and Class 3 cables shall be supported by straps, staples, hangers, or similar fittings designed and installed so as not to damage the cable.

(a) True
(b) False

84. Class 1 circuits must be installed in accordance with Part I of Article 300 and are exempt from the wiring methods in the rest of Chapter 3.

(a) True
(b) False

85. The rated current for _____ power sources for conductors covered in 725.144 is the output current per conductor the power source is designed to deliver to an operational load under normal operating conditions, as specified by the manufacturer.

(a) Class 1
(b) Class 2
(c) Class 3
(d) Class 2 and Class 3

86. Sections 725.144(A) and (B) shall apply to ____ that transmit power and data to a powered device.

(a) all circuits
(b) Class 1, 2, and 3 circuits
(c) Class 2 and 3 circuits
(d) low voltage circuits

87. Where Types CL3P, CL2P, CL3R, CL2R, CL3, or CL2 transmit power and data, the rated current per conductor of the power source shall not exceed the ampacities in Table 725.144 at an ambient temperature of ____.

(a) 30°C
(b) 60°C
(c) 75°C
(d) 90°C

88. Where _____ cables are utilized for fire alarm circuits, the cables shall be installed in accordance with Article 770.

(a) Class 1
(b) Class 2
(c) Class 3
(d) optical fiber

89. Power-limited and nonpower-limited fire alarm cables with green insulation shall be permitted to be used as ungrounded signal conductors.

(a) True
(b) False

90. The fire alarm branch-circuit disconnecting means shall be permitted to be secured in the "on" position.

(a) True
(b) False

91. Power-limited fire alarm cable used in a ____ location shall be listed for use in _____ locations or have a moisture-impervious metal sheath.

(a) dry
(b) damp
(c) wet
(d) hazardous

92. Optical fiber cables installed _____ on the surface of ceilings and walls shall be supported by the building structure in such a manner that the cable will not be damaged by normal building use.

(a) exposed
(b) in raceways
(c) hidden
(d) exposed and concealed

93. Nonconductive optical fiber cables shall not be permitted to occupy the same cabinet, outlet box, panel, or similar enclosure unless the nonconductive optical fiber cables are functionally associated with the electric circuits.

(a) True
(b) False

94. For communications circuit wiring in _____, the requirements of 300.22(C)(3) shall apply.

(a) spaces for environmental air
(b) ducts for dust
(c) ducts for loose stock
(d) ducts for vapor removal

95. Metal conduit containing communications entrance wire or cable shall be connected by a _____ to a grounding electrode or, where present, the building grounding electrode system in accordance with 800.100(B).

(a) copper conductor
(b) steel structure
(c) metal water pipe
(d) bonding or grounding electrode conductor

96. Where communications wires and cables are installed in a Chapter 3 raceway, the raceway shall be installed in accordance with Chapter 3 requirements.

(a) True
(b) False

97. For communications circuits, equipment electrically connected to a communications network shall be _____ in accordance with 805.170.

(a) labeled
(b) approved
(c) field-marked
(d) listed

Straight Order | **Final Exam A**

98. NFPA 780, *Standard for the Installation of Lightning Protection Systems*, provides guidance for the use of the term "rolling sphere" as described in 810.15.

(a) True
(b) False

Author's Commentary:
NFPA 780 sets the rules for lightning protection. It explains how the "rolling sphere" method is applied to determine protection zones in 810.15.

— Michael Hamilton

99. The bonding conductor or grounding electrode conductor for a radio/television antenna system must be protected from physical harm where it is exposed above ground. If it is installed along a metal raceway, both ends of the raceway must be bonded to the conductor.

(a) contained
(b) grounded
(c) ungrounded
(d) largest

Author's Commentary:
This requirement ensures the bonding conductor remains protected and that any metal raceway used is effectively equipped for grounding.

— Michael Hamilton

100. Article ____ covers the installation of coaxial cables for distributing radio frequency signals typically employed in community antenna television (CATV) systems.

(a) 300
(b) 430
(c) 800
(d) 820

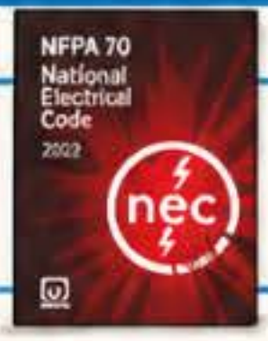
Author's Commentary:
Article 820 is the section of the NEC® that sets the rules for coaxial cable installations used in CATV systems.

— Michael Hamilton

FINAL EXAM

B

RANDOM ORDER



Please use the **2023** *Code* book to answer the following questions.

1. The grounding electrode conductor for an antenna mast shall be ____ where subject to physical damage.

(a) electrically protected
(b) protected
(c) connected
(d) disconnected

2. Isolating devices or equipment disconnecting means for PV system equipment shall be installed within the equipment or within sight and within ____ ft of the equipment.

(a) 3
(b) 10
(c) 25
(d) 50

3. In Class III locations, switches, circuit breakers, motor controllers, and fuses, including pushbuttons, relays, and similar devices, shall be provided with ____.

(a) Class I enclosures
(b) general duty enclosures
(c) dusttight enclosures
(d) seals at each enclosure

4. Permanent safety signs shall be installed to give notice of electrical shock hazard risks to persons using or swimming near a boat dock or marina and shall ____.

(a) comply with 110.21(B)(1) and be of sufficient durability to withstand the environment
(b) be clearly visible from all approaches to a marina, docking facility, or boatyard facility
(c) state "WARNING—POTENTIAL SHOCK HAZARD—ELECTRICAL CURRENTS MAY BE PRESENT IN THE WATER"
(d) all of these

5. A(an) ____ surge protection device shall be installed in or on the fire pump controller.

(a) listed
(b) labeled
(c) identified
(d) approved

6. The ____ of electric vehicle supply equipment located indoors shall be located not less than 18 in. above the floor level.

(a) attachment plugs
(b) fittings
(c) power outlets
(d) coupling means

7. Accessible portions of abandoned fire alarm cable shall be removed.

(a) True
(b) False

8. Only those sections of ____ referenced in Chapter 8 shall apply to Chapter 8.

(a) Chapters 1 through 4
(b) Chapters 2 and 3
(c) Chapters 1 through 7
(d) the Annexes

9. Meter-mounted transfer switches shall be of the ____ type unless rated as determined by 702.4(B)(2).

(a) automatic
(b) manual
(c) monitoring
(d) remote

10. The electrical datum plane for floating piers and boat landing stages shall be a horizontal plane 30 in. above the water level at the floating pier or boat landing stage and a minimum of ____ in. above the level of the deck.

(a) 12
(b) 18
(c) 24
(d) 30

11. Except for the assembly occupancies explicitly covered by 520.1, Article 518 covers all buildings or portions of buildings or structures designed or intended for the gathering together of ____ or more persons.

(a) 16
(b) 50
(c) 100
(d) 125

12. Article 690 applies to solar PV systems, including ____.

(a) array circuit(s), inverter(s), and controller(s) for such PV systems
(b) those interactive with other electrical power production sources or stand-alone, or both
(c) PV systems with ac or dc output for utilization
(d) all of these

13. The point of entrance of a communications circuit is the point ____ a building at which the communications wire or cable emerges from an external wall or from a concrete floor slab.

(a) outside
(b) within
(c) on
(d) penetrating

14. Hazardous (classified) locations shall be classified depending on the properties of the ____ that could be present, and the likelihood that a flammable or combustible concentration or quantity is present.

(a) flammable liquid-produced vapors
(b) flammable gases
(c) combustible dusts
(d) all of these

15. An emergency system shall have adequate ____ in accordance with Article 220 or by another approved method.

(a) lighting
(b) capacity
(c) water flow
(d) ambient temperature

16. A "____ circuit" is one that extends service from the communications utility or service provider up to and including the customer's communications equipment.

(a) limited-energy
(b) remote-signaling
(c) power-limited
(d) communications

17. Signs and outline lighting systems shall be installed so that adjacent combustible materials are not subjected to temperatures in excess of ____.

(a) 60°C
(b) 75°C
(c) 90°C
(d) 105°C

18. A storage battery used to power emergency lighting and other emergency equipment must not deliver less than 87½ percent of its normal voltage when supporting the total connected load for a period of at least ____ hour(s).

(a) 1
(b) 1½
(c) 2
(d) 2½

19. Whenever electric signs are installed in a fountain or within ____ ft of the fountain edge, they must have ground-fault circuit-interrupter protection for the people nearby.

(a) 2
(b) 5
(c) 6
(d) 10

20. Manufactured wiring systems shall be ____ in accordance with the applicable cable or conduit article for the type of cable or conduit used.

(a) inspected and tested
(b) relocated
(c) secured and supported
(d) reassembled

21. An "equipotential plane" is a region where wire mesh or other conductive materials are embedded in or placed under concrete and bonded to ____.

(a) all metal structures
(b) fixed nonelectrical equipment that could become energized
(c) the electrical grounding system
(d) all of these

22. For temporary power outlets that are part of existing or new permanent wiring, GFCI protection can be provided by a listed ____.

(a) circuit breaker
(b) receptacle
(c) cord set
(d) any of these

23. Equipment used for an optional standby system transfer should be suitable for the intended purpose and shall be ____ so as to stop inadvertent interconnection of all supply sources in the transfer equipment.

(a) listed
(b) designed
(c) installed
(d) all of these

24. At motor fuel-dispessing sites, such as motor fuel facilities, race tracks, and similar areas, the metallic armor or sheath on cables and any noncurrent-carrying metal components of permanently installed and portable electrical equipment shall be grounded and bonded ____.

(a) operating at under 600V
(b) regardless of voltage
(c) over 300V
(d) under 50V

25. Threaded conduits or fittings located in classified hazardous areas must be made wrench-tight to ____.

(a) prevent sparking when fault current flows through the conduit system
(b) prevent seepage of gases or fumes
(c) prevent sag in the conduit runs
(d) maintain a workmanship like installation

26. Power-limited fire-alarm cables may be supported by strapping, taping, or being attached to the outside of a conduit or raceway.

(a) True
(b) False

27. Optical fiber cables that are not terminated at equipment and are not identified for future use with a tag are considered abandoned.

(a) True
(b) False

28. In one- and two-family dwellings, a sign must be placed at the disconnecting means required in 230.85 that shows the location of each permanently installed on-site optional standby power source disconnect or means to shut down the ____ as required in 445.18(D).

(a) prime mover
(b) utility supply
(c) secondary source
(d) primary source

Random Order | Final Exam B

29. This *Code* covers the installation of _____ for public and private premises, including buildings, structures, mobile homes, recreational vehicles, and floating buildings.

(a) optical fiber cables
(b) electrical equipment
(c) raceways
(d) all of these

30. Factory-installed _____ wiring of listed equipment need not be inspected at the time of installation of the equipment, except to detect alterations or damage.

(a) external
(b) associated
(c) internal
(d) all of these

31. Raceways enclosing cables and conductors for fire alarm systems shall be large enough to permit the _____ of conductors without damaging conductor insulation as limited by 300.17.

(a) concealment
(b) bending space
(c) splicing
(d) installation and removal

32. The branch-circuit overcurrent devices for legally required standby systems shall be accessible only to _____.

(a) the authority having jurisdiction
(b) authorized persons
(c) the general public
(d) qualified persons

33. Cord connectors for carnivals, circuses, and fairs can be laid on the ground when the connectors are _____ for a wet location.

(a) listed
(b) labeled
(c) approved
(d) identified

34. "Communications circuits" are circuits that extend _____ trond cutside wiring for fire alarms and burglar alarms from the communications utility to the customer's communications equipment up to and including equipment such as a telephone, fax machine, or answering machine.

(a) voice
(b) audio and video
(c) interactive services
(d) all of these

35. Each multiconductor cable installed in conduit in a Class I, Division 1 location shall be considered as a single conductor if the cable is incapable of transmitting _____ through the cable core.

(a) gases or vapors
(b) dust
(c) flying particles
(d) any of these

36. For communications circuit wiring in _____, the requirements of 300.22(C)(3) shall apply.

(a) spaces for environmental air
(b) ducts for dust
(c) ducts for loose stock
(d) ducts for vapor removal

37. Interconnected power production source(s) are permitted to be connected to the load side of the service disconnecting means at any distribution equipment on the premises.

(a) True
(b) False

38. The electrical datum plane for floating piers and boat landing stages, shall be a horizontal plane _____ in. above the water level at the floating pier or boat landing stage and a minimum of 12 in. above the level of the deck.

(a) 12
(b) 18
(c) 24
(d) 30

39. Power-limited fire alarm cables may be installed in plenums within communications pathways, in riser communication shafts, and in general-purpose communications raceways if they are _____, and if the conditions for electrical nonmetallic tubing are met.

(a) selected in accordance with Table 800.154(B)
(b) listed in accordance with the provisions of 800.182
(c) installed in accordance with 800.113 and 362.24 through 362.56
(d) all of these

40. Where indoor carnival, circus, and fair locations have installed flexible cords and cables, they must be listed for wet environments and must also be sunlight resistant.

(a) True
(b) False

41. Where communications system bonding conductors and grounding electrode conductors are exposed to _____, protection must be provided.

(a) line voltage conductors
(b) soil
(c) physical damage
(d) all of these

42. Article 517 specifies the electrical construction and installation standards for healthcare facilities that furnish services to _____.

(a) human beings
(b) animals
(c) children only
(d) intellectually challenged persons

43. If a location contains an emergency system, a sign is required at the service-entrance equipment that shows the type and position of each on-site emergency power source.

(a) True
(b) False

44. When a source of emergency power supplies other than light and other loads, then _____ switchgear sections or switchboard sections, with or without a shared bus, or individual disconnects inside separate enclosures must be used to supply the emergency loads, separating them from all other loads.

(a) separate vertical
(b) separate horizontal
(c) combined vertical and horizontal
(d) identified

45. Install Types CL3P-LP, CL2P-LP, CL3R-LP, CL2R-LP, CL3-LP, or CL2-LP conductors for power and data where they carry the rated current per conductor of the power source and are installed at temperatures above 86°F; the adjustment factors in Table _____ must be used to determine ampacities in Table 725.144.

(a) 310.15(B)(3)(a)
(b) 310.15(B)(7)
(c) 310.15(B)(1)
(d) 310.16

46. Class 1, 2, and 3 circuits run through fire-rated walls, partitions, floors, or ceilings shall be installed to reduce the possible passage of fire or products of combustion.

(a) True
(b) False

47. A conduit portion between a conduit seal and the point at which the conduit exits a Class I, Division 1 location must not have unions, couplings, boxes, or other fittings, except for a listed _____ installed at the conduit seal.

(a) explosionproof
(b) fireproof
(c) vapor-tight
(d) dusttight

48. A single means for disconnecting all ungrounded conductors of each _____ must be provided, and it must be arranged so that it can be operated independent of other disconnects.

(a) elevator or dumbwaiter
(b) escalator or moving walk
(c) platform lift or stairway chairlift
(d) any of these

49. In Class I, Division 1 or Division 2 areas, when enclosures, boxes, or fittings are needed to be explosionproof, the use of a flexible cord is permitted as a termination only with a cord connector or attachment plug that is listed for the location, or with a listed cord connector that is sealed for the location. In Division 2 areas where explosionproof equipment is not required, the cord shall terminate ____.

(a) with irreversible connections
(b) with a listed receptacle
(c) in a splice of any manner
(d) with a listed cord connector or listed attachment plug

50. Vegetation must not be used to support overhead conductor spans when the support is only temporary.

(a) luminaires
(b) receptacles
(c) branch circuits or feeders
(d) lighting conductors

51. Electrical power for temporary applications and lighting is allowed during emergencies and for _____.

(a) tests
(b) experiments
(c) developmental work
(d) all of these

52. Wiring methods permitted in Class I, Division 1 locations are permitted in Class I, Division 2 locations.

(a) True
(b) False

53. Article _____ covers the electrical conductors and equipment installed within or on mobile and manufactured homes and the conductors that connect mobile and manufactured homes to a supply of electricity.

(a) 550
(b) 551
(c) 555
(d) 590

54. Accessible portions of abandoned optical fiber cable must be taken out.

(a) True
(b) False

55. Amplifiers, loudspeakers, and other equipment shall be positioned or protected so they are not subject to environmental exposure or physical damage that could cause _____.

(a) a fire
(b) shock
(c) personal hazard
(d) any of these

56. A permanent _____ must be installed at a building by a stand-alone system at each service equipment location or at an approved readily visible location. This _____ provides a readily accessible location for each power source disconnect for the building or must be grouped with other plaques or directories for other on-site sources.

(a) plaque
(b) directory
(c) marking
(d) plaque or directory

57. Types CL2, CM, and CMG cables may be used within the raised floor area of an information technology equipment room if installed in accordance with 725.154(A).

(a) True
(b) False

58. Wiring for lighting located inside tents and concession areas at carnivals, circuses, and fairs, must be guarded against physical damage.

(a) True
(b) False

59. Wiring methods in a corrosive environment for pool-associated motors in permanently installed pools must comply with 680.14 or must include an insulated copper equipment grounding conductor sized in accordance with Table 250.122, but not smaller than _____ AWG.

(a) 18
(b) 16
(c) 14
(d) 12

60. When the power source conductors supplying circuits located outdoors enter a building, they shall be protected by overcurrent devices in a readily accessible location outside the building or at the first readily accessible location where the power source conductors enter the building.

(a) location
(b) readily accessible location
(c) accessible location
(d) secured location

Author's Commentary:

These questions highlight important safety requirements and code rules found in the 2023 NEC that every electrical professional should know well. Keep reviewing and apply these principles on the job.

— Michael Hamilton

61. In a Class I, Division 2 location, switches and circuit breakers must be installed inside explosionproof enclosures that comply with the standards for Class I, Division 1.

(a) True
(b) False

62. Types NM, NMC, and SE cables can be used for branch circuits in temporary installations without height limits and without the need to conceal the cables.

(a) True
(b) False

63. The maintenance disconnecting means for swimming pool equipment must be located _____, and at least 5 ft from the water's edge, unless a permanent barrier separates them.

(a) secured
(b) at least 24 in. above the highest water level of the pool
(c) capable of being locked in the open position
(d) readily accessible and within sight of the equipment

64. Stand-alone and isolated microgrid systems can provide 120V to single-phase, 3-wire, 120/240V service disconnects or distribution panels if there are no 240V outlets and no multiwire circuits.

(a) True
(b) False

65. Legally required standby system equipment shall be maintained in accordance with _____.

(a) UL listing(s)
(b) local emergency services requirements
(c) manufacturer instructions and industry standards
(d) local jurisdictional requirements

66. An overload is the same as a short circuit or ground fault.

(a) True
(b) False

67. Seals in Class II hazardous (classified) locations shall be explosionproof.

(a) True
(b) False

68. All receptacles installed for other than shore power shall be protected in accordance with _____.

(a) 110.11
(b) 200.3
(c) 210.8
(d) 250.62

69. Where manual transfer equipment is used, an optional standby system shall have adequate _____ for the supply of all equipment intended to be operated at one time.

(a) ventilation
(b) supervision
(c) fuel supply
(d) capacity and rating

70. All 15A and 20A, 125V, single-phase receptacles installed _____ of agricultural buildings shall be GFCI protected.

(a) in areas having an equipotential plane
(b) outdoors
(c) in dirt confinement areas for livestock
(d) any of these

71. Separate information technology equipment units shall be permitted to be interconnected by means of listed cables and cable assemblies. Where exposed to physical damage, supply circuits and interconnecting cables shall be protected.

(a) True
(b) False

72. After the completion of permanently installed swimming pools, the authority having jurisdiction shall be permitted to require _____ inspection and testing.

(a) seasonal
(b) monthly
(c) periodic
(d) annual

73. GFCI protection is required for 15A, 20A, and 30A, 125V receptacle outlets that are installed or existing as part of the permanent wiring of the building/structure when used during construction or remodeling. Listed cord sets or adapters that incorporate listed GFCI protection for portable use can be used to meet this requirement.

(a) True
(b) False

Random Order | Final Exam B

74. Automatic transfer switches on legally required standby systems must be electrically operated and _____ held.

(a) electrically
(b) mechanically
(c) gravity
(d) any of these

75. A conductor used to connect the system grounded conductor, or the equipment to a grounding electrode or to a point on the grounding electrode system, is called the "_____ conductor."

(a) main grounding
(b) common main
(c) equipment grounding
(d) grounding electrode

76. Types CL2P and CL3P plenum cable shall be _____ as suitable for use in ducts, plenums, and other space for environmental air and shall be listed as having adequate fire-resistant and low-smoke producing characteristics.

(a) marked
(b) labeled
(c) listed
(d) approved

77. Type _____ cable shall be permitted to be installed in a branch-circuit raceway in a temporary underground installation.

(a) NM
(b) NMC
(c) SE
(d) any of these

78. The disconnecting means for an elevator or escalator shall be an enclosed externally operable circuit breaker or fused motor circuit switch that is _____.

(a) capable of interrupting six times the locked-rotor current
(b) lockable
(c) inherently protected
(d) suitable for use as service equipment

79. Installations supplying _____ power to ships and watercraft in marinas and boatyards are covered by the *NEC*.

(a) shore
(b) primary
(c) secondary
(d) auxiliary

80. An arc welder shall have overcurrent protection rated or set at not more than _____ percent of the rated primary current of the welder.

(a) 100
(b) 125
(c) 150
(d) 200

81. Paint, plaster, cleaners, abrasives, corrosive residues, or other contaminants may result in an undetermined alteration of optical fiber cable _____.

(a) usefulness
(b) voltage
(c) properties
(d) reliability

82. Rigid metal conduit and IMC shall not be required to be threaded when used in Class II, Division 2 locations.

(a) True
(b) False

83. In accordance with Article 705, the sum of all interconnected power production system-controlled currents, plus all monitored currents fom other sources of supply, shall not exceed _____ percent of the ampacity of any busbar or conductor supplied by the power production sources.

(a) 100
(b) 115
(c) 125
(d) 150

84. When a fire pump motor operates at 115 percent of its full-load current rating, the supply voltage at the load terminals of the fire pump controller shall not drop more than _____ percent below the voltage rating of the motor connected to those terminals.

(a) 5
(b) 10
(c) 15
(d) 20

85. When the *NEC* allows new products that were not offered at the time a prior edition was published, the _____ gives jurisdiction the authority to allow the use of those products that comply with the most recent prior edition of the *Code* adopted by that jurisdiction.

(a) electrical engineer
(b) master electrician
(c) authority having jurisdiction
(d) permit holder

86. In patient care spaces, luminaires that are more than _____ ft above the floor, and switches placed outside the patient care area, can be connected to equipment grounding return paths that follow **517.13(A) or (B)**.

(a) 7
(b) 7½
(c) 7¼
(d) 8

87. Insulated overhead service conductors that are bundled with a bare messenger and operate at more than 750 volts to ground must maintain a _____ ft separation, in any direction, from the water level of pools, fountains, and similar installations.

(a) 14
(b) 16
(c) 20
(d) 22½

88. Stand-alone systems require either energy storage or backup power supplies.

(a) True
(b) False

89. Mobile home and manufactured home feeder circuit conductors must have an ampacity of at least the loads supplied and not less than _____.

(a) 50A
(b) 60A
(c) 100A
(d) 200A

90. In Class III locations, locknut-bushing and double-locknut types of fittings may be depended on for bonding purposes.

(a) True
(b) False

91. Section(s) _____ shall apply to penetrations of the fire-resistant information technology room boundary.

(a) 300.21
(b) 770.26
(c) 800.26
(d) all of these

92. Each sign and outline lighting system shall be controlled by an externally operable switch or circuit breaker that opens all ungrounded conductors simultaneously on _____ branch circuits.

(a) 15A
(b) 20A
(c) multiwire
(d) outdoor

93. In spas or hot tubs, a clearly labeled emergency shutoff or control switch shall be _____, not less than 5 ft away, adjacent to, and within sight of the spa or hot tub.

(a) accessible
(b) readily accessible
(c) available
(d) of the pneumatic type

94. Each resistance welder shall have an overcurrent device rated or set at not more than _____ percent of the rated primary current of the welder.

(a) 80
(b) 100
(c) 125
(d) 300

95. In one- and two-family dwellings, the primary protector bonding conductor or grounding electrode conductor for communications systems shall be as short as practicable, not to exceed _____ ft in length.

(a) 5
(b) 8
(c) 10
(d) 20

DEFINITIONS | From Michael Hamilton Publications

Random Order | Final Exam B

96. Audio system equipment supplied by branch-circuit power shall not be placed horizontally within _____ of the inside wall of a pool, spa, hot tub, fountain, or the prevailing or tidal high water mark.

(a) 18 in.
(b) 2 ft
(c) 5 ft
(d) 10 ft

97. In land areas subject to tidal fluctuation, the electrical datum plane shall be a horizontal plane that is _____ ft above the highest tide level for the area occurring under normal circumstances, based on the highest high tide.

(a) 1
(b) 1½
(c) 2
(d) 2½

Author's Commentary:
When the tide rises and falls, a reference elevation is needed for installing electrical equipment safely. The code establishes that the datum plane must be set at a specific height above the area's highest tide under normal conditions.
— Michael Hamilton

98. Transfer equipment shall be required for all optional standby systems subject to the requirements of _____ and for which an electric utility supply is either the normal or standby source.

(a) the authority having jurisdiction
(b) Article 702
(c) the equipment manufacturer
(d) the owner of the facility

Author's Commentary:
Optional standby systems covered by Article 702 require transfer equipment whenever the utility service is intended to be either the primary or the backup source.
— Michael Hamilton

99. The bottom of sign and outline lighting system equipment shall be at least _____ ft above areas accessible to vehicles unless protected from physical damage.

(a) 12
(b) 14
(c) 16
(d) 18

100. For supply-side connected interconnected power production source(s), the grounding terminal or bus for the supply-side disconnecting means shall be connected to a (n) _____ sized in accordance with 250.102, based on the size of the conductors in 705.11(B).

(a) supply-side bonding jumper
(b) equipment grounding conductor
(c) grounded service conductor
(d) grounding electrode

Author's Commentary:
A supply-side interconnected generator requires the disconnect's grounding terminal or bus to be tied to a conductor sized per 250.102, based on the conductor size specified in 705.11(B).
— Michael Hamilton

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Commercial and Industrial Wiring and Raceway Chart

Overcurrent Protection Size	Copper [1] Wire 75°C Terminal	Maximum [2] Continuous Ampere Load	Raceway [5]	Equipment [4] Ground Wire	Maximum Continuous Single-Phase VA Load [3]					Maximum Continuous Three-Phase VA Load [3]		
					120V	208V	240V	277V	480V	208V	240V	480V
15	14	12	½"	14	1,440	2,496	2,880	3,324	5,760	4,323	4,998	9,976
20	12	16	½"	12	1,920	3,328	3,840	4,432	7,680	5,764	6,651	13,302
25	10	20	¾"	10	2,400	4,160	4,800	5,540	9,600	7,205	8,314	16,627
30	10	24	¾"	10	2,880	4,992	5,760	6,648	11,520	8,646	9,976	19,953
35	8	28	1"	10	3,360	5,824	6,720	7,756	13,440	10,087	11,639	23,278
40	8	32	1"	10	3,840	6,656	7,680	8,864	15,360	11,528	13,302	26,604
45	8	36	1"	10	4,320	7,488	8,640	9,972	17,280	12,999	14,964	29,929
50	8	40	1"	10	4,800	8,320	9,600	11,080	19,200	14,410	16,627	33,254
60	6	48	1"	10	5,760	9,984	11,520	13,296	23,040	17,292	19,953	39,905
70	4	56	1½"	8	6,720	11,648	13,440	15,512	26,880	20,174	23,278	46,556
70	4	64	1½"	8	7,680	13,312	15,360	17,728	30,720	23,056	26,604	53,207
80	4	72	1½"	8	8,640	14,976	17,280	19,944	34,560	25,938	29,929	59,858
90	3	79	1½"	8	9,600	16,640	19,200	22,160	34,600	28,820	33,224	66,509
100	2	88	1½"	6	10,560	18,304	21,120	22,136	42,240	31,703	36,580	73,160
125	1	100	2"	6	12,000	20,800	24,000	27,700	48,000	36,226	41,568	83,136
150	1/0	120	2"	6	14,400	24,960	28,800	33,240	57,600	43,231	49,882	99,763
175	2/0	140	2"	6	16,800	29,120	33,600	38,780	67,200	50,436	58,195	116,390
200	3/0	160	2½"	6	19,200	33,280	38,400	44,320	76,800	57,641	66,509	133,018
225	4/0	180	2½"	4	21,600	37,440	43,200	49,860	86,400	64,846	74,822	149,645
250	250 kcmil	200	3"	4	24,000	41,600	48,000	55,400	96,000	72,051	83,136	166,272
300	350 kcmil	240	3½"	4	28,800	49,920	57,600	66,480	115,200	86,461	99,763	199,222
350	400 kcmil	266[3]	3½"	3	32,160	55,744	64,320	74,236	128,640	95,549	111,402	222,804
400	500 kcmil	304[3]	4"	3	36,480	63,232	72,960	84,208	145,920	109,518	126,367	252,733
400	600 kcmil	320	4"	3	38,400	66,560	76,800	88,640	153,600	115,520	133,108	266,035

(1) Conductor size based on 75°C terminal rating (110.14(C)(1)).
(2) Maximum continuous nonlinear load is an ambient temperature of 30°C and three current carrying conductors in the raceway, whichever is larger (310.15(B)(3)(a), 240.6(A), and 215.2(A)(1)).
(3) Ampacity based on four 90°C current-carrying conductors.
(4) To ensure ease of installation, raceways are sized so that Raceway conductors in PVC conduit fill factor C. 40%.
(5) Raceway ampacity must comply with 75°C conductor ampacity (because the conductor's ampacity is lower than the overcurent protection device rating).

Formulas

Conversion Formulas

Area of Circle = πr^2
Breaker Derating Factor = Breaker Cost $ x Gross Profit %
Boardfoot = Depth x 3.0 x H, in and Cu – 1,000 sq. in. [illegible]
Centimeters = Inches x 2.54
Inch = 0.0254 Meters
Inch² = 6.451 Centimeters²
Inch³ = 25.40 Millimeters³
Kilometer = 0.6213 Miles
Length of Conduit or Raceway = Diameter of End Average x π Diameter of Largest of End / Cocks x π
Lighting Distance = Decimal Average [illegible] Needs x Decimal
MCM = 197.5 Circular Mils
MCM = 197.5 Circular Mils
Meter = 3.2808 Feet Mils
Mile = 5,280 ft, Feet Mils
Gross Profit % [illegible] Inch [illegible]
Millimeter = 0.0[illegible]
Rectangle = [illegible] Mils
Speling of Sound = 784 feet/sec [illegible]
Speed of Sound = 784 feet/sec = 1,128 fps or 769 mph [illegible] mph
Temp °F = (Temp °C x 1.8) + 32
Temp °C = (Temp °F – 32) / 1.8
Yard = 0.9144 Meter

Electrical Formulas Based on 60 Hz

Noninductive Reactance (X_L) in Ohms = $12\pi fL \times 10^{-6}$
Effective (RMS) Current = [illegible]
Effective (RMS) Voltage = Peakvolts x 0.707
Efficiency = Outputwatts/Inputwatts x 100%
Frequency = 1/Duration
Inductive Reactance (X_L) in Ohms = $2\pi fL$
Input = Output/Efficiency

Electrical Formulas Based on 60 Hz (continued)

Noninductive Reactance (X_L) in Ohms = (XL_1 x L1 – XL_2 x L2 [illegible]
XL3 x L3 – XL4 x L4) / L [illegible]
Output = Input x Efficiency
Peak kVA = Total kVA x 141%
Peak Volt-Amperes = Effective [illegible]
Volt-Amperes x $\sqrt{2}$
Frequency = 1/Duration x [illegible]
Inductive Reactance (Volts x Amperes [illegible]
VA Three-Phase = Volts x Amperes x $\sqrt{3}$

Electrical Formulas Based on 60 Hz (continued)

Watts real power (single-phase) = Volts x Amperes x Power Factor
Volts (real power) x Three-Phase = Volts x Amperes x $\sqrt{3}$ x Power Factor
Watts (real power) With Three-Phase = Watts x $\sqrt{3}$
Dist. = kWh ÷ Line Amperes
KWH = Three-Phase VA x Power hrs x $\sqrt{3}$
kWh 3ø, 4-Wire "High Leg" = kW x 5.577 x Power hrs
Line Volts = Phase-to-Neutral Volts x [illegible] x $\sqrt{3}$
Wire Line Amperes = Phase (line) Volts/Amperes

Parallell Circuits

Total R = Total resistance is always less than the smallest resistor
R_t = 1 / ([illegible]
XL3 x [illegible]
Trade 2: Total current is equal to the sum of the currents of all parallel reisstors
Trade 3: Voltage is the same across each of the parallel resistors

Transformer Amperes

Secondary Amperes Single-Phase = [illegible]
Secondary Amperes Three-Phase = [illegible] x $\sqrt{3}$ [illegible]
Equiv. Watts = Transformer Single-Phase
Secondary Audible Band Three-Phase = kVA/(Watts x $\sqrt{3}$) Transformer
Dist. = Watts x Line Amperes
Delta = Wire Line Volts x Phase (line) Volts
Delta 3-Wire = Line kW x Voltage (L-L)
Phase (line winding) Volts x 0.577 x $\sqrt{3}$
Line kVA Volts = Phase (line winding) Volts x $\sqrt{3}$
Wire Line Amperes = Phase (line winding) Amperes

Voltage Drop

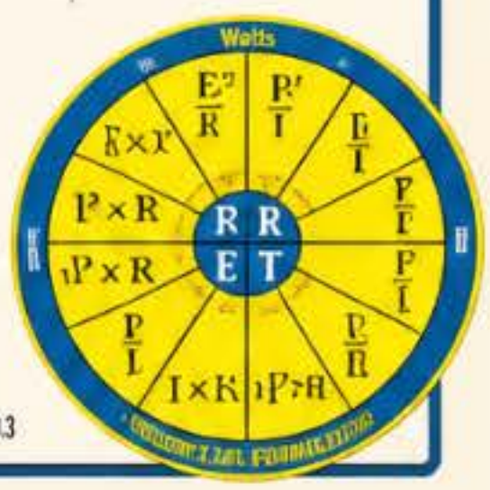
VD (Single-Phase) = 2KVD/CM
(Three-Phase) = $\sqrt{3}$ KD/CM
VD% (Single-Phase) = 2KVD/VD
(Three-Phase) = $\sqrt{3}$ KD/VD

Code Rules

Resistive Reactance = –2πfLω
Conductor Ampacity = 110.15 and Table 310.15B(16)
Equipment Grounding Conductor = 250.122
Grounding Electrode Conductor = 250.66
Motor Conductors = 430.22 (Single) 430.24 (Multiple)
Motor Short-Circuit Protection = 430.52
Transformer Overcurrent Protection = 450.3

Legend

π (Pi) = 3.142 (approximately)
½ = 1.414 (approximately)
$\sqrt{2}$ = 1.732 (approximately)
f = frequency
r = radius
ω = diameter
C = Capacitance (farads)
L = Inductance (henrys)
CM = = Circular Mils
VD = Volts Drop
I = Amperes of load
D = Distance one way
K75°C = (1/2.90 ohms Cu) (21.20 ohms Al)



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